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Design of the composite weather shield MK 71 MOD 2

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INTRODUCTION

The emergence of new materials technologies makes it necessary to constantly evaluate the possibility of their application in defense systems, to give them a state-of-the-art performance.

Nuova Connavi s.r.l., the company where I am doing the internship, proposed to me the conduction of a thesis concerning the design, construction of a prototype, qualification, and industrialization of a weather shield for naval gun system MK 71 MOD 2 of which it has acquired an order.

I gladly accepted this proposal because the work is concerning the design of a large composite structure, with the possibility of participating in the realization of the shield with innovative materials produced by NC and its qualification.

I am particularly excited to have been able to follow this program from the beginning of the design, product development and industrialization. An experience that at the end of my university career has enriched me with the technical and practical approach to the work of an engineer.

The weather shield of a naval gun weapon system is an element of fundamental importance in the operational life of the gun, since it guarantees a defense from the environment (i.e. thermal effects, rain, corrosion, green water load, etc.) in the operational conditions (i.e. protection against electromagnetic interferences, RCS reduction, etc.).

The principal operational functionalities of the shield are here listed:

- to protect the training mass and elevating mass against the attacks of environmental agents
- to provide an adequate accessibility to the gun system in case of inspection, maintenance or repairing
- to contribute to ensure the climatic conditions inside the shield themselves
- to contribute to NBC (Nuclear, Biological, Chemical) protection and water tightness
- to guarantee an RCS (Radar Cross Section) in accordance with the general RCS requirements of the whole combat ship)
- to guarantee an adequate shielding against EMI interferences
- For safety reasons of the personnel operating on the deck and on the bridge, the shields of the cannons must prevent reflection of the secondary lobes of the radar beams if the electric fields exceed 100V/m.

Today's naval warfare scenario has changed and requires the shield only to resist the penetration of 7.62 mm ball ammunition. This made it possible to consider composite material as an alternative to aluminum.

SCOPE

The aim of the thesis is to make the student acquire a working method in the design through participation in all phases of product development including not only the aspects of calculation and drawing, but also the economic aspects (budgeting, production costs, etc..), safety, ergonomics, logistics, workshop and even after sales.

During my presence at Nuova Connavi s.r.l. I participated in all the development activities of the new product which is very innovative in type of structure, materials, and construction technologies. It will solve the problems observed in the field of aluminum shields and later described.
The stages of development in which I participated are the following:
-**comparison of the materials** with which the shield of a naval cannon can be made in order to identify the most suitable and innovative ones and identify construction technologies;
-**complete design** (feasibility study, FEM calculation, construction and assembly drawings, optimization of ergonomics and logistics);
-**design and construction of production equipment** (models, molds, drilling masks, etc.).);
-**construction of the prototype** and preparation of production **documentation;**
-**qualification activities,** including qualification plan, procedures and qualification dossiers;
-**industrialization,** consisting in the introduction into the data package of all modifications made to the shield and equipment during the construction of the prototype;
-**all the documentation required by** the customer in the requirement.

At the moment, the naval guns that mount MK 71 MOD 2 shields are in an aluminum sandwich structure. The redesign was necessary to solve the problems listed below in order of importance.

1. Condensation problems that have occurred in various environmental conditions due to the high thermal conductivity of aluminum and not solvable with the application of insulating paint.
   The phenomenon of condensation is particularly serious since the cannon is in communication through large openings with the under-deck rooms where the loading organs and the plant console are located.
   These rooms are equipped with an air conditioning system that keeps the relative humidity of the air constant at the optimal values for breathing, about 70%. The water re-entered into the air by the air conditioning continues to condense on the cold walls of aluminum that are at temperatures lower than that of dew, preventing the achievement of a balance situation. In some environmental situations, the phenomenon is so serious that ice formation has also occurred.
   Condensation has serious repercussions on the weapon because dripping water on mechanical devices causes early rust formation on the mechanical parts. As has already happened, it can also infiltrate electrical and electronic equipment, causing damage or even short circuits with the danger of fires. All attempts by navies to solve this problem by installing heat fans blowing hot air on the walls of the shield have proved ineffective.

2. Difficulty mounting the shield on the carriage due to the deformations suffered by the aluminum structure during the welding process. These deformations mis-align the base flange fixing holes from the corresponding ones on the carriage. In order to mount the shield on the carriage it is necessary to drill the holes, and this impairs the interchangeability of the shields themselves. Deformations in terms of flatness of the base flange due to welding rites also cause breakage of the beads during tightening of the fixing screws to the joint.

3. As part of a large, welded structure, the tops undergo deformations caused by the phenomena of welding shrinkage whose compensation requires the application of huge quantities of metal stuccoes.

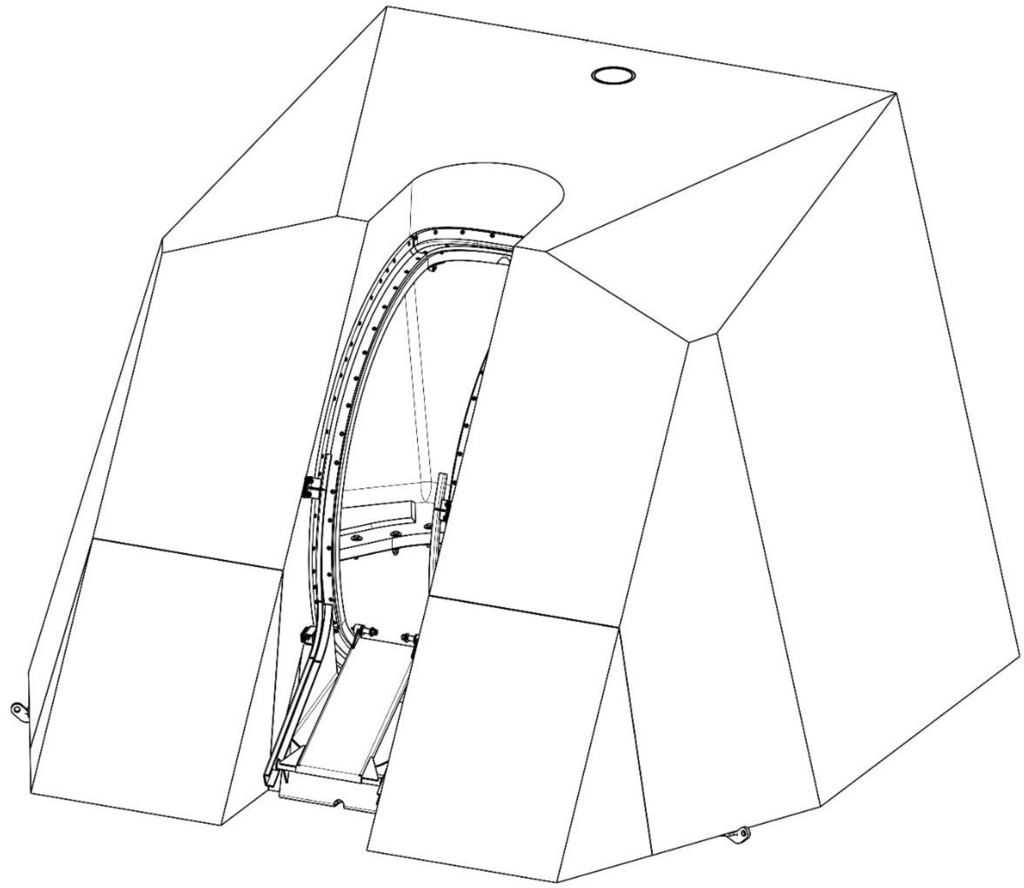
In the area of the hatches these deformations were such that the seals were not compressed, resulting in water infiltration.

4. Excessive weight in relation to resistance to green water load.

Composite materials offer enormous advantages that are mainly:
-a greater resistance to green water load;
-a drastic reduction of weight, resulting in a reduction in the engine powers of the brandishing enslavements;
-no maintenance requirements as the composite has no corrosion problems. This contributes to the reduction of the life cycle cost of the entire weapon system;
-possibility of integrating Radar Absorbing Material into the composite rolling plane;
-exceptional thermal insulation to prevent the formation of condensation that occurs in aluminum shields;
-benefits to the stability of the ship thanks to the reduction in the weight of the gun weapon system normally installed on the highest superstructures of the ship.

The innovations are shown in:
-the utilization of a prepreg epoxy in stage B that does not change its consistency before polymerization. It allows the rolling of large thicknesses on vertical walls and over-the-top without support, that is, without vacuum bag and without autoclave. The most important innovation of this material, identified by the NC company with the trade names of E-PREG QE, consists in mastering the state between liquid and solid;
-the structure, the edges of the shield consist of beams that were made by the E-foam, a syntactic foam, B-staged, based on the same epoxy matrix of the E-PREG QE with hollow glass bubbles. This foam is used in stage B, that is, soft, flexible, sticky, and spreadable, but stable against the movement induced by its own weight and is polymerized at the end together with the laminate. It allows the realization of variable section beams and allows an easy interface with sandwiches with PVC cores. The result is a rigid modified sandwich structure to the advantage of weight reduction;
- the construction technology;
- the production equipment;
-the quality control;
-ecology and occupational hygiene, Nuova Connavi’s prepreg does not contain volatile organic substances (VOC=0). This distinguishes it from polyester and vinyl ester, as they contain more than 40% styrene. Normally a polyester or vinyl ester resin in manual rolling processes loses around 8% by weight by evaporation of styrene, which goes into the atmosphere at odds with current legislation. The E-PREG QE does not contain toxic substances. Low molecular weight epoxy (frequently used as viscosity correctors) and amines have been strictly avoided in the formulation of Nuova Connavi’s prepreg. As a hardener for the epoxy, only high molecular weight anhydrides are used.

TECHNICAL REQUIREMENT SPECIFICATION OF THE COMPOSITE SHIELD FOR NAVAL GUN SYSTEM MK 71 MOD 2



1. APPLICABLE DOCUMENTS

Documentation

Ref. 1 – MIL-STD-810G – *Environmental Engineering Considerations and LaboratoryTests;*

Ref. 2 – AECTP 300 – *Climatic environmental tests;*

Ref. 3 – IEEE-299-2006 – *Standard Method for measuring the effectiveness ofelectromagnetic shielding enclosures;*

Ref. 4 – AQAP-2110 - *NATO Quality Assurance requirements for design, developmentand production;*

Ref. 5 – UNI EN ISO 9001:2008 *Sistemi di gestione per la qualità-requisiti;*

Ref. 6 – ISO 10012:2004 *Sistemi di gestione della misurazione - requisiti per processi e leapparecchiature di misurazione;*

Ref. 7 – AQAP-2070 - *NATO Mutual Government Quality Assurance (GQA) Process;*

Ref. 8 – MIL-STD-1472 G *Design Criteria Standard: Human Engineering;*

Ref. 9 – OTO-VE-0 Rev.0 *Specifica di verniciatura per costruzioni OTO Melara S.p.A.;*

Ref. 10 – OTO–GE.RI.001 - *OTO Melara Packaging Specification;*

Ref. 11 – RQA0001 Rev.06 – *Disposizioni Qualitative per le forniture OTO Melara S.p.A.; Ref. 12 ASTM D2563 – Classifying visual defects in Glass Reinforced Plastic LaminateParts;*

Ref. 13 - ASTM D3039 – *Standard Test Method for tensile properties of Polymer MatrixComposite Materials;*

Ref. 14 - ASTM C393 – *Standard Test Method for core shear properties of sandwichconstructions by beam flexture;*

Ref. 15 - ASTM D2344 - *Standard Test Method for Short-Beam Strength of Polymer MatrixComposite Materials and Their Laminates;*

Ref. 16 - ASTM D638 – *Standard Test Method for Tensile Properties of Plastics*

Ref. 17 - ASTM D790 – *Standard Test Methods for flexural properties of unreinforced andreinforced plastics and electrical insulating materials;*

Ref. 18 - ASTM D3418 - *Standard test method for transition temperatures and enthalpiesof fusion and crystallization of polymers by differential scanning calorimetry;*

2. Subject of supply

The subject of supply shall consist of:

1. the items/sub-items listed in Table 1, and described in the related paragraphs;
2. testing activities and specimens, as by par 6.1;
3. the documentation described in par 5.

The subject of supply shall be quoted in accordance with Purchasing Department.

ITEM	SUB-ITEM
SHIELD	SHIELD
	SHIELD OPENINGS/HATCH
	Right beak
	Left beak
	BOLTS AND NUTS
	PAINTING
TOOLS AND EQUIPMENT	INSTALLATION KIT
	MOLDS
	MANUFACTURE/TRANSPORTATION TOOLS AND STTE
	JIGS
	ELECTRICAL PLANT ATTACHES

Table 1

SHIELD

As anticipated in Table 1, the shield system is composed of shield, hatch, and beaks. Furthermore, it is intended that part of the shield are also considered all the bolts and nuts, and the painting.
In Table 2 are summarized the shield and hatch.

ITEM	N°
SHIELD	1
HATCH *(1050 mm x 1050 mm)*	1

Table 2

As further specified in par 4.1.4, note that both the shield and hatch shall be laminated with sandwich structure (**plies**: pre-preg E-glass quadriaxial woven with epoxy resin / **core**: PVC Foam HT/HP), made in vacuum bag (0.9 bar) and temperature- controlled oven at 80-130°C.

ASSEMBLING

The shield shall be delivered by the supplier to SDI assembled with hatch and smoke extractor.

The beaks will be mounted on the shield after the installation of the gun system on board. The installation of the shield is realized in SDI, by SDI personnel. (NOTE: only during the assembling of the first article, supplier technicians shall be present in SDI to assist SDI personnel in order to explain the right assembling/disassembling procedures.)

In Figure 3 is qualitatively shown the installation of the gun mount on the carriage.

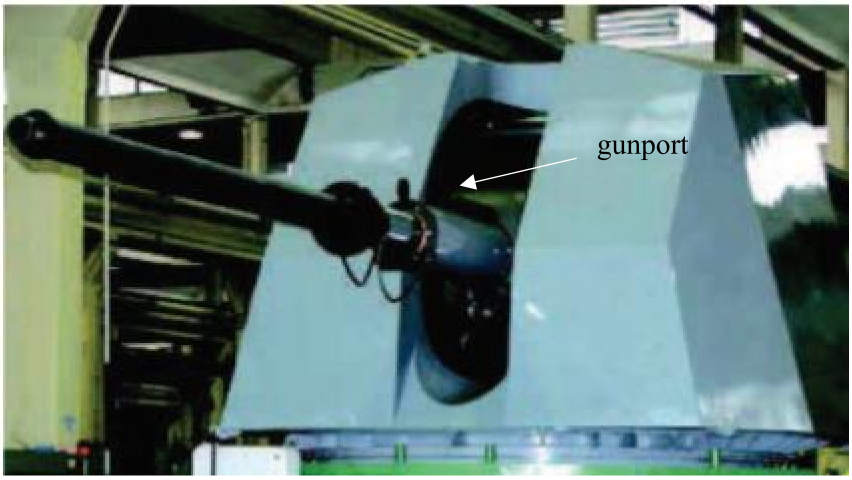


Figure 3: Old aluminium shield without beaks on the carriage and gun port position

SHIELD OPENINGS / HATCH

The shield shall present the following openings:

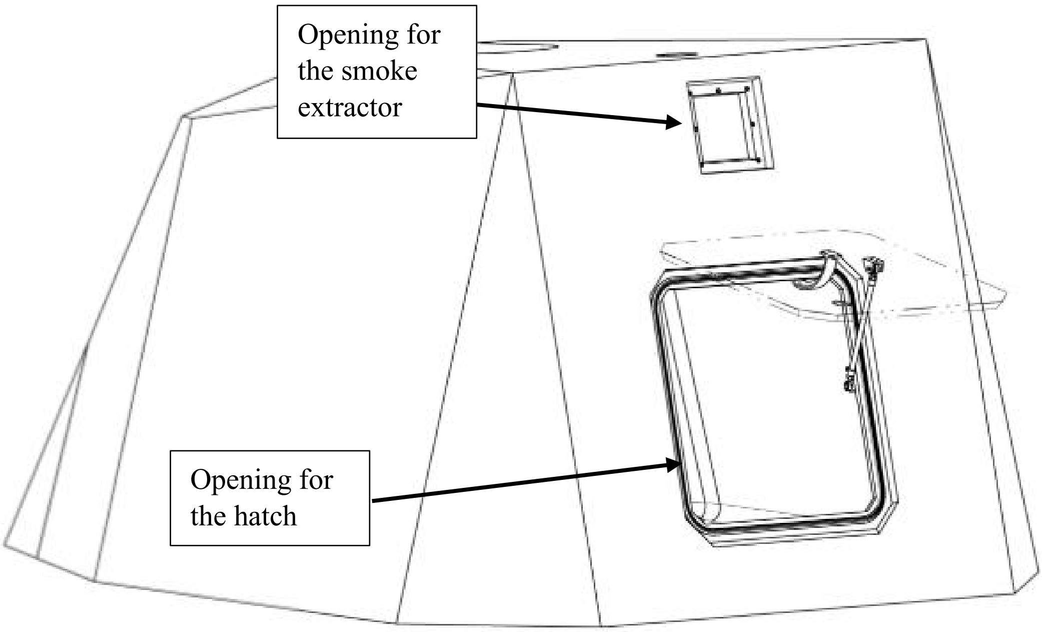


Figure 4: hatches

- **1 opening/hole with flanges and inserts for the *smoke extractor*[3]** (represented in Figure 4). This breach will be on the top of the *rear wall* (the exact position will be defined in design phase); the principal quotes and the shape of these openings can be understood from the *smoke extractor* representation.

[3] The *smoke extractor* is **NOT** part of supply.

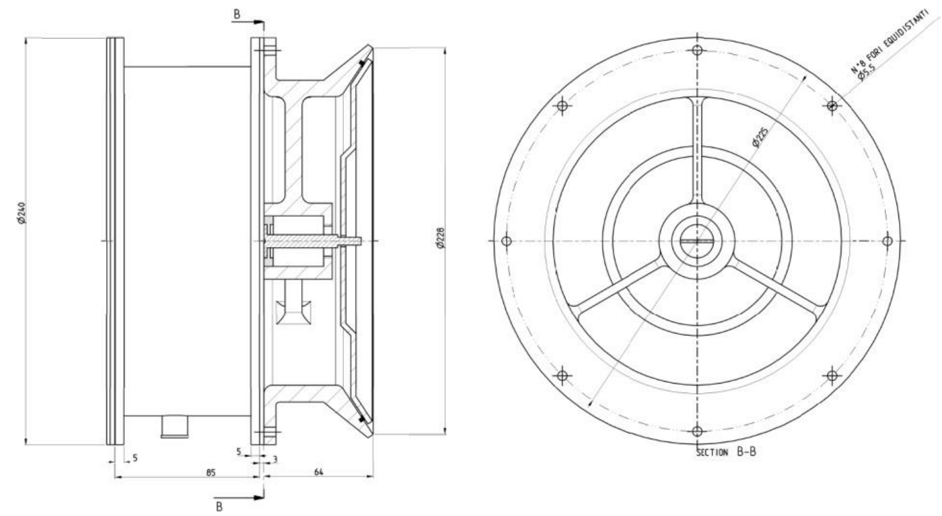


Figure 5: smoke extractor (NOT part of supply)

- **1 access hatch** (1050 mm x 1050 mm) properly sealed and inserted[5]. The hatch is qualitatively shown in Figure 8. The hatch shall be on the *rear wall* of the shield, as qualitatively shown in 4. This hatch is the main access to the gun mount for the personnel, and its positioning shall comply to [Ref. 8]).

Figure 6: hatch

[5] The leverages and the hinges necessary to connect the hatches to the modules of the shield are **NOT** part of supply.

GPS ANTENNAS INSERTS

On the ceiling of the shield, one insert should be placed, according with SDI Engineering Department, in order to install the GPS antenna (the antennas are **NOT** subject of supply). The insert is qualitatively shown in Figure 7, and the possible positions in Figure 8.

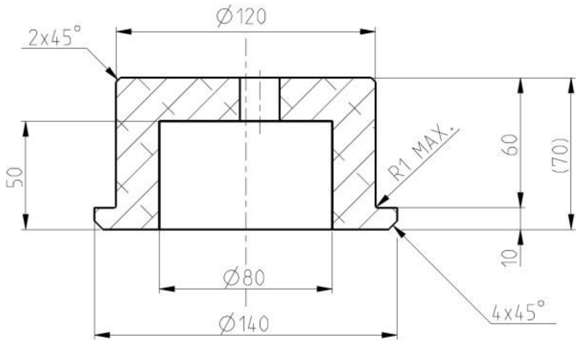


Figure 7

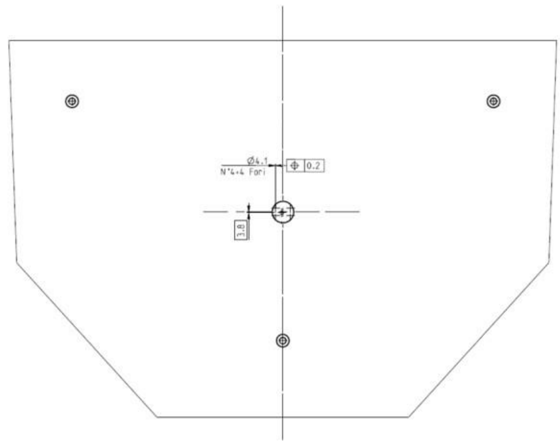


Figure 8

BOLTS AND NUTS

Subject of supply shall also include the bolts and nuts necessary to install the shield system on the carriage.
Nuts and bolts should be made by A4-70 passivated (AISI 316 cold worked).
Electrically not-compatible alloys and/or metals will not be placed in continuity with eachother.

PAINTING

The shield shall be supplied properly painted, according to requirements.

TOOLS AND EQUIPMENT

Here below are listed the tools and equipment which are part of supply. All the tools and equipment shall comply with applicable requirements.

INSTALLATION KIT

An installation kit shall be part of supply. The installation kit shall include, at least:

-installation/disassembly tools;
-seals (according to the drawings);

MOLDS AND MODELS

All the molds used for the manufacture of the shield shall be part of supply. The molds and models are characterized in par “Shielding”.

MANUFACTURE/TRANSPORTATION TOOLS AND STTE

All the manufacture/transportation tools and STTE *(Special To-Type Test Equipment)* shall be part of supply.

JIGS

Shall be part of supply jigs for:

- The individuation of the positions of the training and elevating axes
- The drilling of the holes on the gunport (these holes represent the interface between the gunport and the elevating mass of the gun system)
- The drilling of the hole on the base flange of the shield
- The drilling of the hole to secure the smoke extractor.

ELECTRICAL PLANT ATTACHES

Minor junctions and attaches necessary for the electrical plant:
-shall be part of supply;
-should be in accordance with [Ref. 19] or [Ref. 20], in accordance with SDI Purchasing and Engineering Departments;
-shall be completely defined according with SDI Engineering Department during thedesign and development phases of the shield.

The electrical plant itself is not considered subject of supply.

3. Requirements

The shield shall operate without any functional and physical degradation in continuous service conditions as by the requirements included in the present paragraph.

In the following requirements *shall* means that the requirement is mandatory, *should* means that the requirement is desirable.

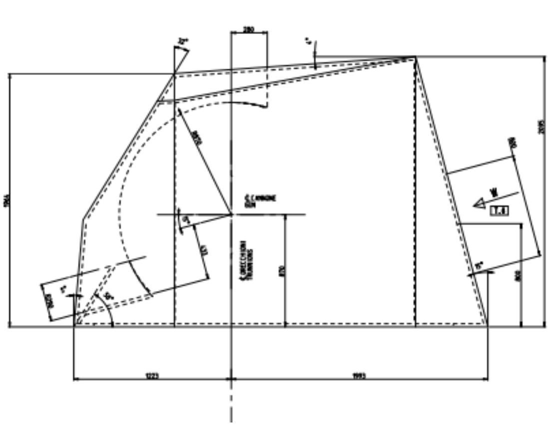
GEOMETRY AND PHYSICAL REQUIREMENTS

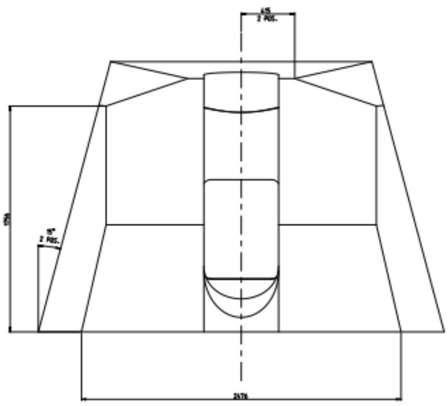
GEOMETRY

The breakdown, the parts, and their characterizations (in terms of materials, geometry, physical properties) as described previously of the present specification shall be adopted for the composite shield.

The shield is intended to be a precise substitute for the aluminum one, so the dimensions and the shape of the aluminum shield ([Ref. 19] or [Ref. 20], in accordance with SDI Purchasing and Engineering departments) should be taken in consideration for the design of the composite one. In particular:

- the external quotes and shape of the aluminum shield (one of the previously indicated configurations) should be still guaranteed in the composite version;
- the interface of the composite shield with the training mass of the Naval Gun System MK 71 MOD 2 shall be the same as the aluminum one's;
- the dimensions of the beakless shield and the geometrical interfaces with the weapon system are those of Figure 9.
- the beaks, Figure 10. Two extremities (beaks) fixed to the shield with bolts, so to ensure the continuity to the shape of the shield. Their presence reduces the RCS. These beaks must be easy to dismount for transportation purposes.
- the structural panels should be sandwiches, and the whole thickness of each one of the panels should not exceed 70 mm.





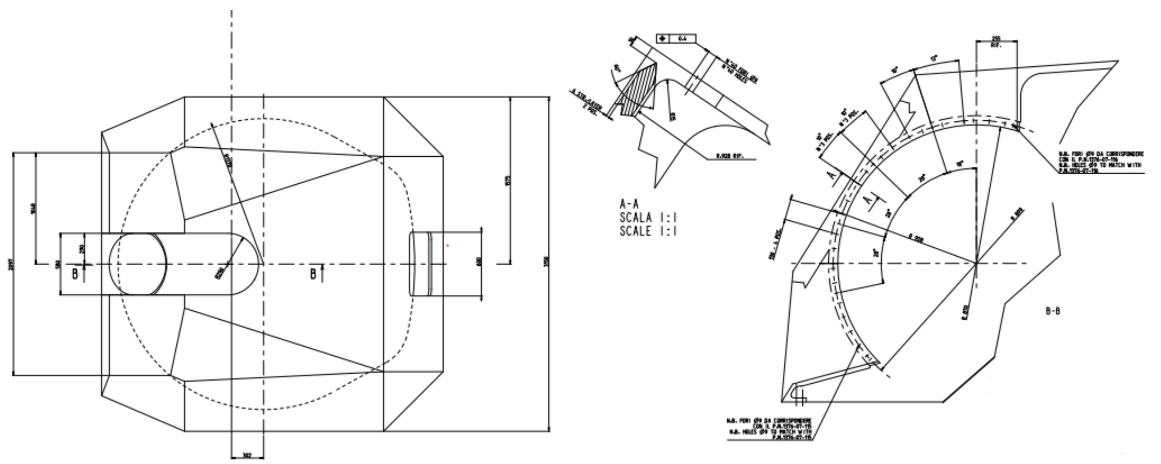


Figure 9

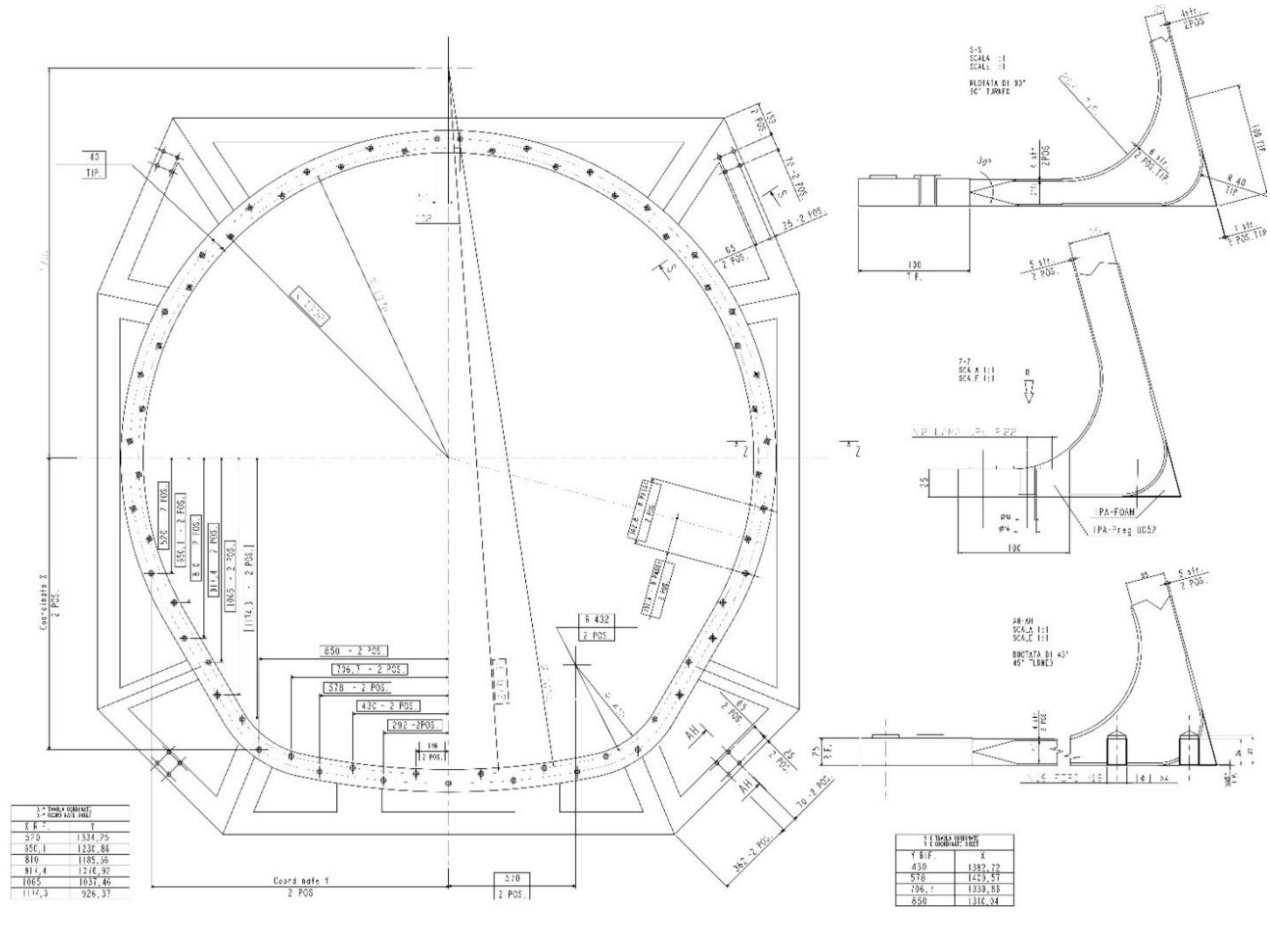


Figure 10

Further modifications to the shape, quotes and tolerances may be proposed by the supplier. It is intended that:

- each proposed modification shall be discussed and agreed with SDI Engineeringand Quality Departments;
- the final drawings of the shield shall be discussed and agreed with SDI Engineering and Quality departments.

MASS

The measured mass of the shield shall not exceed 600 kg (upper bound), including all the sub-items described in the and listed again here below:

- SHIELD
- BEAKS
- HATCH *(with opening and closing mechanism)*
- SMOKE EXTRACTOR
- INSERTS
- BOLTS AND NUTS
- PAINTING

For each one of these sub-items, the measured mass shall be within a positive tolerance of +5% on the nominal one.
Note that the following data – referring only to the part of the shield subject of supply, above listed– shall be specified by the supplier in a dedicated report:

- mass of the whole shield
- position of the center of gravity of the shield.

STRUCTURE, MATERIALS AND MANUFACTORING PROCESSES

The shield and hatch shall be built with a self-supporting sandwich structure with external plies and internal core, and with the possibility of using local reinforcements. The material and the manufacturing processes shall be selected in accordance with Table 3 and Table 4.

The only part which shall not be a sandwich structure is the gunport (which is part of the shield). The gunport shall be a solid laminate composed by prepreg E-glass balanced woven with epoxy resin. The gunport shall be designed to withstand the requirements listed in this document.

All the materials used must be commercial, not built-in house, and easily available on the market.

<table>
<tr><th colspan="2">COMPONENT</th><th>CHARACTERISTIC</th><th>M.U.</th><th>SOLUTION</th></tr>
<tr><td rowspan="4">PRE-PREG</td><td rowspan="2">REINFORCEMENT</td><td>Type</td><td>-</td><td>E-Glass, Multiaxial or Balanced Fabrics</td></tr>
<tr><td>Specific weight</td><td>g / m^2</td><td>270 ÷ 630</td></tr>
<tr><td rowspan="2">RESIN</td><td>Type</td><td>-</td><td>Epoxy</td></tr>
<tr><td>Tg</td><td>°C</td><td>Tg > 100°C
[Ref. 18]</td></tr>
<tr><td colspan="2" rowspan="2"><u>CORE</u></td><td>Type</td><td>-</td><td>PVC Foam HT/HP</td></tr>
<tr><td>Density</td><td>kg / m^3</td><td>70 ÷ 130</td></tr>
</table>

	Type	-	Syntactic foam
	Density	kg / m^3	480

Table 3

TOPIC	M.U.	SOLUTION
Production Process	-	Lamination with Vacuum Bag
Vacuum pressure	bar	~ 0,9
Curing system	-	Temperature-controlled oven
Curing temperature	°C	110 ÷ 130
Trimming and Drilling	-	CNC
Molds	-	• *Type*: female • *Material*: metallic (INOX) or composite • *Duration* > 40 pieces.
Models	-	• If molds metallic -> not necessary • If molds composite -> CNC milled, epoxy paste

Table 4

THERMAL TRANSMITTANCE

A low thermal transmittance is essential to avoid the formation of condensation inthe internal surfaces of the shield, when exposed to the typical environmental conditions.

Hence, the panels of the shield shall guarantee an equivalent thermal transmittance not higher than 1,5 $W/_{m^2K}$.

SHIELDING

The shield shall guarantee on its whole surface (panels, joints, hatches) a minimum shielding effectiveness of 40 dB in the frequency range 2 MHz ÷ 18 GHz. The verification of this requirement will be performed in accordance with [Ref. 3].

ELECTRICAL RESISTANCE

The shield shall have at least one conductive layer without any interruption on its whole surface. The maximum electrical resistance between two points of this layer shall be less than 0.1 Ohm.

Furthermore, the shield shall be electrically connected to the ship's hull through the gun system mount (electrical resistance < 0.1 Ohm).

RCS REDUCTION

The RCS (*Radar Cross Section*) of the shield shall properly be minimized by shaping, according to geometry requirement as by , and using Radar Absorbing Materials.

PAINTING

The shield in general (in particular the exposed surfaces of the shield) should be painted according to [Ref. 9] and according to customer requirements (typically RAL 7xxx). The internal surfaces of the shield should be painted with a light color, to be agreed with SDI Technical Department. All the painting procedures shall be quoted, discussed and approved by SDI Purchasing, Engineering and Quality departments before the delivery of the first shield

DEGREE OF ENCLOSURE

The shield, when installed on the gun mount, shall be dust-tight and able to withstand temporary immersion in water in accordance with international standard IEC 60529, protection class IP67. In particular:

- the hatch shall be properly sealed with conductive gasket
- the specified IP class must be ensured in all the junctions.

AGEING

The shield shall be insensitive to ageing for all the in-service life of the gun mount, which isnot less than 30 years. In addition, the shield shall not be affected by osmosis problems.

STRUCTURAL REQUIREMENTS

SHOCK

The shield shall withstand the following shock loads contemporary applied, considering theconstraints as by the installation on the gun mount, without compromising its integrity and functionality:
- vertical shock: 500 m/s^2 (static load);
- horizontal shock: 300 m/s^2 (static load).

The maximum deflection of each panel/module shall not exceed the one indicated for the green water load requirement, in the worst configuration case.

VIBRATIONS

The shield shall withstand the vibration loads in accordance with [Ref. 1].

GREEN WATER LOAD

The shield shall withstand a green water load equivalent to a static pressure of **1 bar**.
The maximum deflection shall not exceed **100 mm** on the lateral panels, **50mm** on the top panel and **125mm** on the rear panel.

Environmental requirements

TEMPERATURE

In accordance with [Ref. 1], the shield shall:

- operate (without anti-icing systems) in the temperature range: -30°C ÷ +65°C;
- survive, without compromising its integrity and functionality, in the temperaturerange: -40°C ÷ +75°C.

ICING

The shield shall operate with an ice increase of:

- 25 mm/h, up to 70 kg/m^2 (horizontal surfaces);
- 6.4mm/h, up to 24 kg/m^2 (vertical surfaces).

The shield shall survive, without compromising its integrity and functionality, with an iceload up to 125 kg/m^2.

SALT FOG

In accordance with [Ref. 1] and [Ref. 2], the shield shall survive to an environment with a salt fog concentration of 5%, as by the following procedure:

- the salt solution shall be atomized in the test chamber (temperature adjusted to 35°C) for a period of 24 hours;
- the shield shall be dried at standard ambient temperature and RH 50% (or less) for further 24 hours.

The previous procedure shall be repeated at least for a second time (the overall duration of the salt fog trial shall not be less than 96 hours). The status of the shield shall be checked in accordance with the specified standards.

WIND

The shield shall withstand, without compromising its integrity and functionality, to the following wind conditions:

- operative conditions: 75 knots, with gusts up to 135 knots;
- non-operative conditions: 100 knots, with gusts up to 175 knots.

RAIN

The shield, when installed on the gun mount, shall withstand a 6 bar pressure water jet with a diameter of 12 mm, from a distance of 3 m and for a minimum duration of 15 min.

No infiltrations of water inside the shield shall occur after this trial (hence, not-sealed breaches in the shield are unacceptable).

SOLAR RADIATION

In accordance with [Ref. 1], the shield shall withstand without compromising its integrity and functionality a maximum solar radiation of 1120 W / m^2. The spectral distribution of the solar radiation is reported in Table 5. For this radiation, no visual defects shall be detected on the surface of the shield, and the specified geometrical tolerances shall be guaranteed.

Spectral region (a)	Ultra-violet (b)		Visible (c)		Infra-red (d)	
Waveband (μm)	0.28-0.32	0.32-0.40	0.40-0.52	0.52-0.64	0.64-0.78	0.78-3.00
Irradiance (W/m^2)	5	63	200	186	174	492

Table 5

NOTE: considering the environmental temperature profile related to solar radiation intensity specified in [Ref. 1] and the typical reflectivity connected to the painting and treatments usually implemented for the shield, the temperatures of the external surfaces of the shield can reach approximatively 100°C. Hence, the solar radiation requirement is supposed to be stricter than the high temperature one.

HUMIDITY

The shield shall withstand the humidity cycling as by [Ref. 1]. The test consists of n°5 cycles of 48 h (RH 95%), following the temperature profile shown in Figure 11.

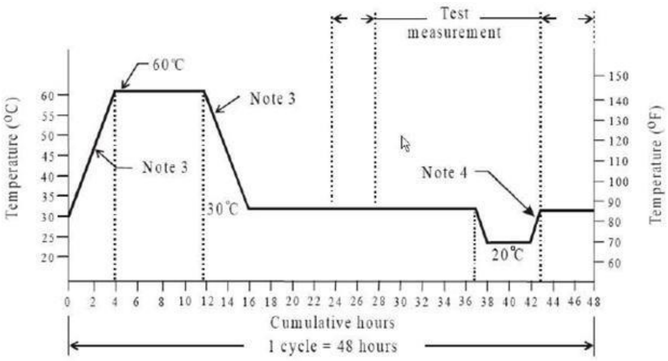


Figure 11

SHIP MOTION

The shield shall withstand a ship motion up to:

- Roll: ±22.5° (period T = 10 s);
- Pitch: ±7.5° (period T = 5 s).

During the specified ship motion:

- the parts of the shield (modules, junctions, hatches, etc.) shall keep staying properlyconnected to each other and to the gun system;
- the relative deflection of the surfaces of the shield shall not exceed the one indicated in “Green water load”.

Logistic and safety requirements

RELIABILITY

The shield shall have an MTBF *(Mean Time Before Failure)* greater than **150000 hours**.

MAINTAINABILITY

The shield shall be replaceable within 4 hours in the harbor with a crane and a specificlifting device by a team of 3 people (including the operator of the crane).
Each module of the shield shall be removable independently from the others.
The number and the mean elapsed time of the preventive maintenance activities shall beminimized.

TRANSPORTABILITY

One of the targets of the breakdown proposed for the shield is the optimization of the shield transportability. In fact, it is very important to minimize the number of exceptional transportation (desirable: no one).
Inserts shall be integrated in the upper part of the modules themselves in order to use eye bolts during integration/disassembly/transportation phases. The so-inserted-parts of the shield shall be properly reinforced.
The supplier shall specify the mass for the shield, in order to let SDI select the eye bolts (**NOT** part of supply).
The final measured mass of each module shall not exceed the value specified by the supplier of more than the 5%.

INTERNAL REINFORCES

Reinforced parts of the panels shall be implemented, with proper internal interfaces, in order to let the handling of heavy items (≤ 150 kg).

SPARES AND TOOLS LIST

A complete list of the spare parts - and associated tools for replacement - shall be supplied.

TOOLS STANDARD

The transportation, installations tools and STTE *(Special To-Type Test Equipment)* shall comply with Directive Machinery 2006/42 CE (when applicable) and shall be delivered with proper operative and maintenance manuals.

HUMAN FACTOR

The shield shall comply with [Ref. 8].

SAFETY-RELATED REQUIREMENTS

SAFETY

The shield shall be capable of being exposed to fire or corrosive environment without representing hazards to personnel and to any parts of the gun mount and onboardequipment/environment. The Materials Safety Datasheet and the REACH certification shallbe provided.

FLAMMABLE MATERIALS

The shield shall be impossible to ignite when exposed to sparks or heat. Self-extinguishing materials shall be used to avoid self-sustaining fires.

POISONOUS GASES, NORMAL OPERATION

The shield shall not contain materials that can emit poisonous gases or can be hazardous to touch under normal operation and storage.

HEALTH HAZARDS

The shield shall not contain materials representing health hazards during normal operation and storage.

NBC PROTECTION

The shield shall withstand the damaging effect of nuclear, biological, and chemical contamination agents and of decontamination agents and relative procedures. The external surfaces of the shield shall be smooth to avoid stagnation of contamination agents. Most of contamination agents belong to the classes as by Table 6.

AGENTS		
Choking agents	PS	(Chloropicrin)
	CG	(Phosgene)
	DP	(Disphosgene)
Blood agents	AC	(Hydrogen Cyanide)
	CK	(Cyanogen Chloride)
Blister agents	H	(Hyperite)
	L	(Lewisite)
	HD	(Mustard)
	THD	(Thickened HD
	HL	(Mustard/Lewisite)
	THL	(Thickened HL)
Nerve agents	GA	(Tabun)
	TGA	(Thickened GA)
	GB	(Sarin)
	TGB	(Thickened GB)
	GD	(Soman)
	TGD	(Thickened GD)
	VX	
	TVX	(Thickened VX)

Table 6

NBC protection shall be granted at the following conditions:

- a round has to be charged into the gun's barrel;

- cartridge evacuator hatch has to be closed;
- smoke extractors turned off;
- internal overpressure up to 1085 mbar (absolute value).

Qualification

The supplier shall demonstrate the compliance of the shield to each one of the requirements explained in the present specification, adopting for each requirement the verification method specified in Table 7.

The supplier shall prepare the following Qualification Documentation[6]:

- Qualification Plan
- Qualification Procedures
- Qualification Dossier

All the Qualification Documentation prepared by the supplier shall be discussed, validated, and approved by SDI Engineering and Quality departments, at least before the delivery of the first shield.
Note that:

- the whole Qualification process is in charge of the supplier;
- the supplier is the responsible of the whole Qualification process;
- SDI will validate and approve all the steps of the Qualification process managed by the supplier, checking the documentation and overseeing the test activities performed by the supplier.

[6] Further listed in Table 7 as part of the whole documentation

As anticipated, for each one of the requirements, the verification method that the supplier shall adopt to verify the compliance is indicated in Table 7 (column "Verification Method").
The possible verification methods are the following:

- **I** (Inspection)*: Check that the article is manufactured in accordance with the required documentation (drawings, reports, certificates etc.);*
- **D** (Demonstration): *Provide a demonstration that a specified functionality/performance is achieved (engineering considerations, analogy, etc.);*
- **A** (Analysis): *Provide an engineering analysis showing the compliance to the requirement (FEM, EMC tools, mathematic tools, etc.);*
- **T** (Test): *Test the article to be delivered, according to standards and test procedures.*

Furthermore, referring to Table 7:

- some of the requirements, whose the compliance shall be demonstrated by the supplier with verification method T (Test), are marked with (*); for these requirements, if needed, SDI will support the supplier in the Qualification activities providing personnel, facilities and test equipment, in accordance with Purchasing Department; the supplier shall indicate in the column "Qualification Dossier Paragraph" the paragraph of the Qualification Dossier in which is the demonstrated the compliance for each one of the requirements.

#	Requirements	Verification Method
4.1.1	GEOMETRY	I
4.1.2	JOINTS	I
4.1.3	MASS	T
4.1.4	STRUCTURE, MATERIALS AND MANUFACTORING PROCESSES	D
4.1.5	THERMAL TRANSMITTANCE	A
4.1.6	SHIELDING (*)	T
4.1.7	ELECTRICAL RESISTANCE	T
4.1.8	RCS REDUCTION	D
4.1.9	PAINTING	D
4.1.10	DEGREE OF ENCLOSURE	T
4.1.11	AGEING	D
4.2.1	SHOCK	A
4.2.2	VIBRATIONS	A
4.2.3	GREEN WATER LOAD	A
4.3.1	TEMPERATURE (*)	T
4.3.2	ICING	A
4.3.3	SALT FOG (*)	T
4.3.4	FUNGUS	T
4.3.5	WIND	A
4.3.6	RAIN	T
4.3.7	SOLAR RADIATION	T
4.3.8	HUMIDITY (*)	T
4.3.9	SHIP MOTION	D
4.4.1	RELIABILITY	D
4.4.2	MAINTAINABILITY	D
4.4.3	TRANSPORTABILITY	D
4.4.4	INTERNAL REINFORCES	T
4.4.5	SPARES AND TOOLS LIST	I
4.4.6	TOOLS STANDARD	D
4.4.7	HUMAN FACTOR	D
4.5.1	SAFETY	D
4.5.2	FLAMMABLE MATERIALS	T
4.5.3	POISONOUS GASES, NORMAL OPERATION	D
4.5.4	HEALTH HAZARDS	D
4.5.5	NBC PROTECTION	D

Table 7

4. Documentation

All the documentation:

- shall be discussed and agreed with SDI Engineering, Quality and Purchasing Departments before the delivery of the shield;
- should be used by SDI, if needed, as reference documentation in final qualification reports (note that the responsibility of the qualifications of the gun system and each part of it are in charge of SDI).

In Table 8 a preliminary list of the required documentation is reported.
It is intended that the final applicable documentation list shall be agreed with SDI Purchasing, Engineering and Quality department before any delivery, as further specifiedin par 6.

Documents Typology	**Area**	**Supplier document numbers**
Manufacturing and inspection plan (MIP)	QUALITY	
Quality Control Plan		
Dimensional Tests		
Qualification Documentation *(including: Qualification Plan, Qualification Procedures, Qualification Dossier, as explained in par 4.6)*		
Technical Specifications	ENGINEERIN G	
Technical Manual		
Drawings (3D and 2D)		
Engineering Analysis		
Test Reports		
Production schedule	PRODUCT ION	
Molds Drawings		
Ply book *(complete definition of layers)*		
Curing-cycle		
Maintenance Plan	LOGISTIC	
Maintenance procedures		
STTE drawings		
Installation and disassembly procedures		
Installation and disassembly tools drawings		
Packing and transportation procedures		
Packing and transportation tools drawings		
Materials characterization	MATERIALS	
Materials characteristics		
Materials certifications		
Materials Safety Datasheet		
REACH certification		

Table 8

5. QUALITY ASSURANCE

Quality Assurance and testing activities shall have the task to verify that the shield complies with all the requirements specified in the present specification.

Testing of rough materials and of manufactured products shall be performed in accordance with the applicable drawings and specifications, as established by [Ref. 4], [Ref. 5] and [Ref. 6].

A government Quality Assurance in accordance with [Ref. 7] can be requested by the end user.

Note that:

- the QUALITY CONTROL PLAN shall refers to the Qualification Plan for describing the applied methodology for any test/analysis performed in order to verify that the shield complies with the requirements as by par 4;
- the MANUFACTURING AND INSPECTION PLAN shall be approved by SDI before starting any manufacturing activities.

It is furthermore specified that:

- acceptance of the shield will be granted if no defective is found during testing and if all the measurements performed are within allowed tolerances.
- SDI reserves itself the right to subject the shield to a final acceptance test at SDI premises.
- Upgrading and recording of the documentation shall be carried out under configuration control management in such a way to ensure product maintenance along the whole life cycle and beyond.

Testing activities

The shield shall be tested as specified in par 4.6, in accordance with test procedures to besubmitted to SDI for approval.

It is intended that:

- the test procedures shall include as a minimum a visual inspection to assessfor workmanship quality and dimensional measurements to verify the compliance with the interface drawings (par 4.1.1);
- the test results shall be collated in Test Reports which shall be signed by the supplier's Quality Assurance and approved by representative SDI;
- as deeply specified in the following paragraph, tests shall performed on specimens made during manufacturing to verify the mechanical properties of the materials used (laminates and sandwiches).

Material characterization

The minimum set of tests to be performed in order to characterize the laminates and sandwiches implemented for the shield is described in Table 9.

TEST	REFERENCE STANDARD	SPECIMEN TYPE	TEMPERATURE [°C]	RELATIVE HUMIDITY [%]	N° OF SPECIMENS
Tensile Properties of Polymer Matrix Composite Materials	ASTM D3039	Laminate	23±3	50±10	3
			-30±3	95±3	3
			65±3	95±3	3
Core Shear Proper-ties of Sandwich Constructions by Beam Flexture	ASTM C393	Sandwich	23±3	50±10	3
			-30±3	95±3	3
			65±3	95±3	3

Table 9

The specimens used for the tests, and the tests themselves, shall be quoted by the supplier, in accordance with SDI Purchasing Department.
The reports of the tests shall be included by the supplier in the delivered documentation.

Further tests not specified in the present paragraph can be proposed, explained, and separately quoted by the supplier, in accordance with SDI Quality, Engineering and Purchasing Department.

6. Preparation for delivery

Preparation for delivery shall ensure the identification of packing and the correctpreservation and protection of the shield during shipping.
Packaging shall comply with [Ref. 10].

In the provided *Packing and Transportation Procedures*, the following information are required:

- type of packing;
- applicable standards;
- packing list;
- masses and dimensions for each pack;
- support activities (i.e. salts substitution, maintenance activities, etc.);
- packing operational life;
- transportation of the packaged system.

Analysis and interpretation of basic requirements

With reference to section “Mass”

The weight of 600 kg also includes all mechanical parts such as smoke extractors, hatch hinges, pneumatic springs, GPS bushings, and ceiling fixing plates, various inserts drowned in the laminate, screws connecting the carriage and cannon. The limit of 600 kg is very strict, also considering that the shield in aluminum configuration weighed 1050 kg.

With reference to section “Thermal transmittance”

This is the minimum value required to prevent the inner walls of the shield from reaching the dew temperature under the different environmental conditions in which the weapon system must operate. In the sandwich detail project, we will try to maximize the thickness of the core and use low density PVC, which has lower conductivity values. All this should lower the transmittance far below the required.

With reference to section “Shielding”

This requirement is required for protection against electromagnetic interferences (EMI) emitted by radars and telecommunications antennas to electronic and sensory devices located on the cannon and inside the shield.

The solution typically adopted by Nuova Connavi is the application on the outer surfaces of the shield of conductive fabrics of slight weight (e.g. 160 g/m^2 carbon balanced or conductive fabrics of the company Soliani). The solutions adopted to meet this requirement will have to be tested in accordance with the procedure described below in specialized measuring laboratories.

Shielding test configuration

To verify the shielding solution of the joints and the material used for the construction of the shield, 2 square-shaped specimen panels of size 700 x 700 mm are used.
The thickness and stratification plan are to be agreed with the supplier.

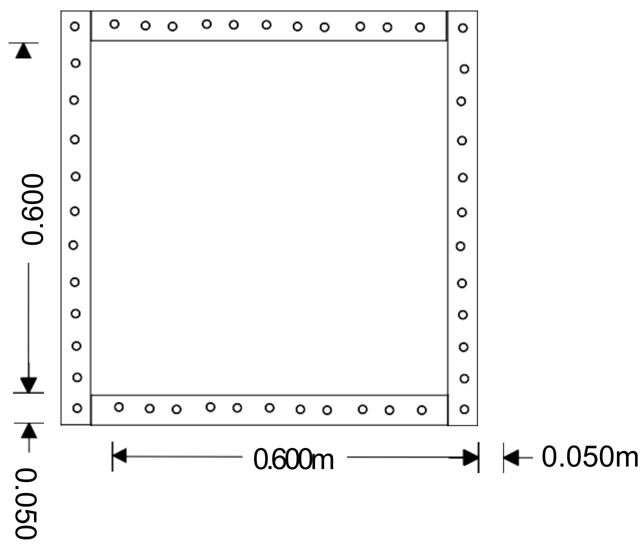


Figure 11

A panel is seamless, with a conductive 5 cm perimeter area, which must be fixed to the metal wall of the chamber to verify the composite-metal junction.
A drilling mask must also be provided to pierce the panel.

The second panel consists of two half-panels. The junction must be done with the same technique as that used to fill in the shield modules. Therefore, the geometry of the merge area must be agreed with the vendor.

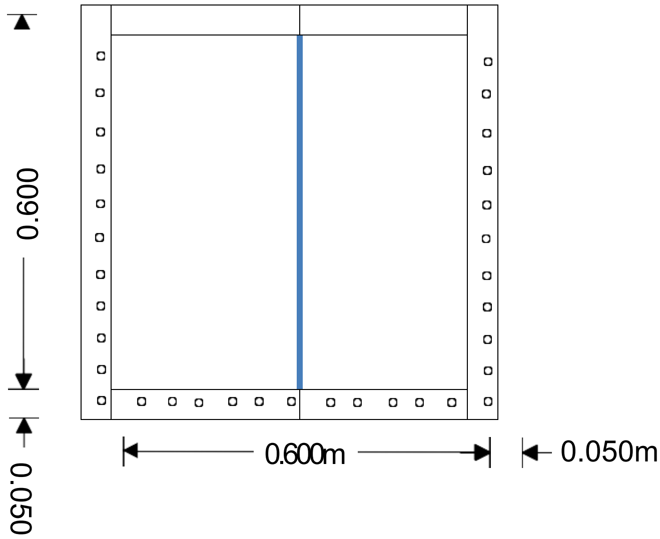


Figure 12

The requirement to be met is to have shielding greater than 40 dB in each configuration in the frequency range between 2 MHz and 18 GHz.

A factor of 100 allows you to be reasonably sure that the full shield requirement (>20 dB) is met.

Test procedures

The measurement was carried out as per following procedure according to the Military Standard 285 and the lEEE standard 299-1997:

-signal recording with open hole

-signal recording with the panel installed

-comparison of signal measured in dB

The measurement is preceded by the site calibration placing on the hole a steel panel with high shielding capability. This test is necessary to know the maximum level of shielding, changing the frequency, that it is possible to measure.

For all measurements both the transmitting antenna as the receiving one are located at 1 m from the tested panel. The transmitting antenna is located in the test room and the receiving one in thecontrol room. The measurements are carried out with the system Hp 8510B in sweeped mode from 45 MHz to 18 GHz.

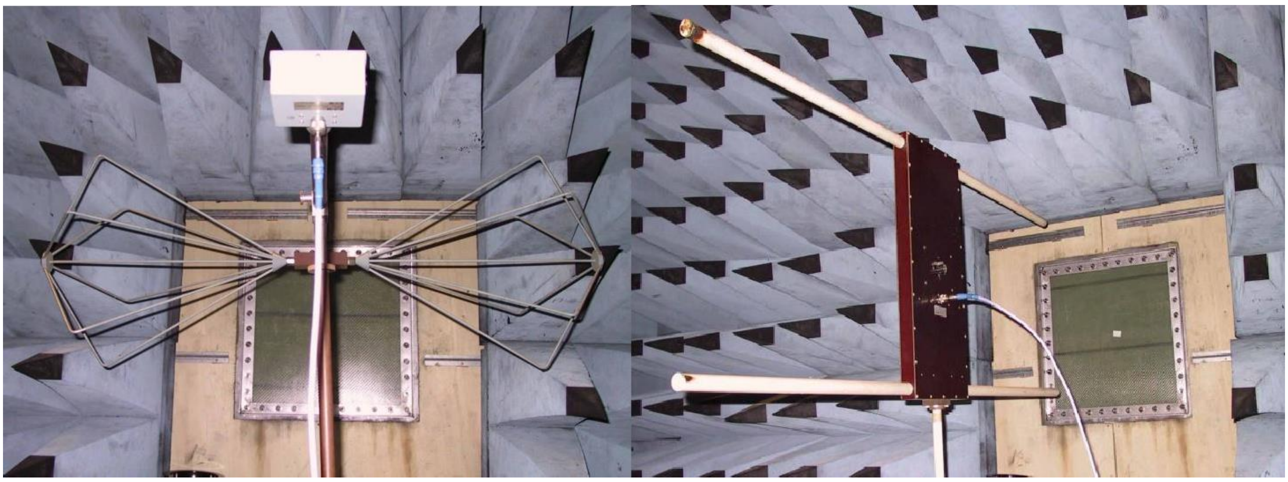


Figure 13

The structure that allows the sample locking on the 600 x 600 mm hole is composed of n° 40 bolts of 10 mm diameter, welded on the central wall of the room around the hole.

The bolts can be interfaced with the sample holes. A light alloy frame of external dimension of 700 x 700 mm and internal dimension of 600 x 600 mm, also holed as the panel, locks the sample. The nuts that lock the frame and the panel against a conductive gasket of the same frame dimensionare screwed on the bolts. The gasket is in electrical contact with the room steel structure. The driving torque on each bolt is 50 Nm.

Photos of the interface structure are shown in the figure below.

Figure 14

With reference to the section "RCS reduction"

The gun equipped with this shield is installed on ships with good stealth characteristics. Therefore, the inclination of its walls must be at least 15° with respect to the vertical to ensure a low RCS (radar cross section). Where this is not possible, particularly in the gunport area where the walls are vertical and in the rear area where there is a risk of reflection towards the dashboard of the secondary lobes of the on-board radar beams, *radar absorbing material (RAM) material should be applied.* This security topic will be better described later.

With reference to section “Shock”

The shield will have to withstand shock loads applied at the same time:

vertical shock: 500 m/s^2 (static load);

horizontal shock: 300 m/s^2 (static load).

These values were provided to us by the shipyard for frigate-type vessels.

It would be convenient to refer to stricter values deriving from the specification of the US navy MIL-S-9010 because it is adopted by all navies.

With reference to section “Green water load”

The shield must withstand a static pressure of **1 bar** applied to the side surfaces and the sky. This way of defining green water load derives from the American legislation for the sizing of ship superstructures and all devices installed on the sun deck.

Comparative analysis of construction materials for naval artillery shields

As already introduced, the emergence of ever new materials technologies makes it necessary to constantly evaluate the possibility of their application in defense systems, to give them performances to the state of the art.
Nuova Connavi has carried out a technical/economic exploratory investigation in the field of composite materials and their usability in place of aluminum alloys for the realization of external protections (from this moment in the text defined shields or domes) placed to cover the organs of naval artillery that do not need to operate in an exposed manner.

Objectives of benchmarking

The purpose of this analysis is to identify the critical parameters that characterize the good functioning of the shields, review what has been achieved previously, critically analyze the characteristics of the new materials available on the market and compare them with those of the products currently used, in relation to performance and costs.

a. Mechanical properties

The shields of naval artillery are primarily intended to preserve mechanical, electrical, and hydraulic organs from the continuous wear and tear operated by marine weather agents, characteristic of the operating environment. This protection is necessary to ensure the reliability of the plants.
The resistance sizing must consider the so-called "wave shot", a feature that takes into account the ability to counteract stresses caused by seawater masses accidents in the event of extreme weather conditions. In relation to this requirement, the "ultimate tensile strength" and the "elasticity modulus" (or Young modulus) are decisive characteristics in the choice of materials.
Mechanical shock resistance is verified according to the requirements dictated by the typically applicable regulations (MIL-S-9010 standard).

b. Thermal transmittance

A low transmittance is the ability a shield must have to thermally isolate an artillery from the external environment. It is an important property in order to allow the delicate components of the plant to operate in a correct range of temperatures and to contain the formation of condensation and water vapors within permissible limits.

c. Decay of characteristics

The materials selected for application must conserve their general characteristics throughout the life cycle of the application if they are ordinary maintained. The corrosion is the classic degradation that metal materials undergo in a marine environment. Non-metallic materials and some composites, however, can also be afflicted by various deterioration phenomena due to environmental agents manifesting themselves by delamination and bubble formations; in this sense, due account must be taken of:

- the intrusion of moisture into the resin;
- the UV agent of sunlight;
- atmospheric oxygen;

- polar solvents (the same seawater);
- the combustion residues of the launch charge;
- acid compounds that may be present in the environment, with aggression dependent on their pH.

The effects of these phenomena are reduced for any material used by separating the sacrificed material from the damaging agent, for example by protection with painting or other.

d. Radar Cross Section

The reduction of the so-called "Radar Cross Section" of modern military naval units is a very influential factor in the design of the emerged part of naval units. The techniques used to reduce it are aimed at postponing the least electromagnetic energy possible to the RADAR emitter; the rules applied are in summary as follows:

- reduction of all reflective roughness;
- spatial arrangement of flat surfaces in such a way as to divert electromagnetic energy in a direction other than that of origin (e.g. upwards; hence the pyramidal forms observable in the superstructures of all modern constructions);
- adoption of Radar Absorbing Material (RAM), materials that have the property of dissipating electromagnetic energy, reflecting an infinitesimal part of the waves or translating their frequency.

All objects whose installation is provided for on deck or on the superstructures of ships must be designed with these criteria; the shields of the cannons should not be an exception. The materials to be used for their realization must therefore be easily shaped to create appropriate shapes and/or have the required radio electrical characteristics or, again, be easily integrable with RAM material.

e. Shielding

Modern artillery is now equipped with distributed electronics even in the vicinity of the gun carriage; these devices are considered for EMI/EMC purposes, since a military vessel is an impervious environment from an electromagnetic point of view.

It is therefore necessary, even for artillery, to reduce the probability of interfering and being interfered with, by preparing appropriate shielding.

Shielding plays another important role in protecting against electromagnetic pulse (EMP) originating from atmospheric discharges (the so-called LEMP) or from a nuclear device (NEMP). To return to the more common case of an atmospheric discharge on sea surface, it can produce currents of the order of millions of Amperes over the ionization arc; this current causes electromotive forces induced in closed circuits which, in turn, they can generate high-value currents that can damage the components of electronic circuits and put them out of use.

The shielding is obtained through the realization of the so-called Faraday Cage, that is, a container whose surface enjoys a condition of electrical equipotentiality, and for this reason it is impervious to the propagation of the electromagnetic field.

The design of the new generation shields must take this feature into account; it is intrinsic if these are metal domes while it is to implement if these are domes in non-conducting material. In the latter case, the application of film or conductive mesh must be easy to make.

f. Weight containment

The weight of the product and another important parameter for the choice of the materials that make it up. Reducing weights that are distant from the ship's centre of gravity helps to increase its stability. For this particular application, the limitation of the masses also allows, with the same power of the gear motors, to obtain higher angular accelerations or, with the same angular accelerations, the use of lower electrical power.

g. Aesthetic defects

The artillery domes constitute, also from the point of view of design, a continuum of the aesthetic line of the naval unit and the quality of the finishes must be as constant as possible over time, without prejudice to ordinary maintenance operations.
Immunity from deterioration already described in paragraph 3 above should be considered, also in relation to aesthetic aspects, in the selection of the material to be used for the realization of shields.

h. Dangerousness, safety

In this analysis it is particularly important to consider for safety purposes the effects of the fields generated by ship's on-board radars and reflected by superstructures including the shield, which is normally installed at a great distance from radars.
The radiation generated by a radar system is radiated predominantly within the main lobe even though a not inconsiderable part of the energy is transmitted by the secondary lobes. The secondary lobes, compared to the main lobe, have different angles, and depend on the frequency, size of the radar and the type of radar. So, while the main lobe never impacts the structures of the ship, the secondary lobes instead can illuminate part of the superstructures and in particular the areas further from the radar, thus the bow is the most exposed area. These zones are usually forbidden to the personnel when the radar is emitting as fields of 500-600 V/m can be reached (population exposure limit 6 v/m limit for workers 60 V/m).
Naval cannons are generally installed on the bow of ships and constitute an obstacle to radiation which is reflected, as seen in Figure 15, and depending on the geometries or other obstacles may affect any point above deck.
Theoretically, simulations can predict, for all possible shield positions, the location of hazardous areas by modeling ideal surfaces and simplifying structures. Unfortunately, the lack of perfect surface flatness and lack of important details for radar frequencies make this type of analysis unreliable.
The not perfect flatness of the cannon shield surfaces (particularly noticeable in an aluminum shield) can direct reflections in predictable directions. In addition, in real operating conditions, even small objects (crates, etc.) can be placed on the deck of the ship, reflecting the field in uncontrolled directions.
Fields of several hundred div/m are dangerous to health and are not eligible by law. There are also serious risks of malfunctions and safety on equipment invested by super radar fields of 200 V/m, this is in fact the maximum field provided during the qualification phase for all the equipment installed on the deck of the ship.
Serious problems can also arise if such reflections are towards the same radar source, which generated the field, in fact the consequences can range from the malfunction of the radar to the breakage of the receiving stage.

As a result of these observations, the construction of the composite shield will be entirely made with broadband Radar Absorbent Material.
This would allow us to shoot down the incident energy up to 100 times and the reflected fields up to 10 times.
The adoption of broadband material would allow it to operate over a wide spectrum of frequencies covering all radar emission frequencies on board the ship.

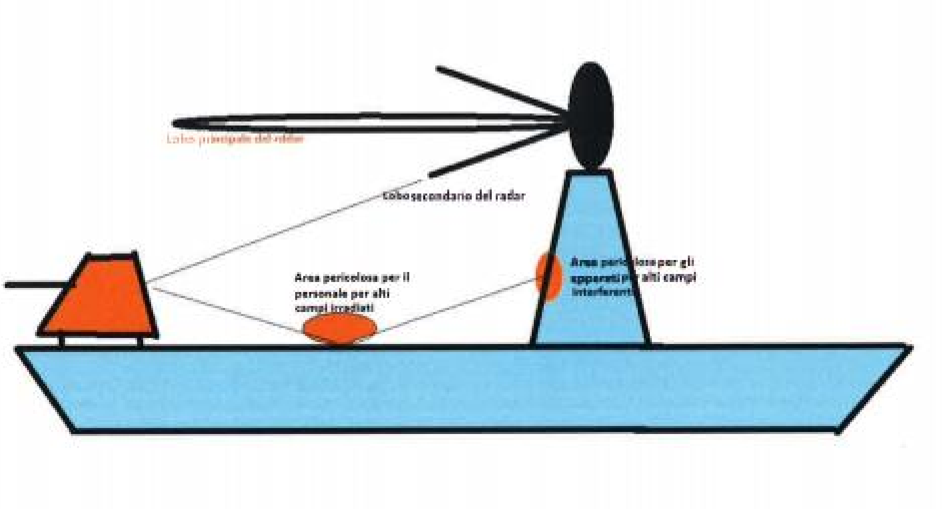


Figure 15

In the case of aluminum shields, if shield incident field simulations generated by the ship's radar confirm high fields >100 V/m, it is necessary to reduce shield reflections with Radar Absorbing Materials. An aluminum shield in these cases is not suitable since:

- RAM cannot be integrated on its surface. In fact, the environmental conditions to which the shield is subjected do not allow any anchoring or bonding of absorbent composite materials.
- There are no methods for reducing incident fields on the shield or fields reflected by the shield towards radars/equipment and areas occupied by workers.
- The external processing of the surfaces of the aluminum shield does not allow to reach the flatness tolerances of a composite artifact, this leads to a dispersion of the fields in uncontrolled areas.

The attached table provides an in-depth benchmark of the main requirements of the composite solution compared to the aluminum one.

		Composite	**Aluminium**
Capability	**Description**	**Note**	**Note**
Green Water Load resistance	*Capability of the shield to withstand the impact of the waves without compromising its integrity and functionality in terms of structural resistance and capability to absorb the energy associated to the phenomenon*	The composite materials have a UTS at least of 300 MPa and Young's modules of 14 GPa, hence they can withstand loads up to 3 times the ones in aluminium solution, and deformations up to 5 times.	The UTS of aluminium Al 5083 (employed for the shields) is 130 MPa and the Young's modulus is 70 GPa. The green water resistance of this shield has been evaluated with FEM analysis.
Condensation behaviour	*Capability of the shield to avoid or minimize the formation of condensation on the inner surfaces. This phenomenon is strictly connected to the insulation capability of the walls of the shield. This phenomenon is particularly dangerous to the whole gun system, because of the continuous ooze above all the mechanical and electrical equipment installed on the carriage, which cause precocious corrosion, ageing and possibility of failures.*	The thermal conductivity of the shield composite sandwich structure is 0.033 W / m K.	The thermal conductivity of the aluminium structure of the shields is 13 W / m K, considering the internal insulating paint. It can be observed that this value is about 400 times higher than the composite structure one. Furthermore, for installation of the gun system on ships with air-conditioned gunbay, where the condensation phenomenon is more severe, the use of aluminium shield will force the installation on the carriage of dehumidifiers or thermal/ventilation systems.

Weight	*Capability to reduce the proper weight without affecting the resistance.*	Using the composite sandwich structure and following a new manufacturing process, the shield's mass is expected to be 600 kg without compromising the resistance of the system.	The weight of the employed aluminium shields is more than 1050 kg.
Shock resistance	*Capability of the shield to withstand the shock load in accordance with MIL-S-901D and STANAG 4142*	Similar shields with sandwich made of honeycomb passed without any problem the shock trials performed by US Navy on the gun systems.	The aluminium shield should withstand the indicated standards according to the results of performed simplified analysis. However, it must be pointed out that no systems have ever been tested.
Corrosion resistance	*Capability of the shield to survive in extreme environmental conditions with no external corrosion and minimize the maintenance activities.*	The plies of the composite sandwich structure are made by epoxy resins which do not suffer corrosion. There are shields in service since 1965 which accomplish the corrosion requirement without any problem.	Even if the employed aluminium is the 5083 one, which is the best in terms of corrosion resistance, it does not guarantee the same behaviour of the composite. Furthermore, it has to be pointed out that corrosion phenomena have occurred on the carriage of the gun system, made by the Al 5083, after 7 years of service during the first main overhaul.
Radar Cross Section (RCS) reduction	*This capability represents the behaviour in terms of RCS reduction due to the shield. It must be specified that RCS is an index of how detectable an object is with a radar.*	The composite materials structures can be easily implemented by means of RAM (Radar-absorbent materials), which can be integrated in the layers of the outer ply of the composite sandwich. In addition, it can be stated that the RAM so implemented become a structural element of the shield. The RAM should be applied only on the front part of the shield, where some areas are supposed not to be stealth for their shapes (and so reduce their RCS of more than 1 order of magnitude).	It is not possible to apply the RAM as in the composite structures.
Shielding	*Material or system capability to protect electronic equipment located inside the shield from electromagnetic interference generated by radar, communication antenna, jammer and so on.*	In a composite material structure is possible to integrate shielding function by means of process which ensure the stability of their performances along the time against the attack of marine environment. This is of fundamental importance in the joint area.	The metal has a good shielding feature, burnt must be taken into account that such performances can be affected by the presence of oxidated area on the outer surface and mainly in the joint area. The cause of such performance degradation is since the oxidated parts are electrically insulated.
Dangerousness, safety	*The ship radar emissions can be reflected by the shield structures toward uncontrolled directions and the electromagnetic field can rich high values in area were the personal may operate.*	The composite material can incorporate in its structure the electromagnetic absorbing function (Radar Absorbing Material), thus reducing significantly the radiation reflected part. In this way the level of electromagnetic field can be reduced to acceptable value by the safety standard.	On aluminium structure it is almost impossible to integrate radar absorbing material.

State-of-the-art materials and technologies

In the case of both aluminum alloys and composite materials, the structure typically adopted for shield paneling is the sandwich.

Thanks to its geometry, the sandwich guarantees adequate safety coefficients to the design loads, maximizing stiffness and exponentially minimizing weights compared to single-ply structures.

Sandwiches consist of the following distinct elements:

1. Two plies, one internal and one external, with high mechanical characteristics, able to withstand flexional loads, in particular wave blow;
2. An internal core, which has the task of stabilizing the plies and making them work homogeneously, which must withstand cutting efforts.

Sandwich panels are connected to each other by angular junction elements, which can be welded or cold connected with the panels themselves, in the case of aluminum shields. In the case of composite shields, they are made together with sandwich plies in the process of rolling the artifact. You can also easily increase the moment of inertia of the junction zone by applying syntactic foam cords that are then included in the sandwich after rolling the inner ply. The composite allows stratification limited to the junction area of unidirectional fabrics that give exceptional strength and stiffness to the junction.

Plies

In the case of composite sandwiches, the plies are composed of different layers made of glass or carbon fibers (multidirectional or unidirectional fabrics) typically impregnated with epoxy resins. The stratifications of several orthotropic layers are suitable to give the plies a near-isotropy, a property guaranteed in the case of aluminum plies (which, up to plasticization, can be considered homogeneous linear elastic isotropic).

The mechanical characteristics of the composite product are strongly conditioned by the production process adopted: manual impregnation does not guarantee high performance, nor structural homogeneity of the artifact and repeatability of the manufacturing process; the use of pre-preg (pre-impregnated fiberglass/carbon fabrics under controlled environmental conditions) and vacuum bag technology guarantees superior performance and greater possibilities of control and repeatability.

Aluminium products have alloy plies of Al (typically alloys of the 5000 and 6000 series, resistant to corrosion in the marine environment are used).

The following table shows the yield load Ys, the Young module E, and the specific weight W of the typical materials used for the plies. It should be highlighted that the data for pre-pregs are the optimal data achievable by autoclave manufacturing process.

Caratt	Unità di misura	Descrizione	Alluminio 5083	Alluminio 6082	PRE-PREG CON RESINA EPOSSIDICA			
					Grafite tessuto	Grafite unidirez	Fibra di vetro	Kevlar
Ys	MPa	*Carico di snervamento*	≈ 150	≈ 310	≈ 550	≈ 1400	≈ 430	≈ 400
E	GPa	*Modulo di Young*	70	70	70	≈ 140	24	30
W	kg/(m²*mm)	*Peso specifico*	≈ 2.7	≈ 2.7	≈ 1.6	≈ 1.6	≈ 1.9	≈ 1.4

Figure 16

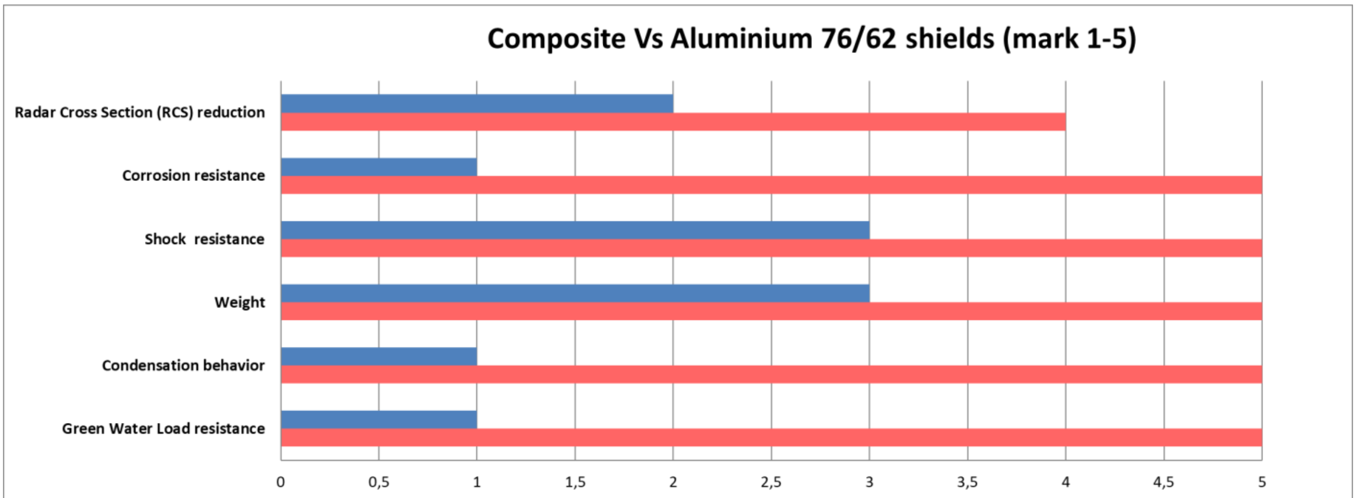
Core

In the case of composite products, the core is a honeycomb or expanded foam structure with low density (typically 80-100kg/m^3, and in any case not exceeding 200 kg/m^3). Cores with high density syntactic foam (over 400kg/m^3) are also adopted, which involve significant weights.
In the case of aluminum panels, the plies are typically separated by aluminum reinforcement elements (transverse or Greek saucer), which can be welded or riveted to the plies themselves. Alternatively, the entire panel (plies and internal reinforcement elements) can be made by extrusion.

Joints

In the case of both aluminum and composite panels, particular attention must be paid to the realization of the joints between panels. In the case of aluminium panels, these joints are profiled in aluminium to which the panels are welded or connected by cold joints.
In the case of composite shields, angular elements can be obtained by appropriate stratification of the same material as the sandwich plies, with which they guarantee a structural continuity.

The comparison table of the most important requirements of a shield shows the undisputed superiority of composite material. One of the greatest strengths of the composite is the mechanical resistance that is strengthened by the possibility of weight containment and thermal insulation. We point out that the type of manufacturing process adopted, especially in the case of composite products, is essential in order to guarantee the required technological performance over time, as the controls on the finished product do not allow to guarantee its quality exhaustively.
The development of new composite solutions will also have to consider the choice of the most suitable technology to be used to make the most of the potential of these materials.



	Green Water Load resistance	Condensation behavior	Weight	Shock resistance	Corrosion resistance	Radar Cross Section (RCS) reduction
Aluminium	1	1	3	3	1	2
Composite	5	5	5	5	5	4

Figure 17

The conclusions drawn by NC from this comparison of materials confirm that the validity of the requirement requiring the use of epoxy resin-based laminates that are the best in this type of application and also state-of-the-art solutions for structures (pvc core sandwiches, syntactic foam and prepreg use) and for production processes (use of vacuum bag and autoclave).

Choice of structure type, materials, and construction technology for the realization of the composite shield

Choice of type of structure

The proposal for the structure of the Nuova Connavi shield is based on the mechanical characteristics of the E-preg QE and the E-foam of its own production. The concept of structure is that of a modified sandwich structure. The sandwich consists of layers of E-preg QE and PVC cores in flat areas and E-preg QE layers, E-preg UE and E-foam cores in the corners.

The change to a pure sandwich structure is that the corners of the structure are reinforced to form a rigid and durable frame. The beams of this frame consist of the overlapping laminates of the flat surfaces with the addition of unidirectional laminates in the direction of the beam and with a sharp increase in the thickness of the core in E-foam. The structure is smooth even inside with continuous surfaces where the beam structure is not noticeable. This result can be obtained thanks to the possibility of E-foam constructions that allows the continuous connection of thicknesses and that allows to build products with the technology of Nuova Connavi single and double curvature surfaces.

Figure 18 shows the frame, it must be considered that this frame is not built apart but arises from reinforcements and overlaps of the sandwich structure.

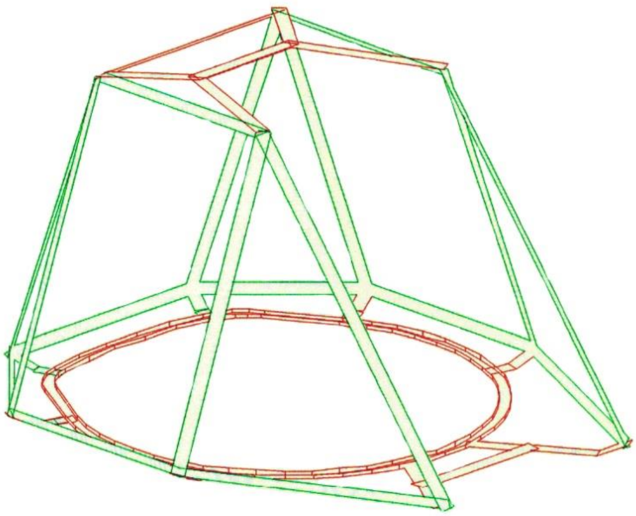


Figure 18: frame

Choice of material for the manufacture of plies: choice of the resin

Polyester, vinyl, epovinyl and epoxy resins could be used for our application. Given the environmental conditions in which the shield will operate, and the high stresses it will be subjected to when hit by the waves, there is no doubt that the most suitable resin system is the epoxy one, which has high static mechanical characteristics, fatigue, and impact, together with perfect resistance to seawater, hydrocarbons and does not contain toxic substances.

Great attention in the choice of epoxy resin should be paid with reference to the following parameters:

-workability

-toughness

-tacky (collosity) important because rolling will have to take place on vertical walls and over-the-top.

Choice of material for the manufacture of plies: Choice of the reinforcement

The choice is made between carbon fiber, S-glass and E-glass.

The carbon fiber is discarded, it could allow a significant weight saving but that we do not consider it suitable because its elastic modulus is too high and limits the elastic deformations (low deformation energy and resilience) necessary to better withstand the loads due to the wave shots. In addition, the use of carbon fiber would increase the costs of the product.

S-glass has a breaking load and an elasticity module about 20% higher than E-glass. It may be the right material for our application, but it has a cost close to that of carbon, which does not justify its use.

Our choice falls on the E-glass which is less resistant than the S-glass, has good resilience and low costs. Our choice was based on the results of many resilience tests made on carbon, S-glass and E-glass specimens at the CTS laboratory in Ceparana.

Characteristics of products of the E-PREG NC family used in the shield construction

Matrix material

The basis of the matrix material is an epoxy anhydride system, combined with a new B-staging method. (B-staging is a term taken from traditional Prepreg technology, it describes the process of changing the rheology of the matrix from liquid to a highly viscous or gel consistency, which is needed to work the material).

The B-staging is based on an IPN (Inter Penetrating Network). This means a second thermoset polymer is added to the resin. This second polymer is cured independently and is used for B-staging.

The result of this B-staging method is that the workability of the B-staged material can be perfectly adapted to the needs and that the consistency of the B-staged material does not change essentially during the heat up for curing. Therefor the material does not need any fixing, nor pressure for curing. This is the key for making large structures in an economically feasible way.

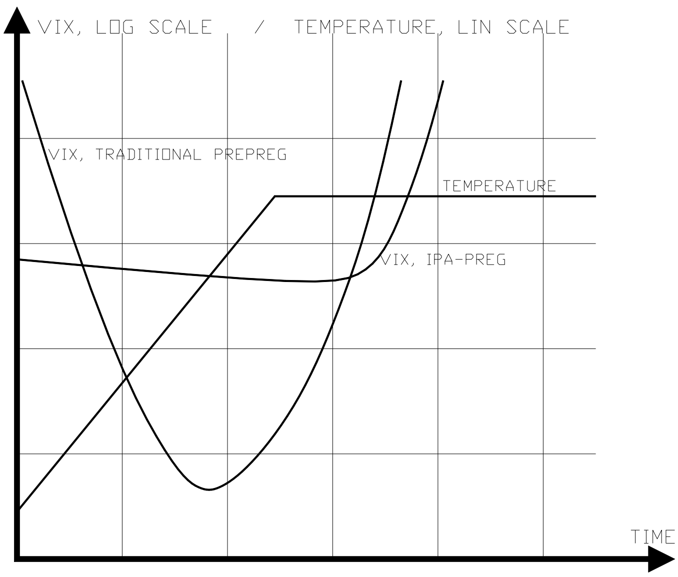


Figure 19

Figure 19 shows the difference in rheological behaviour between the proposed matrix material and traditional prepreg matrix materials. In heating up to 80°C the proposed matrix material changes its consistency by a factor of two. Traditional prepreg matrixes change by a factor of 10000 – 100000.

Features of the matrix:

- The material is nontoxic in all phases of transformation
- The volatile organic content (VOC) of the material is zero.
- The resins make a chemical bond with the glass fibre surface. The interlaminate shear strength of a laminate is 72 MPa (against 20 MPa in polyester laminates).
- The epoxy anhydride system has an excellent behaviour of chemical resistance (this type of matrix is used also for hot water pipes for district heating).
- The matrix has very good mechanical properties (3.5 GPa of modulus, 3.5 % of elongation at break). The optimal degree of toughening (by substituting epoxy and/or anhydride types) can be chosen for each application.
- The matrix is suitable to obtain a very good fire and smoke behaviour with limited amounts of additives (Al_2O_3, Phosphorous). The material is successfully used for external claddings in “Pendolino trains” in 7 European countries with a M1 F1 fire – smoke behaviour rating. (It is not possible to obtain a similar behaviour with polyesters because at high temperatures styrene depolymerises and feeds the flame).

Fibres

Standard E-PREG QE is produced with a 632 g/m^2 of E-glass quadriaxial fabrics. The E-glass fiber content is 52% by weight

Laminate and optimal fibre content

E-PREG QE does not follow the classical opinion “the higher the fibre content, the better the laminate”.

Too high fibre contents cause matrix cracks. These matrix cracks limit the fatigue resistance and are ways for water to penetrate.

The glass fibre content of E-PREG QE for ship building is 52% for optimal matrix crack behaviour.

The theory:

In cross plies, transverse fibres practically do not contribute to the deformation (the transverse modulus of glass fibres is 25 times greater than that of the matrix). The deformation concentrates in the matrix. The increase of deformation in the matrix as a function of the glass fibre content has been calculated:

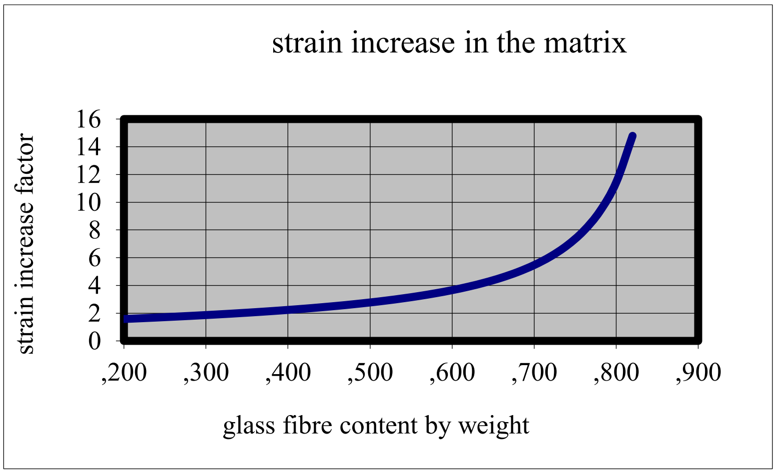


Figure 20: with increasing glass content the strain in the matrix grows much stronger then proportionally.

With the elongation at break of the matrix and the strain in the matrix the stress at microcrack limit has been calculated:

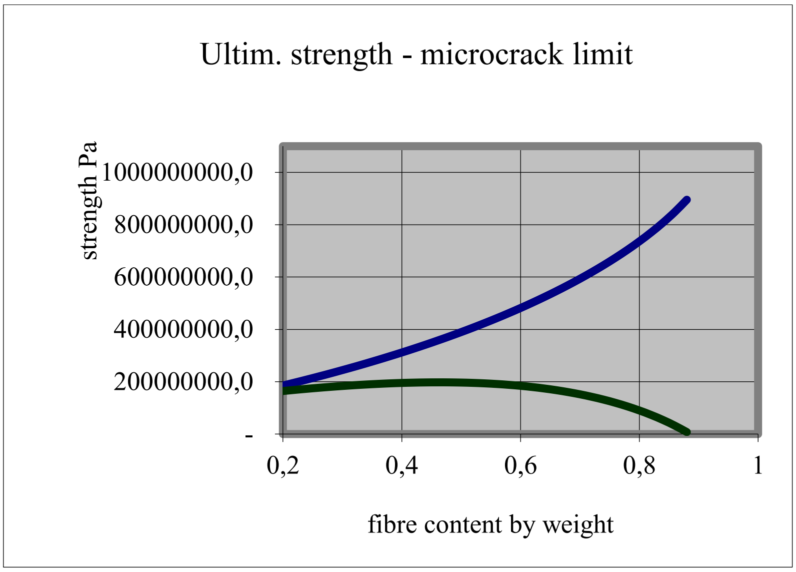


Figure 21 :The upper curve is the ultimate strength of an orthotropic laminate; the lower curve shows the stress at micro cracks in the matrix. These results show that the glass fibre content in cross plies must not exceed 55% by weight.

The E-PREG QE characteristics are

- Very high mechanical properties (UTS ≥ 270 MPa) for E-glass fibre.
- Very high fatigue resistance
- Very high shock resistance due its high resilience and tenacity
- Easy workability. It polymerizes without pressure; Autoclave or vacuum bag are not needed.

E-PREG QE has been developed for the building of hulls and structures of boats and ships with the aim to improve the performance compared to traditional glass fibre and to delete environmental and health problems due to evaporation of styrene and polyester used in nautical building.

Working with E-PREG QE

E-PREG QE is soft and sticky. It can be applied on molds like a biadhesive.

To obtain a stable stick the minimum radius of curvature is 40 mm.

Great thickness can be applied wet on wet. NC ha laminato su superfici piane orizzontali (sonar dome of the FREMM frigate) spessori fino a 100 mm

E-PREG QE can be laminated on vertical and overhead surfaces wet on wet up to about 10 mm of thickness without loss of stability. For greater thickness, the laminated must be stabilized before continuing by a thermal treatment. This stabilization could be accelerated with higher temperatures.

Characteristics of EPREG QE cured:		
Glass fibre content	52	% by weight
Ultimate Tensile strength	280	MPa
Young’s modulus	16800	MPa

Interlaminar shear strength	70	MPa
HDT temperature	110	C°
Thickness of one layer	0.72	mm
Weight	1.24	Kg/m²

CURING OF E-PREG QE

Stabilization

Stabilization is necessary if laminates with more than 10 mm thickness are produced on vertical molds or if you want to remove the counter molds from particulars with curvature rays below 50 mm.

Stabilization is obtained with a thermal treatment at 40°C for about 12 hours. After this treatment, the laminate cannot rise up or slide any more.

If the lamination should continue the 50°C temperature must not be overcome.

This to avoid a loss of superficial reactivity and a bad bonding of successively applied layers.

Semi-hardening

The semi hardening allows you to remove a piece from the mold and trim it without completely losing the responsiveness of the material. On semi-hardened products, a perfect adhesion of a subsequent rolling can be obtained.

Semi-hardening is obtained with a thermal hardening of 24 h at 64°C. it is important not to exceed this temperature so as not to lose the possibility of a chemical bond at successive stratifications.

Final curing

E-PREG QE cures with one of the following combination Time/Temperature:

16 hours at 80 °C

7 hours at 90°C

3.5 hours at 100°C

1.5 hours at 110°C

45 minutes at 120°C

30 minutes at 130°C

Solo dopo l'indurimento completo si ottengono le caratteristiche meccaniche e chimiche tipiche del prodotto. Un prodotto completamente indurito non permette un legame con ulteriori laminazioni.

Syntactic foam

E-Foam is a unique high performance sandwich core material. It is the same epoxy – anhydride system as the prepreg, with the same B-staging filled with hollow glass spheres. The unique property is that is a core material in B-stage.

This allows totally new way of producing sandwich structures. These new sandwich structures can easily be made with curves, also double curves and with varying thickness. On the base this new core material a completely new way of conceiving ship structures in composite material has been worked out. It will be explained later under "structures".

Sandwich structures with this syntactic foam as core have been tested for buckling under top load. Buckling load three to four times greater than with comparable aluminium honeycomb core sandwiches have been achieved.

This core material polymerises together with the prepreg, assuring a perfect bonding between core and laminate.

The polymerised foam has a mechanical consistency sufficient for keeping screws. Steel screws (chipboard type) of 5 mm of diameter and 90 mm of length have been put unto the foam (leading holes must be drilled, otherwise it is impossible to drive the screws. The screws have been driven for half of their length and then bent with a hammer. The screw does not lose its grip in the foam.

The capability of the foam to keep screws can be used in assembly for fixing parts by adhesive bonding.

Properties of E-Foam

The characteristics are:

- Very high mechanical properties (20 MPa)
- High HDT >85°C and good thermal stability
- High fatigue and shock resistance.
- Easy workability in b-stage
- It polymerizes without pressure. Autoclave or vacuum bag are not needed.
- Excellent resistance to compression, suitable for underwater applications with low weight (520 kg/m^3).
- Easy to machine and mill, same cutting speed as high-density polyurethane foam.
- Very high adhesion to sandwich E-Preg laminates

Working with E-Foam

E-Foam is soft and sticky. It can be applied on molds or laminates like a bi-adhesive film.
E-Foam can be laminated on vertical surfaces.
For great thickness, the underlying E-foam layers must be stabilized before continuing bya thermal treatment of 12 hours at 40°C.
This stabilization can be accelerated with high temperature (never more than 55°C.anyway).

Characteristics of E-Foam cured:

Property	Unit	Value
Specific mass	kg/m^3	480
Flexural strength	MPa	20
Tensile strength	MPa	15
Compressive strength	MPa	35
Shear strength MPa	5	
Young Moudulus	GPa	1,5
Elongation at break	%	1%
Heat Deflection Temperature or HDT/A(ASTM D 648 at 0,8 MPa)	°C	85

Curing of E-Foam

Stabilization

Stabilization is obtained with a thermal treatment at 40°-50°C for about 12 hours. After this treatment, the laminate cannot rise up nor slide.

If lamination must continue, the laminate should not be exposed to temperatures above50°C. This to avoid a loss of superficial reactivity and a bad bonding of successively applied layers.

Curing

E-Foam cures with this Time/Temperature diagram:

1 hours from 20°C to 50 °C

5 hours at 50 °C

3 hours from 50°C to 80°C
8 hours at 80 ° C

Choice of the PVC core

The cores we select belong to the Family of Divinycel H. They can withstand temperatures up to 110°C during the curing process, against the 80°C required for the curing of Nuova Connavi's E-preg QE and E-foam products.

Choice of construction technology

In the realization of the shield, we have provided Nuova Connavi's pre-preg epoxy specifically designed for applications of this type. It will be made with an impregnator equipped with an ultraviolet light lamp system to bring the resin system more anhydride to the gel state (B-stage) already at room temperature.
The treatment will take place after the application of the vacuum bag, at a temperature of 80°C through the use of a preheated mold. The access hatch will be processed in an autoclave.

Type of moulds

The mould will be open in stainless steel, heated with a flow of hot air in a closed circuit, equipped with a temperature sensor system for the control of hot air flow and prepared to make the vacuum bag seals. In the air circulation circuit, they are arranged with homogeneous distribution electrical resistors that heat the air, the air circulates at 10 m/s of speed. It has been shown that under these conditions the air shows a very effective heat exchange with the surface of the moulds and a temperature control accuracy of 1°C at 80°C has been obtained. The installed power allows the moulds to reach the temperature of 80°C in about 2 hours.
The choice to make stainless steel moulds, which do not require the prior construction of a model such as composite ones, was made to lower non-recurring production costs.

FEM analysis for the verification of specification requirements

1 REFERENCE DOCUMENTS

	Riferimento/Numero	**Titolo.Doc**
R1	SST157616888	Technical Requirement Specification of Composite Shield for MK 71 MOD 2
R2	CNR-UNI 10011	Costruzioni di acciaio (istruzioni per il calcolo, l'esecuzione, il collaudo e la manutenzione)
R3	RELAZIONE CTS 3408	
R4	RELAZIONE CTS 165617	
R5	RELAZIONE CTS 151117	

Tabella 1 - Lista documenti di riferimento

This paragraph describes the results of the analyses carried out to verify the compliance of the Shield of the MK 71 MOD 2 with the specification requirements. The approach adopted initially involves the characterization of the materials used in the realization of the shield, followed by the determination of the stresses acting on the shield (global model), and finally the detailed analysis of bolted joints and the most urged areas by sub-modeling.

An analysis of the requirements showed that the load condition induced by the wave impact pressure (Green Water Load) is by far the most significant.

This condition was therefore adopted for the verification of design parameters (rolling thicknesses and cores).

Having obtained the sizing able to meet the heaviest load condition, we moved on to the verification, for analysis, of the remaining specification requirements.

1. SAFETY COEFFICIENTS

In the following analyses the stresses will be evaluated in the different elements that make up the composite with which the shield is made.

1. As far as fiberglass layers are concerned, the stress is translated into the Tsai-Wu coefficient (TW) which, with a maximum of 1 corresponding to the breakage of the first foil, provides an index of the stress on the foils.
2. As far as cores are concerned, the shear stress of the cores is investigated, representing the latter the most common cause of breakage.
3. The safety coefficient adopted is 1.5; this value is adopted in view of the particular burdensomeness of some of the stresses applied (in particular the wave shot) and the detail of the models made.

2. MATERIALS

The shield will be made of sandwiches of composite material consisting of layers of quadriaxial laminate of glass-E (the number of which varies in the different portions of the shield) and polyurethane core of type and thickness also variable.

In particularly solicitous areas and areas of complex geometry, the core is replaced with a syntactic foam.

3. QUADRIAXIAL LAMINATE

The quadriaxial laminate used for sandwich skins has the characteristics summarized in the following table.

Proprietà	
Young modulus E_{xx} [MPa]	15066
Young modulus E_{yy} [MPa]	13895
Young modulus E_{zz} [MPa]	8375
Shear modulus G_{xy} [MPa]	2940
Shear modulus G_{yz} [MPa]	2940
Shear modulus G_{xz} [MPa]	2940
Poisson coefficient ν_{xy}	0.33
Poisson coefficient ν_{yz}	0.15
Poisson coefficient ν_{xz}	0.15
Tensile strength (direction x) [MPa]	256
Compression strength (direction x) [MPa]	-267
Tensile strength (direction y) [MPa]	228
Compression strength (direction y) [MPa]	-262

Tensile strength (direction z) [MPa]	103
Compression strength (direction z) [MPa]	-155
Failure in the plane xy (laminar cut) [MPa]	59
Failure in the plane yz (transversal) [MPa]	156
Failure in the plane xz (transversal) [MPa]	156

Table 2 – Characteristics of composite material

From the properties listed in the table it can be seen that the behavior of the material in the plane, strongly influenced by the presence of glass fibers, is equal in the x and y directions.

As far as the third direction is concerned, the behaviour is linked to the mechanical properties of epoxyresin.

A single foil has an average thickness of 0.7mm.

The density of the laminate is 1.52×10^{-6} kg/mm^3.

The properties shown in Table 2 have been extracted from the experimental report ref. R4 and, for values not shown in it,from a relation to ref. R3

2 CORE

The core of the sandwich will be made using two different polyurethane cores, The Divinycell H100 and Klegecell R80.

The properties of the above materials are summarized below:

Proprietà	Test	Unità	H35	H45	H60	H80	H100	H130	H160	H200	H250
Densità Nominali 1)	ISO 845	kg/m^3	38	48	60	80	100	130	160	200	250
Resistenza a compressione 2)	ASTM D 1621	MPa	0.45	0.6	0.9	1.4	2.0	3.0	3.4	5.4	7.2
Modulo a compressione 2)	ASTM D 1621	MPa	40	50	70	90	135	170	200	310	400
Resistenza a trazione 2)	ASTM D 1623	MPa	1.0	1.4	1.8	2.5	3.5	4.8	5.4	7.1	9.2
Modulo a trazione 2)	ASTM D 1623	MPa	49	55	75	95	130	175	205	250	320
Resistenza a taglio	ASTM C 273	MPa	0.4	0.56	0.76	1.15	1.6	2.2	2.6	3.5	4.5
Modulo a taglio	ASTM C 273	MPa	12	15	20	27	35	50	73	73	97
Allungamento a taglio	ASTM C 273	%	9	12	20	30	40	40	40	45	45
1) Tolleranza di densità ± 10%.											
2) Perpendicolare al piano. Valori misurati a +23°C.											

Figure 20 – Divinycell H Property Table

Dati Tecnici **Klegecell® R80**

Dati Tecnici Preliminari Klegecell R80

Proprietà	Test	Unità	R80
Densità Nominali	ISO 845	Kg/m³	80
Resistenza a compressione*	ASTM D 1621	MPa	1.35
Modulo a compressione*	ASTM D 1621	MPa	90
Resistenza a trazione*	ASTM D 1623	MPa	2.30
Modulo a trazione*	ASTM D 1623	MPa	95
Resistenza a taglio	ASTM C 273	MPa	1.15
Modulo a taglio	ASTM C 273	MPa	28
Allungamento a taglio	ASTM C 273	%	28
Conduttività termica +20°C	ASTM C 518	W/Mk	0.03

Figura 12 - Tabelle proprietà Klegecell R80

3 SINTATTIC FOAM

In particularly solicitous and/or complex geometric areas, the core is made using a moldable syntactic foam. The properties of the material are shown in the following figure.

Characteristics of E-Foam cured:

Property	Unit	Value
Specific mass	kg/m³	520
Flexural strength	MPa	20
Tensile strength	MPa	15
Compressive strength	MPa	35
Shear strength	MPa	5
Young Moudulus	GPa	1,5
Elongation at break	%	1%
Heat Deflection Temperature or HDT/A (ASTM D 648 at 0,8 MPa)	°C	85
Deflection Temperature under load DTUL-HDT/B (ASTM D 648 at 5 MPa)	°C	70
Thickness of one layer	mm	5-15

Figure 22

4 FEM MODEL

5 INTRODUCTION TO THE ANALYSIS

The purpose of the FEM model is the assessment of stress status and deformations in the different load conditions imposed by the specification requirements.

In this regard, a 3D model is created in which the walls of the shield are discretized by elements of type SHELL99, to which are attributed the rolling sequences, thicknesses and mechanical properties of the materials that make up the different portions of shield.

5.1 DEFINITION OF THE MODEL

The purpose of a global FEM model of the shield for the MK 71 MOD 2 cannon is to assess the stress status of the flat zones of the model and the forces exchanged in the junction zones. In this regard, a 3D model will be created in which the walls of the shield will be modeled with elements of type SHELL93 to which the properties of the equivalent homogeneous material will be attributed.

The SHELL99 element has six degrees of freedom at the nodal directions x, y and z and rotations around the nodal axes x, y and z, as can be seen in the figure 100.

The mesh has been defined by looking for the right compromise between the number of elements (and therefore the speed of calculation) and the accuracy of the results.

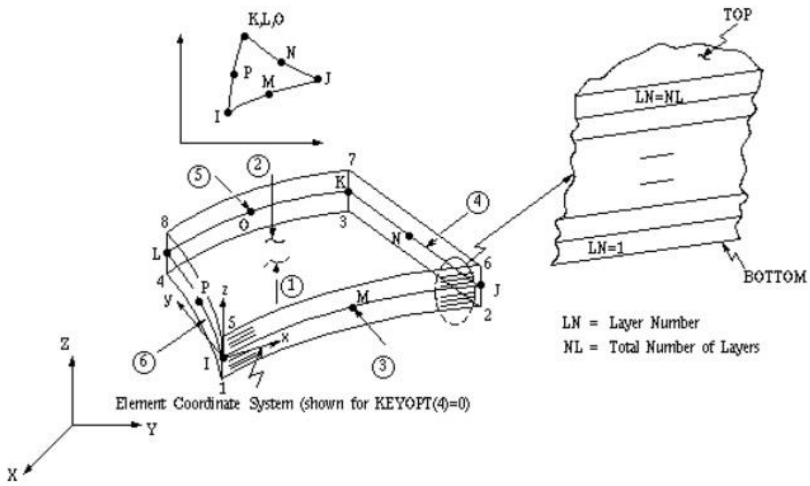


Figure 3 – SHELL Element 99

The thicknesses of the walls and the properties of the material, used in the FEM model, are those obtained by modeling the virtual specimen; the choice of the equivalent homogeneous material is made on the basis of weight minimization but ensuring that the requirements in the specification are met (as can be seen from the material library shown in the previous paragraph, in order to comply with the specification requirements, action has been taken on the thickness of the core, the density and consequently the elastic properties of the Divinycell, on the amount of quadriaxial laminate plies).

At this stage of design, after having determined the most suitable material for the realization of the shield, the flanges representing the junction zones were also modeled: on them the nodal constraining reactions were calculated on a line that ideally represents the junction. The purpose of calculating the forces exchanged in the junction is to optimize the diameter of the connections and their spacing.

For the purpose of evaluating stresses, flanges are considered glued to the junction zone.

Following the optimization analysis, it was possible to define the configuration of the shield as a combination of sandwich composed of 4+4 plies with cores in Divinycell H130 (thickness 30mm), sandwich composed of 4+4 plies with core in Divinycell H130 (thickness 40mm), and solid fiberglass.

The determination of materials and thicknesses was made on the basis of the load of green water load, which following several analyses carried out, required in technical specification, and described below, was found to be the most critical load condition.

6 DESCRIPTION OF THE FEM MODEL

Below is presented, in terms of materials and thicknesses used, the structure of the shield.

Each area is assigned a color corresponding to a different sequence of materials and thicknesses.

The following words are adopted:

1. nQX = n layers of quadriaxial laminate;
2. xmm K80 = x mm of Klegecell R80 core;
3. xmm H100 = x mm of Dyvinicell H100 cores;
4. xmm E-Foam = x mm of syntactic foam.

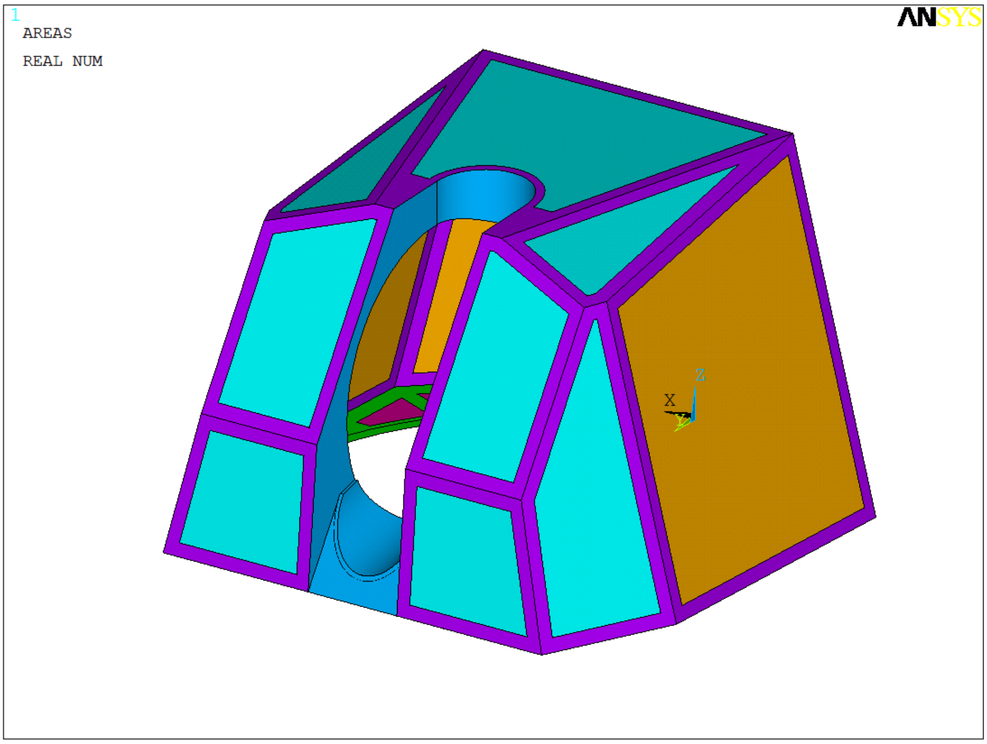


Figure 24

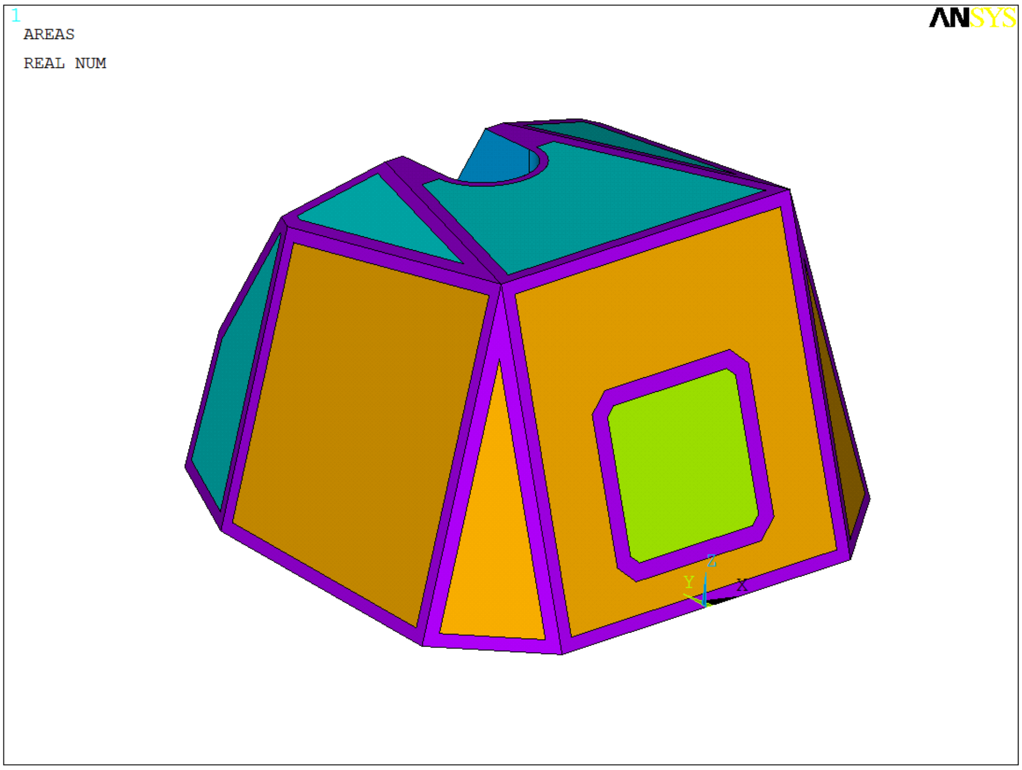


Figure 25 – Shield model - rear view5

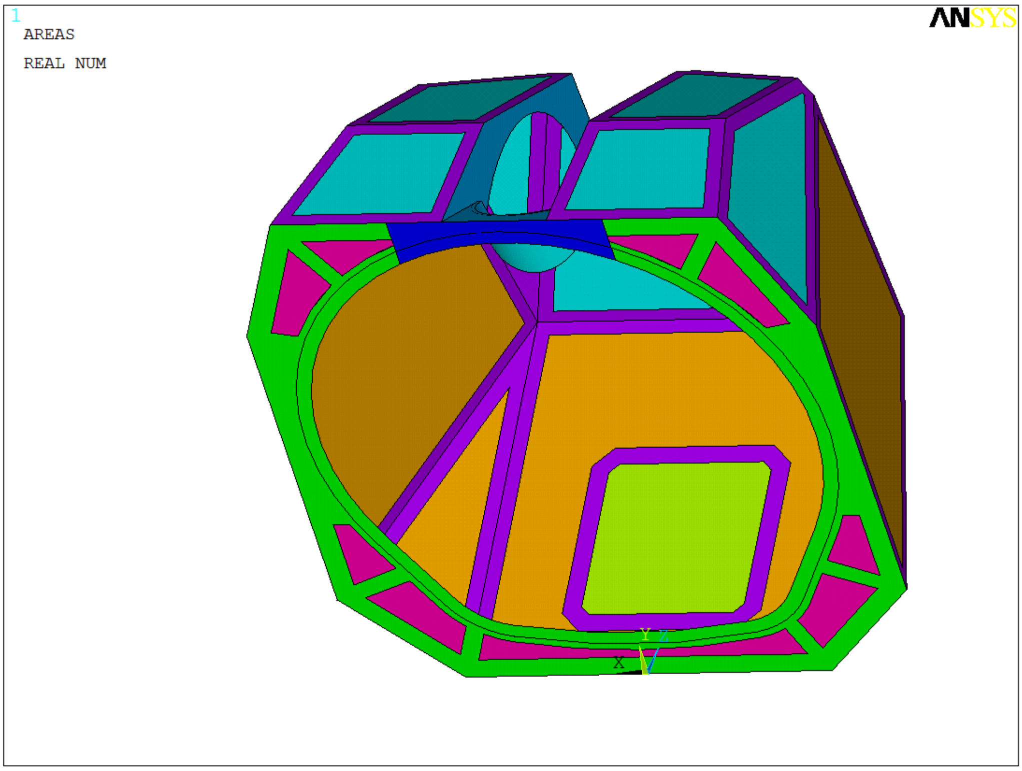


Figure 26 – Shield Model - Bottom View6

	3QX + 30mm H100 + 3QX

	4QX + 35mm E-Foam (min)* + 4QX
	3QX + 50mm k80 + 3QX
	3QX + 20mm E-Foam + 3QX
	3QX + 40mm H100 + 3QX
	5QX + 50mm k80 + 5QX
	5QX + 35mm E-Foam (min)* + 5QX
	20mm QX**

Figure 27guide

* = minimum thickness of syntactic foam

** = solid thickness 20mm

The model thus made has been discretized using Shell99 elements with a characteristic element size of 30mm. The discretized model is shown below.

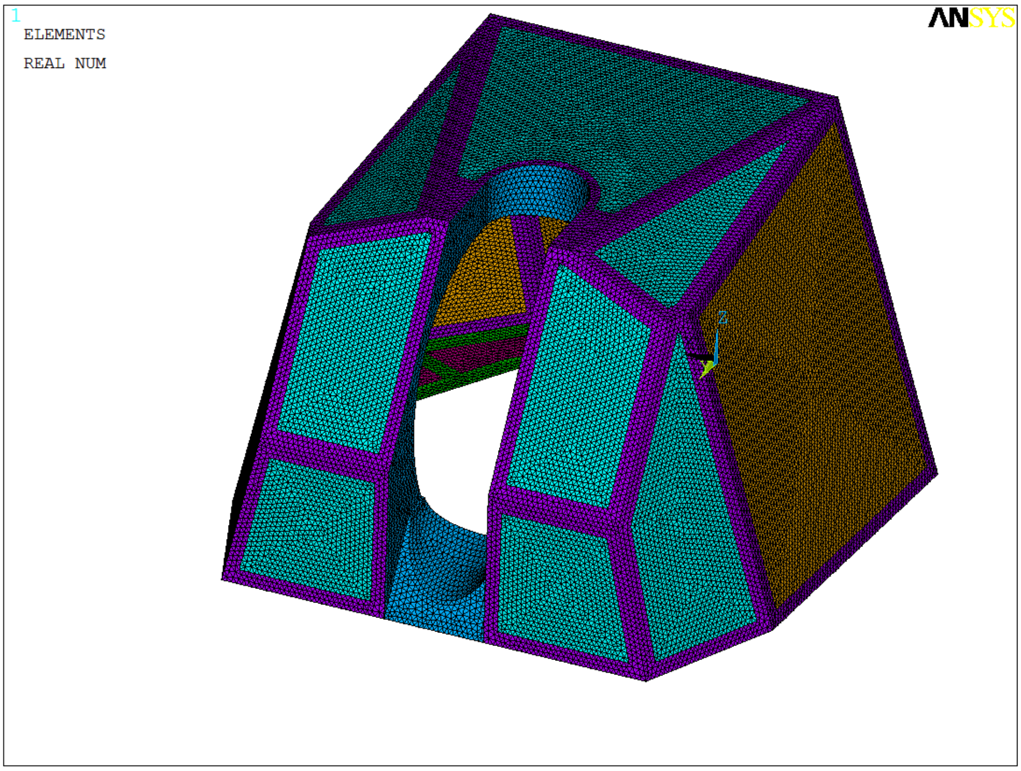


Figure 28

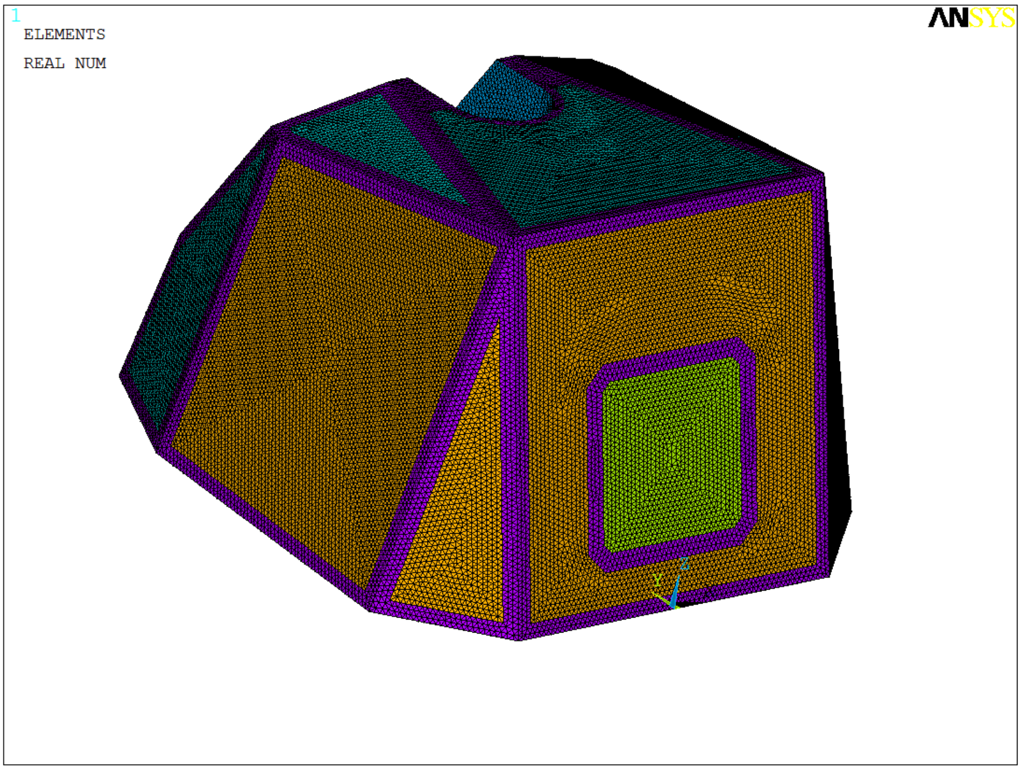


Figure 29

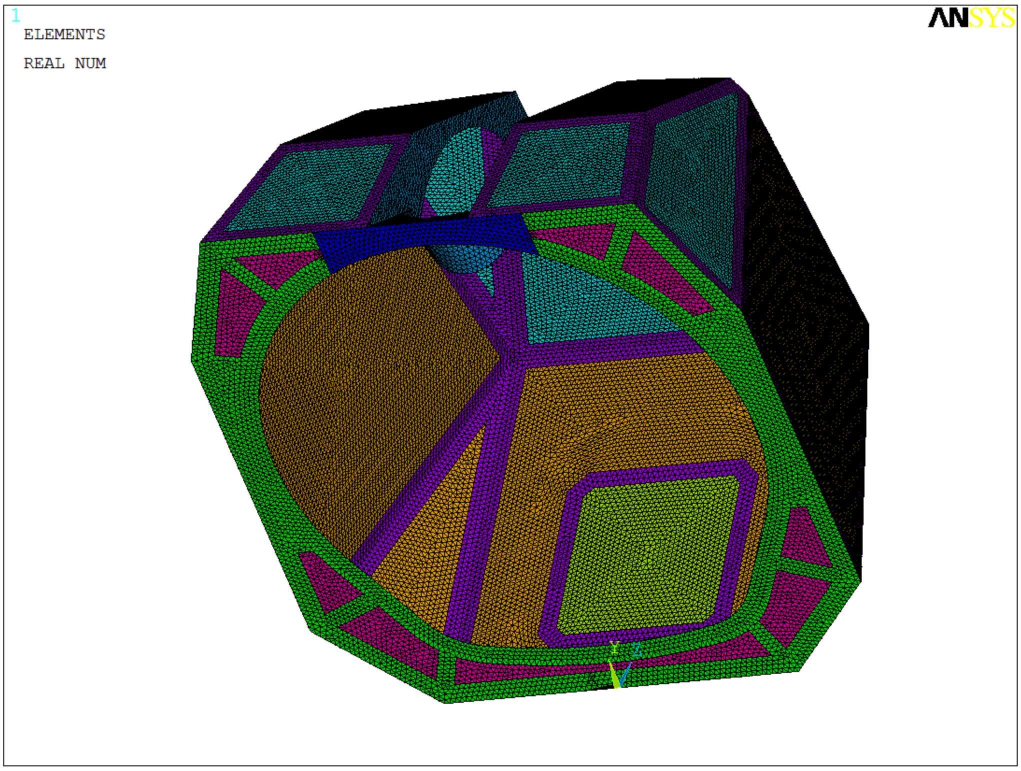


Figure 10

7 GREEN WATER LOAD (GWL)

The wave impact pressure is set at **1 bar** (0.1 MPa).

This pressure is applied as a hydrostatic load on all shield walls (with the exception of the base flange).

In addition to the loading condition described above, the starboard bow sea condition that best represents reality has also been analyzed. The pressure is applied only to the front, side, and top.

We do not report the results of the calculation because the values of stresses and deformations fall within the specification limits.

8 DEFORMATIONS

The maximum deflection allowed, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

In the following figures it is possible to appreciate the deflection, expressed in mm, in the various shield panels, subjected to the GWL load.

As you can see, the maximum value, equal to about 92mm, at the rear access hatch, is below the specification limits as well as the displacement on the upper panel equal to about 41mm.

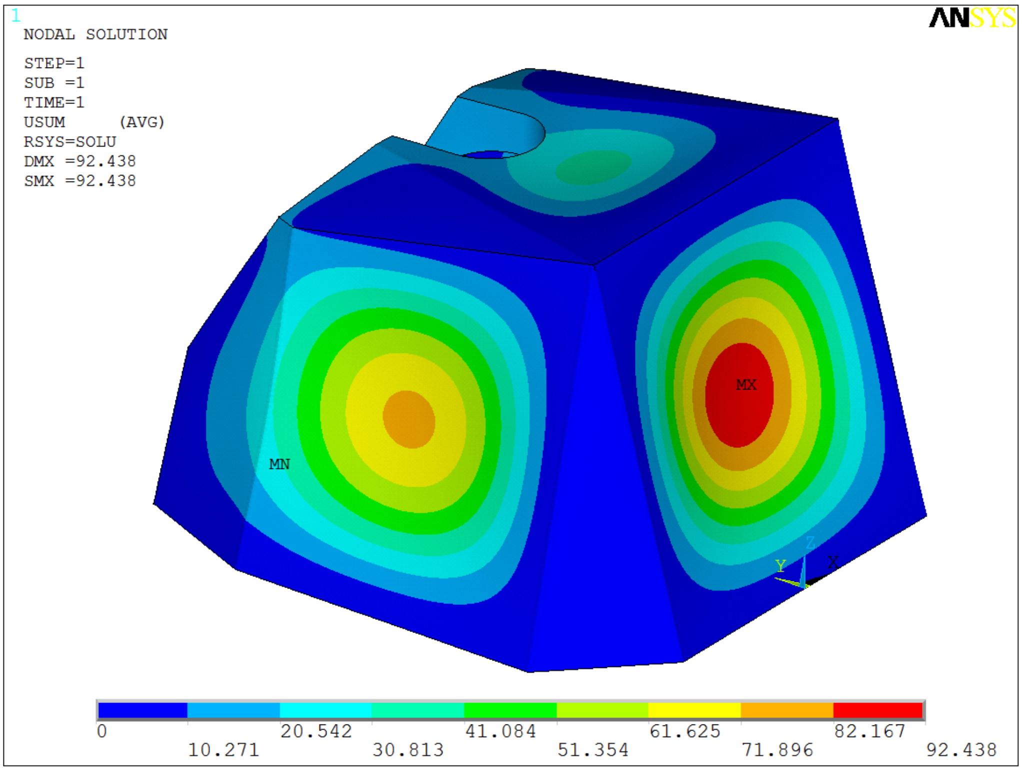


Figure 31 – GWL - displacement (mm)11

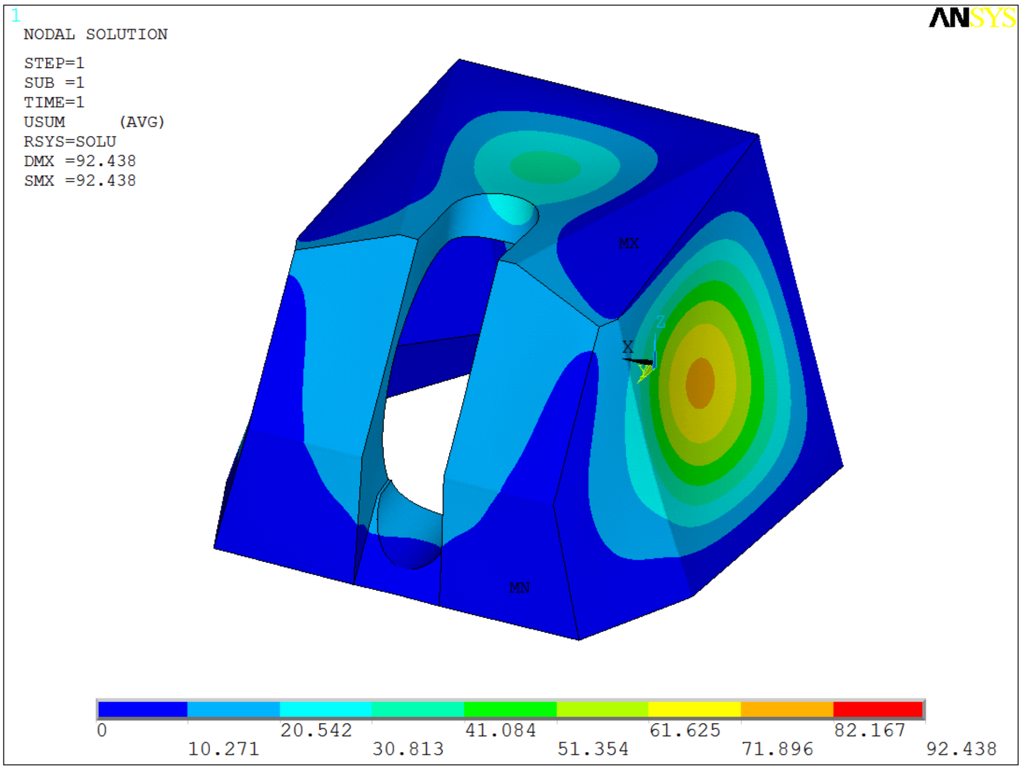


Figura 12 – GWL - spostamento (mm)

9 STRESSES

The stresses induced in the shield by the GWL load shall be compared with the maximum permissible loads for each material used.

10 FIBERGLASS STRESSES – TW COEFFICIENT

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

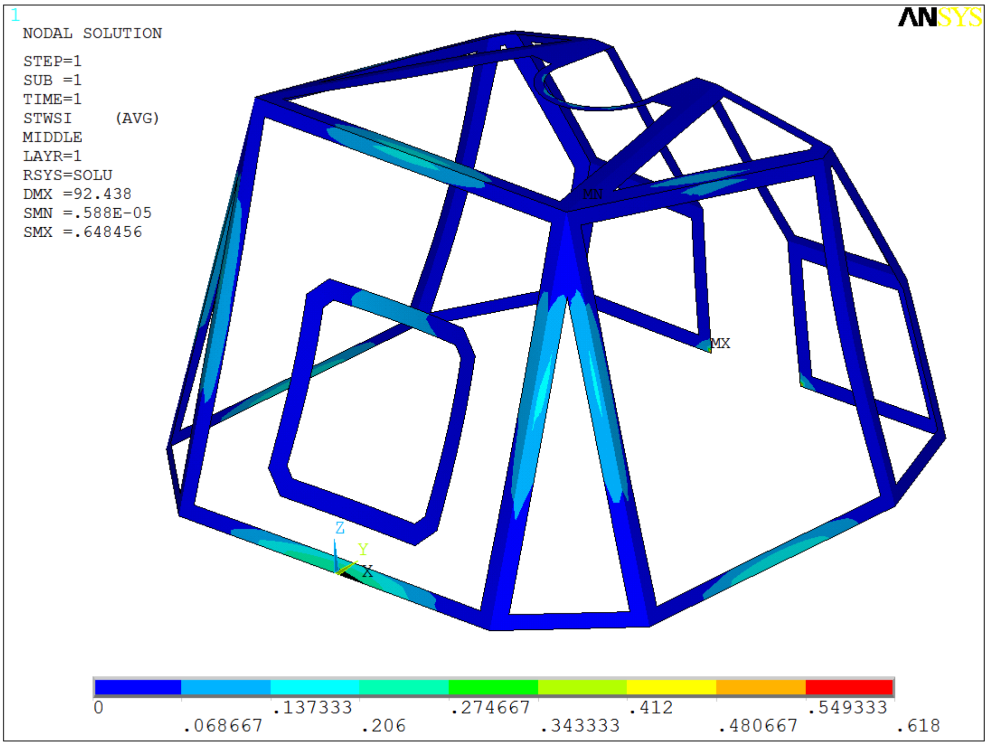


Figura 33 – GWL - Coefficiente TW

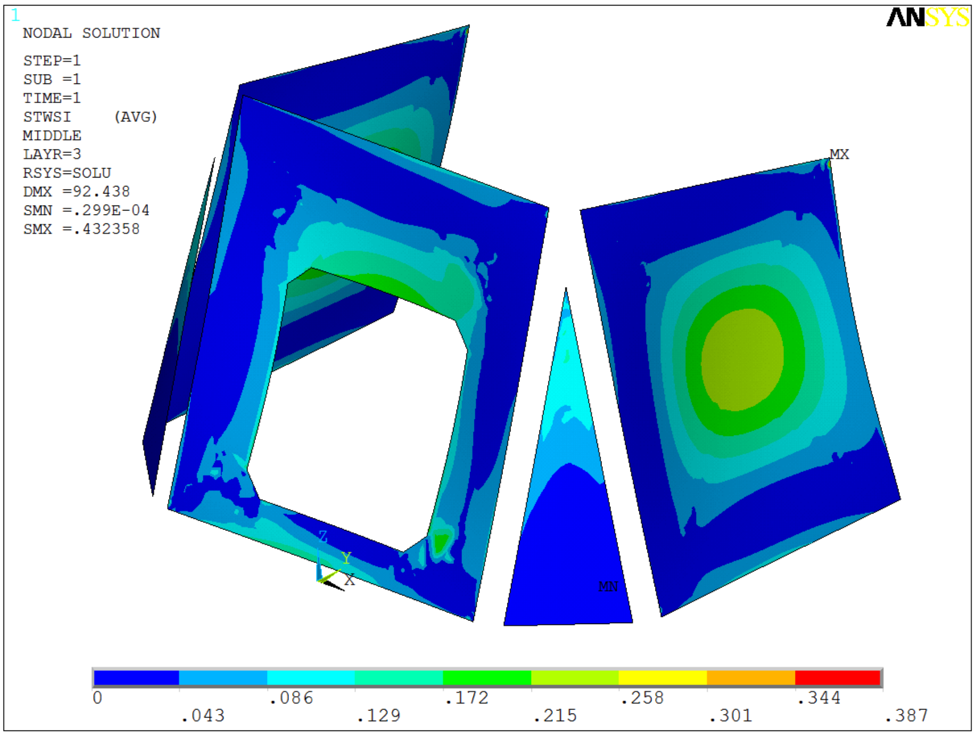


Figura 13 – GWL - Coefficiente TW

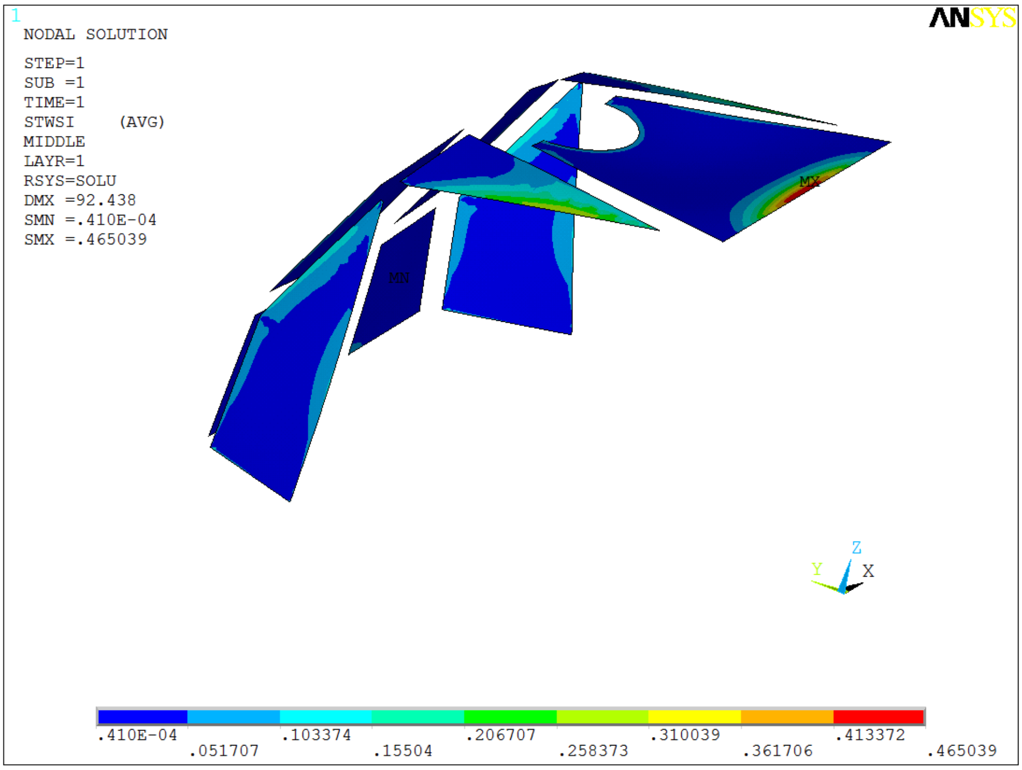


Figura 14 – GWL - Coefficiente TW

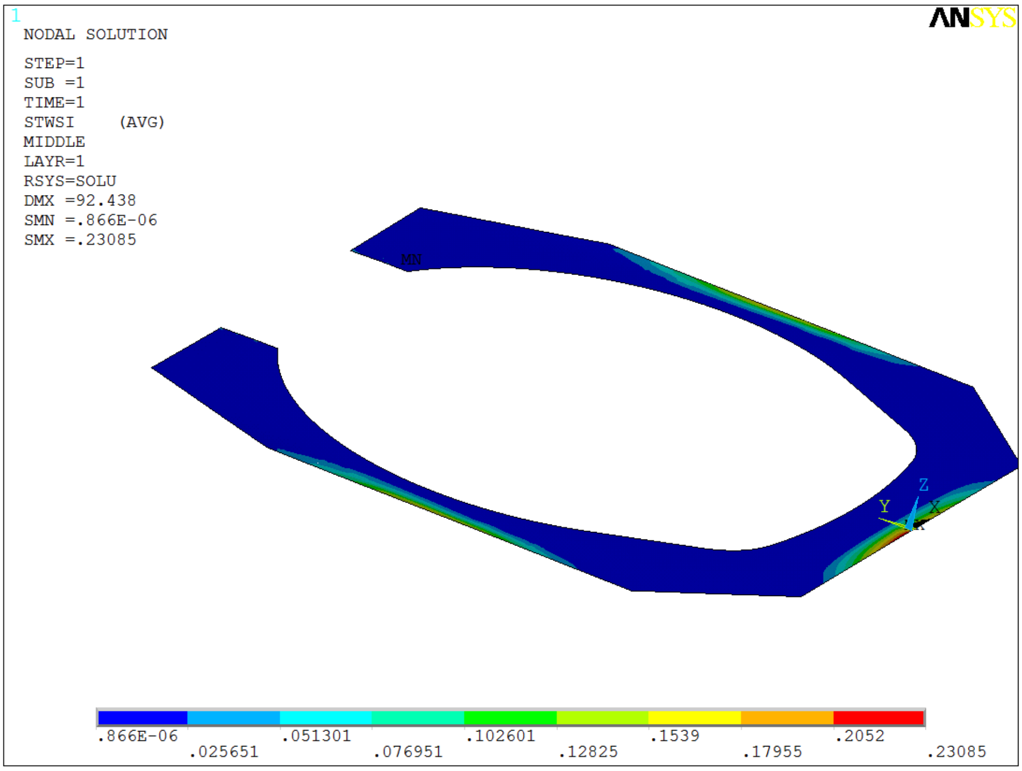


Figura 15 – GWL - Coefficiente TW

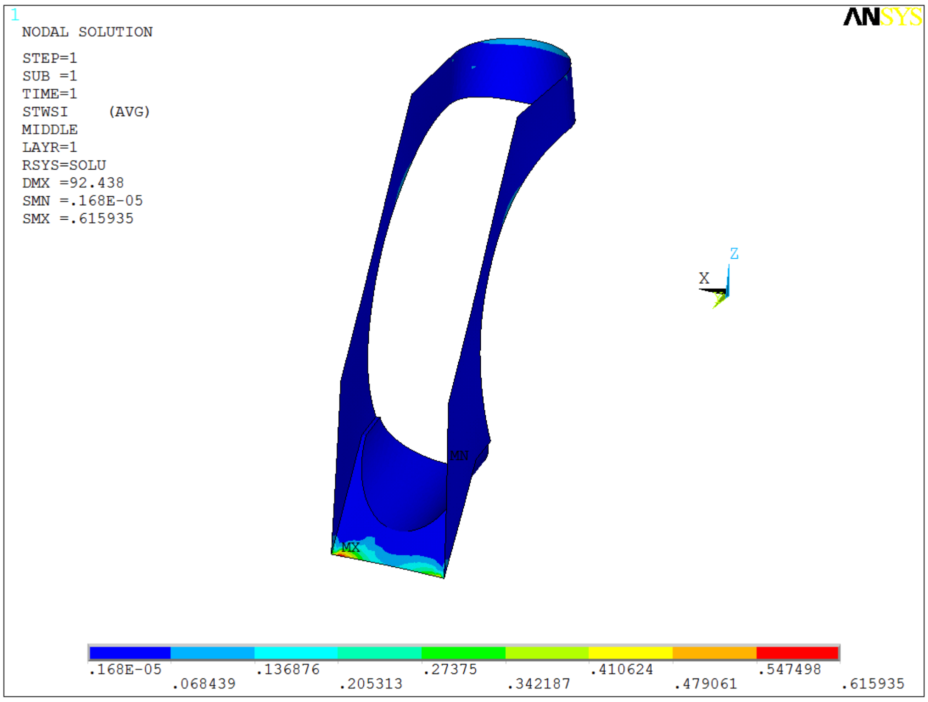


Figura 16 – GWL - Coefficiente TW

The maximum stress is on the front panels at the gunboat.
In these areas the coefficient of TW is about 0.61.
The resulting safety coefficient is CS = 1/0.61 = 1.63.

11 ANALISI A TAGLIO CORE

The following figure shows the trend of shear stress in shield areas made using syntactic foam.

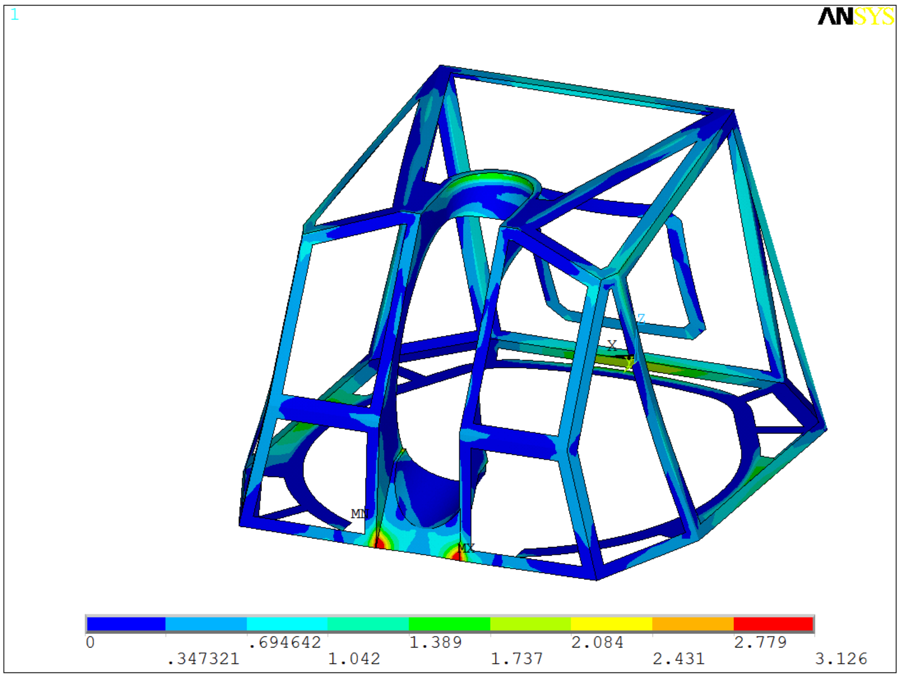


Figura 38 – GWL - Taglio (MPa) schiuma sintattica

La massima sollecitazione è pari a 3.1 MPa.

The shear strength of the syntactic foam is 5 MPa.
The resulting safety coefficient is CS = 5/31 = 1.61.

The following figure shows the trend of shear stress in shield areas made using Dyvinicell H100 panels.

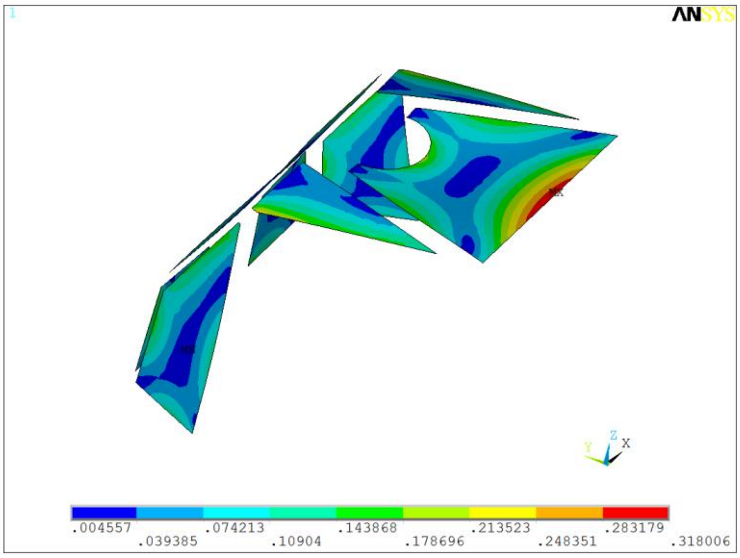


Figura 17 – GWL - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.3 MPa.
The shear strength of the Dyvinicell K100 is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.3 = 5.3.

The following figure shows the trend of shear stress in shield areas made using Klegecell R80 panels.

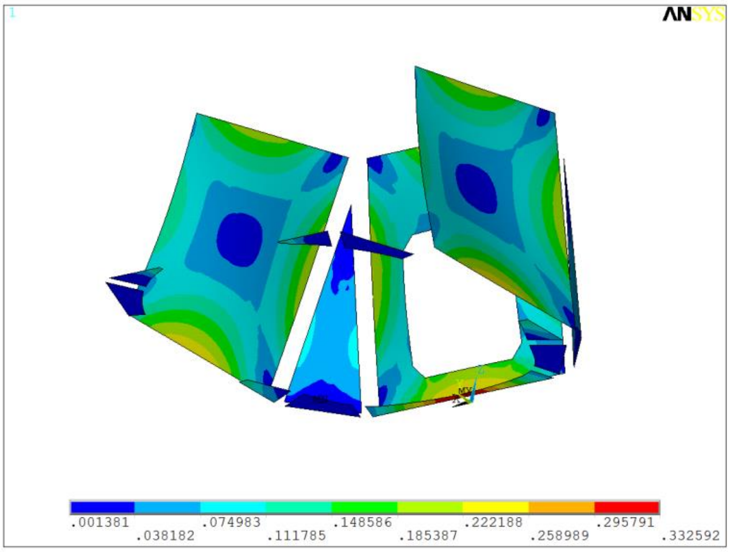


Figura 18 – GWL - Taglio (MPa) Klegecell R80

La massima sollecitazione è pari a 0.3 MPa.
La resistenza a taglio del Klegecell R80 è pari a 1.15 MPa.
Il coefficiente di sicurezza risultante è pari a CS = 1.15/0.3 = 3.8.

12 SHOCK

13 SHOCK VERTICALE

The vertical shock stress results in static acceleration (positive or negative), equal to 500 m/s^2.

Of the two, the acceleration that best corresponds to a real load condition, and therefore the most frequent, is the negative one (slamming), and is certainly less burdensome, as shown below, than the condition of green water load.

The results are then reported, in terms of displacement and load, obtained by loading with negative vertical acceleration the usual model that was used to determine displacements and loads in the GWL load condition.

14 SPOSTAMENTI

The maximum allowed arrow, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

In the following figures it is possible to appreciate the arrow, expressed in mm, in the various panels of the shield, subjected to negative vertical acceleration.

As you can see, the maximum value, equal to about 9 mm, at the upper panel of the shield, is below the specification limits.

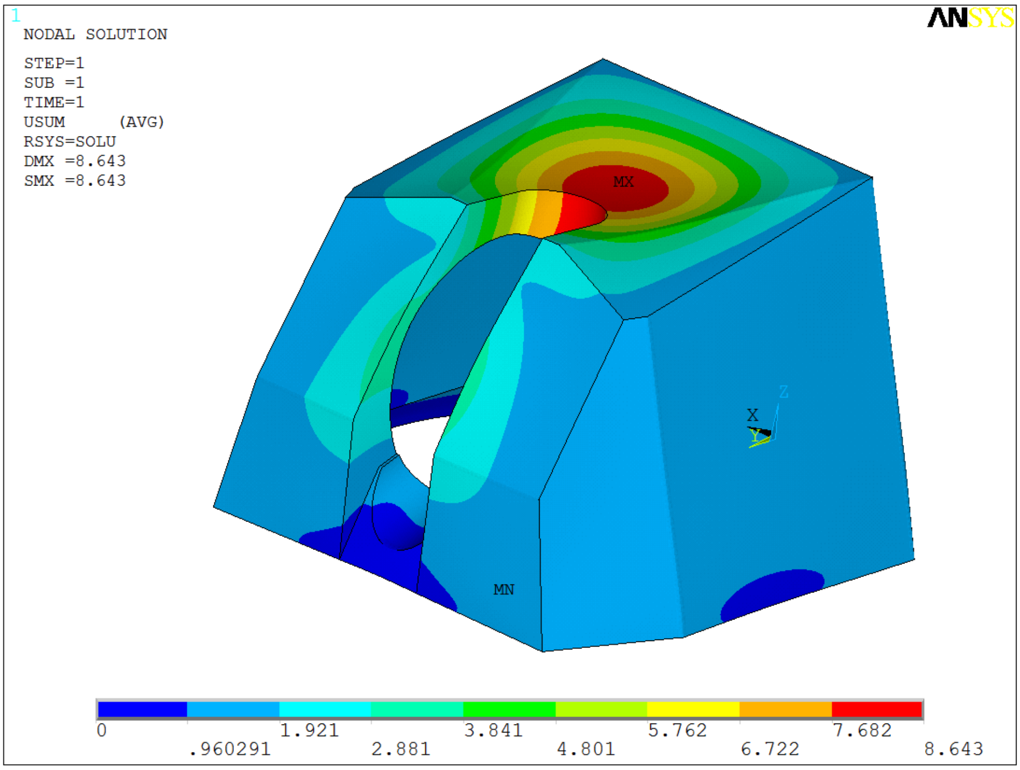


Figura 19 – Shock verticale - spostamento (mm)

15 SOLLECITAZIONI

The stresses induced in the vertical acceleration shield shall be compared with the maximum permissible stress for each material used.

16 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

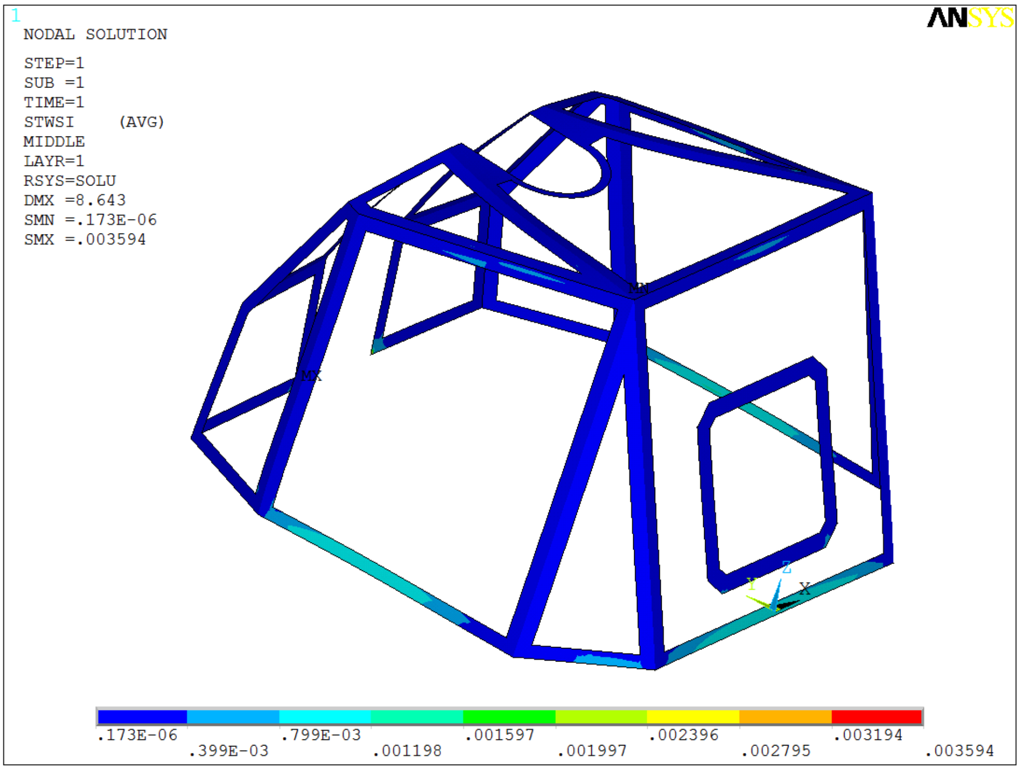


Figura 20 – Shock verticale - Coefficiente TW

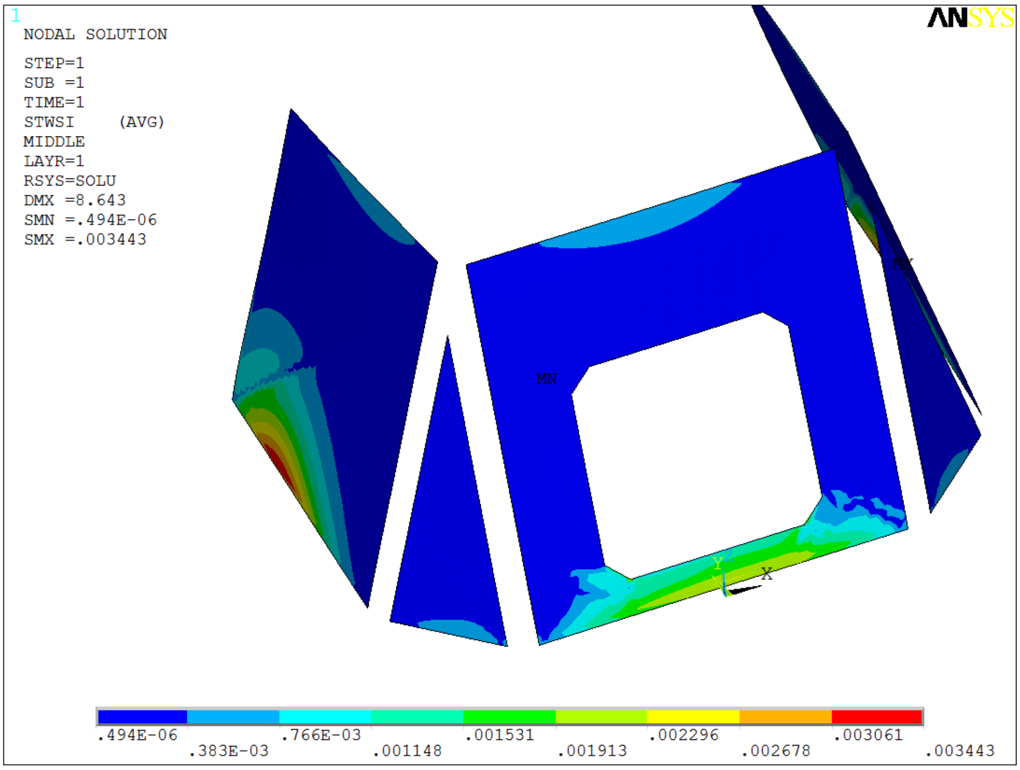


Figura 43 – Shock verticale - Coefficiente TW

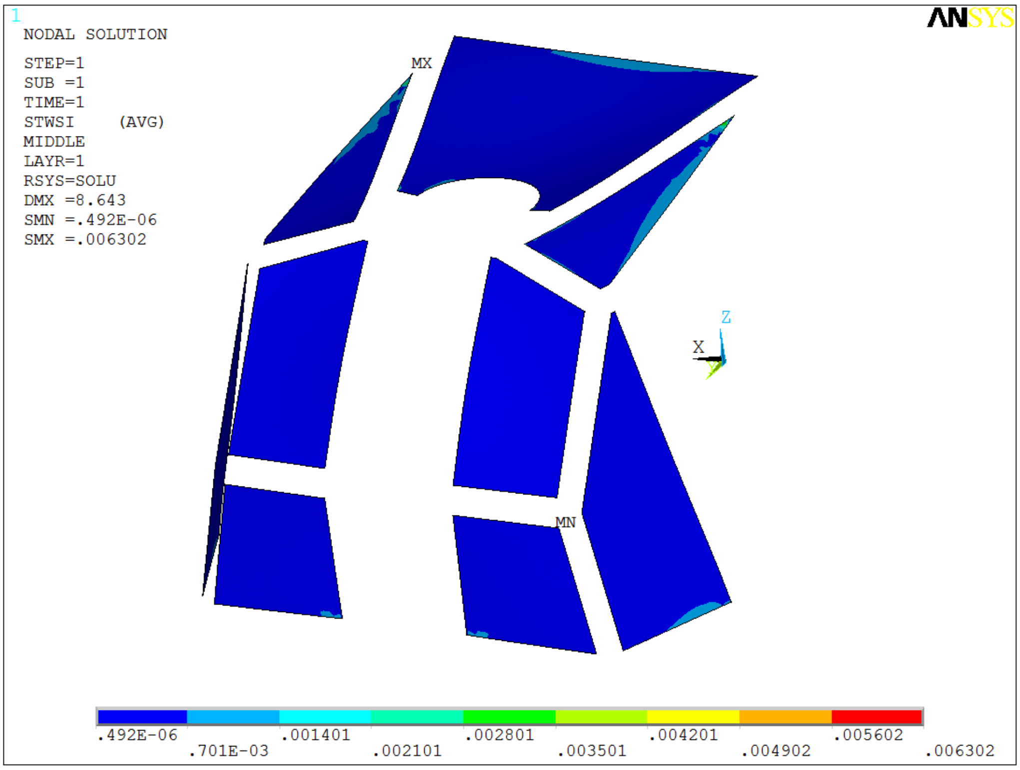


Figura 21 – Shock verticale - Coefficiente TW

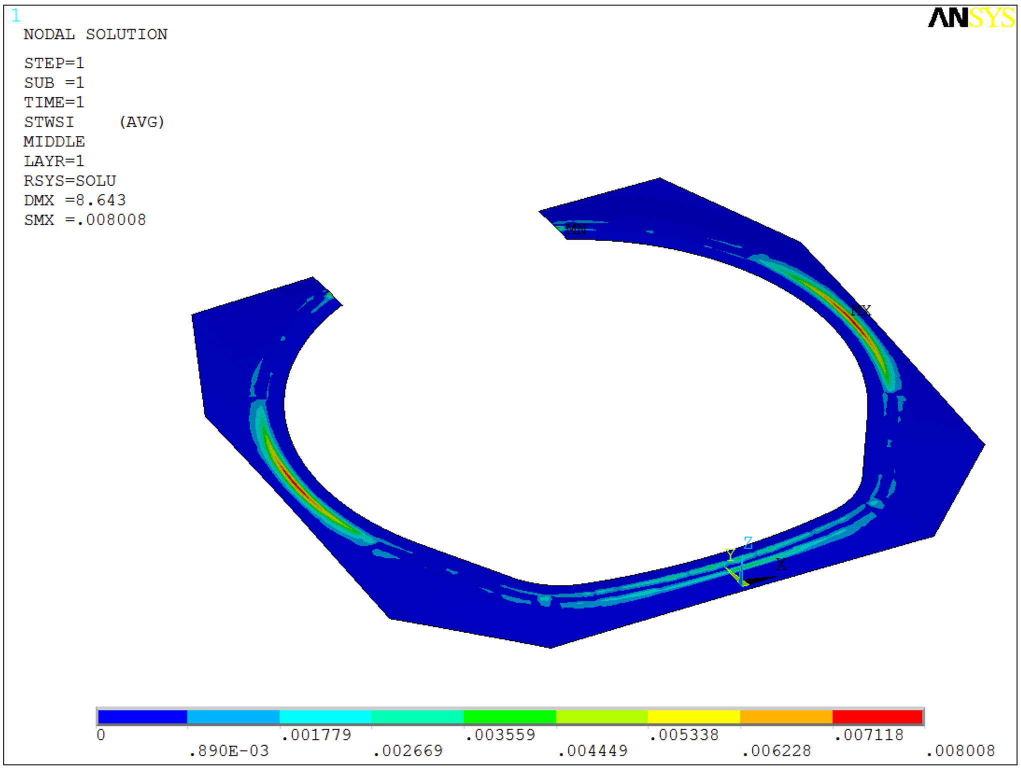


Figura 22 – Shock verticale - Coefficiente TW

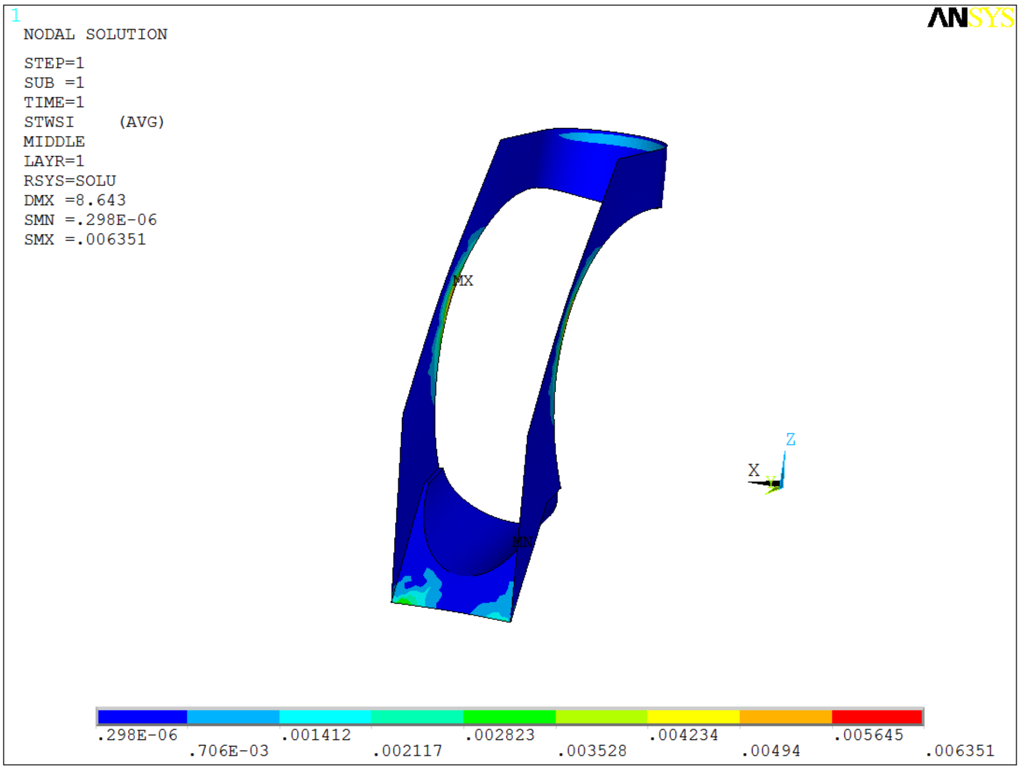


Figura 23 – Shock verticale - Coefficiente TW

The maximum stress is on the basic interface panels.
In these areas the coefficient of TW is about 0.008.
The resulting safety coefficient is CS = 1/0.008 = 125.

17 ANALISI A TAGLIO CORE

The following figure shows the trend of shear stress in shield areas made using syntactic foam.

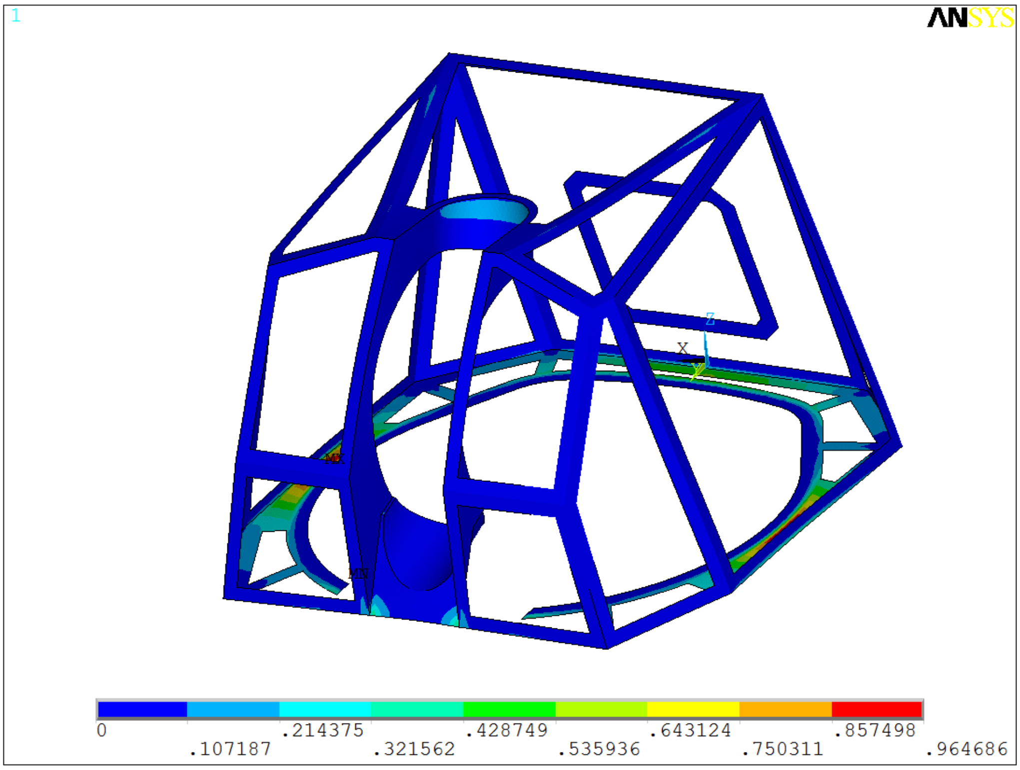


Figura 24 –Shock verticale - Taglio (MPa) schiuma sintattica

The maximum stress is 0.96 MPa.
The shear strength of the syntactic foam is 5 MPa.
The resulting safety coefficient is CS = 5/0.96 = 5.2.

The following figure shows the trend of the shear stress in the shield areas made using panels of Dyvinicell H100.

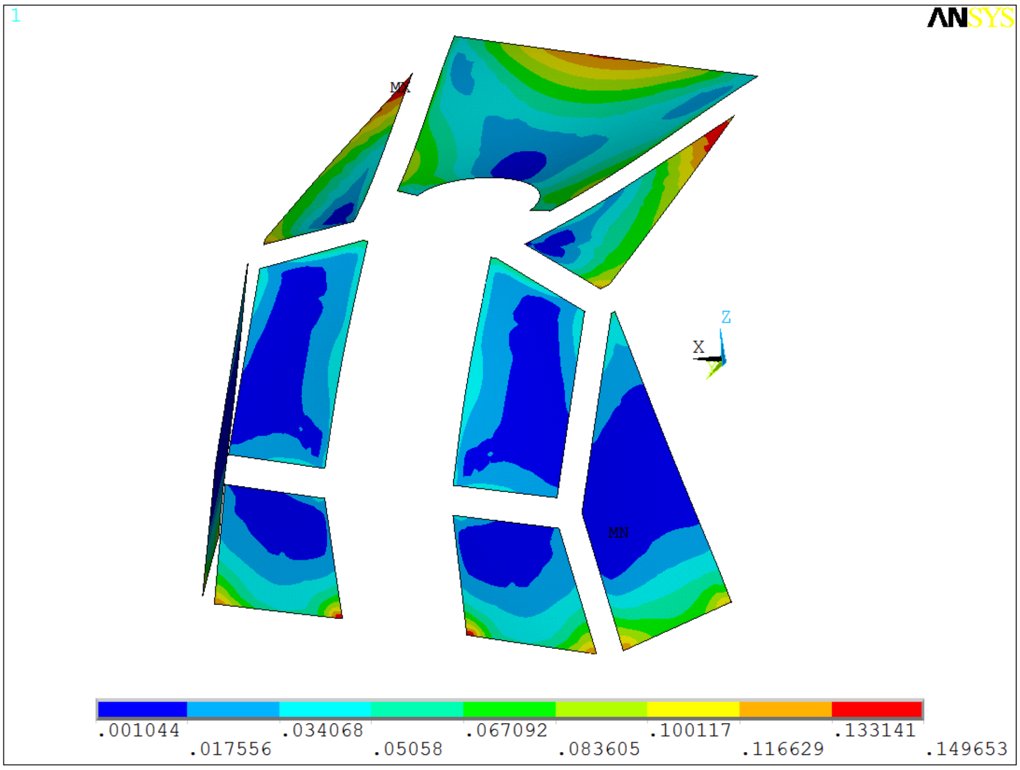


Figura 25 – Shock verticale - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.15 MPa.
The shear strength of the Dyvinicell H100 core is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.15 = 10.6.

The following figure shows the trend of shear stress in shield areas made using Klegecell R80 panels.

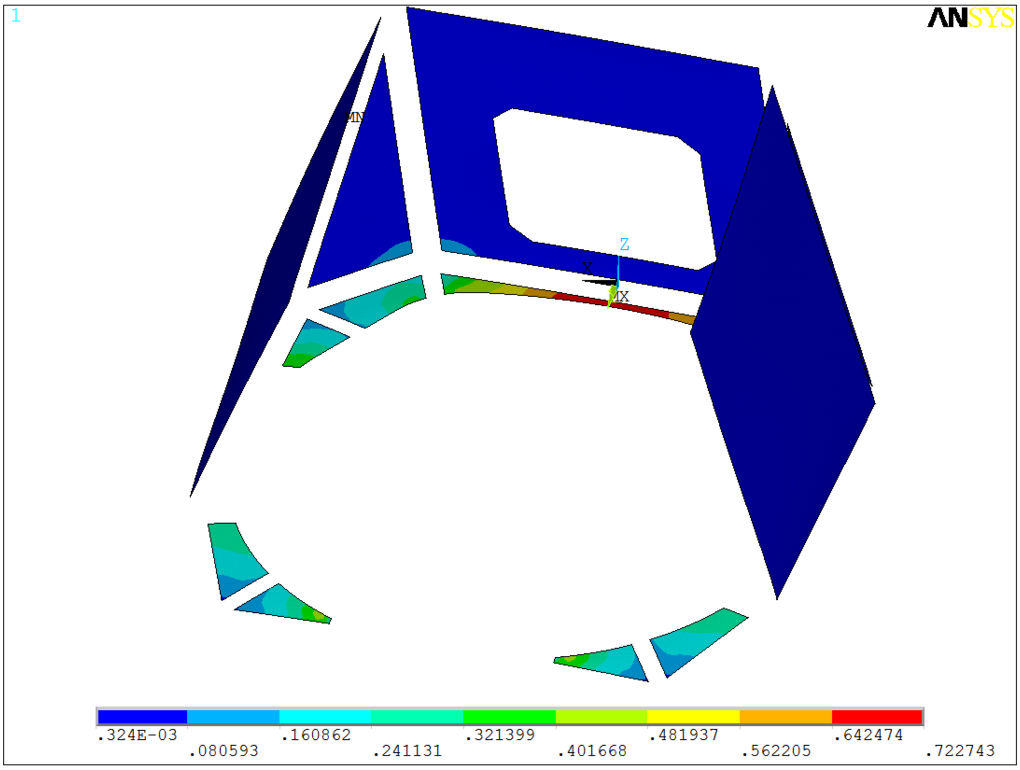


Figura 49 – Shock verticale - Taglio (MPa) Klegecell R80

The maximum stress is 0.72 MPa.

The shear strength of the Klegecell R80 core is 1.15 MPa.

The resulting safety coefficient is CS = 1.15/0.72 = 1.59.

NOTE

The analysis of the positive vertical shock load condition provides the same results (unless the opposite sign) as that conducted for negative vertical acceleration.

The linearity hypothesized in the elastic behaviour of the materials used make it possible to outdo the safety coefficients obtained at §20 13

18 SHOCK TRASVERSALE

The transverse shock stress results in static acceleration of 300 m/s^2.

19 SPOSTAMENTI

The maximum allowed deformation, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

In the following figures it is possible to appreciate the deformation, expressed in mm, in the various panels of the shield, subjected to transverse acceleration.

As you can see, the maximum value, equal to about 7.2 mm, at the upper panel of the shield, is below the specification limits.

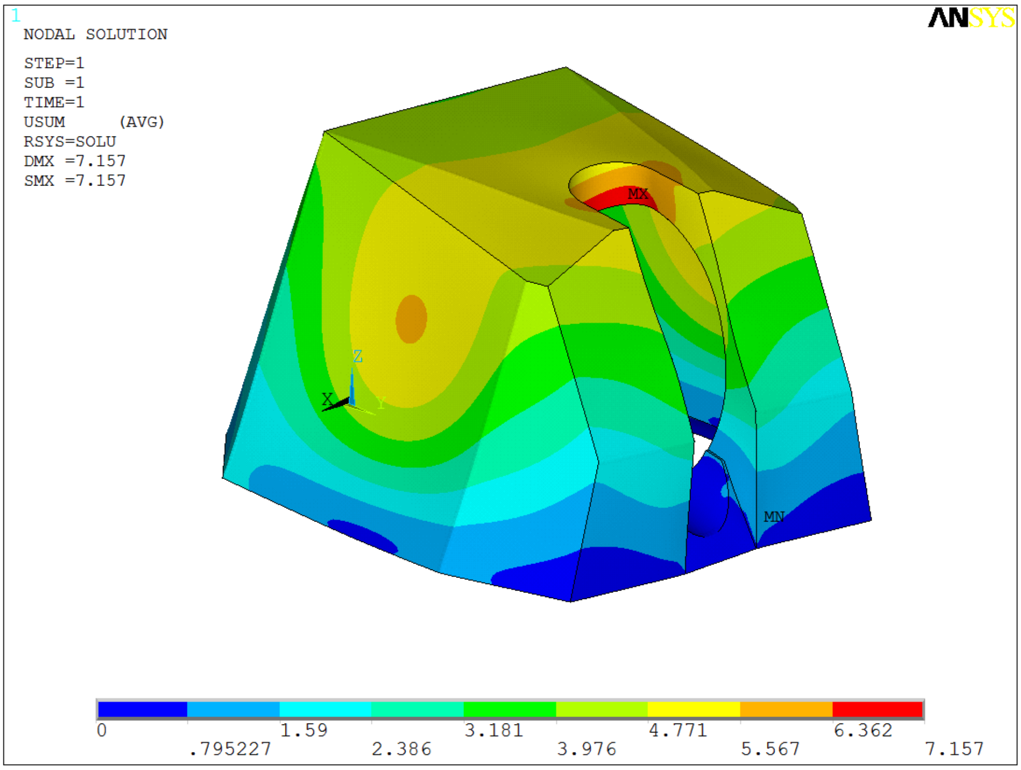


Figura 26 – Shock laterale - spostamento (mm)

20 SOLLECITAZIONI

The stresses induced in the transverse acceleration shield are compared with the maximum permissible stresses for each material used.

21 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

Le immagini che seguono mostrano l'andamento del coefficiente di TW nelle lamine di composito che costituiscono le pareti esterne dei sandwich.

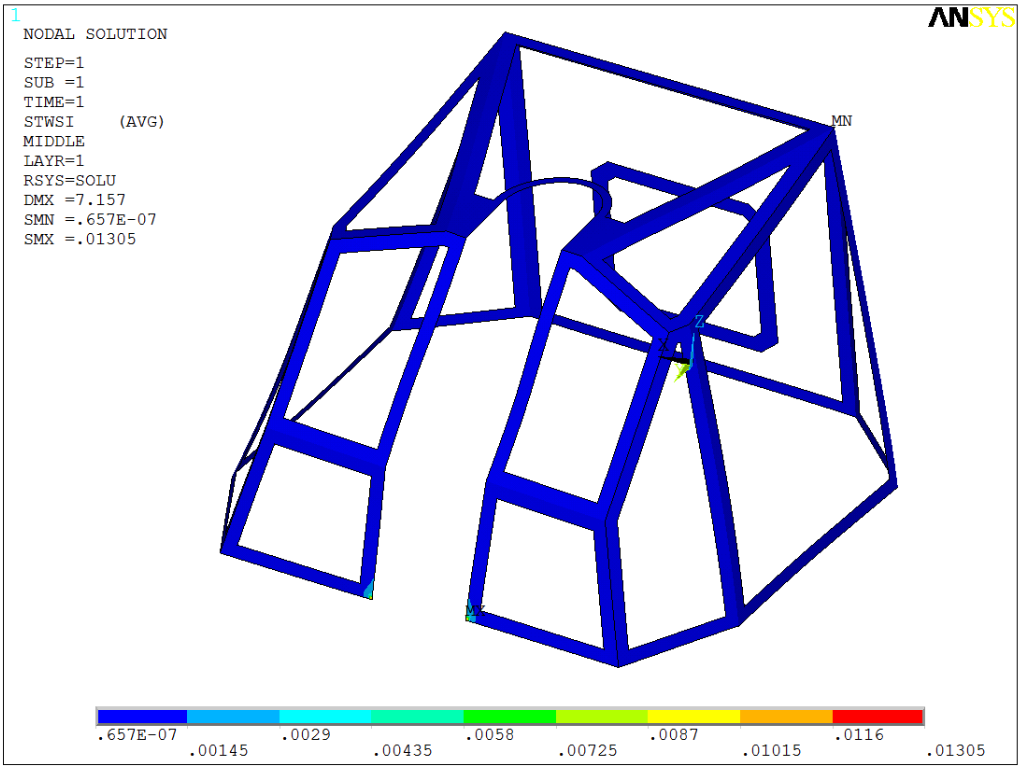


Figura 51 – Shock leterale - Coefficiente TW

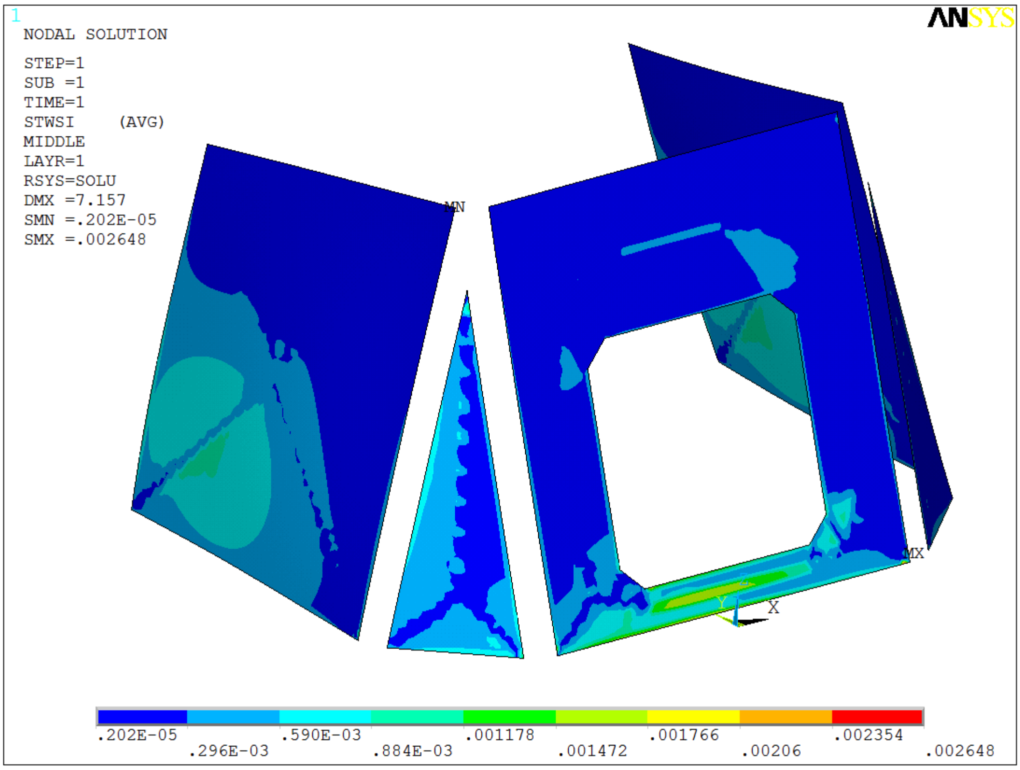


Figura 27 – Shock laterale - Coefficiente TW

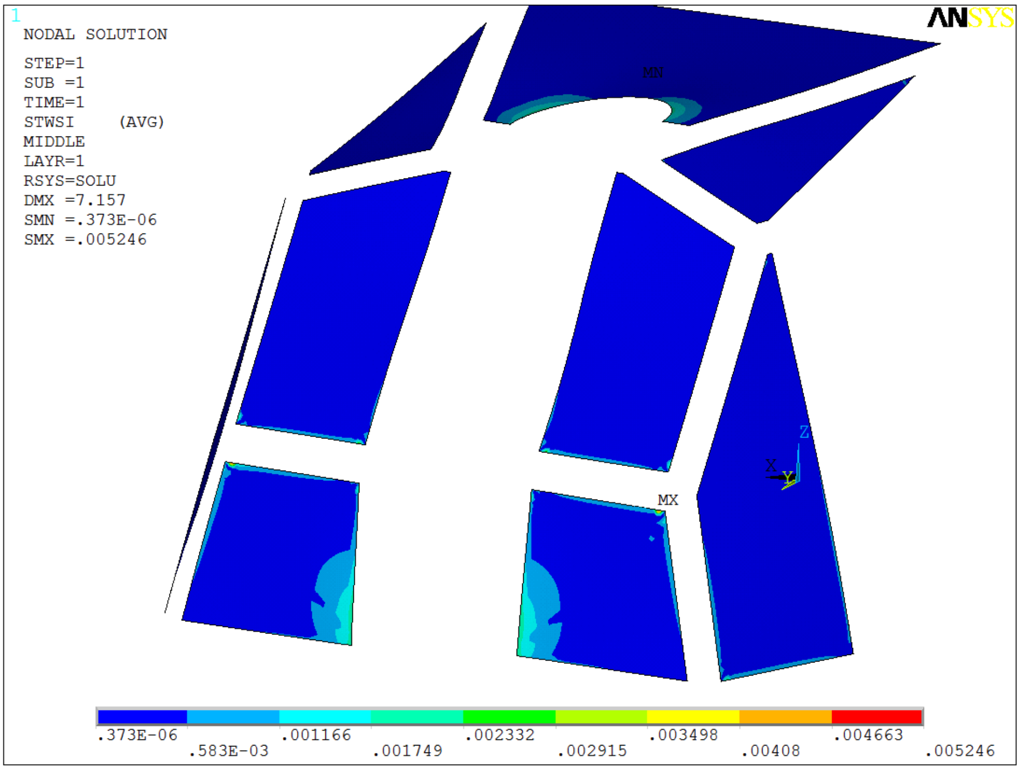


Figura 28 – Shock laterale - Coefficiente TW

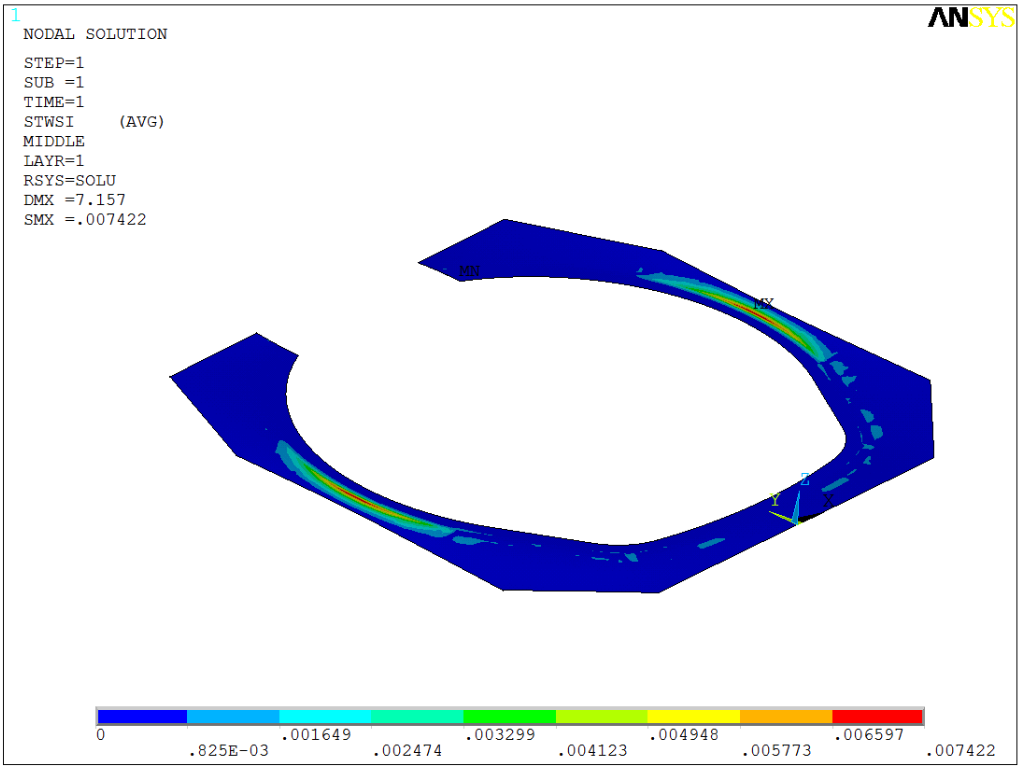


Figura 29 – Shock laterale - Coefficiente TW

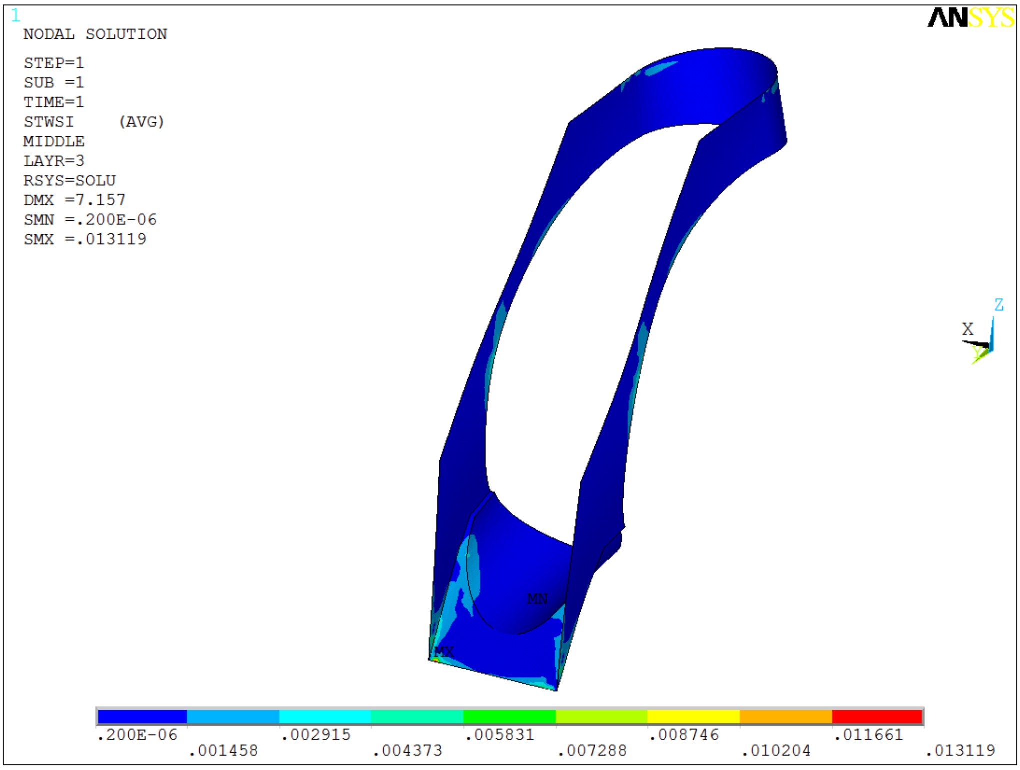


Figura 30 – Shock laterale - Coefficiente TW

The maximum stress is on the front panels.
In these areas the coefficient of TW is about 0.014.
The resulting safety coefficient is CS = 1/0.008 = 71.4.

22 ANALISI A TAGLIO CORE

The following figure shows the trend of shear stress in shield areas made using syntactic foam.

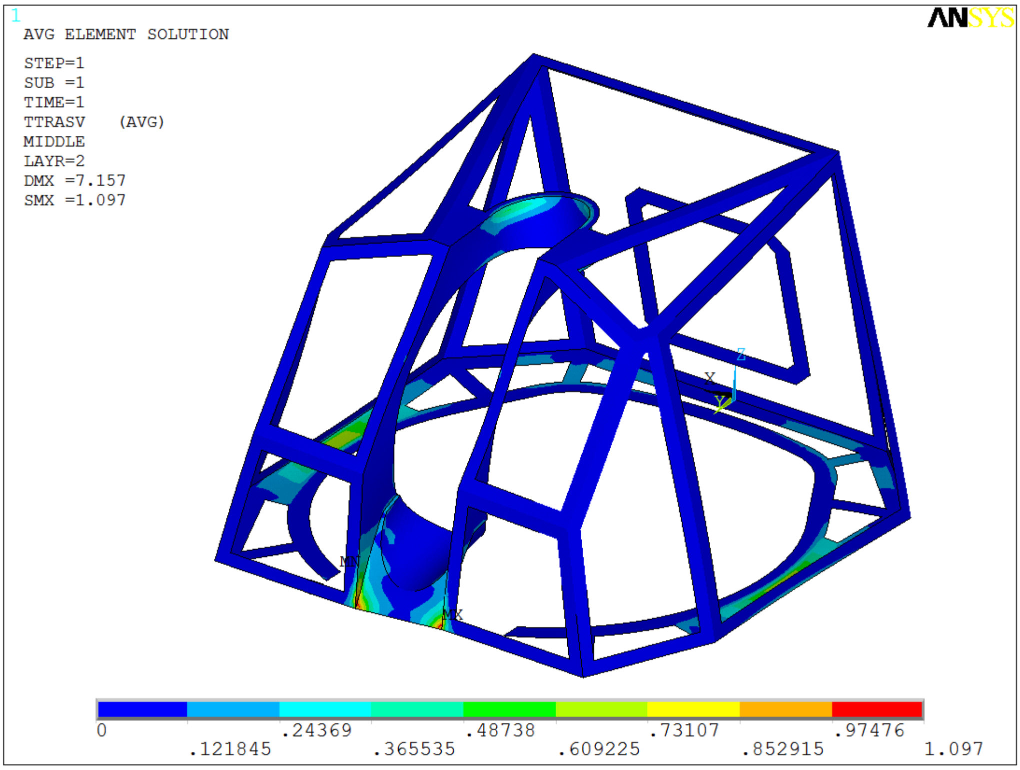


Figura 31 – Shock laterale - Taglio (MPa) schiuma sintattica

The maximum stress is 1.1 MPa.

The shear strength of syntactic foam is 5 MPa.

The resulting safety coefficient is CS = 5/0.96 = 4.5.

The following figure shows the trend of shear stress in shield areas made using Dyvinicell H100 panels.

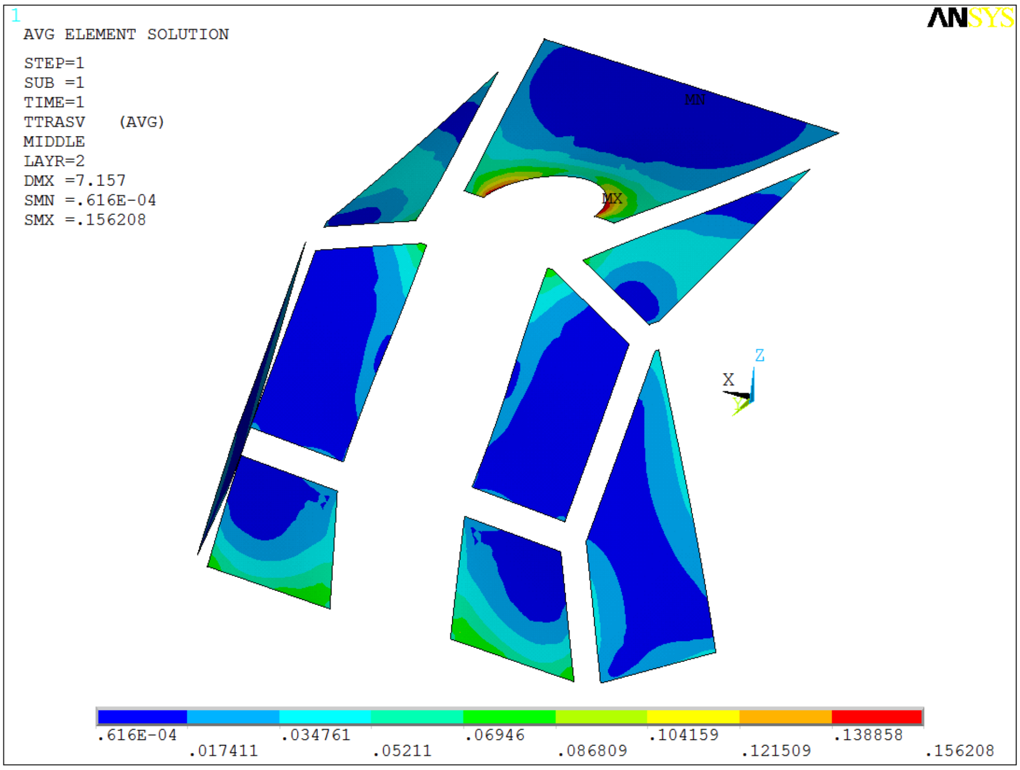


Figura 32 – Shock laterale - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.15 MPa.
The shear strength of the Dyvinicell H100 core is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.15 = 10.6.

The following figure shows the trend of shear stress in shield areas made using Klegecell R80 panels.

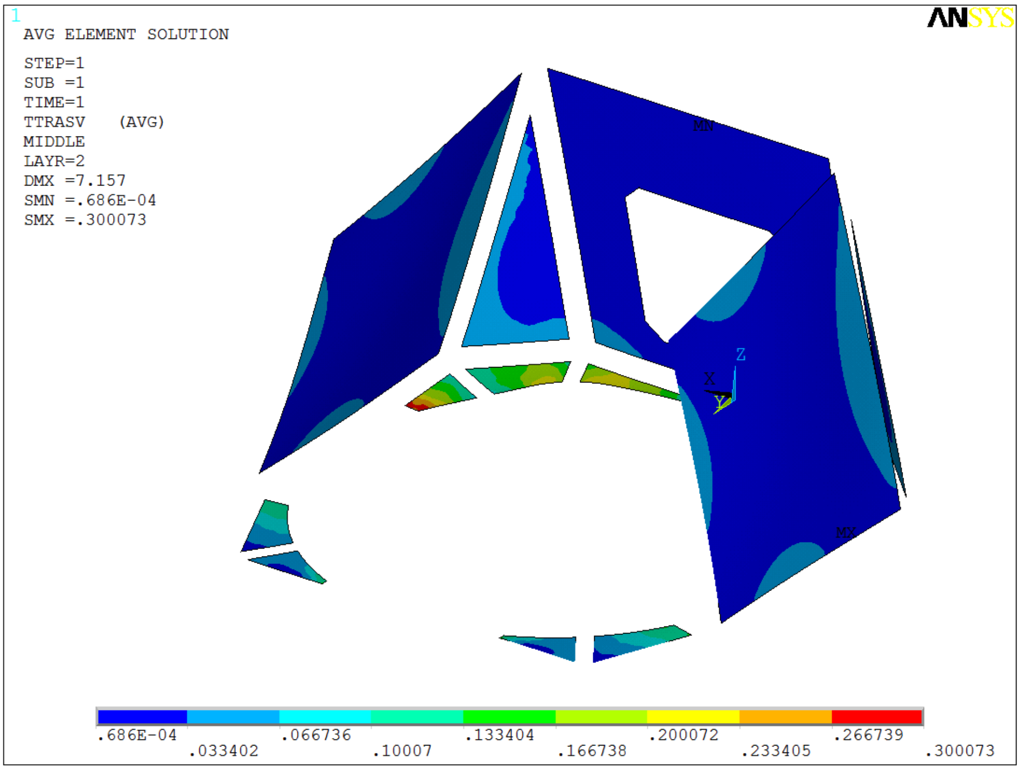


Figura 33 – Shock laterale- Taglio (MPa) Klegecell R80

The maximum stress is 0.3 MPa.

The shear strength of the Klegecell R80 core is 1.15 MPa.

The resulting safety coefficient is CS = 1.15/0.72 = 3.83.

23 SHOCK LONGITUDINALE

The longitudinal shock stress results in a static acceleration of 300 m/s^{2}.

24 SPOSTAMENTI

The maximum allowed deformation, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

In the following figures it is possible to appreciate the deformation, expressed in mm, in the various panels of the shield, subjected to longitudinal acceleration.

As you can see, the maximum value, equal to about 9.3 mm, at the front panel of the shield, is below the specification limits.

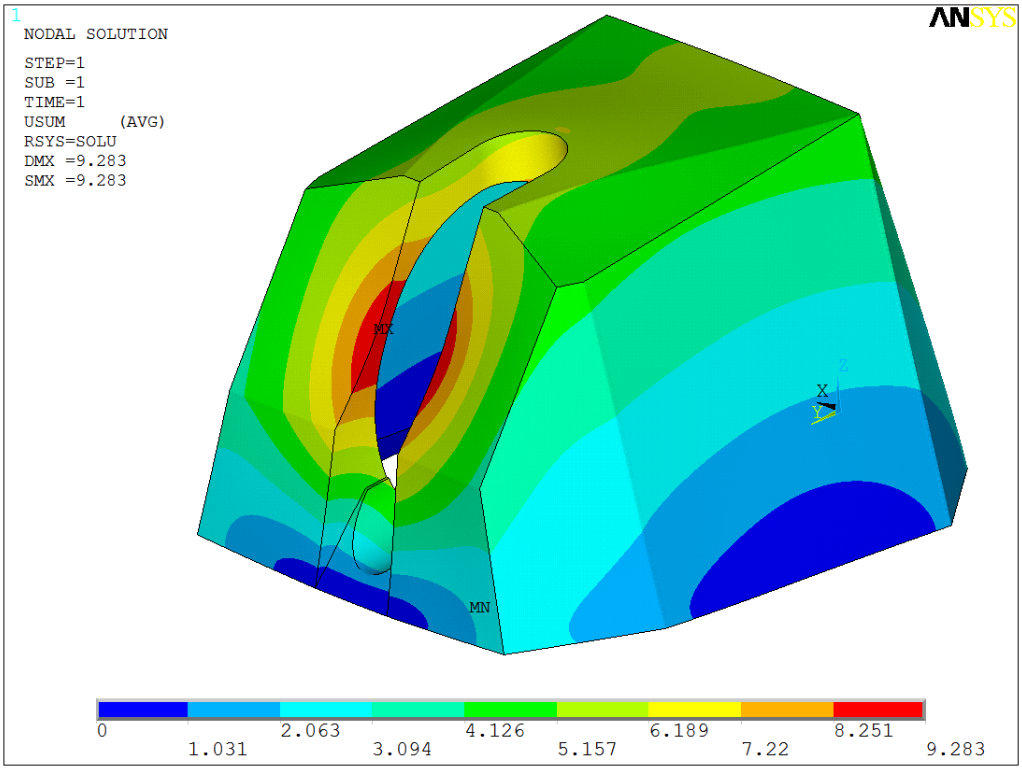


Figura 59 – Shock longitudinale - spostamento (mm)

25 SOLLECITAZIONI

The stresses induced in the longitudinal acceleration shield are compared with the maximum permissible stresses for each material used.

26 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

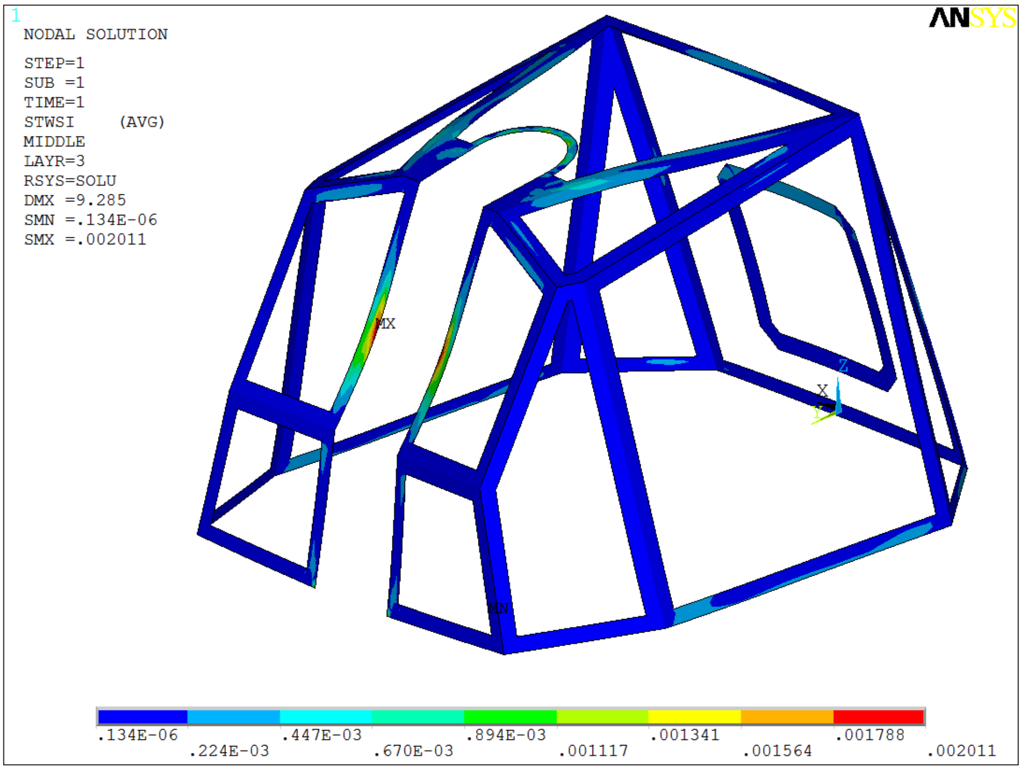


Figura 34 – Shock longitudinale - Coefficiente TW

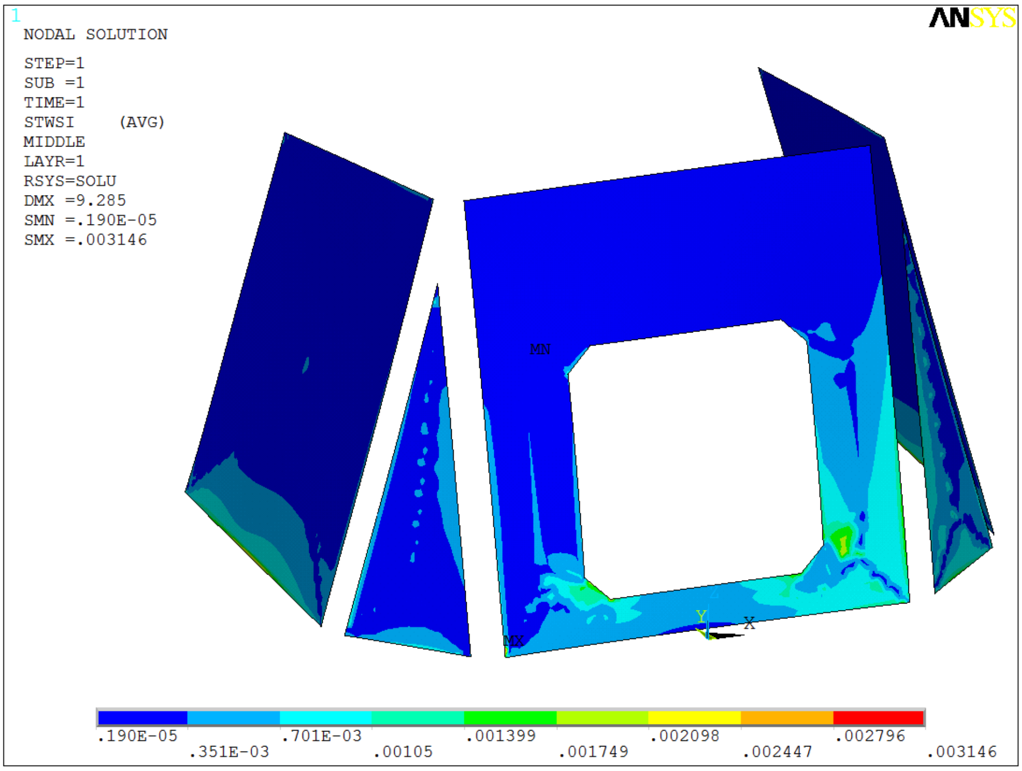


Figura 35 – Shock longitudinale - Coefficiente TW

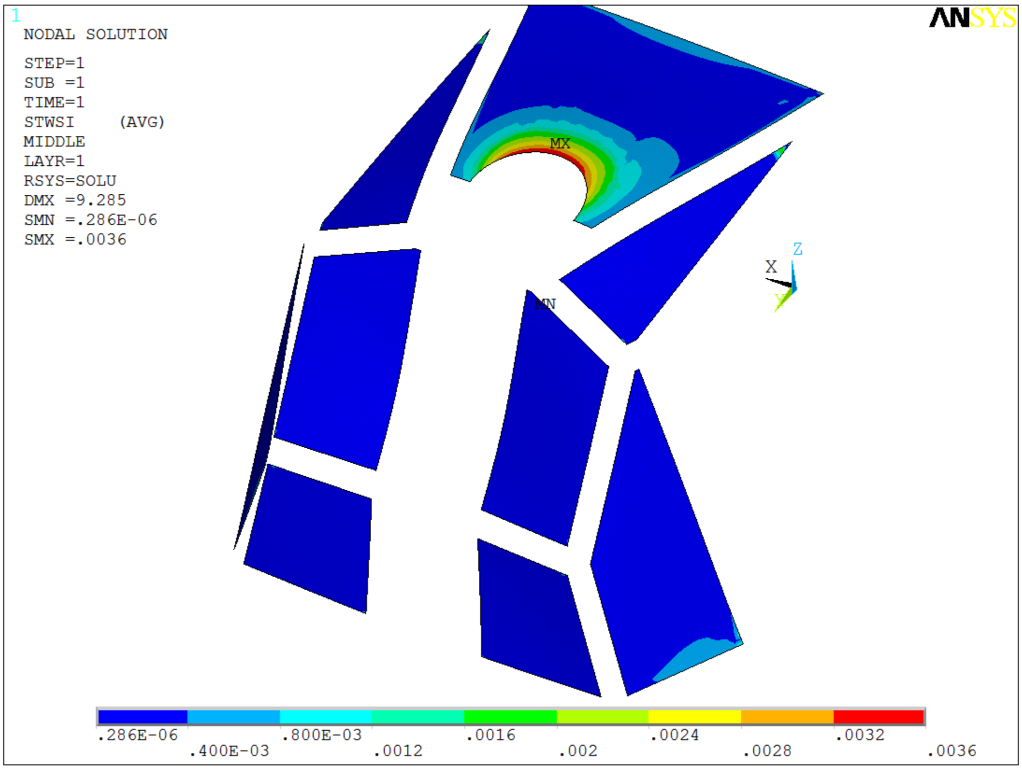


Figura 36 – Shock longitudinale - Coefficiente TW

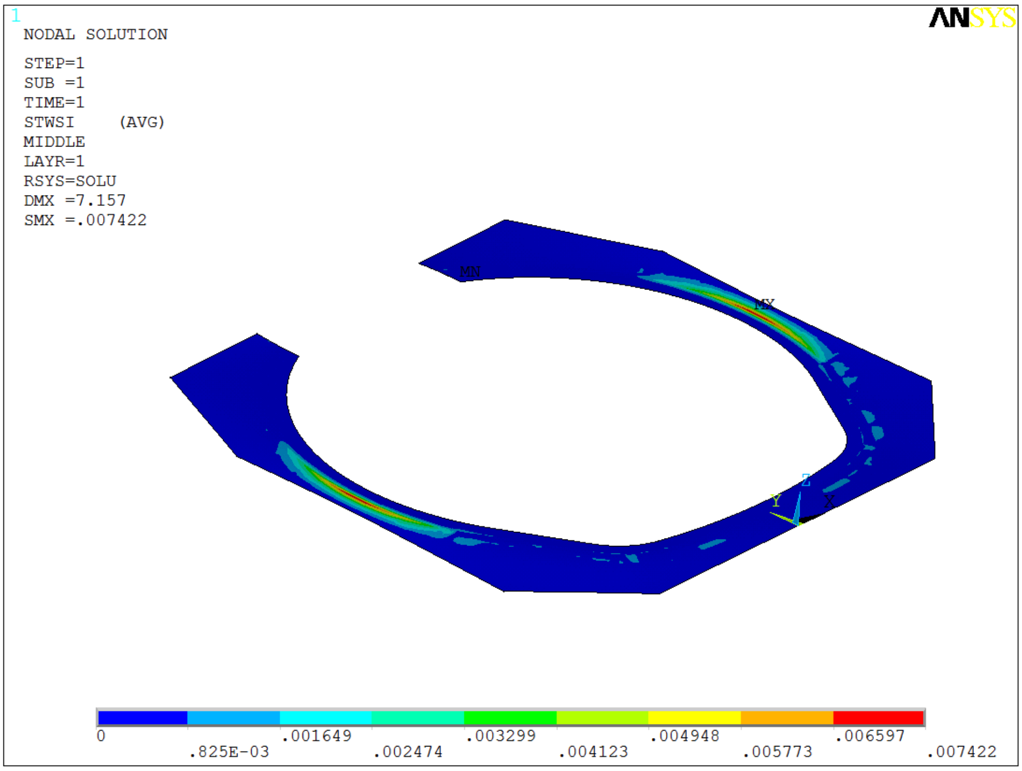


Figura 37 – Shock longitudinale - Coefficiente TW

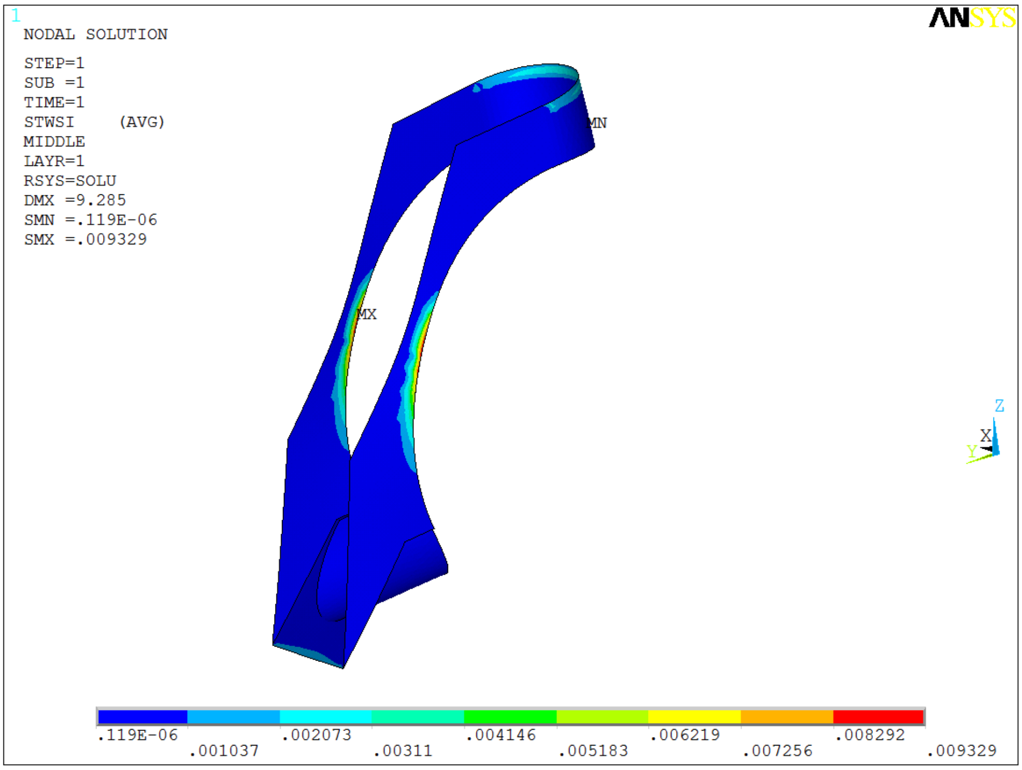


Figura 38 – Shock longitudinale - Coefficiente TW

The maximum stress is on the front panels.
In these areas the coefficient of TW is about 0.009.
The resulting safety coefficient is CS = 1/0.009 = 111.

27 ANALISI A TAGLIO CORE

The following figure shows the trend of shear stress in shield areas made using syntactic foam.

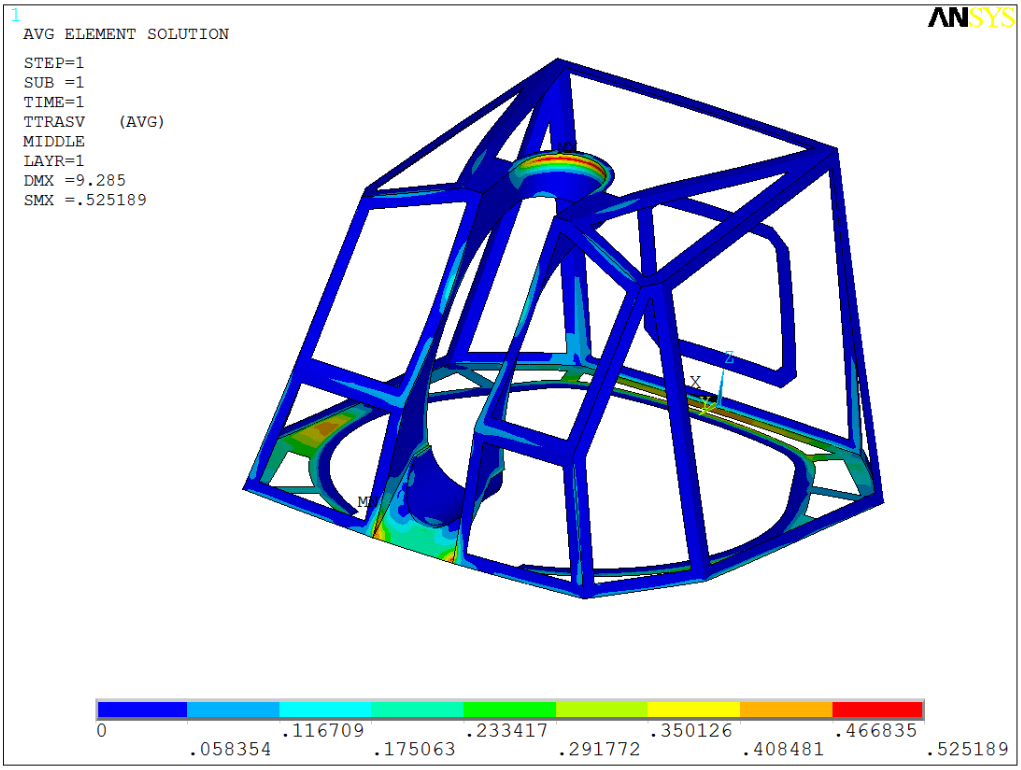


Figura 39 – Shock longitudinale - Taglio (MPa) schiuma sintattica

The maximum stress is 0.5 MPa.
The shear strength of the syntactic foam is 5 MPa.
The resulting safety coefficient is CS = 5/0.5 = 10.

The following figure shows the trend of shear stress in shield areas made using Dyvinicell H100 panels.

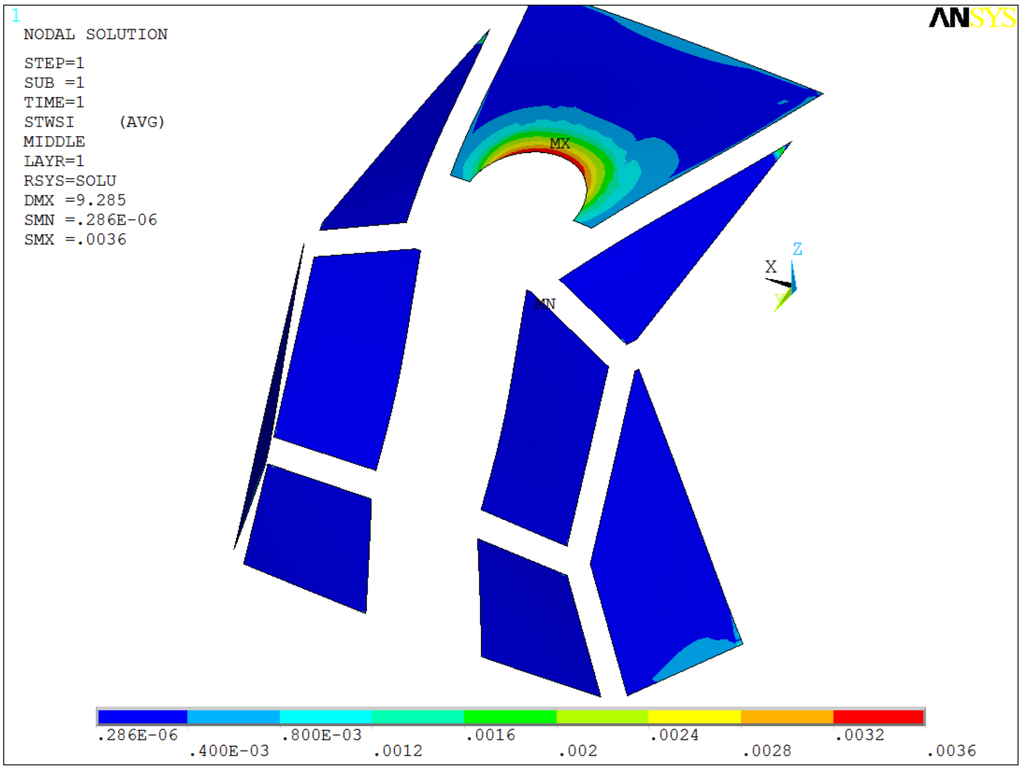


Figura 40 – Shock longitudinale - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.0036 MPa.
The shear strength of the Dyvinicell H100 core is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.0036 = 444.

The following figure shows the trend of shear stress in shield areas made using Klegecell R80 panels.

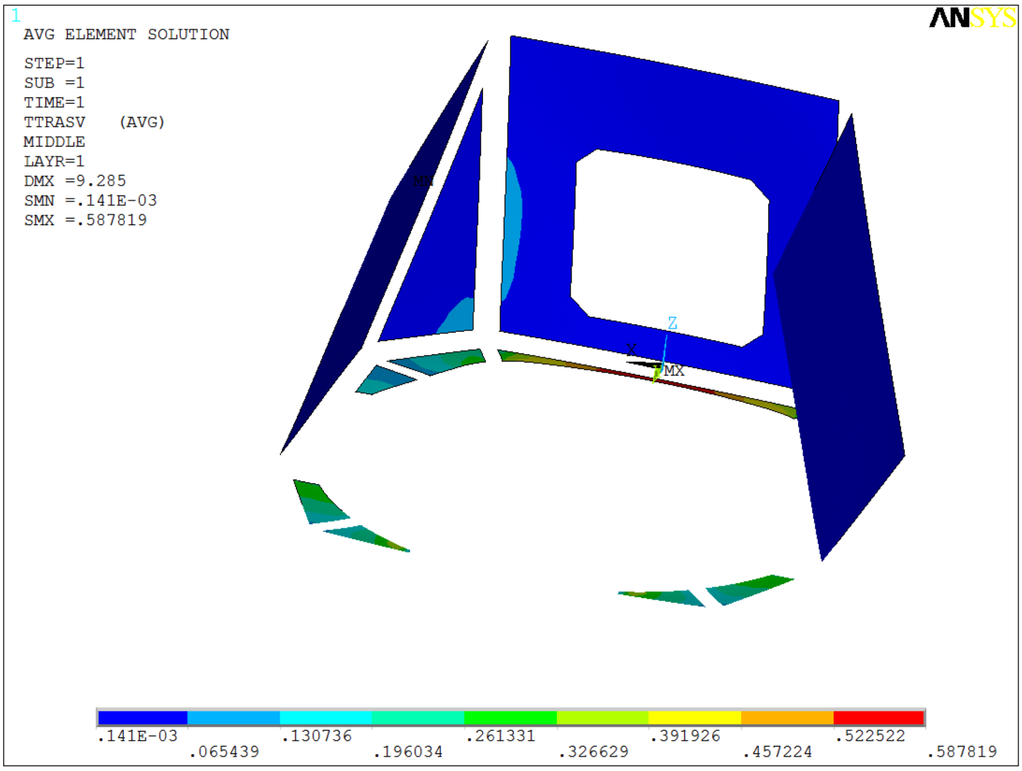


Figura 41 – Shock longitudinale - Taglio (MPa) Klegecell R80

The maximum stress is 0.59 MPa.
The shear strength of the Klegecell R80 core is 1.15 MPa.
The resulting safety coefficient is CS = 1.15/0.59 = 1.95.

28 WIND

The shield will have to withstand wind and gusts:

1. in operating conditions: wind up to 75kn with gusts up to 135kn;
2. in non-operational conditions: wind up to 100kn with gusts up to 175kn.

The following analysis shows the results obtained by subjecting the FEM model of the shield to a wind of 175kn in three different cases: frontal wind, rear wind, and transverse wind.

In order to insert a realistic load due to the wind into the analysis, the pressure acting on the shield due to the wind itself according to the formula is considered:

$$p = \frac{1}{2} * \rho * V^2$$

In this formula:

- p is the pressure, measured in Pascal $[Pa]$=$[N/m^2]$;
- ρ is the density, in this case of the air, measured in $[kg/m^3]$, $\rho = 1.225\ kg/m^3$;
- V is the speed, measured in $[m/s]$.

So: $p = 4961.25\ Pa \cong 0.005\ MPa$.

29 FRONTAL WIND

The frontal wind load condition is matched, as explained above, to a pressure distributed only on the front panels equal to 0.005 MPa

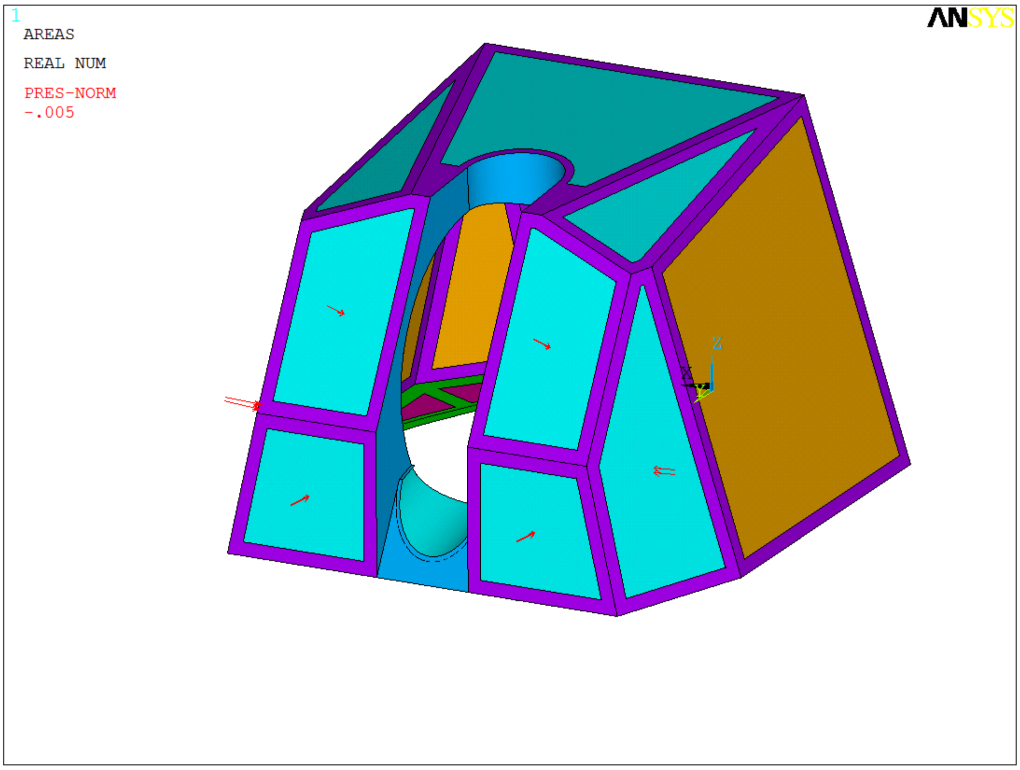


Figura 42 – Vento frontale

30 SPOSTAMENTI

The maximum allowed arrow, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

As you can see, the maximum value, equal to about 2.8 mm, at the front panel of the shield, is below the specification limits.

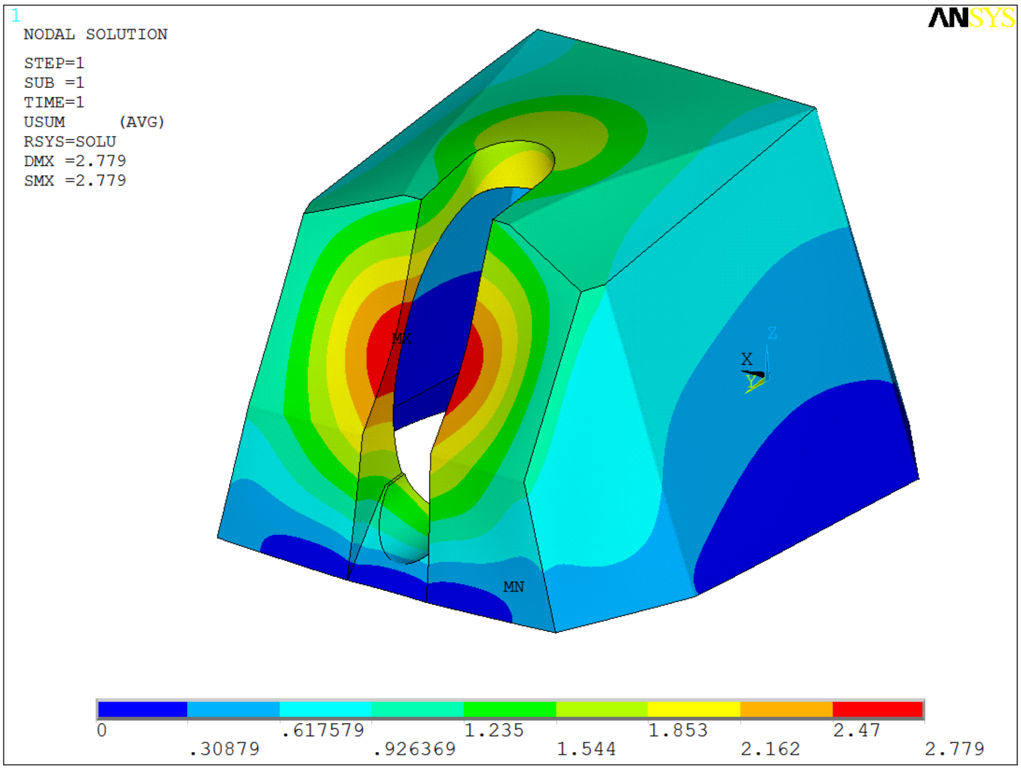


Figura 43 – Vento frontale - spostamento (mm)

31 SOLLECITAZIONI

The stresses induced in the shield by the frontal wind stress are compared with the maximum permissible stresses for each material used.

32 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

Given the local distribution of the load, the stress values at those areas are reported.

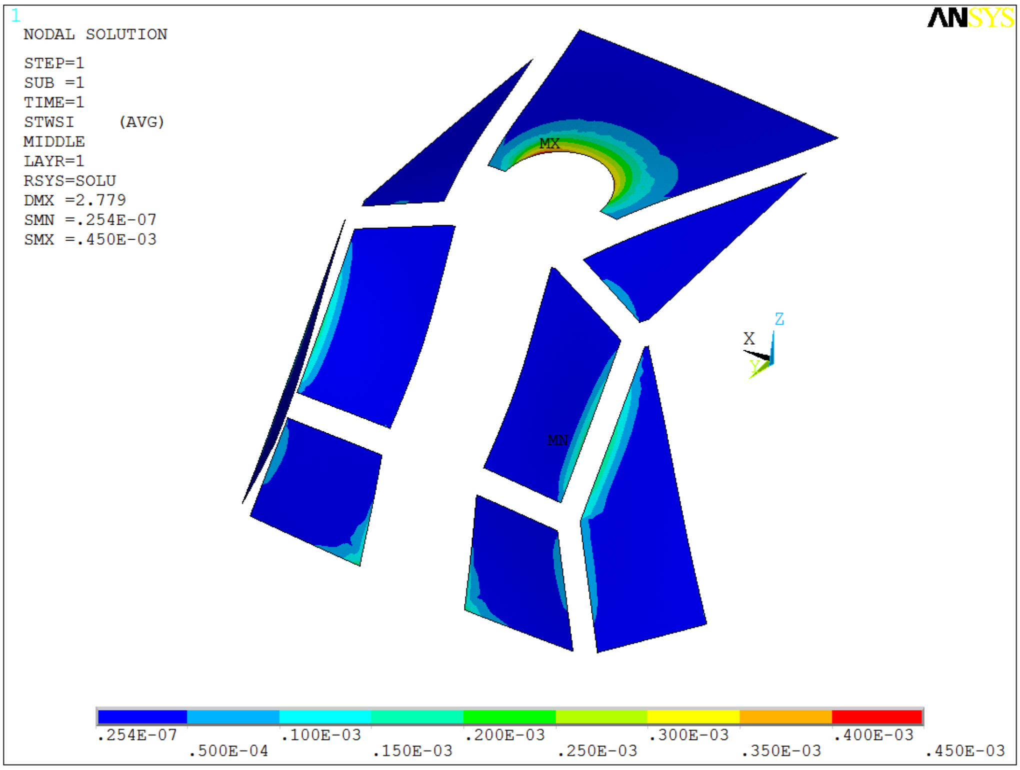


Figura 44 – Vento frontale - Coefficiente TW

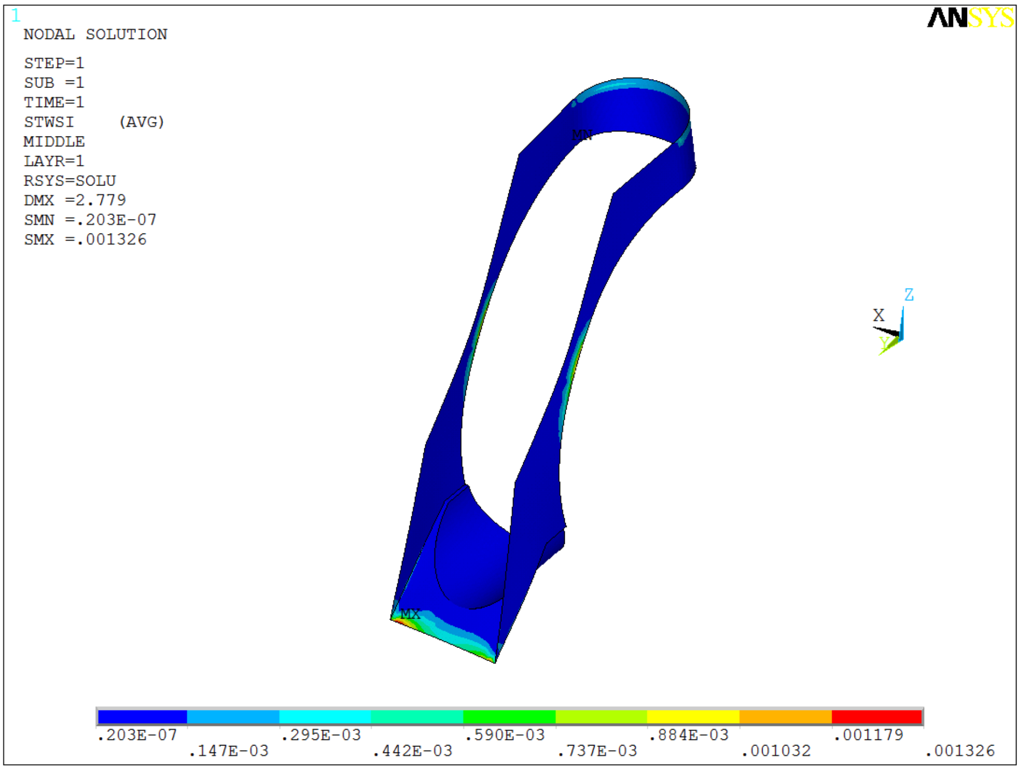


Figura 45 – Vento frontale - Coefficiente TW

In TW coefficient in the areas affected by the wind it is about 0.014.
The resulting safety coefficient is CS = 1/0.014 = 71.4.

33 ANALISI A TAGLIO CORE

The following figure shows the trend of shear stress in shield areas made using syntactic foam.

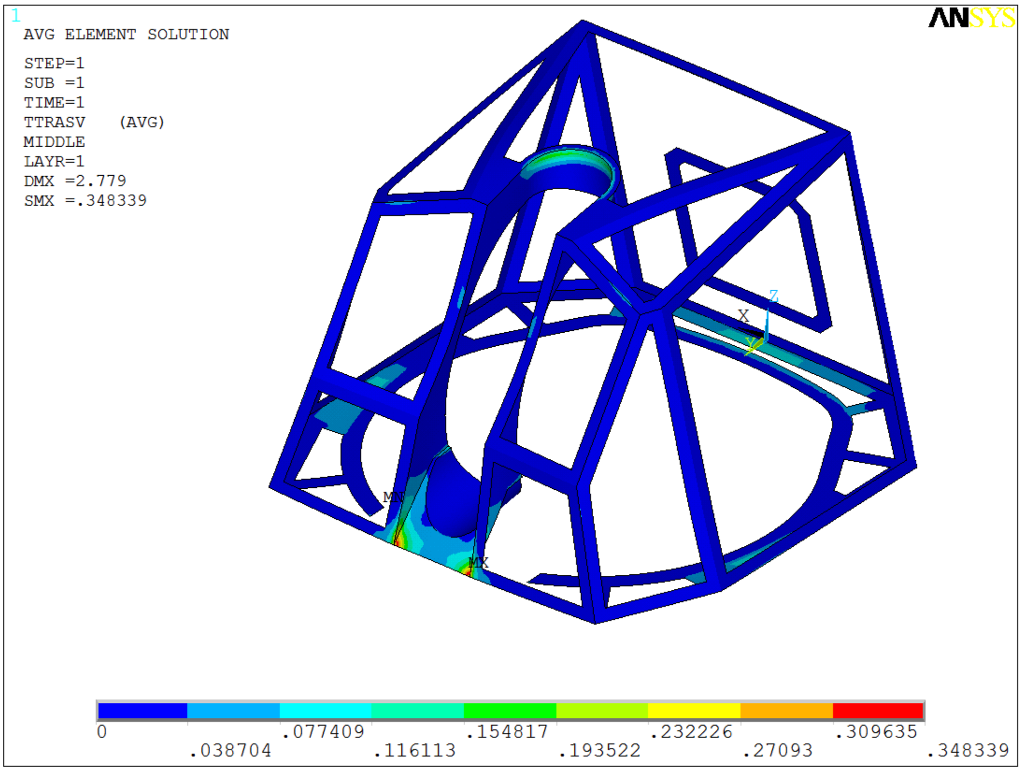


Figura 46 – Vento frontale - Taglio (MPa) schiuma sintattica

The maximum stress is 0.34 MPa.

The shear strength of the syntactic foam is 5 MPa.

The resulting safety coefficient is CS = 5/0.34 = 14.7.

The following figure shows the trend of shear stress in shield areas made using Dyvinicell H100 panels.

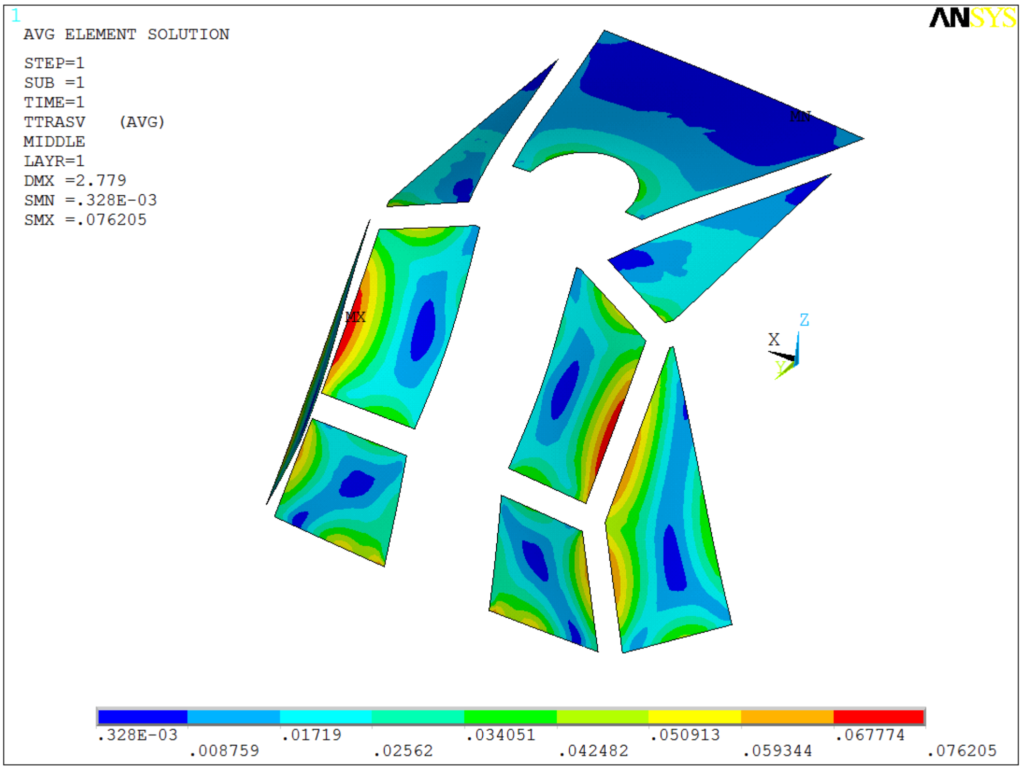


Figura 47 – Vento frontale - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.08 MPa.
The shear strength of the Dyvinicell H100 core is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.08 = 20.

34 VENTO LATERALE

The condition of side wind load is matched, as explained above, to a pressure distributed only on the side panels of .0.005 MPa

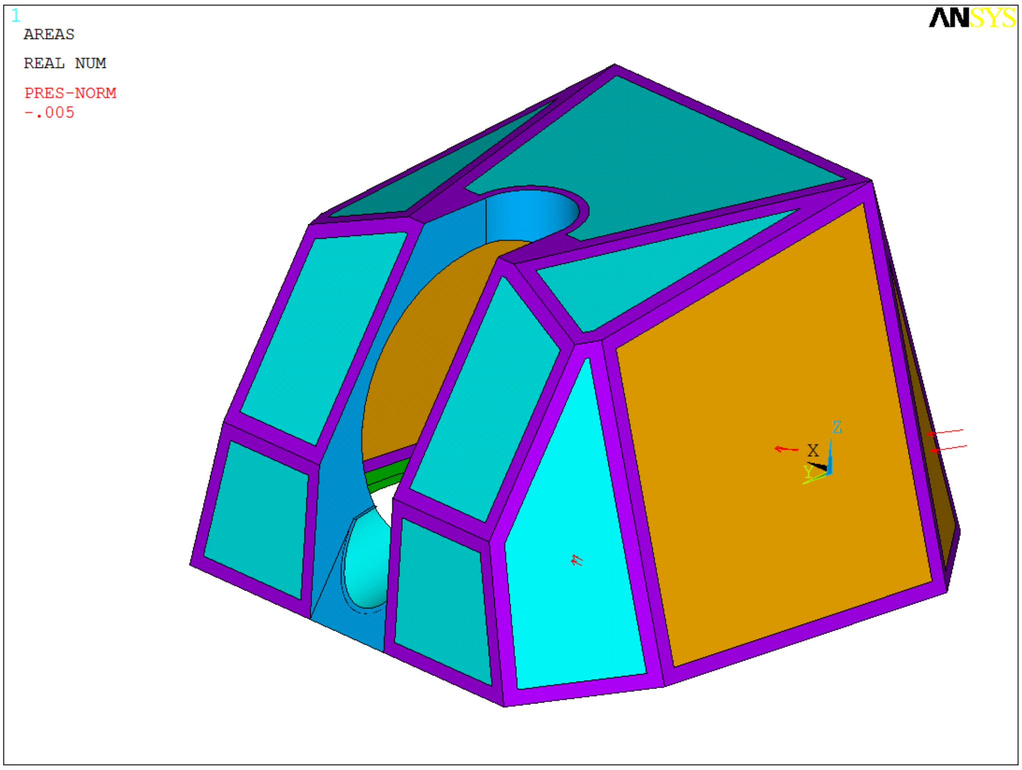


Figura 48 – Vento laterale

35 SPOSTAMENTI

The maximum deformation allowed, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

As you can see, the maximum value, equal to about 5 mm, at the side panel of the shield, is below the specification limits.

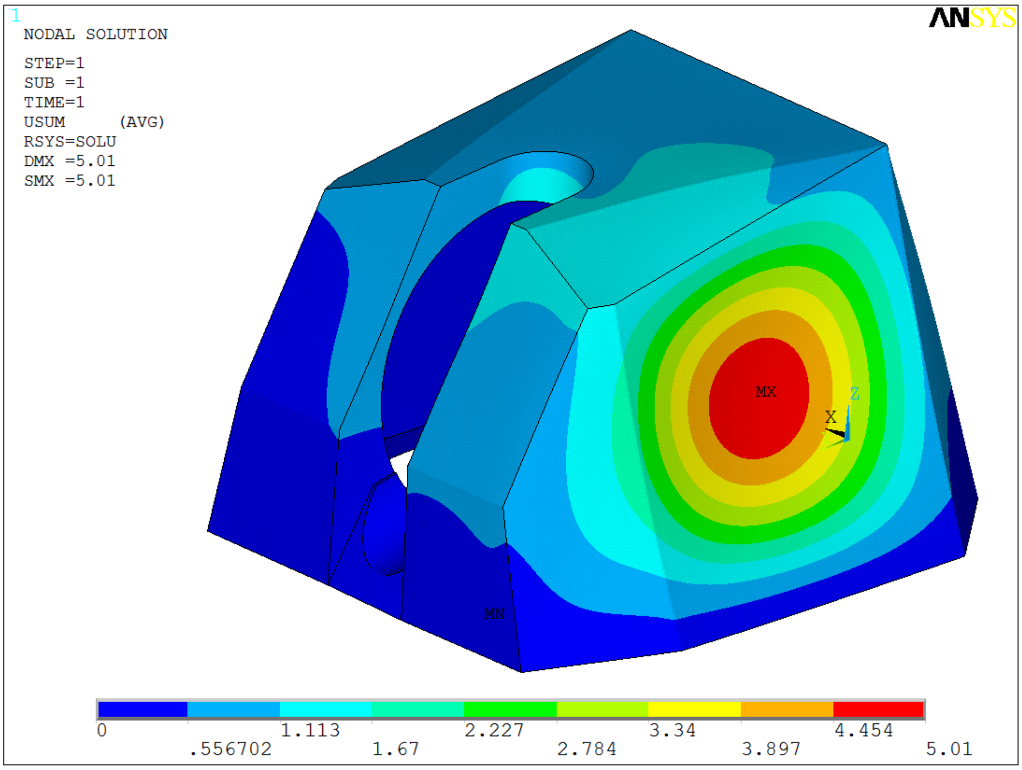


Figura 49 – Vento laterale - spostamento (mm)

36 SOLLECITAZIONI

The stresses induced in the shield by the side wind stress are compared with the maximum permissible stresses for each material used.

37 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

Given the local distribution of the load, the stress values at those areas are reported.

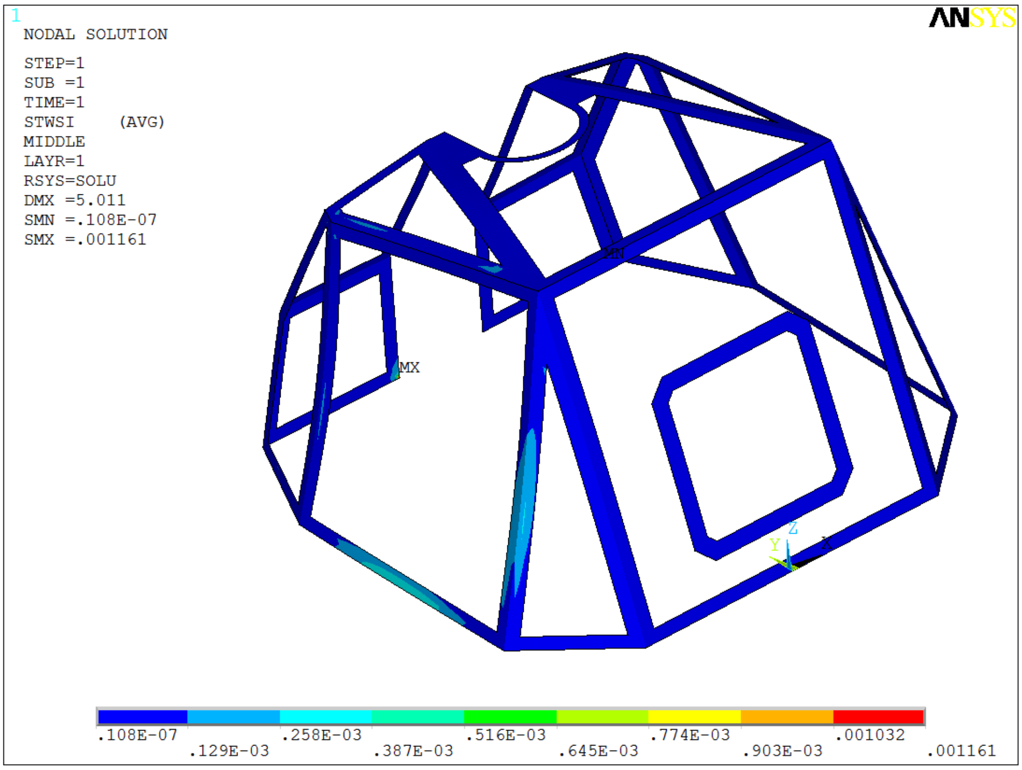


Figura 50 – Vento laterale - Coefficiente TW

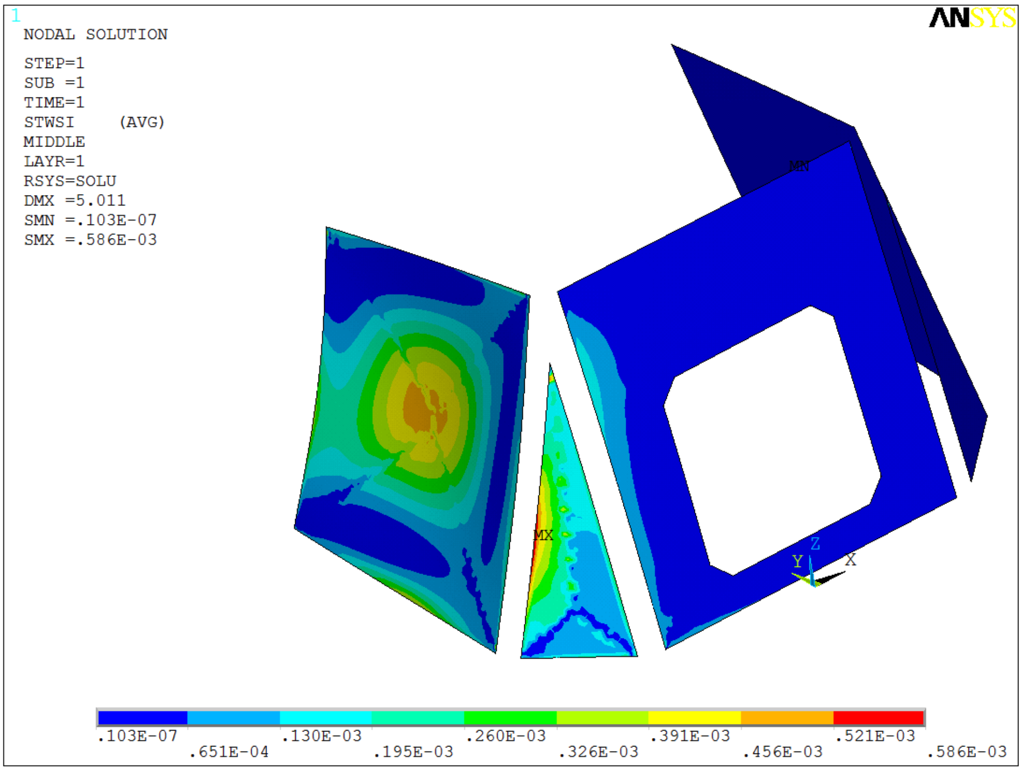


Figura 51 – Vento laterale - Coefficiente TW

In TW coefficient in wind-affected areas it is about 0.0012.

The resulting safety coefficient is CS = 1/0.0012 = 833.

38 ANALISI A TAGLIO CORE

The following figure shows the trend of shear stress in shield areas made using syntactic foam.

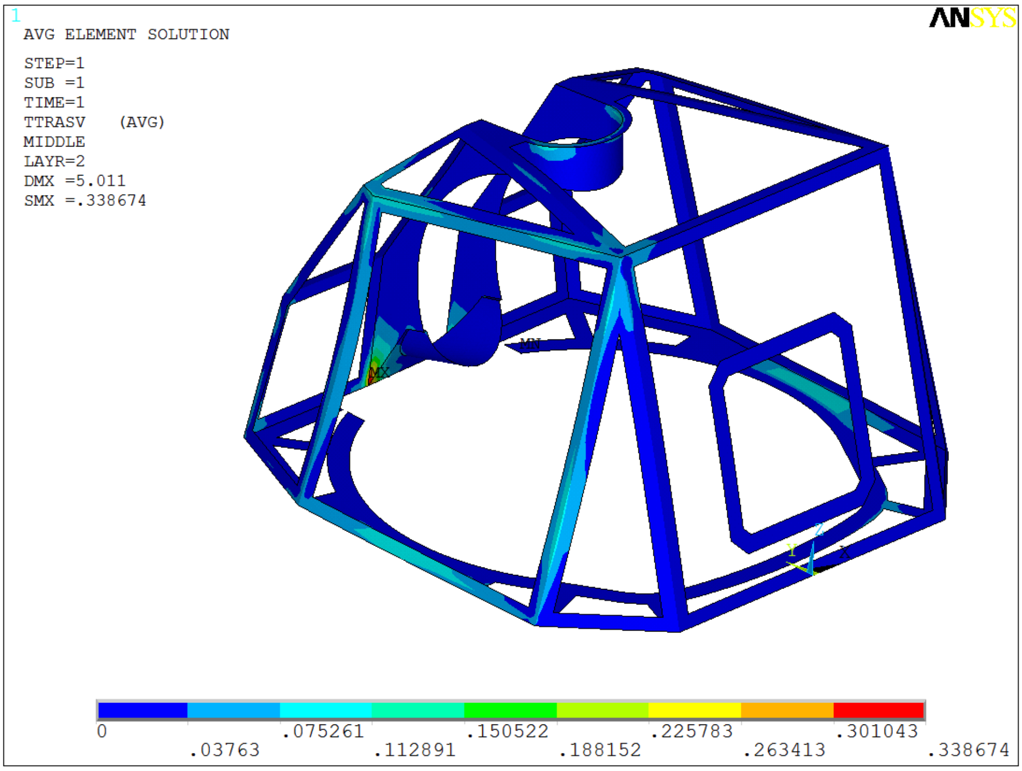


Figura 52 – Vento laterale - Taglio (MPa) schiuma sintattica

The maximum stress is 0.34 MPa.
The shear strength of the syntactic foam is 5 MPa.
The resulting safety coefficient is CS = 5/0.34 = 14.7.

The following figure shows the trend of shear stress in shield areas made using Klegecell R80 panels.

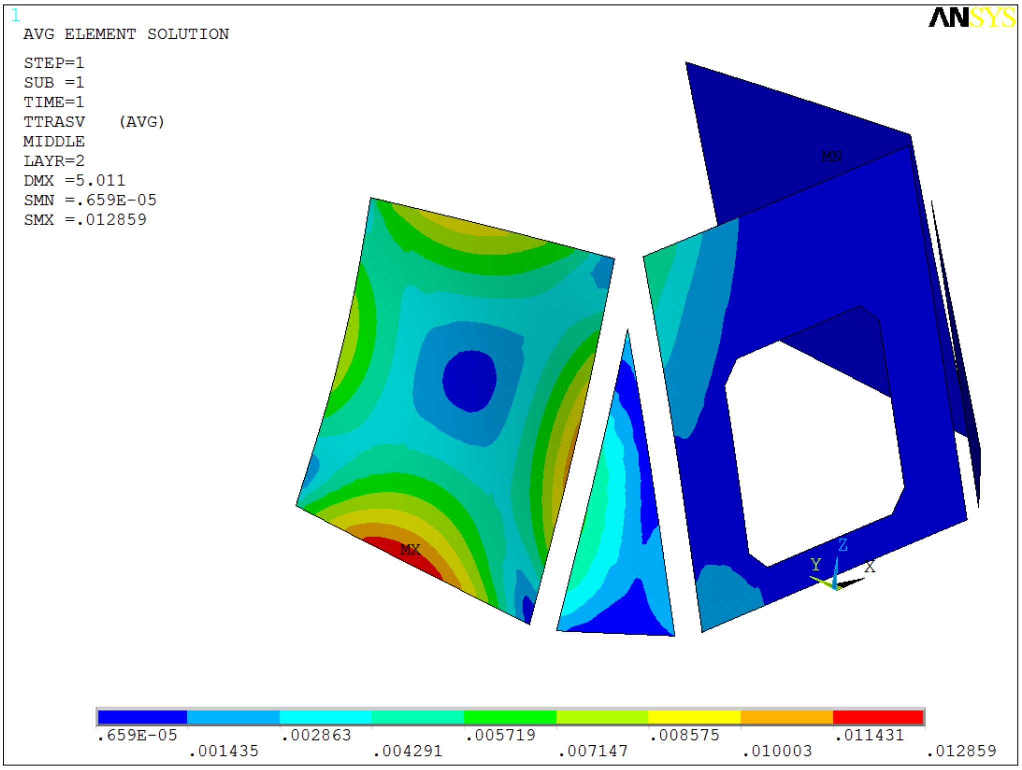


Figura 53 – Vento laterale - Taglio (MPa) Klegecell R80

The maximum stress is 0.012 MPa.

The shear strength of the Klegecell R80 core is 1.15 MPa.

The resulting safety coefficient is CS = 1.15/0.012 = 96.

39 VENTO POSTERIORE

The rear wind load condition is matched, as explained above, to a pressure distributed only on the side panels of .0.005 MPa

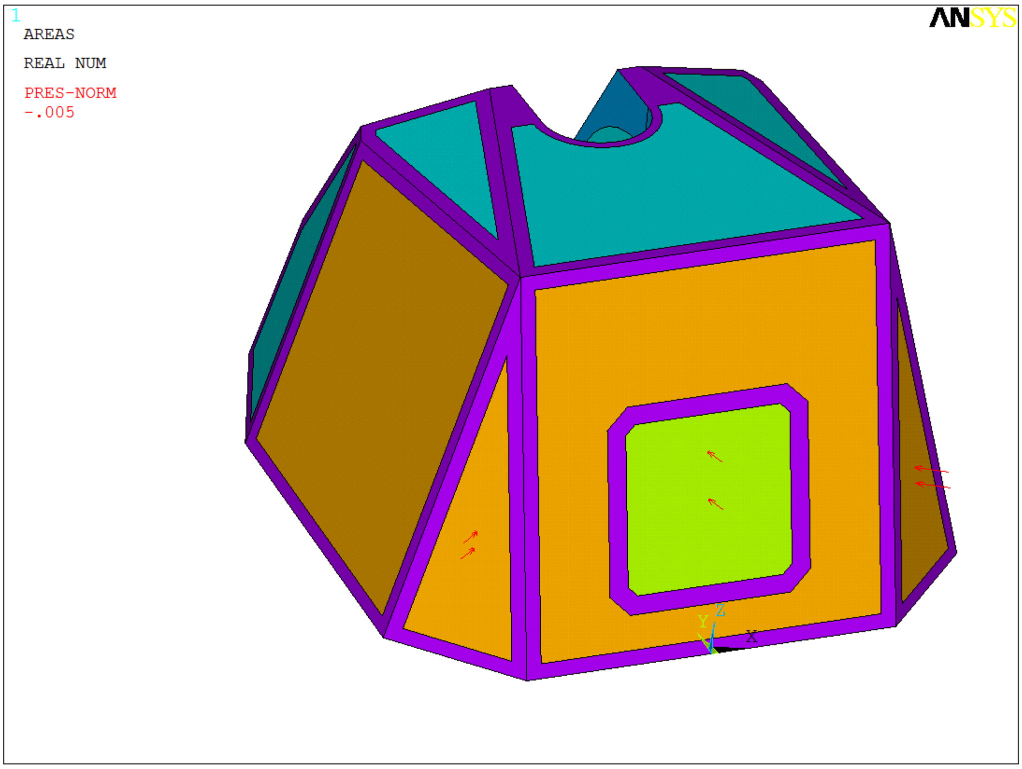


Figura 54 – Vento posteriore

40 DISPLACEMENTS

The maximum allowed deformation, defined in technical specification, is 100 mm on the side walls, 50mm on the top panel and 125mm on the back panel.

As you can see, the maximum value, equal to about 7 mm, at the back panel of the shield, is below the specification limits.

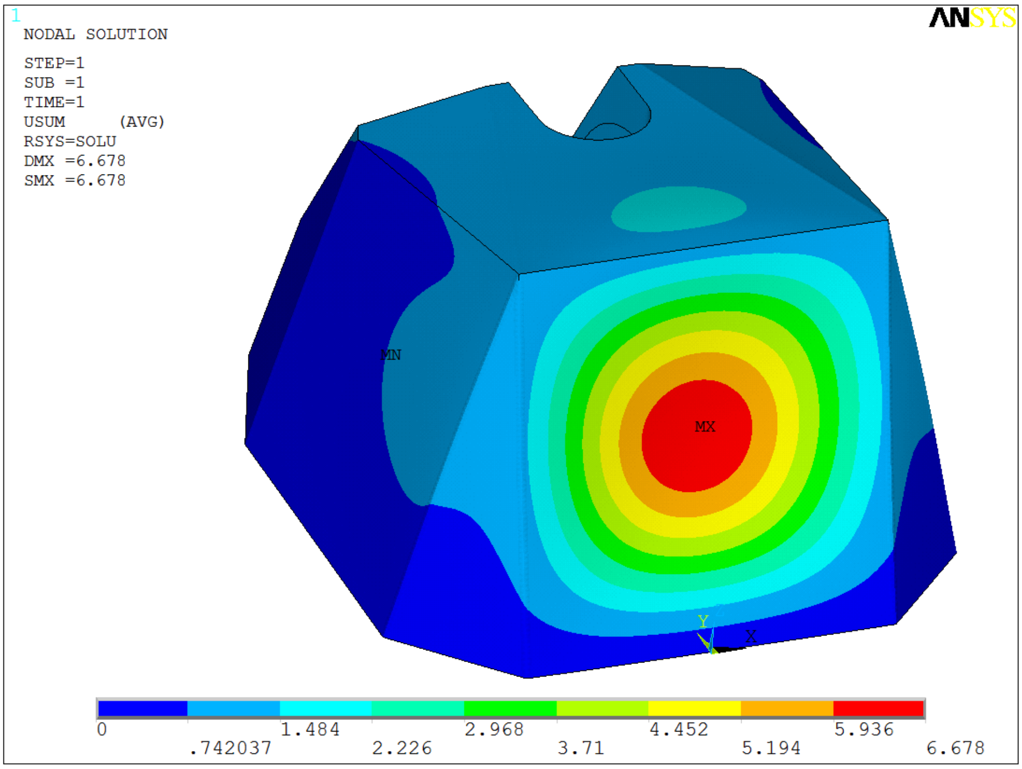


Figura 55 – Vento posteriore - spostamento (mm)

41 SOLLECITAZIONI

The stresses induced in the shield by the rear wind stress are compared with the maximum permissible stresses for each material used.

42 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

Given the local distribution of the load, the stress values at those areas are reported.

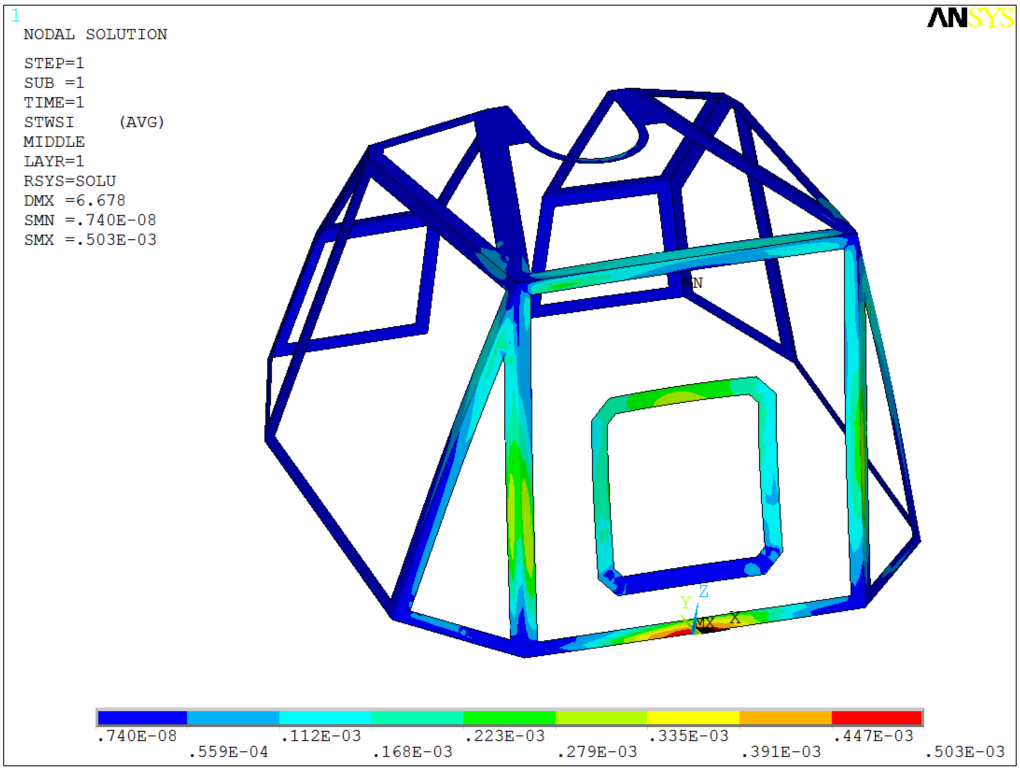


Figura 56\ – Vento posteriore - Coefficiente TW

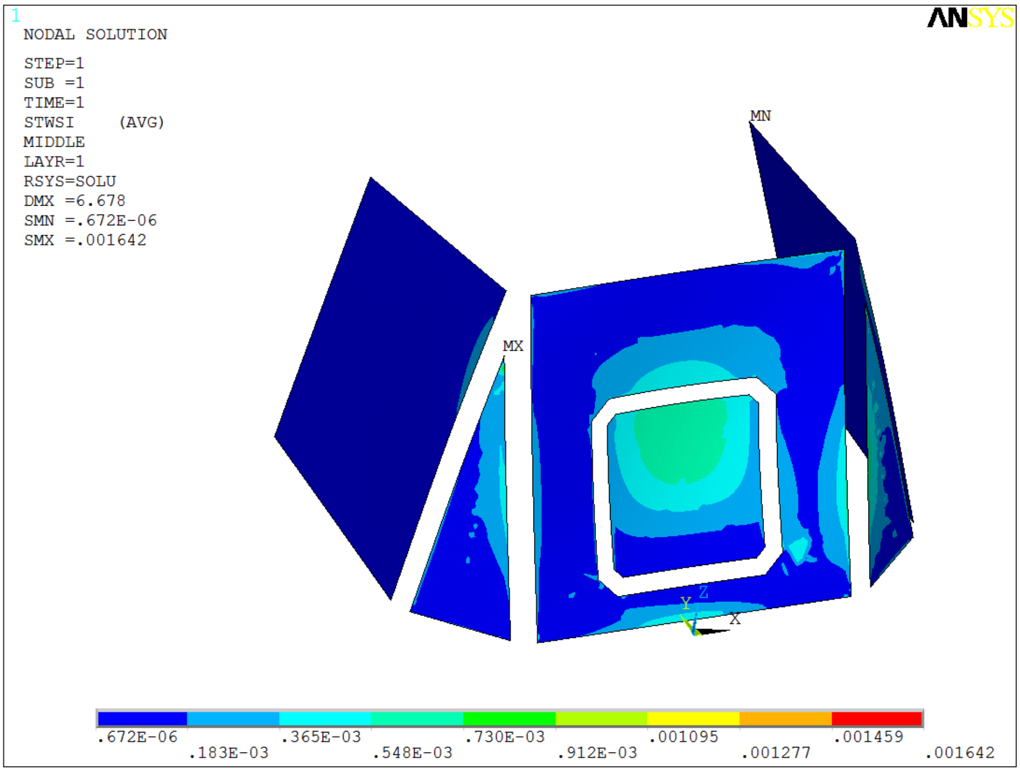


Figura 57 – Vento posteriore - Coefficiente TW

In coefficiente di TW nelle zone investite dal vento è pari a circa 0.0016.

Il coefficiente di sicurezza risultante è pari a CS = 1/0.0016 = 625.

43 ANALISI A TAGLIO CORE

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree dello scudo realizzate impiegando la schiuma sintattica.

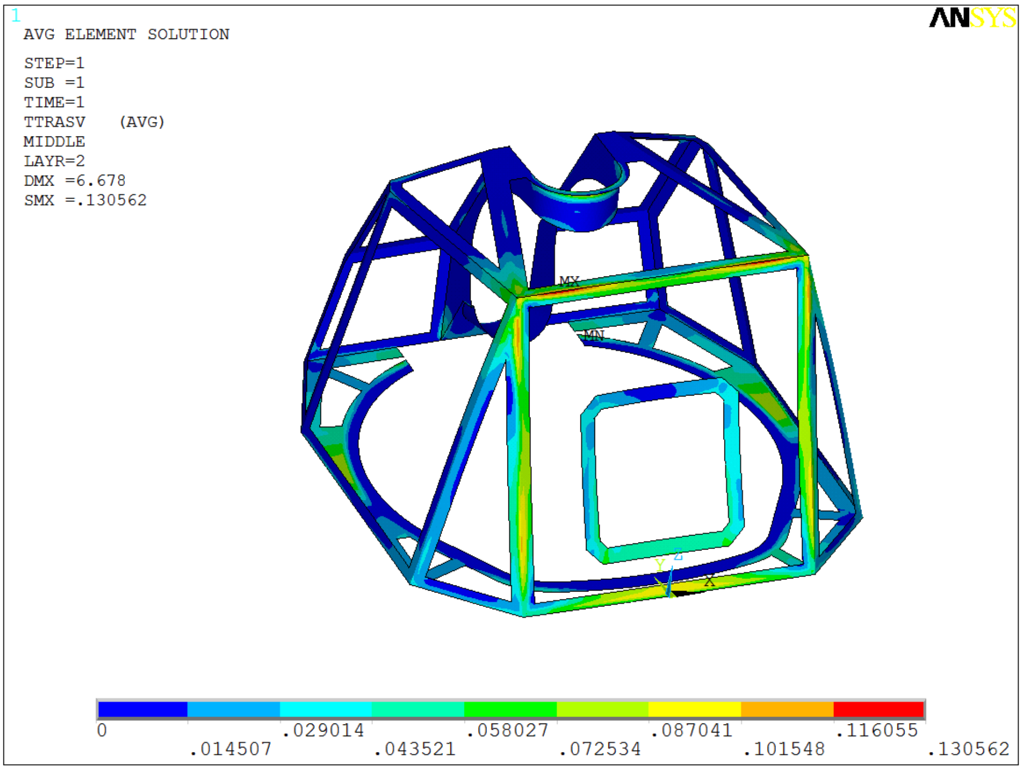


Figura 58 – Vento posteriore - Taglio (MPa) schiuma sintattica

The maximum stress is 0.13 MPa.

The shear strength of the syntactic foam is 5 MPa.

The resulting safety coefficient is CS = 5/0.13 = 38.4.

The following figure shows the trend of shear stress in shield areas made using Klegecell R80 panels.

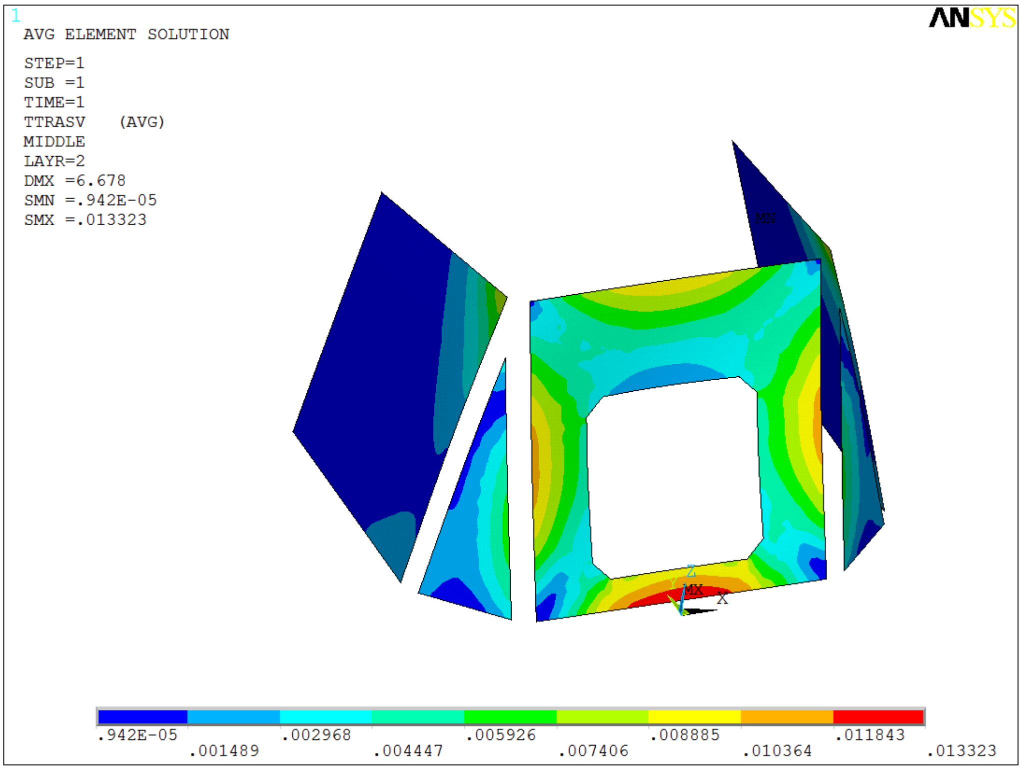


Figura 59 – Vento posteriore - Taglio (MPa) Klegecell

The maximum stress is 0.013 MPa.
The shear strength of the Klegecell R80 core is 1.15 MPa.
The resulting safety coefficient is CS = 1.15/0.013 = 88.5.

44 ICE

The Shield must be able to withstand the formation of ice, without seeing its integrity and functionality compromised, up to a maximum of $.125\ kg/m^2$.
The pressure exerting ice on the panels turns out to be:

$$125\ \ kg/m^2 = \frac{125}{9.81} N/m^2 = 12.74\, N/m^2 = 0.00001274\, MPa$$

This pressure is much lower than that due to the stress of green water load allows you to consider the requirement satisfied.

45 THERMAL TRANSMITTANCE

Thermal transmittance (U) is the amount of thermal power exchanged per unit of surface and per unit of temperature difference. It is required that: $U \leq 1.5 \frac{W}{m^2K}$

A sandwich panel consists of several layers of three different materials:

1. Quadriaxial laminate for a thickness of 2.8 mm
2. Divinycell H130 for a thickness of 30 mm or 40 mm
3. Quadriaxial laminate for a thickness of 2.8 mm

In this case the thermal transmittance (U) is calculated as follows:

$$U = \frac{1}{\sum R_i} \left[\frac{W}{m^2K}\right]$$

Where R_i is the thermal resistance of the layer and is calculated as the ratio of the thickness of the layer to its thermal conductivity $i(\lambda)$:

$$R = \frac{t}{\lambda} \left[\frac{m^2K}{W}\right]$$

As for the materials used in the shield sandwich, the following are valid:

- $\lambda_{divinycell} = 0.036 \ \frac{W}{mK}$
- $\lambda_{laminate} = 0.3 \ \frac{W}{mK}$

46 PANNELLO SANDWICH CON CORE DA 40 mm

In the case of a panel consisting of 4 quadriaxial laminate plies (0.7 mm each), 40 mm thick Divinycell H130 cores and 4 other quadriaxial laminate plies (0.7 mm each), the following are obtained:

- $R_{divinycell} = \frac{40*10^{-3}}{0.036} \frac{m^2K}{W} = 1.11 \frac{m^2K}{W}$
- $R_{laminato} = \frac{2.8*10^{-3}}{0.036} \frac{m^2K}{W} = 9.33 * 10^{-3} \frac{m^2K}{W}$

Then, the thermal transmittance is:

$$U = \frac{1}{(1.11 + 9.33 * 10^{-3} * 2)} \frac{W}{m^2K} = 0.886 \frac{W}{m^2K}$$

47 PANNELLO SANDWICH CON CORE DA 30 mm

In the case of a panel consisting of 4 quadriaxial laminate plies (0.7 mm each), 30 mm thick Divinycell H130 cores and 4 other quadriaxial laminate plies (0.7 mm each), the following are obtained:

- $R_{divinycell} = \frac{30*10^{-3}}{0.036} \frac{m^2K}{W} = 0.833 \frac{m^2K}{W}$
- $R_{laminato} = \frac{2.8*10^{-3}}{0.036} \frac{m^2K}{W} = 9.33 * 10^{-3} \frac{m^2K}{W}$

Then, the thermal transmittance is:

$$U = \frac{1}{(0.833 + 9.33 * 10^{-3} * 2)} \frac{W}{m^2K} = 1.176 \frac{W}{m^2K}$$

48 MOTI NAVE

The shield must withstand, maintaining its integrity and functionality, the acceleration due to the movements of the ship, i.e. the rolling and pitching motions.

49 MOTO DI ROLLIO

As far as the roll is concerned, the shield must withstand the acceleration due to a motion characterized by the following data:

- Rolling angle: $\vartheta_r^{max} = \pm 22.5° = \pm 0.3927\ rad$;
- Rolling period: $T_r = 10\ s$;
- Shield distance from the roll axis: $l_r = 10\ m$ (characteristic value for naval units capable of carrying the weapon).

The equation describing the motion of the shield during roll is as follows:

$$\vartheta(t) = \vartheta_{max} * \cos(\omega t)$$

The angular acceleration is therefore:

$$\ddot{\vartheta}(t) = -\omega^2 * \vartheta_{max} * \cos(\omega t)$$

This acceleration is maximum when $\cos(\omega t) = 1$.

As regards the pulsation present in the equations, it is equal to: $\omega_r = \frac{2*\pi}{T_r} = 0.628\frac{1}{s}$.

Therefore, it appears that the maximum angular acceleration of rolling is: $\ddot{\theta}_r = 0.155\ rad/s^2$

Linear acceleration is therefore: $a_r = l * \ddot{\vartheta}_r = 1.55\ m/s^2$

This acceleration turns out to be much lower than that used to verify the resistance of the shield to transverse shock, therefore it is not necessary to prepare an analysis to verify the shield in the roll motion, as it is qualitatively identical to that of vertical shock.

50 MOTO DI BECCHEGGIO

As far as pitching is concerned, the shield must withstand the acceleration due to a motion characterized by the following data:

- Pitch angle: $\vartheta_p^{max} = \pm 7.5° = \pm 0.131\ rad$;
- Period of pitch: $T_p = 5\ s$;
- Shield distance from the pitch axis: $l_p = 5\ m$ (valore caratteristico per unità navali in grado di imbarcare l'arma).

The equation describing the motion of the shield during pitching the same as for the rolling:

$$\vartheta(t) = \vartheta_{max} * \cos{(\omega t)}$$

The angular acceleration is, as written in the previous paragraph:

$$\ddot{\vartheta}(t) = -\omega^2 * \vartheta_{max} * \cos{(\omega t)}$$

This acceleration is maximum when $\cos(\omega t) = 1$.
As regards the pulsation present in the equations, it is equal to: $\omega_p = \frac{2*\pi}{T_p} = 1.2566\frac{1}{s}$.

Therefore, it appears that the maximum angular pitch acceleration is: $\ddot{\theta}_p = 0.21\ rad/s^2$
Linear acceleration is therefore: $a_r = l * \ddot{\vartheta}_r = 12.41\ m/s^2$

This acceleration is much lower than that used to verify the vertical shock shield, so it is not necessary to prepare an analysis, qualitatively identical to that of vertical shock, to verify the shield in pitch motion.

51 VIBRAZIONI

In order to assess the resistance of the shield to vibration imposed by the technical specification, a modal analysis of the artifact was first carried out.

The fundamental frequencies identified are shown in the following figures.

1. f_1 =1.15hz - 42% of the total weight of the participating shield in the Y direction (longitudinal)

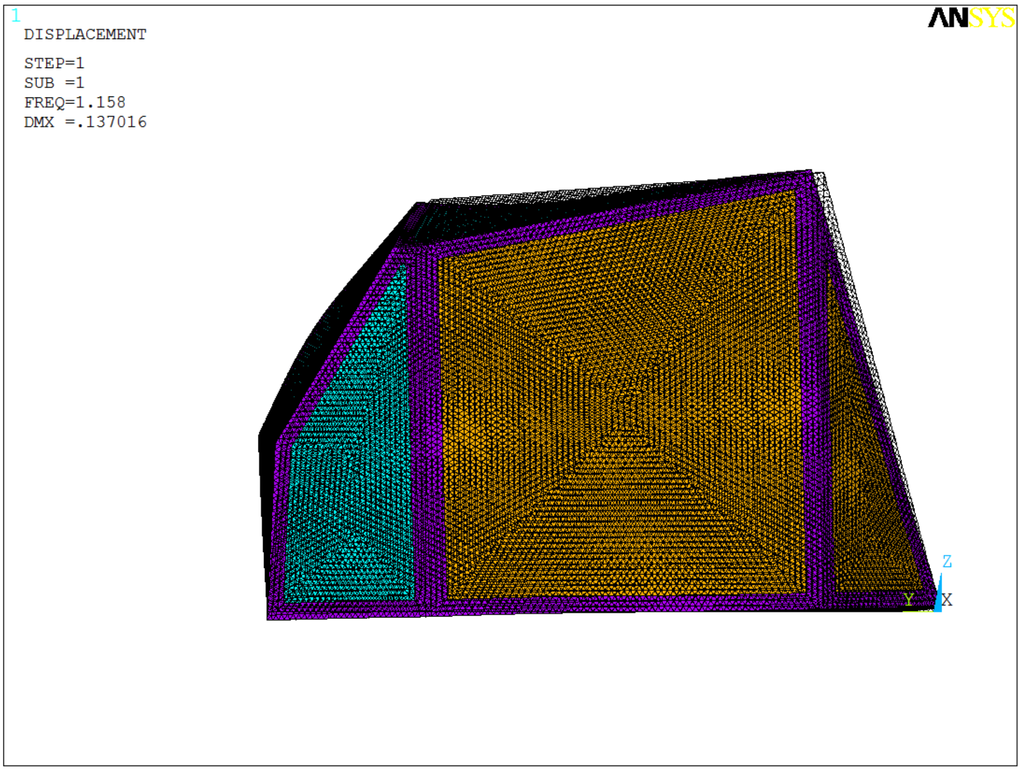


Figura 60 - Frequenza f1 - 1.15hz

2. f_2 =1.29hz - 46% of the total weight of the participating shield in direction X (transversal)

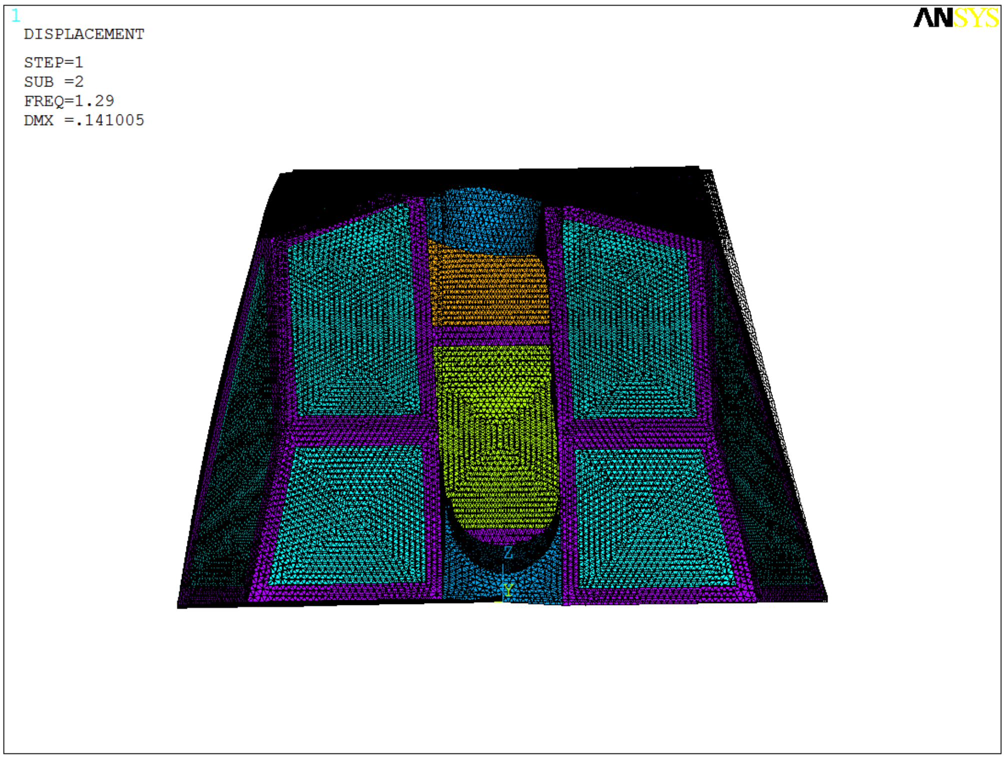


Figura 61 - Frequenza f2 - 1.29hz

3. f_3 =3.23hz - 42% of the total weight of the participating shield in the Z direction (vertical)

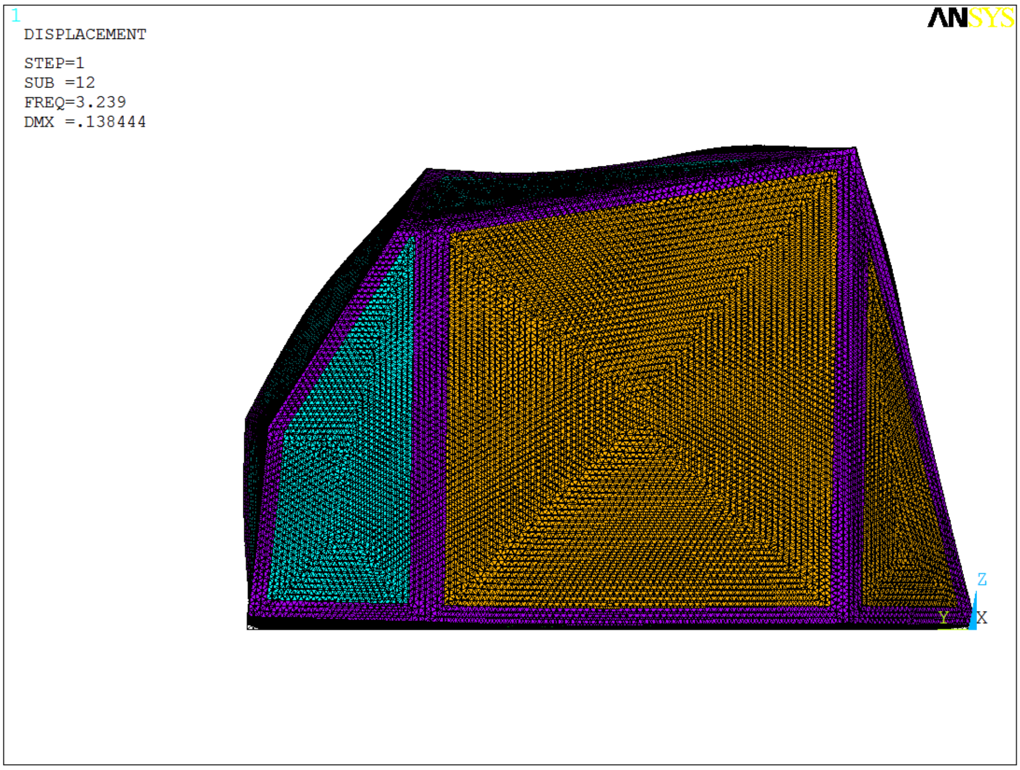


Figura 62 - Frequenza f3 - 3.23hz

Vibrations are oscillating phenomena.
The expression of time displacement is:

$$x = X_m \sin(\omega t)$$

where Xm is the vibration amplitude.
Deriving twice results in acceleration;

$$a = -\omega^2 X_m \sin(\omega t)$$

The maximum acceleration is:

$$a_m = -\omega^2 X_m$$

Substituting ω with 2πf, where f is the frequency:

$$a_m = (2\pi f)^2 X_m$$

The specification requirement is that the shield must bear the vibrational load indicated in the MIL-STD-167A Equipment Type, with interval 4 - 33 hz, and displacement 0.25 mm.

In this case we have the following accelerations:

Freq. [hz]	**Spost. [mm]**	**Accel. (m/s^2)**
4-33	0.25	10.7

Tabella 3 - Accelerazioni vibrazionali

Previously, we have verified that the most significant fundamental frequencies of the shield are outside the range 4-33 Hz, being below 4 Hz.
Moreover, it can be expected that these frequencies will in fact be slightly lower since the assembly on the screws has not been taken into account in the analysis.
For these reasons, the accelerations imposed on the shield are much lower than those used for vertical and horizontal shock verification.
The above therefore makes it possible to consider the requirement satisfied.

52 VERIFICA GIUNZIONI BULLONATE AFFUSTO

In this chapter the local resistance of the shield will be compared at the screws connecting with the affusto with the strength of the screws themselves to verify that the maximum load transmissible from the latter is bearable by theshield.

Damage around the hole can occur in two ways:

- By re-displacement, in case of transversely transmitted load;

- For shearing in case of load along the axis of the screw.

For both types of load, the analytical model used for verification is described below.

53 MODELLO ANALITICO VERIFICA A RIFOLLAMENTO

The following figure shows a typical transverse load condition (T) on the walls of a circular opening in the sandwich.

Such a load induces a state of compression on the walls of the hole.

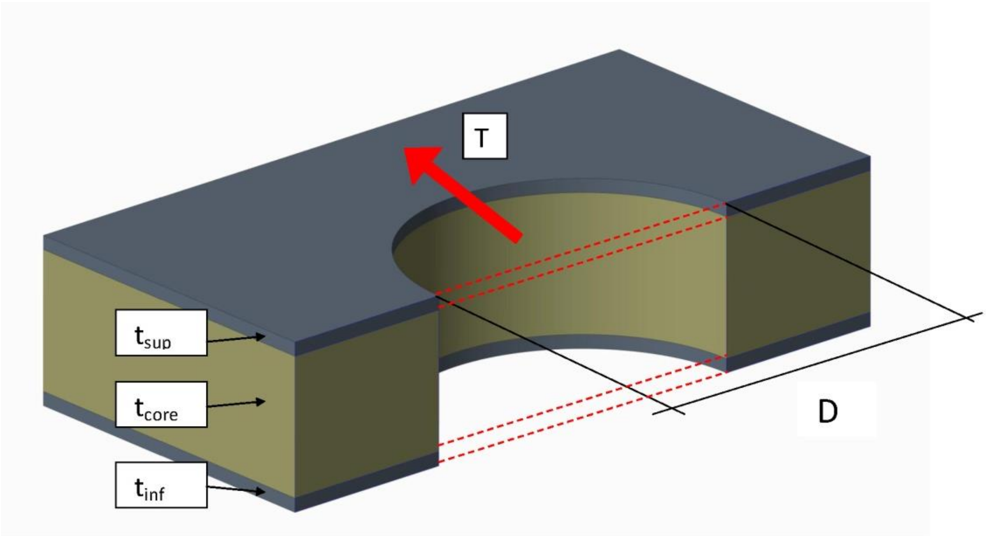


Figura 63 – Modello rifollamento sandich

Considering the sequence of layers as a set of rigidities in series, the average stiffness of the composite E_m is assessed:

$$E_m = \frac{A_{sup}E_{sup} + A_{core}E_{core} + A_{inf}E_{inf}}{A_{TOT}}$$

Where:

- $A_{sup} = D(t_{sup})$ – Area resistente laminato superiore del composito;
- $A_{core} = D(t_{core})$ - Area resistente core;
- $A_{inf} = D(t_{inf})$ - Area resistente laminato inferiore del composito;
- $A_{TOT} = D(t_{sup} + t_{inf} + t_{core})$ - Area totale resistente a compressione;
- $\sigma_m = \frac{T}{A_{TOT}}$ - Pressione media di compressione sulle pareti del foro;
- E_{sup} , E_{inf} , E_{core} - moduli di Young dei materiali componenti il sandwich.

From E_m the average deformation of the walls of the hole is obtained:

$$\epsilon_m = \frac{\sigma_m}{E_m}$$

Finally, the stress state in the individual layers is obtained from the following relationships:

- $\sigma_{sup} = \epsilon_m E_{sup}$
- $\sigma_{core} = \epsilon_m E_{core}$
- $\sigma_{inf} = \epsilon_m E_{inf}$

54 MODELLO ANALITICO VERIFICA A TRANCIATURA

The following figure shows a typical longitudinal load condition T transmitted by a screw on the area surrounding a circular opening in the sandwich.

This load induces a state of tangential tension through the composite (dotted line).

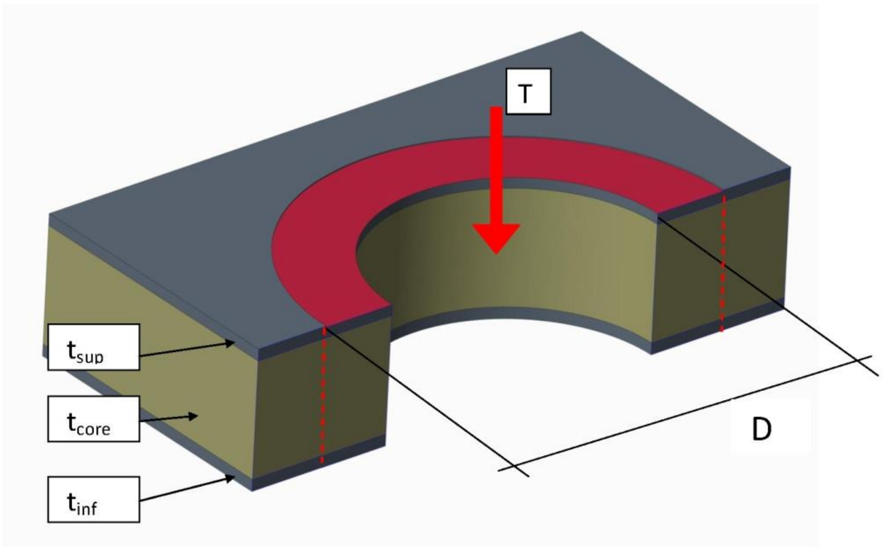


Figura 64 - Modello tranciatura sandwich

Considering the sequence of layers as a set of rigidities in series, the average shear stiffness of the composite G_m is assessed:

$$G_m = \frac{A_{sup}G_{sup} + A_{core}G_{core} + A_{inf}G_{inf}}{A_{TOT}}$$

Where:

- $A_{sup} = \pi D(t_{sup})$ - Area resistente laminato superiore del composito;
- $A_{core} = \pi D(t_{core})$ - Area resistente core;
- $A_{inf} = \pi D(t_{inf})$ - Area resistente laminato inferiore del composito;
- $A_{TOT} = D(t_{sup} + t_{inf} + t_{core})$ - Area totale resistente a compressione;
- $\tau_m = \frac{T}{A_{TOT}}$ - Tensione tangenziale media attraverso il composito;
- G_{sup} , G_{inf} , G_{core} - moduli elastici tangenziali dei materiali componenti il sandwich

From G_m the average deformation of the walls of the hole is obtained:

$$\gamma_m = \frac{\tau_m}{G_m}$$

Finally, the stress state in the individual layers is obtained from the following relationships:

- $\tau_{sup} = \gamma_m G_{sup}$
- $\tau_{core} = \gamma_m G_{core}$
- $\tau_{inf} = \gamma_m G_{inf}$

55 VERIFICA CARICO TRASMISSIBILE

Il collegamento tra scudo e affusto avviene mediante viti M12 classe A4-70.

Il numero e la disposizione delle viti non sono oggetto di ottimizzazione essendo imposti per motivi di intercambiabilità.

In questo paragrafo verrà verificato, utilizzando l'approccio appena descritto, che il massimo carico trasmissibile della viti sia localmente compatibile con la resistenza dello scudo.

Per la valutazione del carico trasmissibile dalle viti si adottarà quanto indicato dalla normativa a Rif. R3.

Non essendo contemplati nella norma i collegamenti in acciaio inossidabile si farà conservativamente riferimento alle viti classe 8.8.

Siano $\sigma_{b,adm}$ e $\tau_{b,adm}$ la massima tensione assiale e trasversale ammisibile dalla vite e A_{res} la sezione resistente per le viti M12.

Si ha:

$$\sigma_{b,adm} = 373 \text{ MPa}$$
$$\tau_{b,adm} = 264 \text{ MPa}$$
$$A_{res} = 84 \text{ mm}^2$$

I carichi massimi trasmissibili dalle viti in direzione assiale (F_a) e trasversale (F_t) sono dunque:

$$F_a = \sigma_{b,adm} A_{res} = 31332 \text{ N;}$$
$$F_t = \tau_{b,adm} A_{res} = 22176 \text{ N;}$$

La flangia di base, in corrispondenza delle viti di collegamento è realizzata, ad eccezione della zona frontale, in sandwich di vetroresina e schiuma sintattica con la seguente stratificazione: 3.5mm vetroresina / 35mm schiuma sintattica / 3.5mm vetroresina.

La zona frontale del basamento è realizzata in massello di vetroresina spessore 20mm la cui resistenza è evidentemente superiore di quella in sandwich.

Intorno ai fori delle viti verrà collocata la bussola in acciaio inossidabile illustrata nella figura che segue:

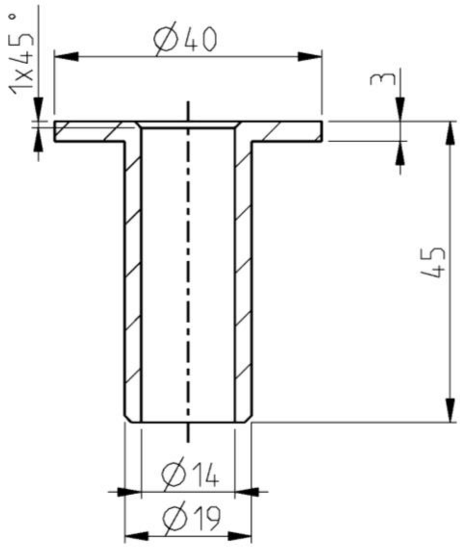


Figura 65 - Bussola viti di fissaggio affusto

Per quanto riguarda la verifica a rifollamento (vedi §0) si ha:

- $A_{sup} = 66.5\ mm^2$ - Area resistente laminato superiore del composito;
- $A_{core} = 665\ mm^2$- Area resistente core;
- $A_{inf} = 66.5\ mm^2$ - Area resistente laminato inferiore del composito;
- $A_{TOT} = 798\ mm^2$ - Area totale resistente a compressione;
- $\sigma_m = \frac{F_t}{A_{TOT}} = 27.7\ MPa$ - Pressione media di compressione sulle pareti del foro;
- E_{sup} , $E_{inf} = 15000\ MPa$ - Modulo di Young vetroresina;
- $E_{core} = 1500\ MPa$ - Modulo di Young schiuma sintattica;

Applicando quanto al §0si ottiene:

- $\sigma_{sup} = 165\ MPa$
- $\sigma_{core} = 0.4\ MPa$
- $\sigma_{inf} = 165\ MPa$

La tensione di rottura a compressione della vetroresina è pari a 262 Mpa (vedi **Errore. L'origine riferimento non è stata trovata.**).
La tensione di rottura a compressione della schiuma sintattica è pari a 35 MPa.
Il coefficiente di sicurezza sul danneggiamento a compressione del fori è dato dalla componente in vetroresina ed è pari a CS = 262/165 = 1.58

Per quanto riguarda la verifica a tranciatura si ha:

- $A_{sup} = 440\ mm^2$ - Area resistente laminato superiore del composito;
- $A_{core} = 4400\ mm^2$- Area resistente core;
- $A_{inf} = 440\ mm^2$ - Area resistente laminato inferiore del composito;
- $A_{TOT} = 5280\ mm^2$ - Area totale resistente a tranciatura;

- $\tau_m = \frac{F_a}{A_{TOT}} = 5.93\ MPa$ - Tensione tangenziale media attraverso il composito;
- G_{sup} , $G_{inf} = 2940\ MPa$ - Modulo elastico tangenziale vetroresina;
- $G_{core} = 500\ MPa$ - Modulo elastico tangenziale schiuma sintattica (stimato ipotizzando υ=0.5) ;

Applicando quanto al §54 si ottiene:

- $\tau_{sup} = 19.2\ MPa$
- $\tau_{core} = 3.3\ MPa$
- $\tau_{inf} = 19.2\ MPa$

La tensione di rottura a taglio della vetroresina è pari a 156 Mpa (vedi **Errore. L'origine riferimento non è stata trovata.**).

La tensione di rottura a taglio della schiuma sintattica è pari a 5 MPa.

Il coefficiente di sicurezza sul danneggiamento a tranciamento del fori è data dalla componente in schiuma sintattica ed è pari a CS = 5/3.3 = 1.51

Concludendo, il basamento dello scudo è in grado di trasmettere localmente il carico massimo ammissibile dalle viti M12 impiegate nel collegamento.

56 ANALISI BECCHI RIPORTATI

57 INTRODUZIONE

In base alle evidenze delle analisi condotte nei precedenti capitoli si ritiene di verificare la resistenza del becco riportato alle sollecitazioni di Green Water Load (GWL), Shock e vibrazioni.

Le altre sollecitazioni, infatti, producono nel manufatto deformazioni e tensioni mediamente di un ordine di grandezza inferiori.

I collegamenti filettati tra becco e scudo vengono verificati in condizione GWL.

58 MODELLO FEM

Lo scopo del modello FEM è la valutazione dello stato di sollecitazione e le deformazioni nelle diverse condizioni di carico imposte dai requisiti di specifica.

A tal proposito viene realizzato un modello 3D in cui le pareti del becco sono discretizzate mediante elementi di tipo SHELL99 (vedi Appendice A) a cui vengono attribuite le sequenze di laminazione, gli spessori e le proprietà meccaniche dei materiali che compongono le diverse porzioni del becco.

59 DESCRIZIONE DEL MODELLO FEM

Di seguito viene presentata, in termini di materiali e spessori utilizzati, la struttura del becco.

Ad ogni area è assegnato un colore corrispondente ad una differente sequenza di materiali e spessori.

Si adottano le seguenti diciture:

- nQX = n strati di laminato quadriassiale;
- xmm H100 = x mm di core Dyvinicell H100;
- xmm E-Foam = x mm di schiuma sintattica.

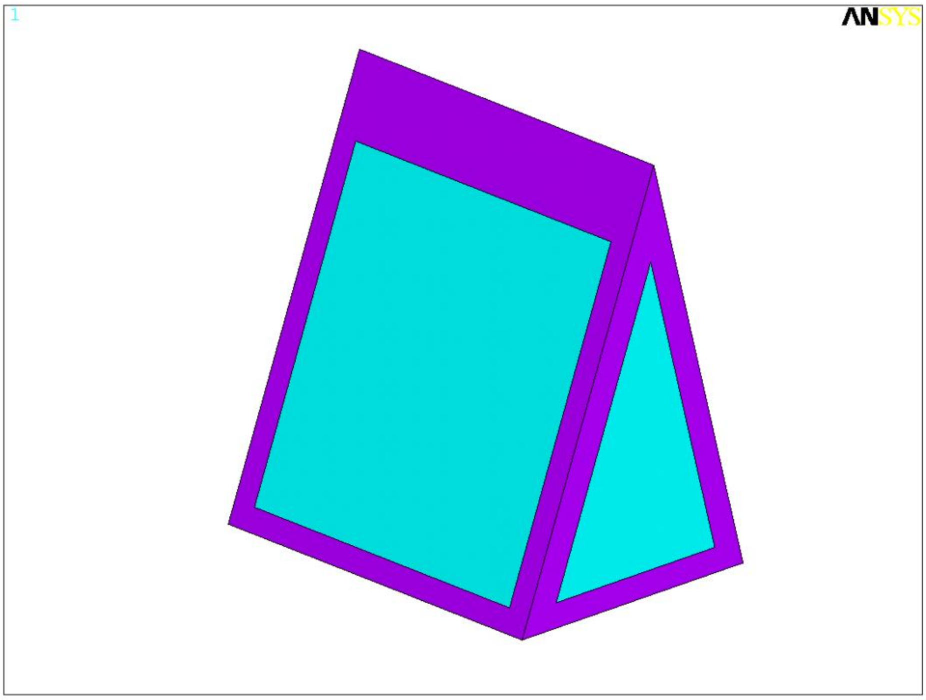


Figura 66 – Modello becco - vista anteriore

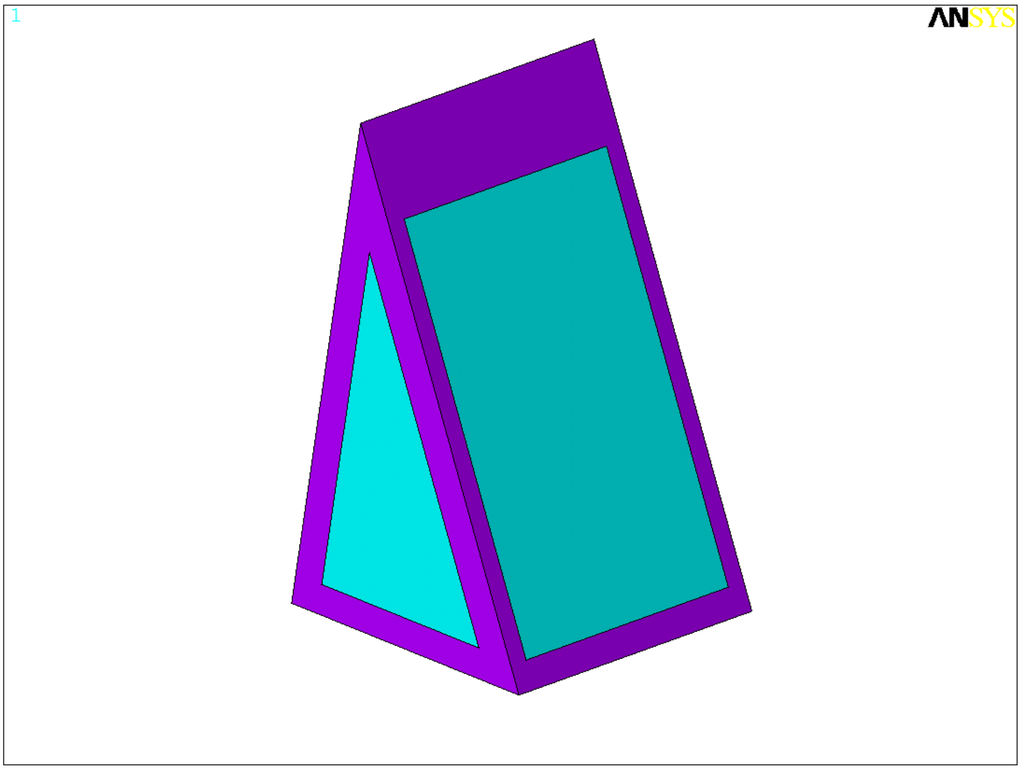


Figura 67 – Modello becco - vista laterale

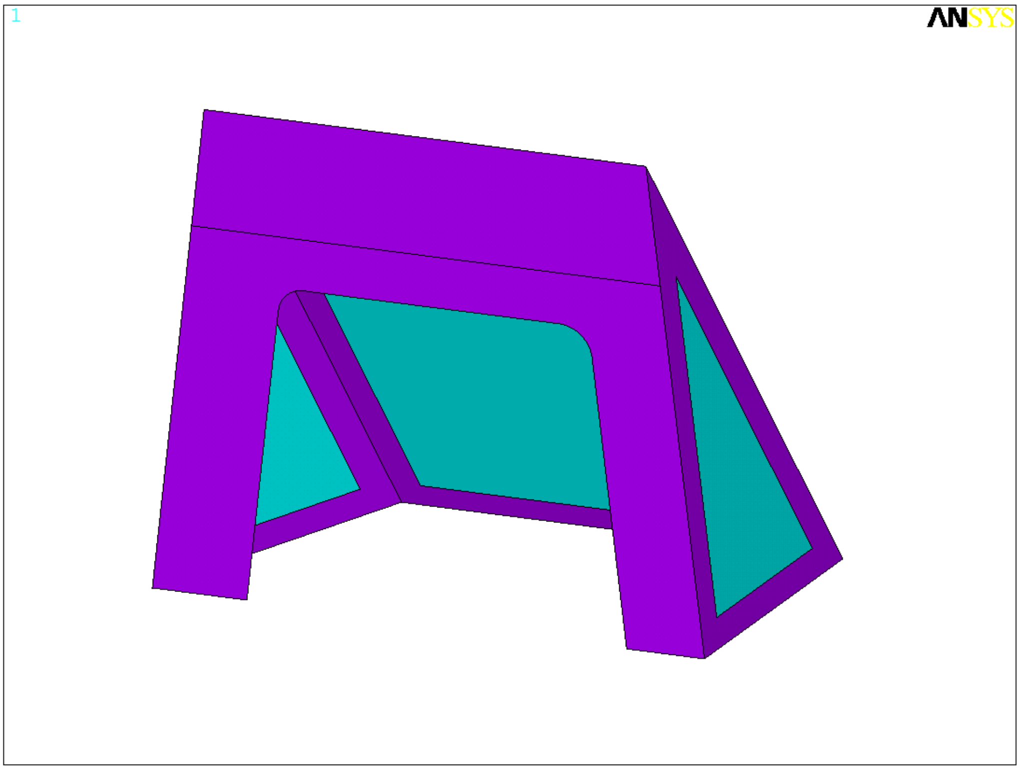


Figura 68 – Modello becco - vista posteriore

	2QX + 20mm H100 + 2QX
	2QX + 20mm E-Foam + 2QX

Figura 69 – Legenda composizione becco

Il modello così realizzato è stato discretizzato impiegando elementi Shell99 con una dimensione caratteristica dell'elemento pari a 5mm.
Di seguito viene mostrato il modello discretizzato.

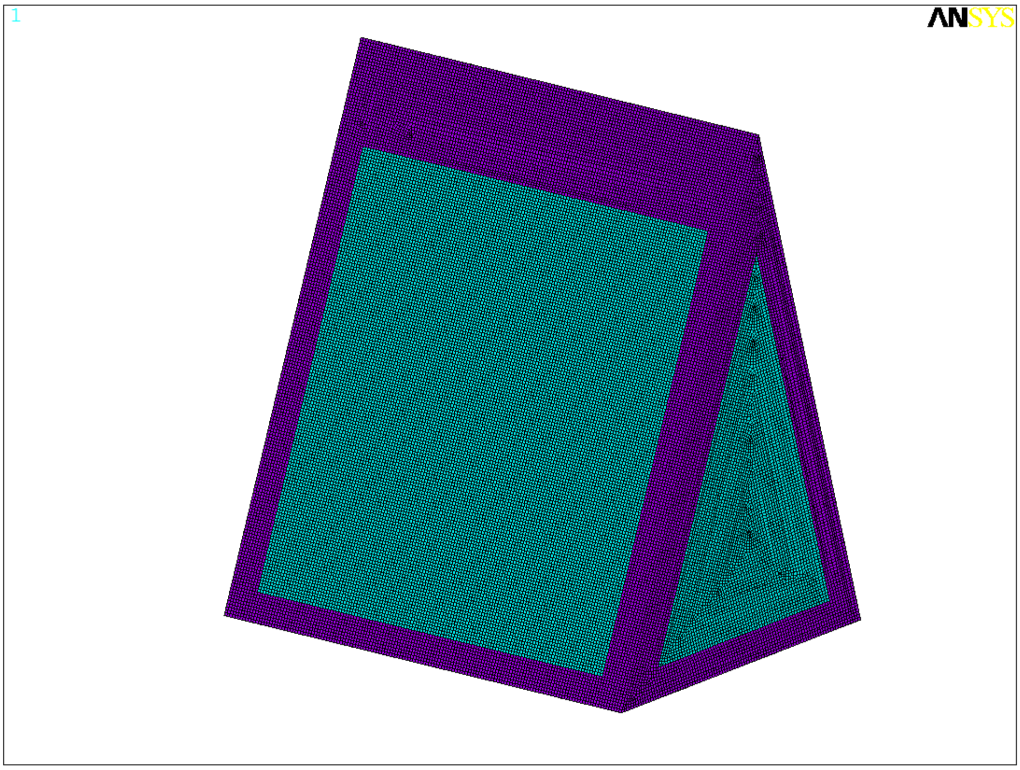


Figura 70 - Modello FEM - vista anteriore

60 GREEN WATER LOAD (GWL)

La pressione di impatto dell'onda è imposta pari a 1bar (0.1 MPa).

Tali pressione viene applicata come carico idrostatico su tutte le pareti del becco (ad eccezione della flangia posteriore di accoppiamento che viene vincolata).

61 SPOSTAMENTI

La freccia massima consentita, definita in specifica tecnica, è di 100 mm.

Nelle figure seguenti è possibile apprezzare la freccia, espressa in mm, nei vari pannelli dello scudo, sottoposti al carico GWL.

Come si può notare il valore massimo, pari a circa 41mm, è al di sotto dei limiti di specifica.

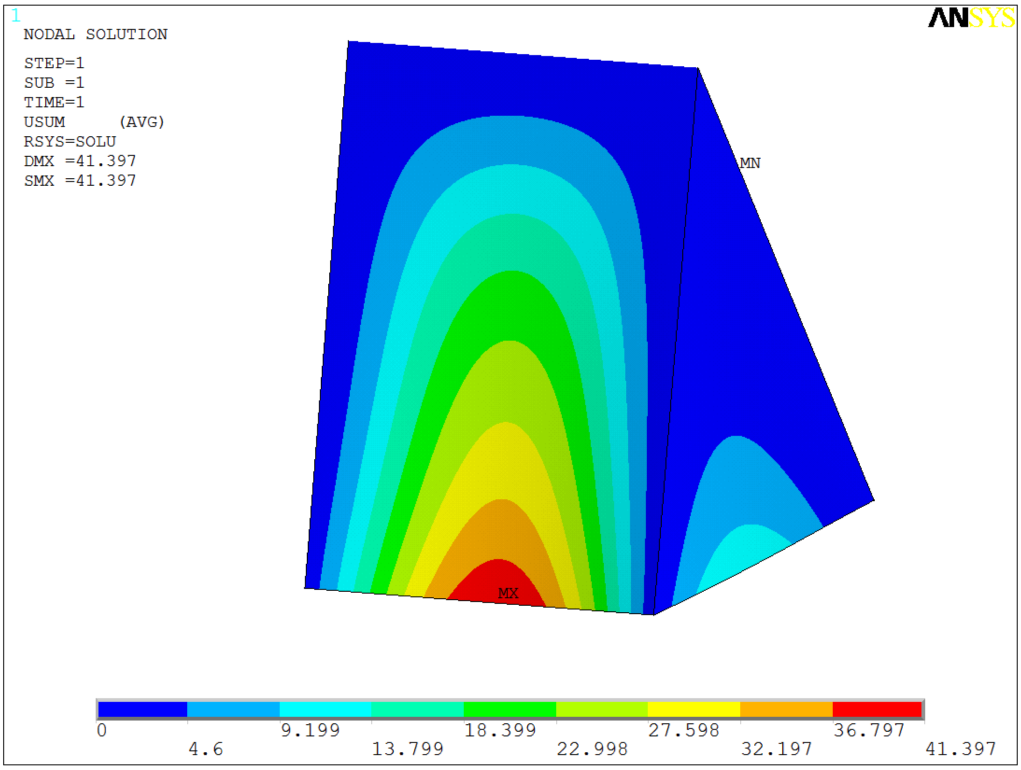


Figura 71 – GWL - spostamento (mm)

62 SOLLECITAZIONI

Le tensioni indotte nel becco dal carico GWL vanno confrontate con le massime tensioni ammissibili per ciascun materiale utilizzato.

63 *SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW*

Le immagini che seguono mostrano l'andamento del coefficiente di TW nelle lamine di composito che costituiscono le pareti esterne dei sandwich.

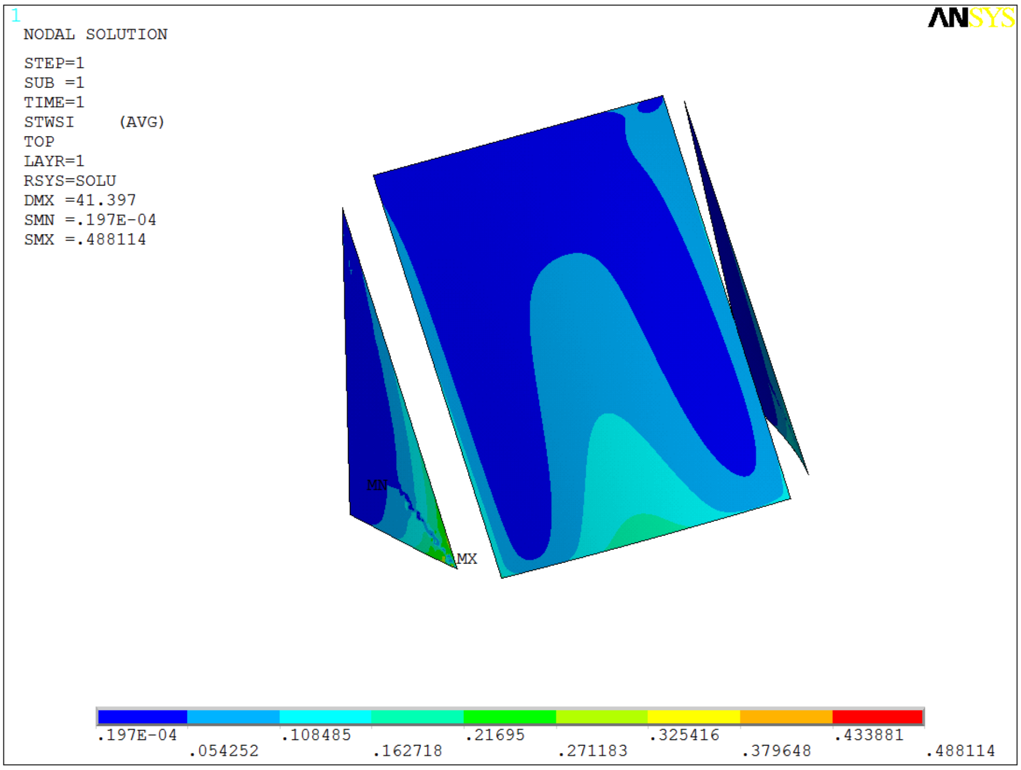


Figura 72 – GWL - Coefficiente TW

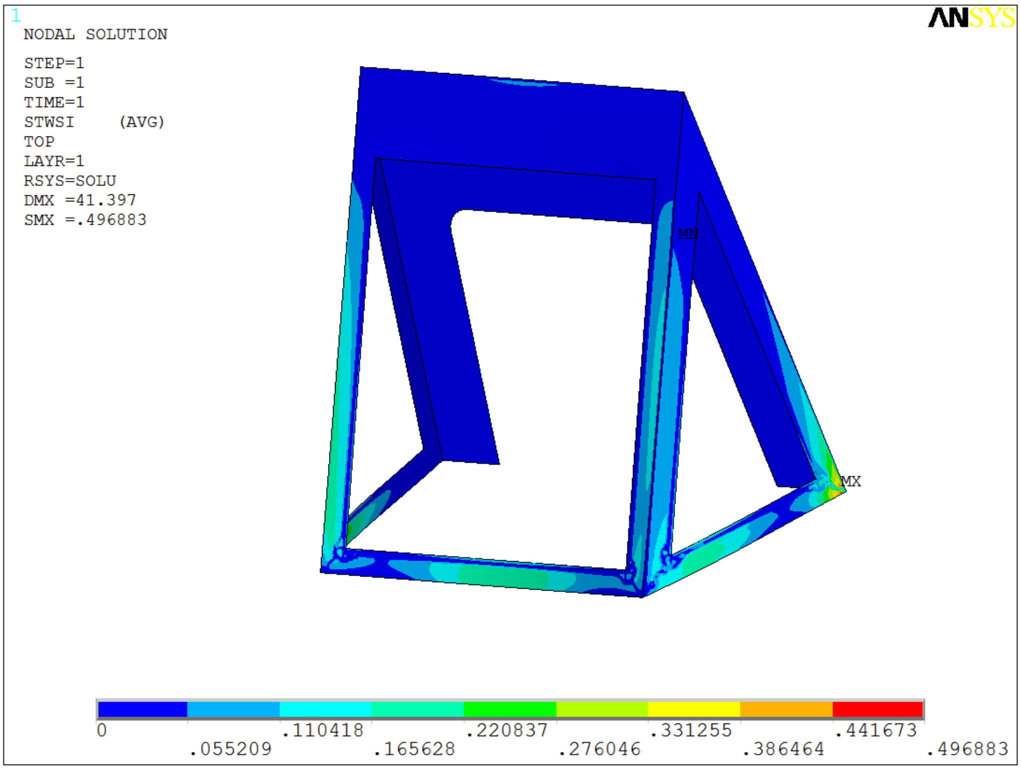


Figura 73 – GWL - Coefficiente TW

Il massimo valore del coefficiente di TW è pari a circa 0.5.
Il coefficiente di sicurezza risultante è pari a CS = 1/0.5 = 2.

64 ANALISI A TAGLIO CORE

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree realizzate impiegando pannelli di Dyvinicell H100.

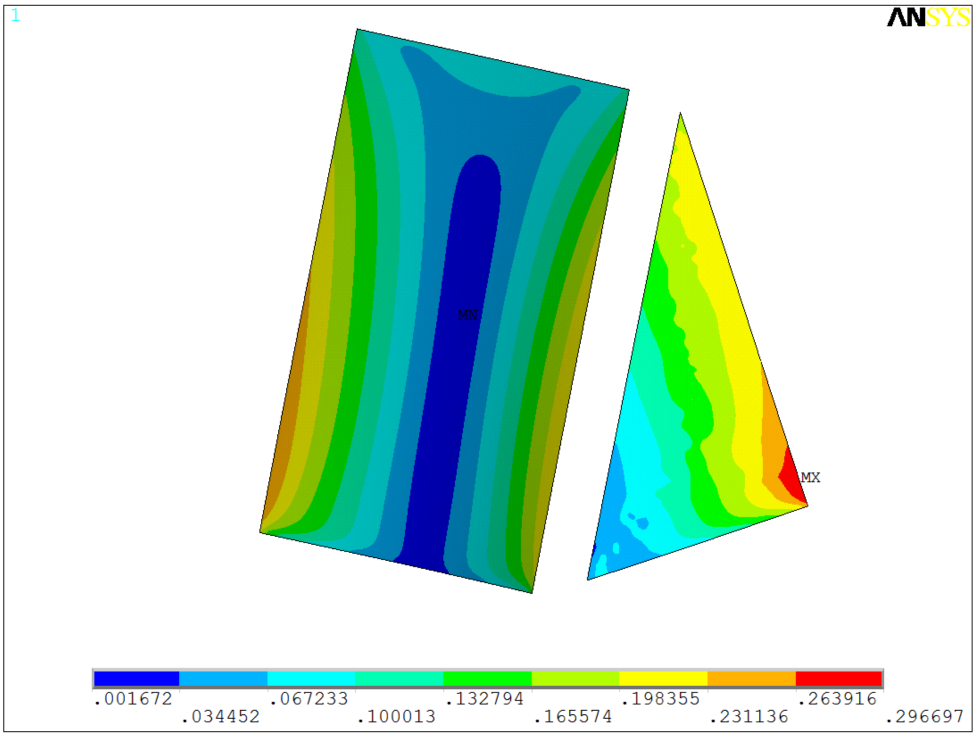


Figura 74 – GWL - Taglio (MPa) Dyvinicell H100

La massima sollecitazione è pari a 0.3 MPa.

La resistenza a taglio del core Dyvinicell H100 è pari a 1.6 MPa.

Il coefficiente di sicurezza risultante è pari a CS = 1.6/0.3 = 5.3.

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree dello scudo realizzate impiegando schiuma sintattica.

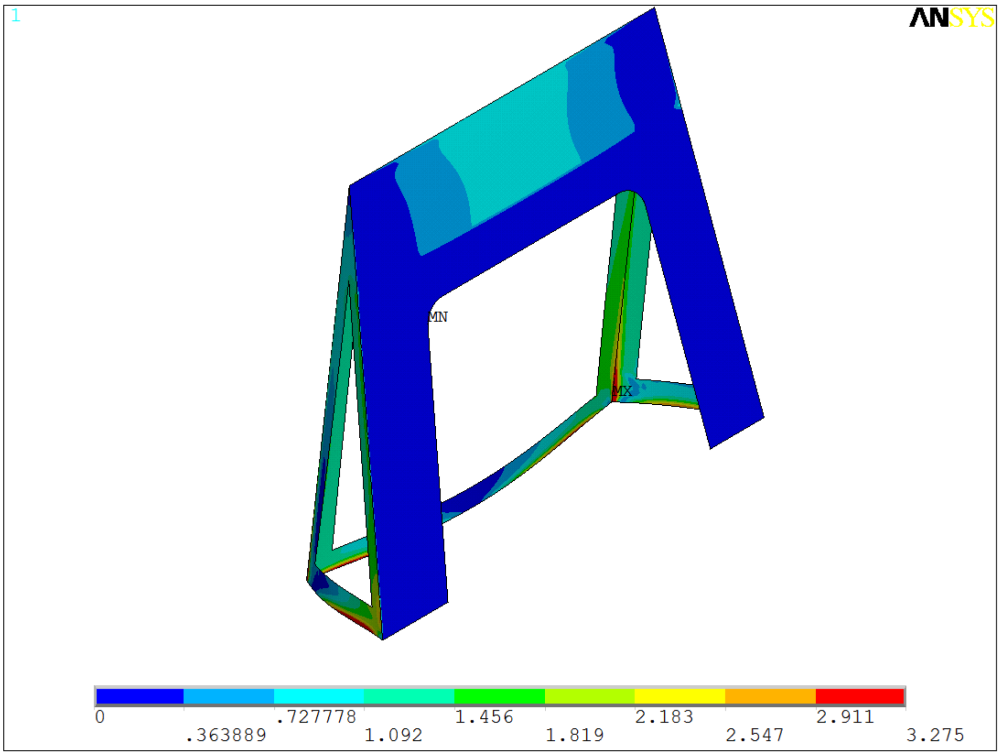


Figura 75 – GWL - schiuma sintattica

La massima sollecitazione è pari a 3.275 MPa.
La resistenza a taglio della schiuma sintattica è pari a 5 MPa.
Il coefficiente di sicurezza risultante è pari a CS = 5/3.275 = 1.53.

65 VERIFICA COLLEGAMENTO BECCO SCUDO

66 VERIFICA COLLEGAMENTI FILETTATI BECCO-SCUDO

Il collegamento tra ciascun becco e lo scudo avviene mediante n°13 elementi filettati M12 / A4-70.

La verifica dei collegamenti filettati tra becco e parete frontale dello scudo viene effettuata in condizione di carico GWL pari a 1bar (p_{GWL} = 0.1MPa).

In tale condizione, ipotizzando conservativamente la pressione dell'onda agente solo sulla parete laterale esterna, di area pari a $A_l = 0.2m^2$ e sulla superficie frontale, di area pari a $0.74m^2$.

Per la nostra analisi considereremo la proiezione verticale dell'area frontale in modo da valutare la forza trasversale e carico dei collegamenti filettati.

Si ha dunque una superficie $A_2=0.34m^2$.

La figura che segue mostra la disposizione delle viti di collegamento tra becco e affusto.

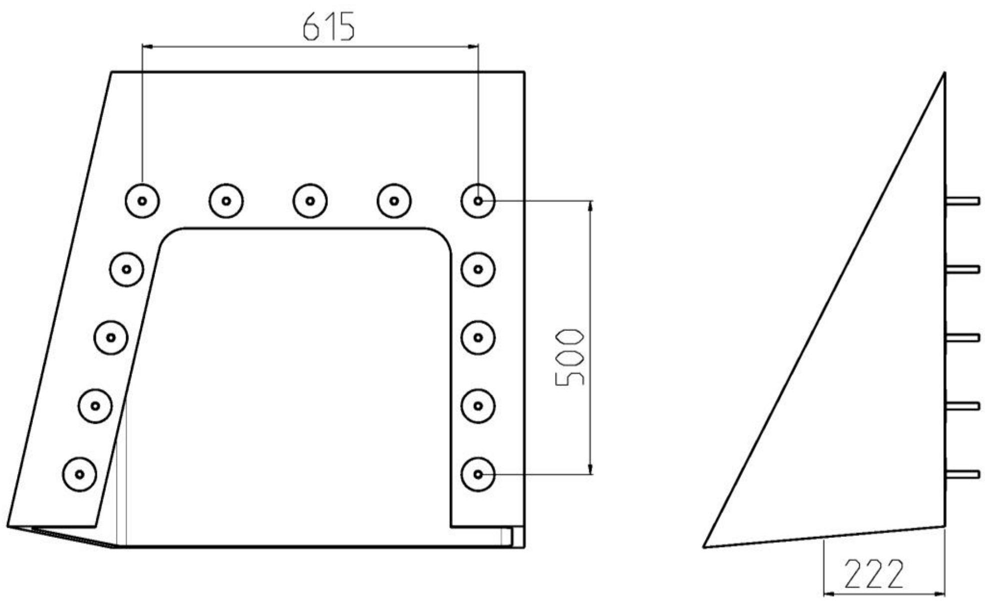


Figura 76 - Disposizione collegamenti becco

La distanza minima tra le due fili di viti disposte in verticale è pari a L_o = 615mm e rappresenta il braccio della coppia che si oppone al momento (M_{1GWL}) indotto dalla pressione d'onda sulla parete laterale.

Tale momento, ipotizzando conservativamente un braccio pari a L_l = 222mm (vedi figura), sarà pari a:

$$M_{1GWL} = A_l p_{GWL} L_l = 4440Nm.$$

Esso si traduce in un carico di trazione assiale sulla fila di viti esterne del collegamento becco/scudo e di compressione in corrispondenza della fila di viti interne.

Il carico di trazione F_{atot} si ottiene dalla relazione:

$$M_{1GWL} = F_{a1tot} L_o$$

che fornisce F_{a1tot} = 7155N.

Su ciscuna delle 5 viti della fila agirà dunque un carico pari a:

$$F_{a1} = F_{a1tot} / 5 = 1431N.$$

Discorso analogo per il momento indotto dalla componente verticale della forza generata dalla pressione d'onda sulla parete frontale.

Ipotizzando conservativamente che tale momento sia sostenuto solamente dalle due coppie di viti distanti L_V = 500mm (vedi figura) si ha:

$$M_{2GWL} = A_2 p_{GWL} L_l = 7548Nm$$
$$M_{2GWL} = F_{a2tot} L_v$$

che fornisce $F_{a1tot} = 15096N$.

Su ciscuna delle 2 viti della fila agirà dunque un carico pari a:

$$F_{a1} = F_{a2tot} / 2 = 7548N.$$

Sulle viti agisce inoltre una carico di taglio F_{Ttot} che, ipotizzando non venga compensato dall'attrito tra le flange di accoppiamento, è dato dalla somma della componente verticale $F_v = A_2 p_{GWL}$ e di quella trasversale $F_{Tr} = A_1 p_{GWL}$.

Si ha:

$$F_{Ttot} = \sqrt{F_V^2 + F_{Tr}^2} = 39446N$$

Tale carico corrisponde ad una forza media per ciascuna delle 13 viti pari a

$$F_t = F_{Ttot}/13 = 3034N$$

Riassumendo, sui collegamenti più sollecitati si avrà:

$$F_{amax} = F_{a1} + F_{a2} = 8979 \text{ N (massimo carico assiale)}$$
$$F_t = 3034 \text{ N (massimo carico trasversale)}$$

Considerando una sezione resistente $A_{res} = 84mm^2$ per i collegamenti M12 valutiamo le massime tensioni assiali e tangenziali derivanti dalle sollecitazioni appena ottenute:

$$\sigma = 8979/84 = 106.9 \text{ MPa};$$
$$\tau = 3034/84 = 36.1\text{MPa};$$

Per la verifica di collegamenti viene adottata la normativa a riferimento R3.

Non essendo contemplati nella norma i collegamenti in acciaio inossidabile si farà conservativamente riferimento alle viti classe 8.8.

Siano $\sigma_{b,adm}$ e $\tau_{b,adm}$ la massima tensione assiale e trasversale ammisibile dalla vite e A_{res} la sezione resistente per le viti M12.

Si ha:

$$\sigma_{b,adm} = 373 \text{ MPa};$$
$$\tau_{b,adm} = 264 \text{ MPa};$$
$$A_{res} = 84 \text{ mm}^2$$

La normativa prescrive la seguente verifica che tiene in conto l'azione combinata di sforzi normali e di taglio.

$$\left(\frac{\tau}{\tau_{amm}}\right)^2 + \left(\frac{\sigma}{\sigma_{amm}}\right)^2 \le 1$$

Nel caso in questione si ottiene:

$$\left(\frac{\tau}{\tau_{amm}}\right)^2 + \left(\frac{\sigma}{\sigma_{amm}}\right)^2 = 0.1 \le 1$$

Quanto sopra consente di ritenere verificata la resistenza dei collegamenti filettati impiegati per giuntare i becchi ai pannelli frontali dello scudo.

67 VERIFICA DANNEGGIAMENTO DEL COMPOSITO NEL COLLEGAMENTO BECCO/SCUDO

Con riferimento a quanto esposto nel Cap. 52 verrà verificata la capacità del collegamento tra le parti in composito di becco e scudo di trasferire i carichi valutati nel precedente paragrafo.

Per quanto riguarda la verifica a tranciamento verrà analizzata la sola struttura del becco essendo localmente realizzata secondo la stratificazione *1.4 mm vetroresina / 20mm schiuma sintattica / 1.4 mm vetroresina* a differenza della parete frontale dello scudo costruita invece impiegando la evidentemente più resistente stratificazione *2.1mm vetroresina / 30mm schiuma sintattica / 2.1 mm vetroresina.*

La figura che segue mostra il montaggio di un elemento di collegamento sul becco.

La rondella in acciaio inossidabile diametro 50mm ha il compito di distribuire il carico di tranciamento su una adeguata superficie.

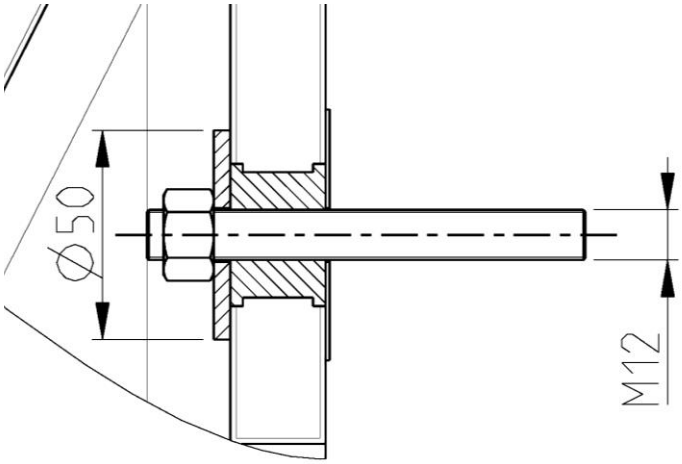


Figura 77 - Montaggio collegamento filettato becco

Si ha (vedi §54) :

- $A_{sup} = 220\ mm^2$ - Area resistente laminato superiore del composito;
- $A_{core} = 3140\ mm^2$- Area resistente core;
- $A_{inf} = 220\ mm^2$ - Area resistente laminato inferiore del composito;
- $A_{TOT} = 3580\ mm^2$ - Area totale resistente a tranciatura;
- $\tau_m = \frac{F_a}{A_{TOT}} = 2.5\ MPa$ - Tensione tangenziale media attraverso il composito;
- G_{sup} , $G_{inf} = 2940\ MPa$ - Modulo elastico tangenziale vetroresina;
- $G_{core} = 500\ MPa$ - Modulo elastico tangenziale schiuma sintattica (stimato ipotizzando υ=0.5) ;

Applicando quanto al §54 si ottiene:

- $\tau_{sup} = 9.2\ MPa$
- $\tau_{core} = 1.6\ MPa$
- $\tau_{inf} = 9.2\ MPa$

La tensione di rottura a taglio della vetroresina è pari a 156 MPa (vedi **Errore. L'origine riferimento non è stata trovata.**).

La tensione di rottura a taglio della schiuma sintattica è pari a 5 MPa (vedi **Errore. L'origine riferimento non è stata trovata.**)..

Il coefficiente di sicurezza sul danneggiamento a tranciamento del fori è data dalla componente in schiuma sintattica ed è pari a CS = 5/1.6 = 3.125.

Per quanto riguarda la verifica a rifollamento verrà invece verificata la parete frontale dello scudo.

I fori praticati in essa verranno completati montando, con la flangia all'interno dello scudo, le bussole in acciaio inossidabile illustrate nella figura che segue:

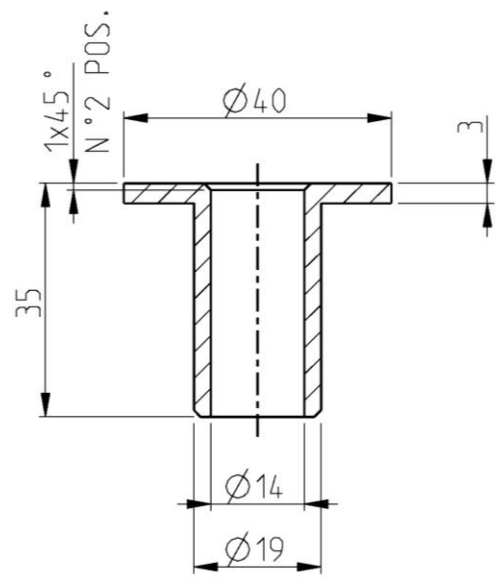


Figura 78 - Bussola collamento becco

Con riferimento al §0 si ha:

- $A_{sup} = 40\ mm^2$ - Area resistente laminato superiore del composito;
- $A_{core} = 570\ mm^2$- Area resistente core;
- $A_{inf} = 40\ mm^2$ - Area resistente laminato inferiore del composito;
- $A_{TOT} = 650\ mm^2$ - Area totale resistente a compressione;
- $\sigma_m = \frac{F_t}{A_{TOT}} = 4.7\ MPa$ - Pressione media di compressione sulle pareti del foro;
- E_{sup} , $E_{inf} = 15000\ MPa$ - Modulo di Young vetroresina;
- $E_{core} = 1500\ MPa$ - Modulo di Young schiuma sintattica;

Applicando quanto al §0si ottiene:

- $\sigma_{sup} = 22.2\ MPa$
- $\sigma_{core} = 2.2\ MPa$
- $\sigma_{inf} = 22.2\ MPa$

La tensione di rottura a compressione della vetroresina è pari a 262 MPa (vedi **Errore. L'origine riferimento non è stata trovata.**).
La tensione di rottura a compressione della schiuma sintattica è pari a 35 MPa.
Il coefficiente di sicurezza sul danneggiamento a compressione del fori è dato dalla componente in vetroresina ed è pari a CS = 262/ = 11.8.

Concludendo, i collegameni filettati tra becco e scudo sono in grado di sopportare le sollecitazioni indotte dal colpo d'onda considerato applicato sulle parete laterale esterna e su quella frontale del becco stesso.

68 SHOCK

69 SHOCK VERTICALE

La sollecitazione di shock verticale si traduce in una accelerazione statica (positiva o negativa), pari a 500 m/s^2.

70 *SPOSTAMENTI*

La freccia massima consentita, definita in specifica tecnica, è di 100 mm.

Come si può notare il valore massimo, pari a circa 1 mm è al di sotto dei limiti di specifica.

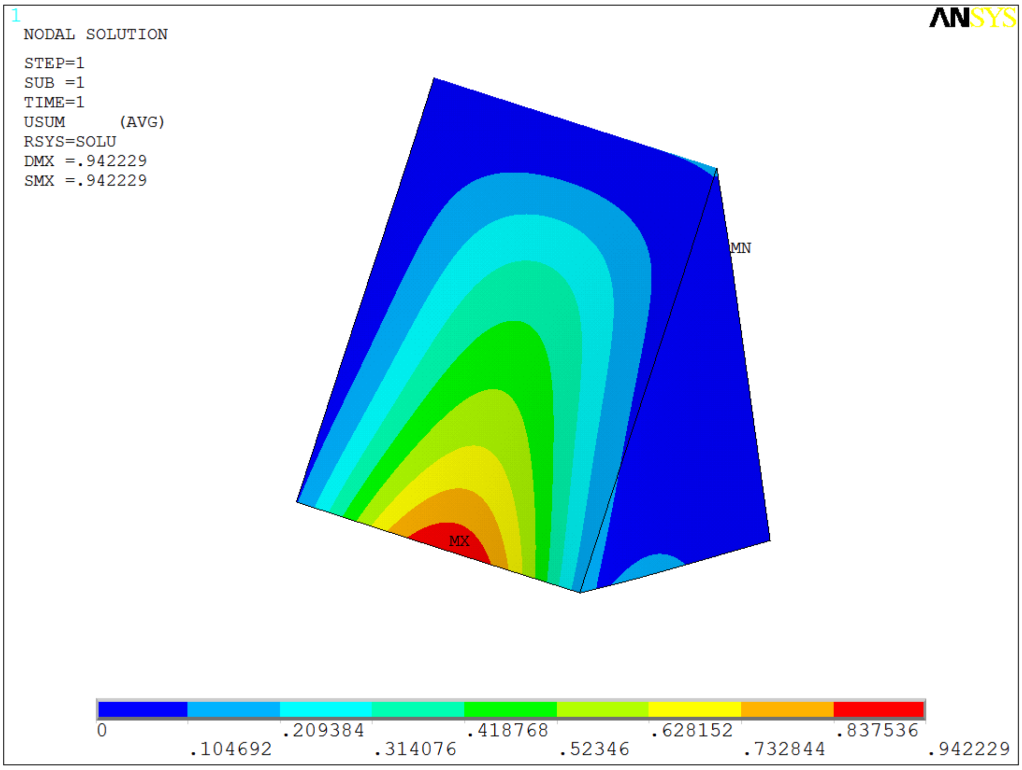


Figura 79 – Shock verticale - spostamento (mm)

71 *SOLLECITAZIONI*

Le tensioni indotte nel becco dell'accelerazione verticale, vanno confrontate con le massime tensioni ammissibili per ciascun materiale utilizzato.

72 SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW

Le immagini che seguono mostrano l'andamento del coefficiente di TW nelle lamine di composito che costituiscono le pareti esterne dei sandwich.

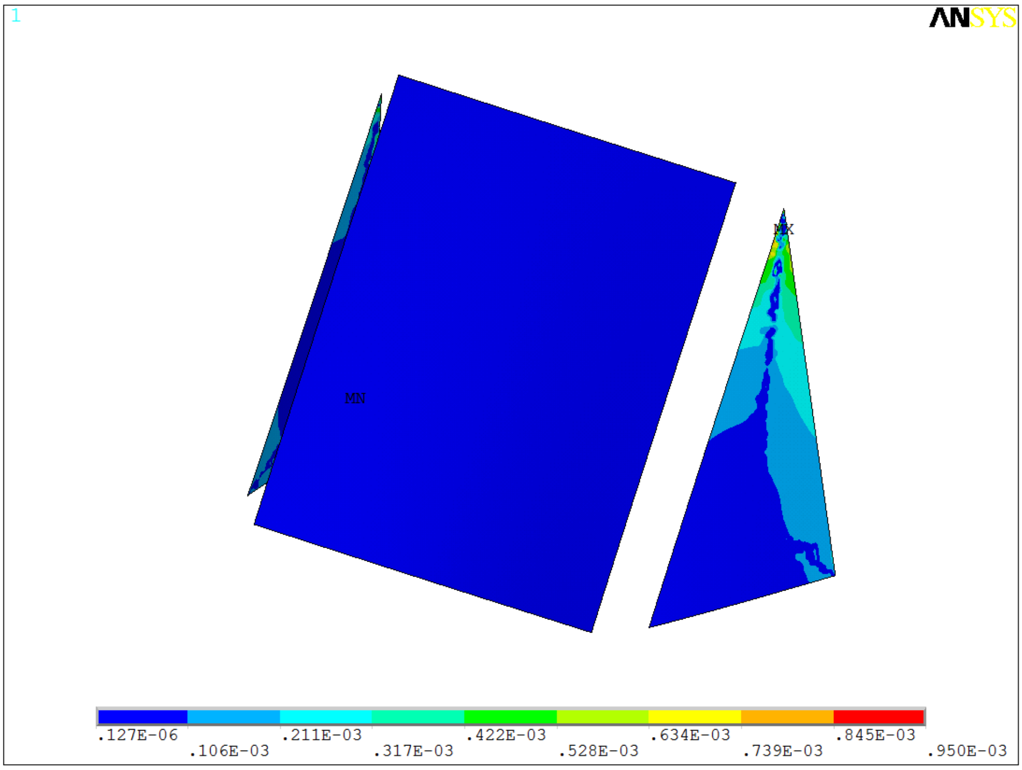


Figura 80 – Shock verticale - Coefficiente TW

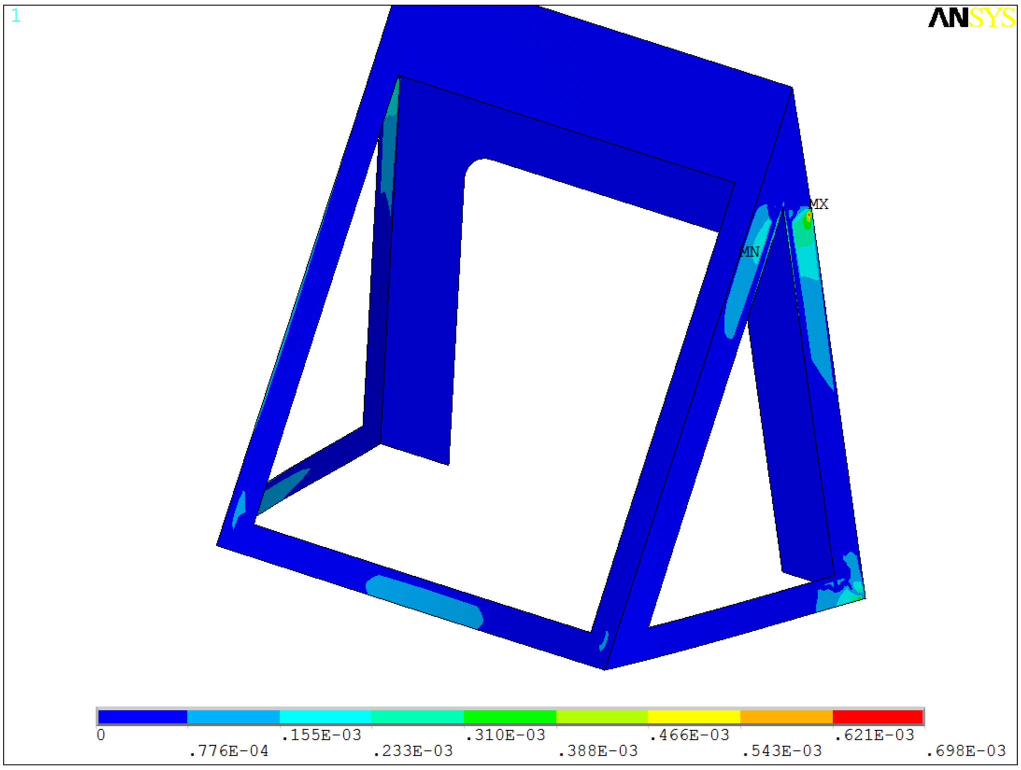


Figura 81 – Shock verticale - Coefficiente TW

Il coefficiente di TW ha valore massimo pari a circa 0.0007.

Il coefficiente di sicurezza risultante è pari a CS = 1/0.0007 = 1430.

73 ANALISI A TAGLIO CORE

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree del becco realizzate impiegando la schiuma sintattica.

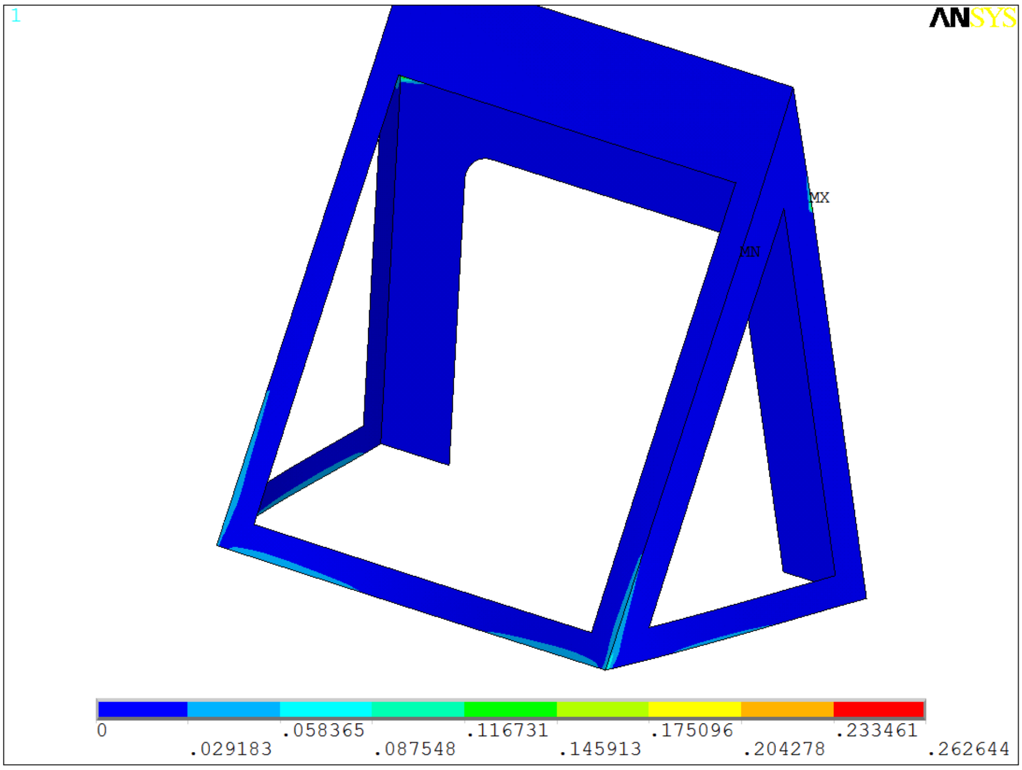


Figura 82 –Shock verticale - Taglio (MPa) schiuma sintattica

La massima sollecitazione è pari a 0.26 MPa.
La resistenza a taglio della schiuma sintattica è pari a 5 MPa.
Il coefficiente di sicurezza risultante è pari a CS = 5/0.26 = 19.2.

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree dello scudo realizzate impiegando pannelli di Dyvinicell H100.

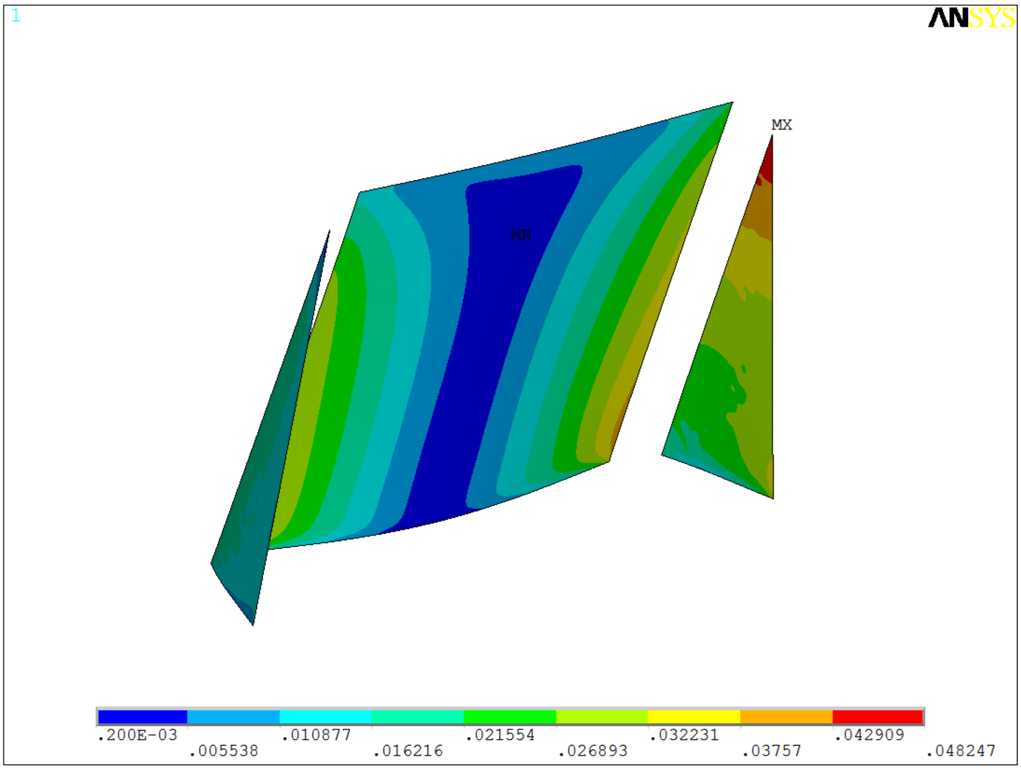


Figura 83 – Shock verticale - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.05 MPa.
The shear strength of the Dyvinicell H100 core is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.05 = 32

note

The analysis of the positive vertical shock load condition provides the same results (unless the opposite sign) as that conducted for negative vertical acceleration.
The linearity hypothesized in the elastic behaviour of the materials used make it possible to outdo the safety coefficients obtained at §20 13

74 SHOCK TRASVERSALE

La sollecitazione di shock verticale si traduce in una accelerazione statica (positiva o negativa), pari a 300 m/s^2.

75 *SPOSTAMENTI*

La freccia massima consentita, definita in specifica tecnica, è di 100 mm.

Come si può notare il valore massimo, pari a circa 0.3 mm è al di sotto dei limiti di specifica.

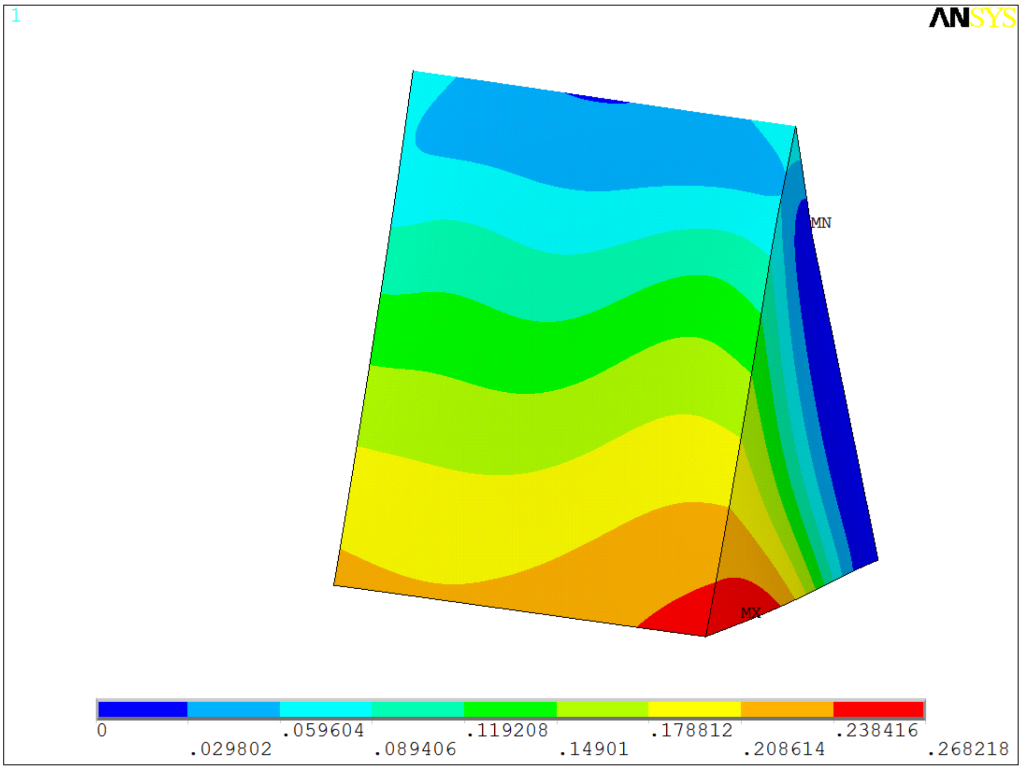


Figura 84 – Shock trasversale - spostamento (mm)

76 *SOLLECITAZIONI*

Le tensioni indotte nel becco dell'accelerazione trasversale, vanno confrontate con le massime tensioni ammissibili per ciascun materiale utilizzato.

77 SOLLECITAZIONI VETRORESINA - COEFFICIENTE TW

Le immagini che seguono mostrano l'andamento del coefficiente di TW nelle lamine di composito che costituiscono le pareti esterne dei sandwich.

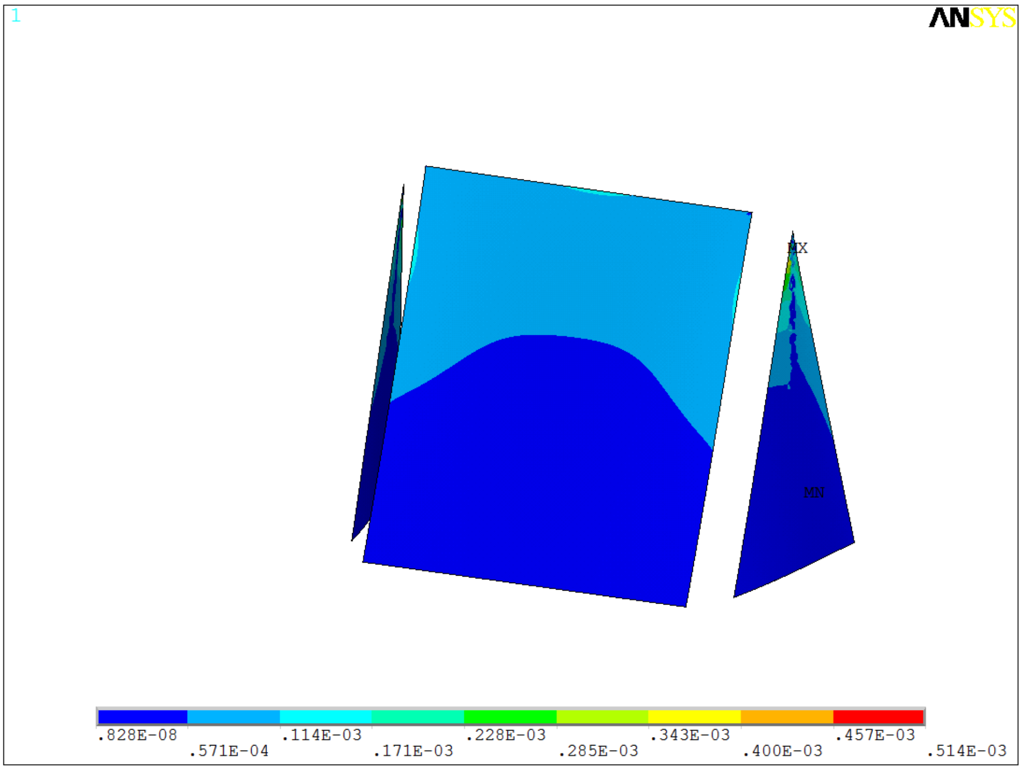


Figura 85 – Shock trasversale - Coefficiente TW

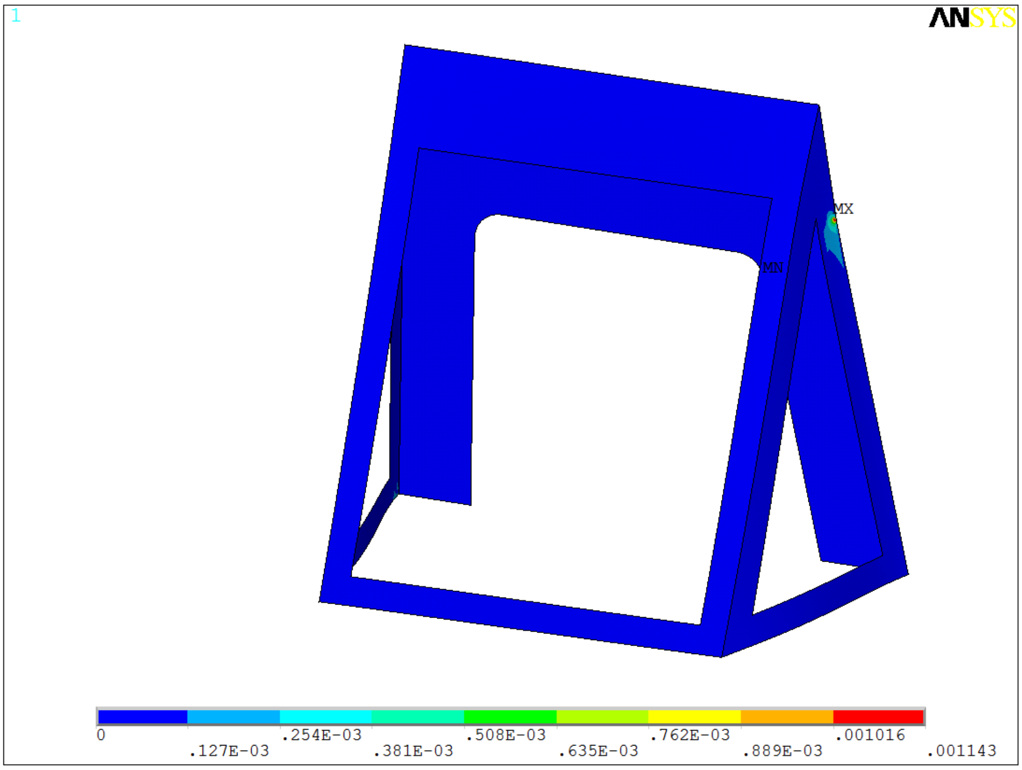


Figura 86 – Shock trasversale - Coefficiente TW

Il coefficiente di TW ha valore massimo pari a circa 0.001.

Il coefficiente di sicurezza risultante è pari a CS = 1/0.001 = 1000.

78 ANALISI A TAGLIO CORE

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree del becco realizzate impiegando la schiuma sintattica.

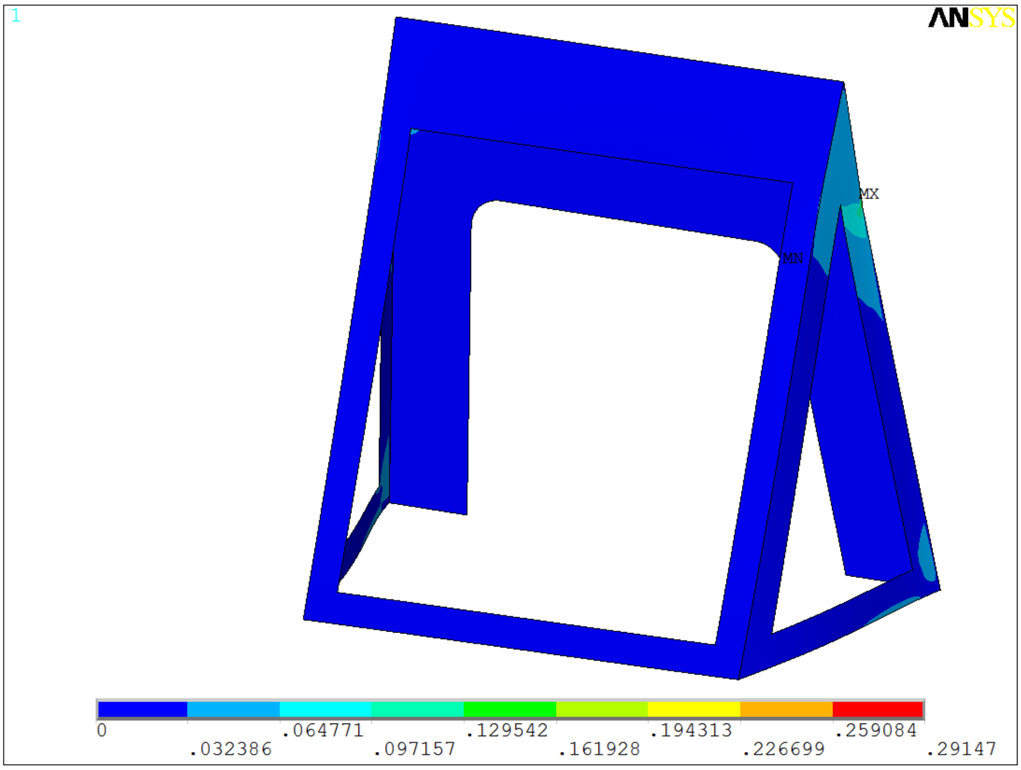


Figura 87 –Shock trasversale - Taglio (MPa) schiuma sintattica

La massima sollecitazione è pari a 0.29 MPa.
La resistenza a taglio della schiuma sintattica è pari a 5 MPa.
Il coefficiente di sicurezza risultante è pari a CS = 5/0.29 = 17.2.

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree dello scudo realizzate impiegando pannelli di Dyvinicell H100.

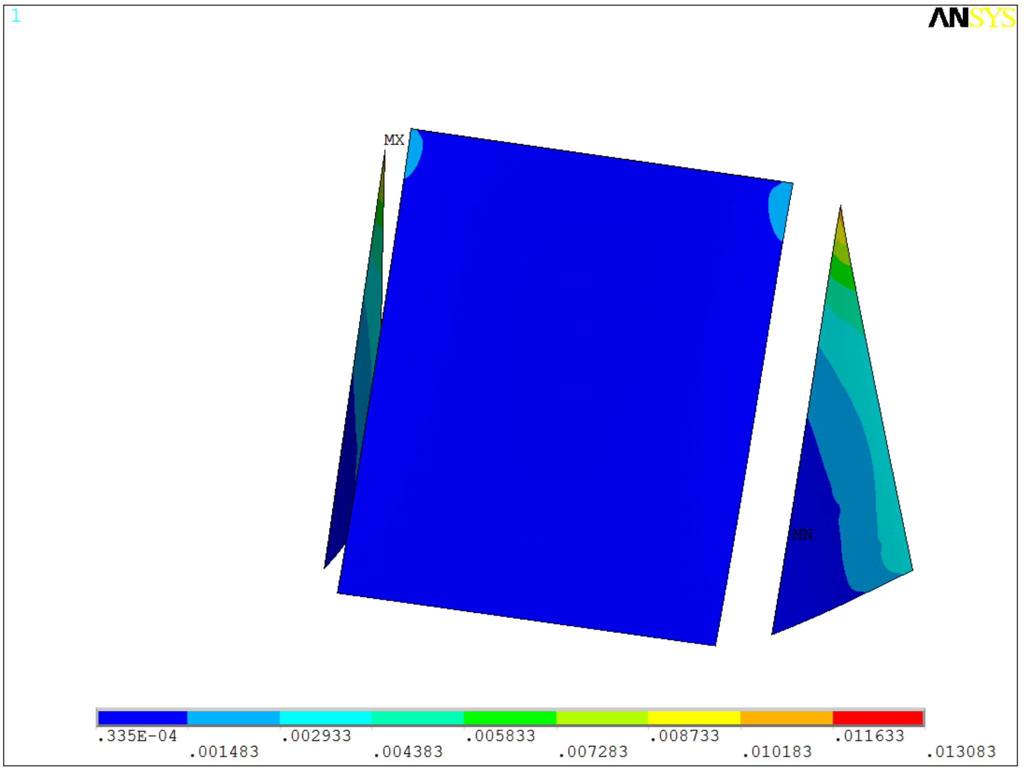


Figura 88 – Shock trasversale - Taglio (MPa) Dyvinicell H100

The maximum stress is 0.013 MPa.
The shear strength of the Dyvinicell H100 core is 1.6 MPa.
The resulting safety coefficient is CS = 1.6/0.013 = 123

79 SHOCK LONGITUDINALE

The vertical shock stress results in static acceleration (positive or negative), equal to 300 m/s^{2}.

80 *SPOSTAMENTI*

The maximum allowed arrow, defined in technical specification, is 100 mm.

As you can see the maximum value, about 0.8 mm is below the specification limits.

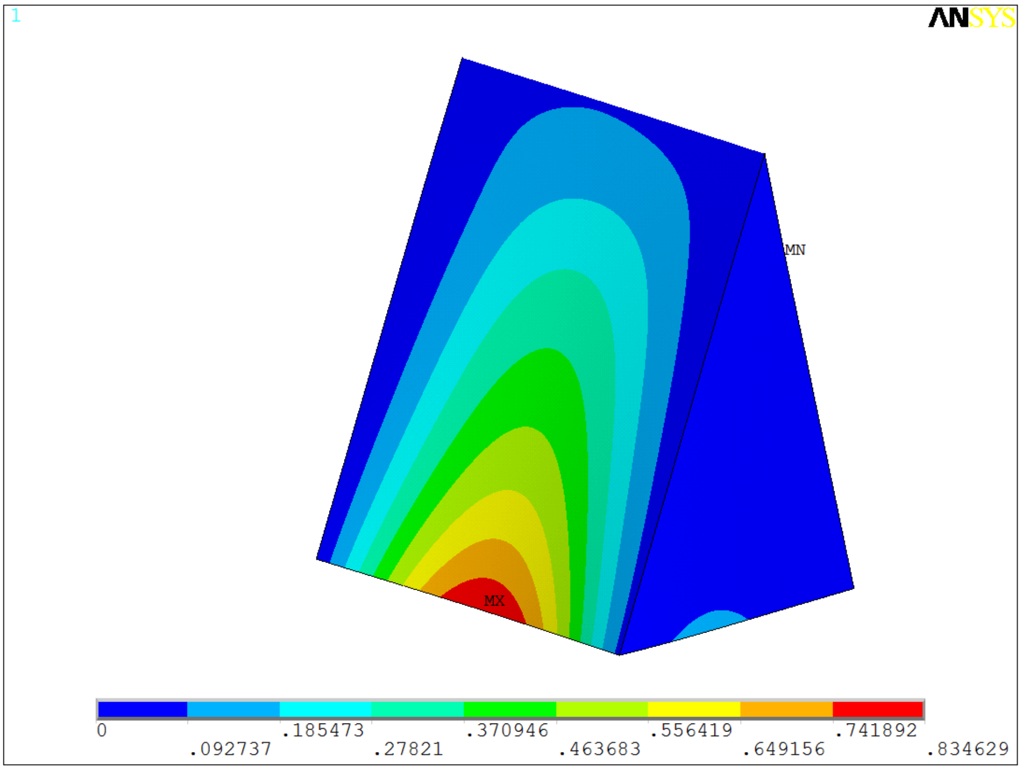


Figura 89 – Shock longitudinale - spostamento (mm)

81 *STRESSES*

The stresses induced in the beak of the longitudinal acceleration shall be compared with the maximum permissible stresses for each material used.

1. FIBERGLASS STRESSES - COEFFICIENT TW

The following images show the trend of the TW coefficient in the composite foils that make up the outer walls of the sandwiches.

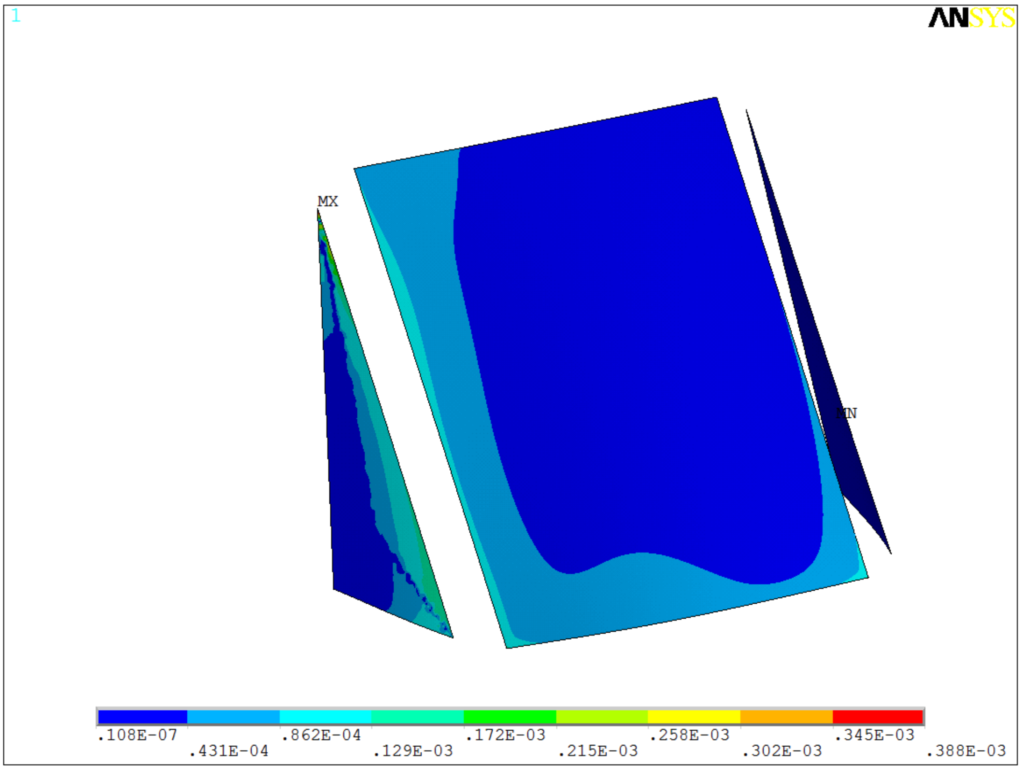


Figura 90 – Shock longitudinale - Coefficiente TW

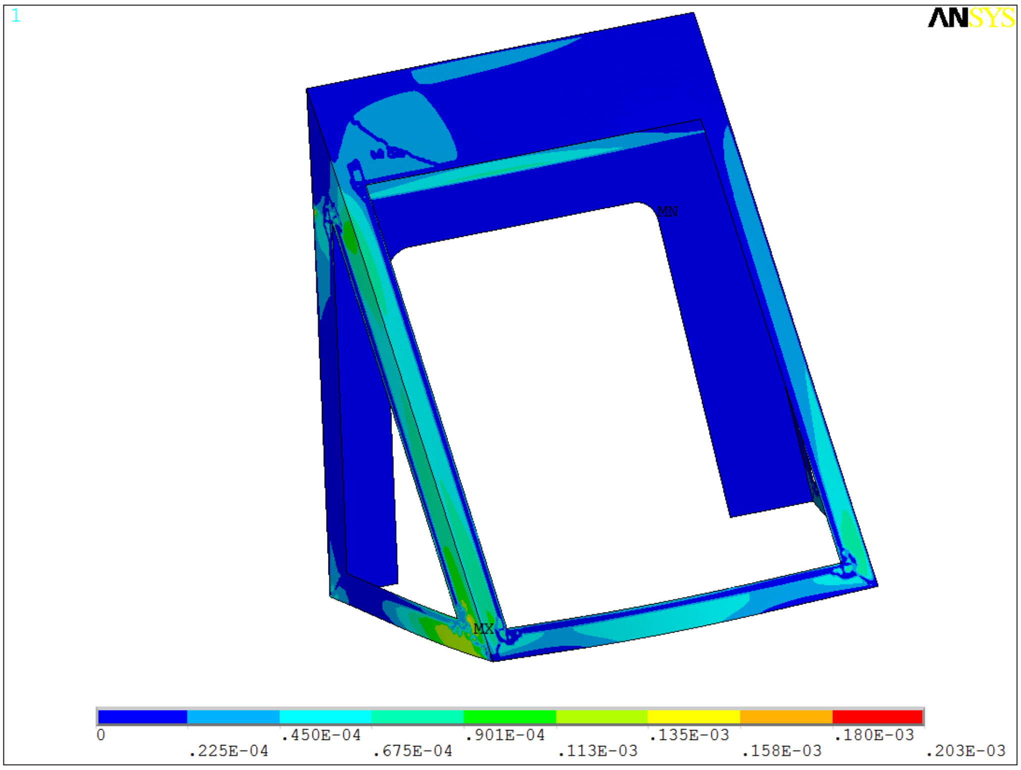


Figura 91 – Shock longitudinale - Coefficiente TW

The coefficient of TW has a maximum value of about 0.004.
The resulting safety coefficient is CS = 1/0.004 = 250.

1. CORE SHEAR ANALYSIS

La figura che segue mostra l'andamento della sollecitazione di taglio nelle aree del becco realizzate impiegando la schiuma sintattica.

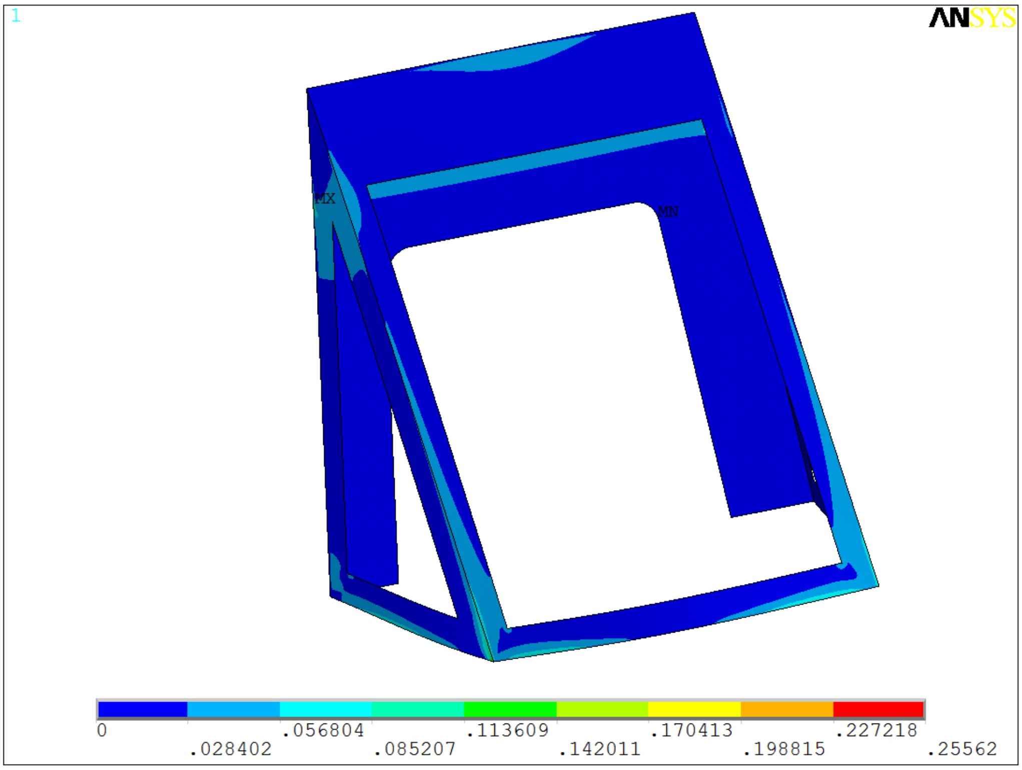


Figure 92 – Longitudinal Shock - Cut (MPa) Syntactic Foam

The maximum stress is 0.26 MPa.
The shear strength of the syntactic foam is 5 MPa.
The resulting safety coefficient is CS = 5/0.26 = 19.2.

The following figure shows the trend of shear stress in shield areas made using Dyvinicell H100 panels.

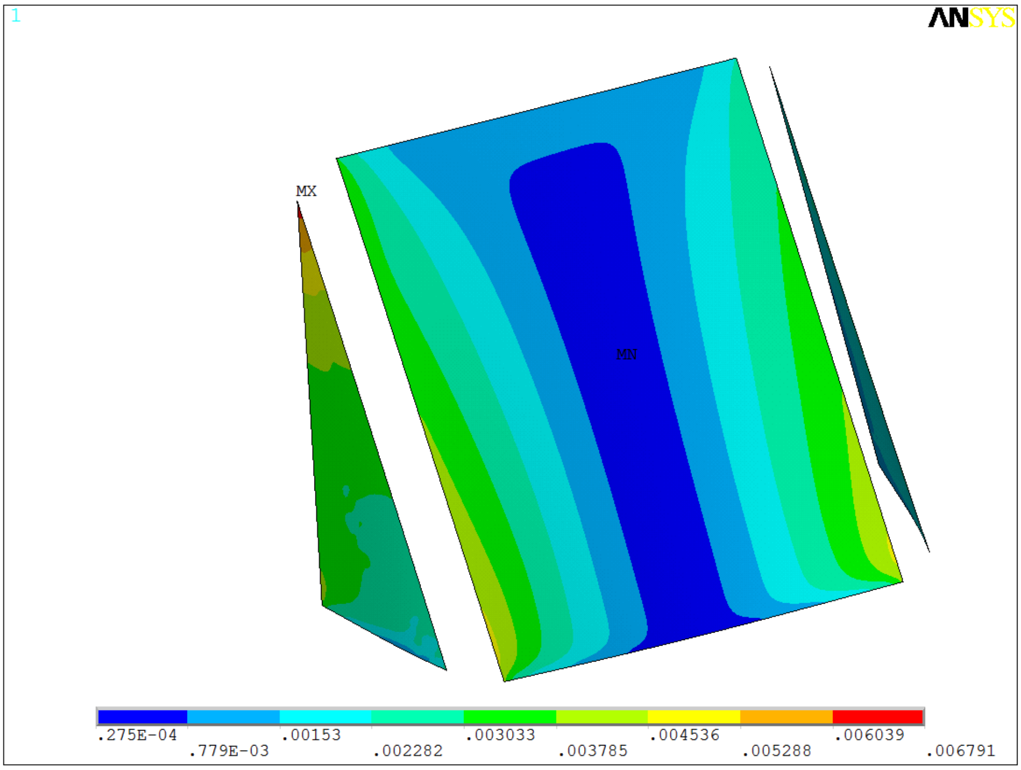


Figure 93 – Longitudinal Shock - Cut (MPa) Dyvinicell H100

The maximum stress is 0.007 MPa.

The shear strength of the Dyvinicell H100 core is 1.6 MPa.

The resulting safety coefficient is CS = 1.6/0.007 = 228

1. Vibration

In order to assess the resistance of the beak to vibration imposed by the technical specification, a modal analysis of the artifact was first carried out.

The analysis carried out in the range 4-33 hz showed no relevant proper frequencies.

For this reason it is possible to repeat the cap. 51 in which the accelerations due to vibration were evaluated in the absence of resonance phenomena.

Freq. [hz]	Move. [mm]	Accel. ($m/s^{2)}$
4-33	0.25	10.7

Table 4 - Vibrational accelerations

The accelerations at the beak are shown to be much lower than those used for vertical and horizontal shock verification.

The above therefore makes it possible to consider the requirement satisfied.

Minimization of the Radar Signature (RCS)

The model has been evaluated only from an electromagnetic point of view. A coefficient defined as index of goodness has been adopted to give an indication of the degree of stealth of the shield. The goodness index (IB) is a parameter that depends on the following factors:

- slope of flat surfaces with respect to the horizon plane (θ)
- area of each surface (A)
- electromagnetic wave frequency (f)
- linear dimensions of the surface(d)

therefore:

IB (θ, A, f, d)

Dove l'indice i indica la superficie iesima dello scudo.

IB takes into account the following factors.

The higher the slope of flat surfaces relative to the horizon, the lower the RCS in the sector of interest.

The larger the area of flat surfaces relative to the horizon, the greater the RCS in the sector of interest.

The larger the linear size of the surfaces, the smaller the width of the radiation lobe of the surfaces themselves.

The RCS of flat surfaces increases as the frequency increases, the width of the radiation lobes increases as the frequency decreases.

The index formulation includes the summation of all partial contributions of flat areas. The lower IB, the greater the degree of stealth of the shield.

The results of this analysis, carried out with dedicated software by a specialized company, show that this shield geometry has a low radar signature in the interested areas only if it is possible to check the shares given by the below listed areas identified as crucial in the RCS study:

1. Corner reflector between the frontal surface of the shield and deck
2. Gap between shield and deck.

3 Gaps on the entrance hatch.

The RCS requirements of the shield were supplied by general considerations.
Four directions were defined to concentrate the most part of reflected radiations.
The angle sectors, that we define of low priority, are the front direction, the back direction and the two side directions.
For the others it is required a low Radar Signature and then they are considered of high priority.
In the sectors of low priority, the ship has a great Radar Signature and it is associated an engage probability, by a typical threat of a missile, that depends by her width and by the reflection lobe.
More the lobe is narrow then less it is the engage probability.
To achieve narrow lobes the shield is composed by strictly plane surfaces.
Other requirements are due to frequency bands in which we want to reduce the RCS.

Generally, have been specified the following bands: 3, 6, 10, and 18 Ghz.

There are two different conditions in which the gun requires a different stealthy level.

In not operative condition the ship has to approach stealthy to the enemy, so it is required the maximum stealthy level.

In the operative conditions i.e., when the ship it is sighted by the enemy and it has to use the weapon systems, the RCS is unavoidable augmented because the frontal surface of the gun is exposed to the enemy radar.

3. TECHNICAL DESCRIPTION

The gun RCS study considers the strictly requirements that have fixed almost in a univocal way the shield shape. In fact, the plane surface must be directed towards the four low priority sectors, and they have defined inclinations towards the vertical axis.

3.1. SHIELD SHAPE

The shield shape is showed in Fig. 1.

The shield surfaces are directed towards the four directions, front, back, sides.

The inclination towards the vertical axis of the back and sides is 15°, the front surface's inclination is 32°.

The shield RCS study has showed crucial areas that have been deeply studied in the project.

These areas are listed below in order of importance:

1. Corner reflector between the frontal surface of the shield and deck
2. Gap between shield and deck.
3 Gaps on the entrance hatch.

The particular shield geometry gives a low Radar Signature in the interested areas only if it is possible to check the shares given by the above listed areas.

FRONTAL CORNER REFLECTOR

The reflection of the corner reflector generated by the frontal surface and the deck must be reduced in order to assure a low signature of the shield also in the operative condition when the gun engages the threat.

The reduction of the reflectivity is obtained covering the vertical surface orthogonal to the deck by a Radar Absorbing Structural material.

The electromagnetic characteristics are included in 4.0.

GAP BETWEEN SHIELD AND DECK

The mechanism that generate the reflectivity of a gap are many and their simulations is difficult and many times not so reliable instead proper measurements can supply a fast solution to the problem.

The reflection mechanism are:

Reflection of the structure internal parts due to the radiation that enters through the gap.

This phenomenon is the main danger and the quantity of the reflected radiation depends by the frequency and on the gap dimension.

The quantity of radiation transmitted through the gap increases with the increase of frequency.

Inside the gun the radiation is reflected by the steel frames, a part of it is absorbed inside instead the other part comes out from the same gap.

Reflection due to gap diffraction phenomenon

The phenomenon becomes more clear corresponding to the gap resonance frequencies i.e when the wave length of radiation is comparable with the dimension of the gap itself.

Reflections due to the traveling waves bring together with the steel surface of the deck

A part of incident energy on the gun brings together to the steel surface for skimming light angles between 0° - 20°, enters underneath the shield and it is reflected by the first crack inside the shield.

Among the three-reflection mechanism the first one surely gives the bigger share.

The better solution to minimize the gap dimension in order to reduce all the contribution under the reflectivity of the shield.

tests have showed that it is possible to keep lower those reflections if the dimension gap is not more of 25 mm.

ENTRANCE HATCH

The entrance hatch of the gun is located on the rear face of the shield.

The more detailed and opening system description are reported in the drawings.

From the RCS point of view the crucial point are the dimension of the gap and the electromagnetic conductivity between the shield and the hatch.

The dimension of 1 cm of the gap generates a negligible reflectivity and a good electrical contact between the hatch and the shield assures the electromagnetic continuity of the material.

The structural RAM material broadband will be also applied on the rear side of the shield to break down incident energy up to 100 times and reflected fields up to 10 times, covering all radar emission frequencies on board of the ship.

MATERIAL – PROPRIETIS

From the electromagnetic point of view, the material used for the shield construction are the following:

1 - Reflecting composite materials

2 - Absorbing composite materials

The composite material used to manufacture the shield, reflect the electromagnetic energy as a steel surface because its outer skin is metallized by a nickel treatment.

Concerning the absorbent materials, they are very useful for the reflections reducing generated by the following factors:

- Specular reflections
- Edges and corners
- Surfaces waves
- Multiple reflections
- Reflections of holes and gaps

The radar absorbent materials are generally multilayers (composite materials) of different thickness and weight depending by the absorbed frequency band and by their use.

Their composition, thickness and the layer number are variable and generally are composed by the following layers:

1. External paint ply
2. Inert layers
3. Absorbent or dissipative layers
4. Final reflecting layer

The material applied to the shield is a structural of Radar Absorbing multilayer about 9.3 mm of thickness.

The material is composed by the following layers:

1 internal layer 1 mm fiberglass

2 " 0.5 mm dissipative fiberglass

3 1.5 mm fiberblass

4 0.25 mm dissipative fiberglass

5 3.2 mm fiberglass

6 2.4 mm honeycomb

7 0.5 mm fiberglass

The Absorbing material guarantees an attenuation of at least 15 dB from 6 to 18 GHz and 10 dB from 4,5 to 6 GHz.

It is applied over the carbon conductive layer which ensures attenuation capacity EMP and shielding EMI. The mechanical characteristics of the RAM are:

-UTS 20 N/mm^2

-elongation to failure 3.6%

-Young modulus in traction 600 N/mm^2

-Young modulus in bending 2500 N/mm^2

-max pressure superficiale 0.77N/mm^2

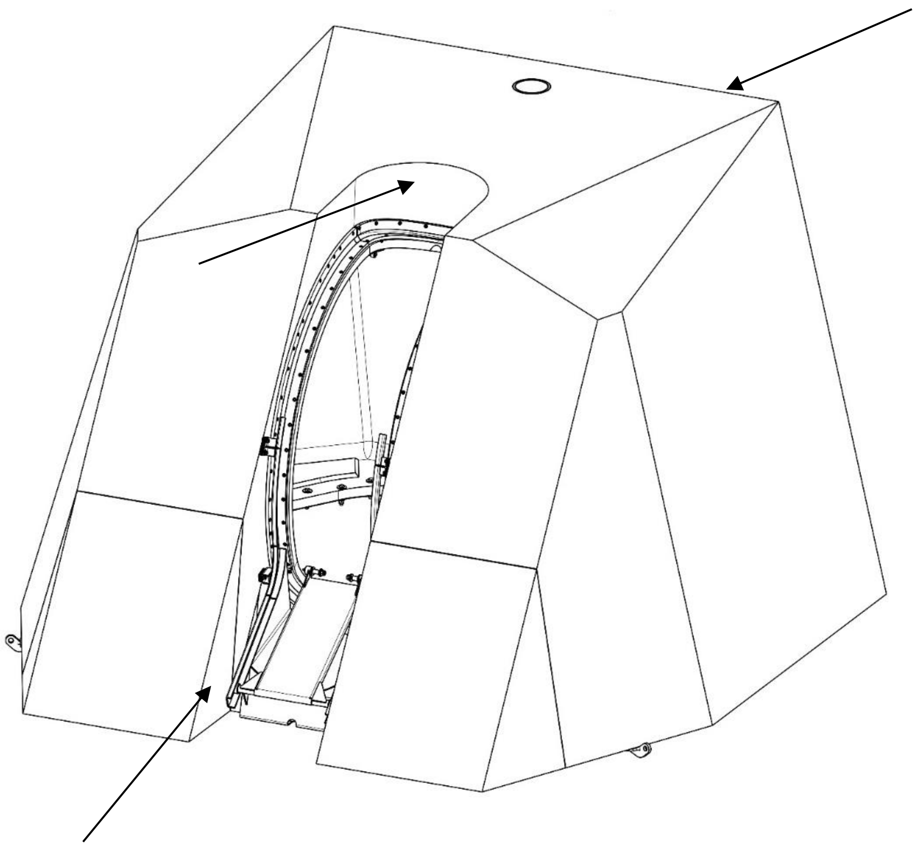
-durezza 85 shore B

Applicazione del materiale RAM sullo scudo stealth

Il materiale RAM sarà applicato nelle seguenti zone:

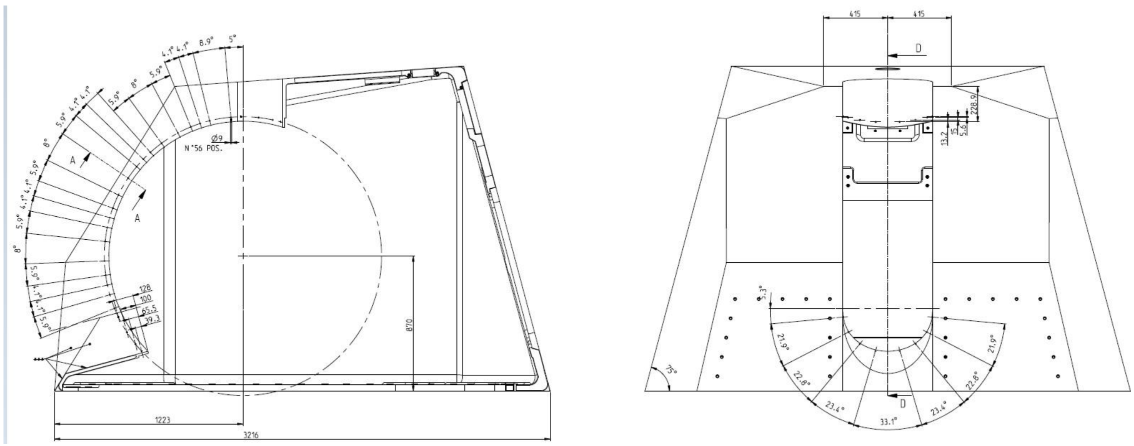
1) superfici verticali della zona gun port

2) The structural RAM material a banda larga will be also applied on the rear side of the shield per abbattere l’energia incidente fino a 100 volte e I campi riflessi fino a 10 volte, coprendo tutte le frequenze di emissione dei radar a bordo nave.



COSTRUZIONE DEL PROTOTIPO

Ciclo di lavorazione e definizione del plybook



Fase	Operazione		Elenco Materiali ed attrezzature
-	-		

Produttore	Identificazione Materiale	Fornitore
POLY 3	GELCOAT VINILICO POLY3-35	POLY3
OXIDO	RETIC C112 CATALIZZATORE	POLY 3
SAERTEX	FIBRA DI VETRO UD 1000gr	SAERTEX
SAERTEX	FIBRA DI VETRO QE 600gr	SAERTEX
NCN	E-PREG QE	NCN
NCN	E-PRED UD TVU-1000	NCN
NCN	SCHIUMA SINTATTICA EPOSSIDICA	NCN
RESIPOL	CORE DIVINICELL H 100	MATES
RESIPOL	CORE KLEGECELL H80	MATES
SOLIANI	FIBRA DI CARBONIO	SOLIANI

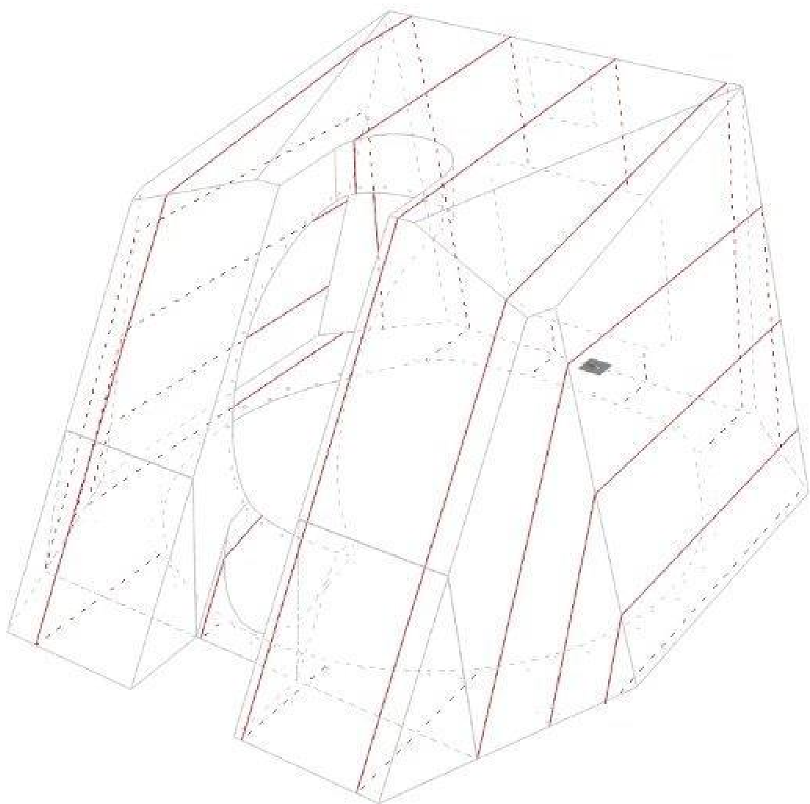
Trattamento Distaccante
Prima dell'inizio della lavorazione si procede alla pulizia dello Stampo mediante aspirazione di eventuali residui di lavorazione

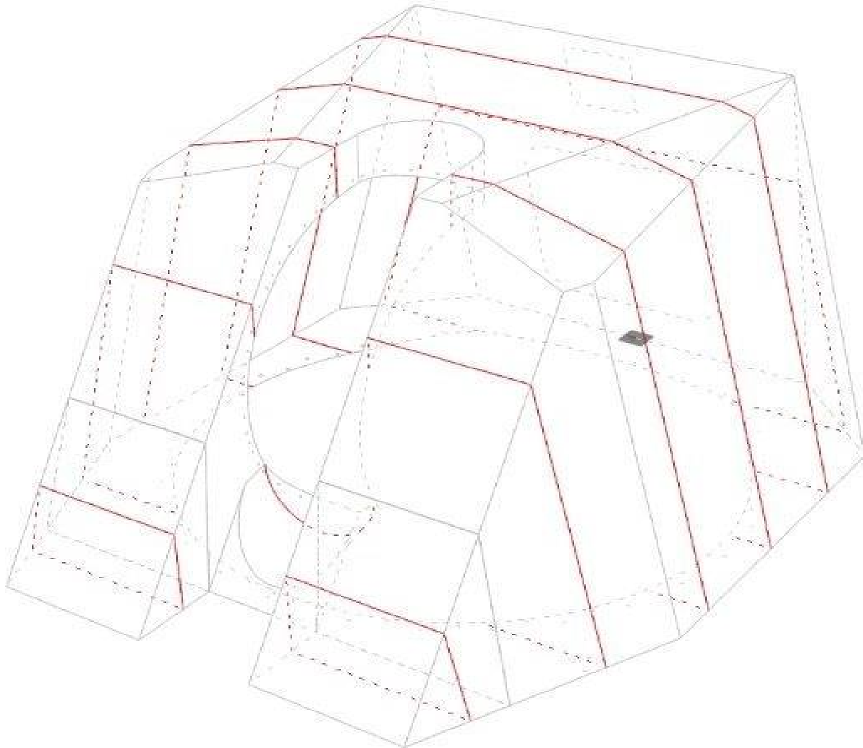
Sequenza di lavorazione
Fare prova di distacco su piccole superfici del Modello con Gelcoat Vinilico Poly 3-35, in caso in cui il distacco non funzioni ripetere la lavorazione.

Applicazione del Gelcoat
Prima dell'inizio della lavorazione verificare il buon funzionamento dell'attrezzatura (Gelcottatrice) da utilizzare e fare una prova di funzionamento.

Sequenza di lavorazione

Fase: 1 - Prima Laminazione Operazione: Laminazione Carbonio

<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td colspan="6" rowspan="2">Fase: 1 - Prima Laminazione Operazione: Laminazione Carbonio</td></tr>
<tr><td>1</td><td>1</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="7">LAM-1-T-CARBONIO</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="7">FIBRA DI CARBONIO</td></tr>
<tr><td colspan="2">Spessore (mm)</td><td>0.15</td><td>Angolo (deg)</td><td>0</td><td>Tipo Ply</td><td>-</td><td>Ripetizioni</td><td>1</td></tr>
<tr><td colspan="2">Note operative:
1. Stendere il tessuto di Carbonio in senso longitudinale (vedi disegno) su tutta la superficie interna dello stampo
2. Le ply dovranno essere laminate affiancate e non sovrapposte</td><td colspan="7"></td></tr>
</table>

<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td colspan="5" rowspan="2">Fase: 2 - Seconda Laminazione
Operazione: Laminazione QE 1 LONGITUDINALE</td></tr>
<tr><td>2</td><td>1</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="6">LAM-2-L-QE</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="6">FIBRA DI VETRO QE</td></tr>
<tr><td>Spessore (mm)</td><td>0.7</td><td>Angolo (deg)</td><td>0</td><td>Tipo Ply</td><td>-</td><td>Ripetizioni</td><td>1</td></tr>
<tr><td colspan="2">Note operative
1. Stendere il tessuto QE in senso longitudinale (vedi disegno) su tutta la superficie interna dello stampo
2. Le ply dovranno essere laminate affiancate e nonsovrapposte:</td><td colspan="6"></td></tr>
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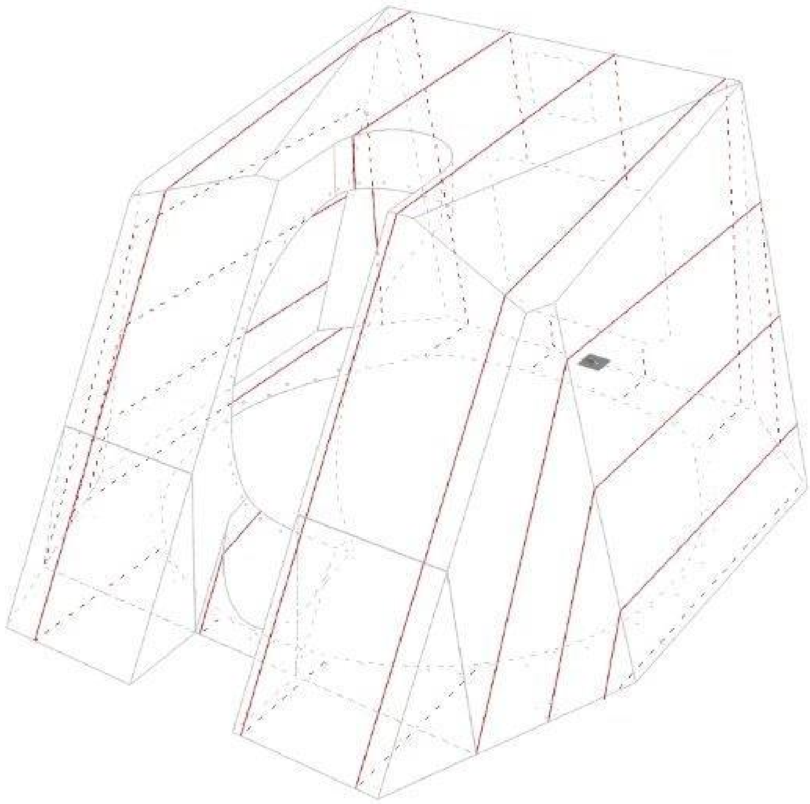
<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td colspan="5" rowspan="2">Fase: 2 - Terza Laminazione
Operazione: Laminazione QE 2 TRASVERSALE</td></tr>
<tr><td>2</td><td>2</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="6">LAM-3-T-QE</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="6">FIBRA DI VETRO QE</td></tr>
<tr><td>Spessore (mm)</td><td>0.7</td><td>Angolo (deg)</td><td>0</td><td>Tipo Ply</td><td>-</td><td>Ripetizioni</td><td>1</td></tr>
<tr><td colspan="2">Note operative:
1. tendere il tessuto QEin senso trasversale (vedi disegno) su tuttala superficie interna dello stampo
2. Le ply dovranno esserelaminate affiancate e non sovrapposte</td><td colspan="6"></td></tr>
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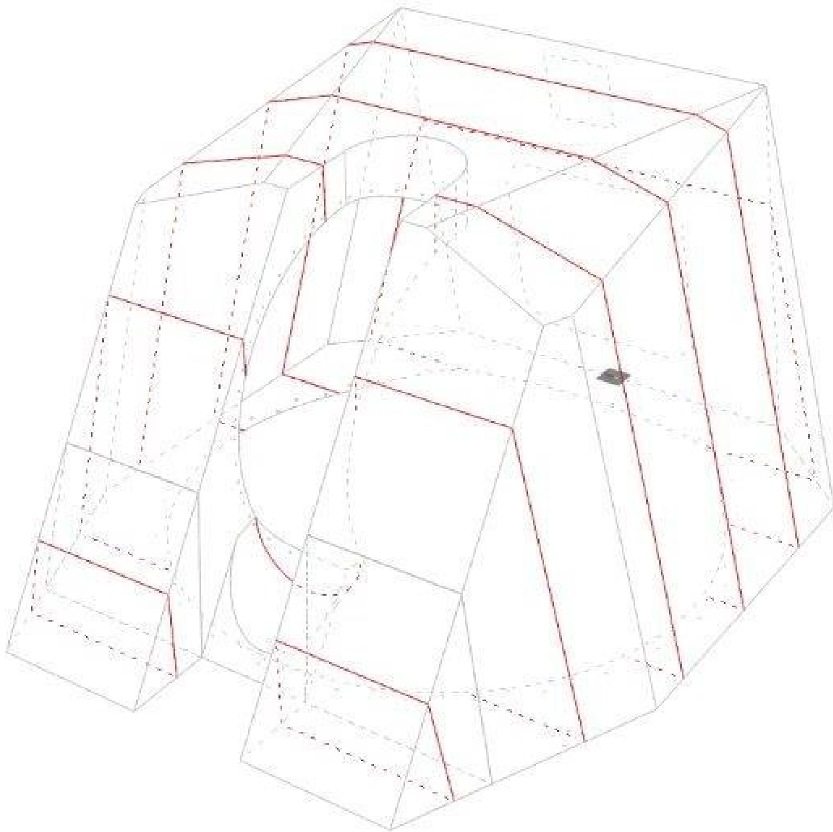
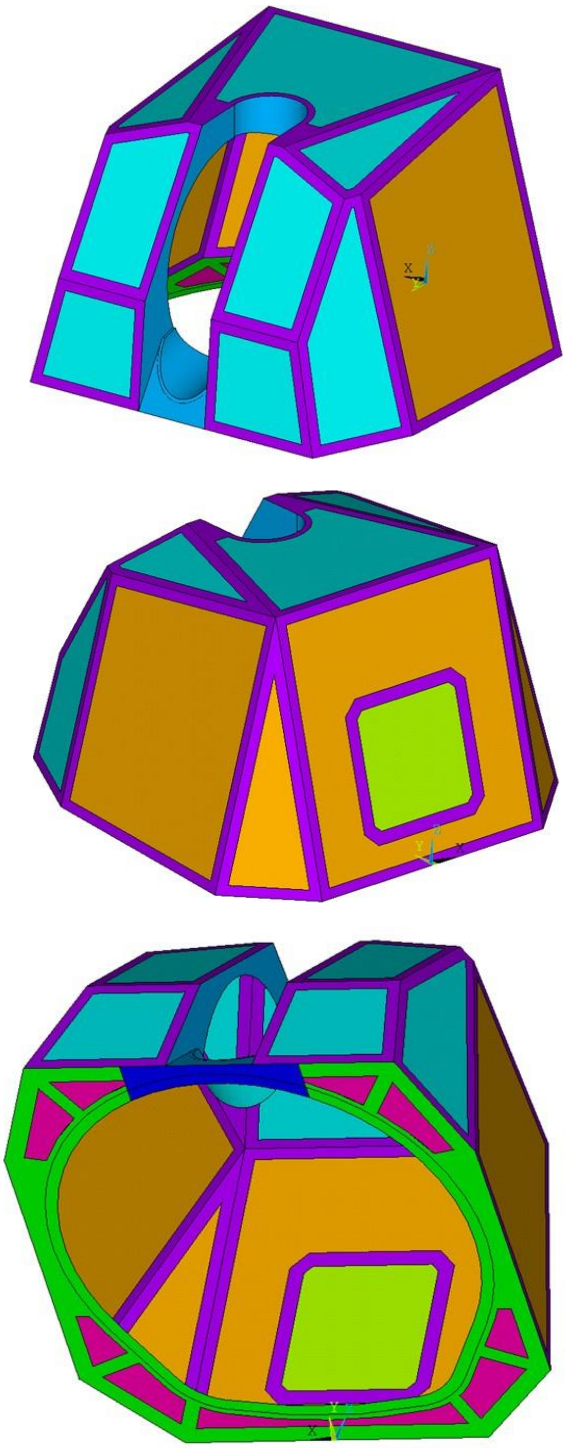
<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td colspan="6" rowspan="2">Fase: 2 - Quarta Laminazione
Operazione: Laminazione QE 4 LONGITUDINALE</td></tr>
<tr><td>2</td><td>3</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="7">LAM-4-L-QE</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="7">FIBRA DI VETRO QE</td></tr>
<tr><td colspan="2">Spessore (mm)</td><td>0.7</td><td>Angolo (deg)</td><td>0</td><td>Tipo Ply</td><td>-</td><td>Ripetizioni</td><td>1</td></tr>
<tr><td colspan="2">Note operative:
1. tendere il tessuto QE in senso longitudinale (vedi disegno) su tutta la superficie interna dello stampo
2. Le ply dovranno essere laminate affiancate e non sovrapposte</td><td colspan="7"></td></tr>
</table>

<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td colspan="6" rowspan="2">Fase: 3 – APPLICAZIONE CORE
Operazione: Applicazione Core</td></tr>
<tr><td>3</td><td>1</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="7">n/a</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="7">Core H100 e K80</td></tr>
<tr><td>Spessore (mm)</td><td>30/40/50 mm</td><td>Angolo (deg)</td><td>0</td><td>Tipo Ply</td><td>-</td><td>Ripetizioni</td><td>1</td><td></td></tr>
<tr><td colspan="2">Note operative:
1. Applicare core K80 con spessore 50 mm nelle zone evidenziate in ARANCIO
2. Applicare core K80 con spessore 50 mm nelle zone evidenziate in ROSA
3. Applicare core H100 con spessore 30 mm nelle zone evidenziate in AZZURRO
4. Applicare core H100 con spessore 40 mm nelle zone evidenziate in GIALLO</td><td colspan="7"></td></tr>
</table>

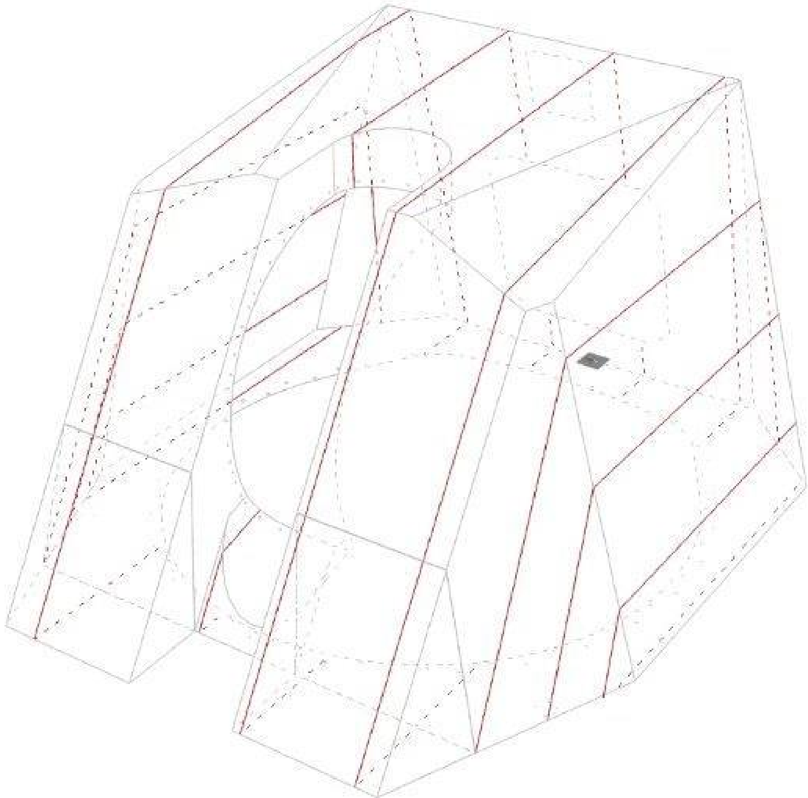
Fase	Operazione		Fase: 4 - Quinta Laminazione Operazione: Laminazione QE 1 TRASVERSALE
4	1		

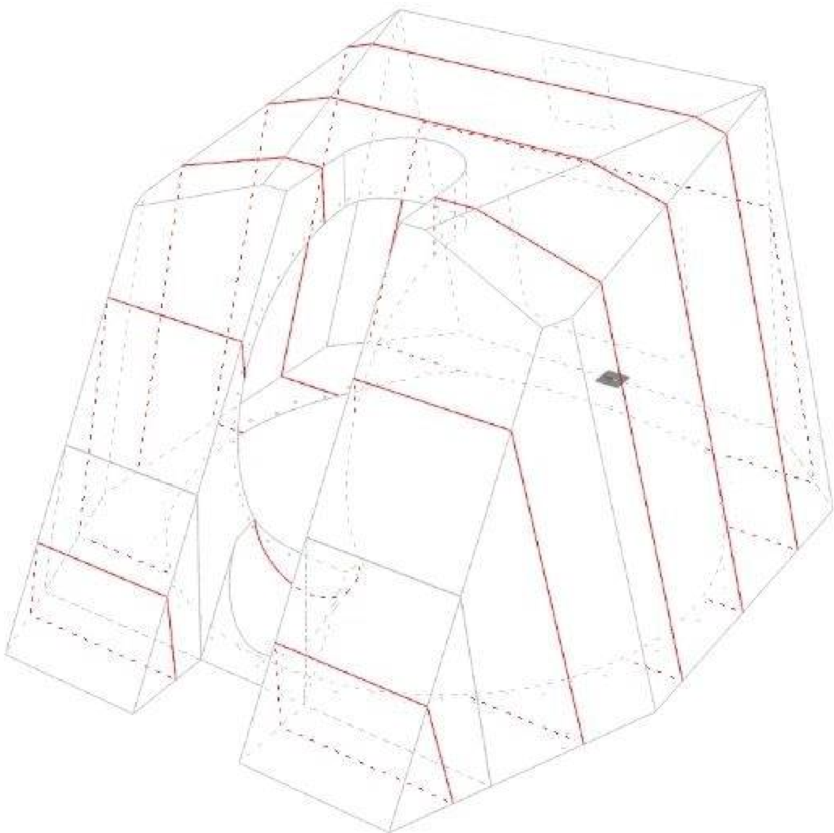
Nome Ply	**LAM-5-T-QE**
Materiale	FIBRA DI VETRO QE

Spessore (mm)	0.7	Angolo (deg)	0	Tipo Ply	-	Ripetizioni	1

Note operative:

3. Stendere il tessuto QE in senso trasversale (vedi disegno) su tutta la superficie interna dello stampo
4. Le ply dovranno essere laminate affiancate e non sovrapposte



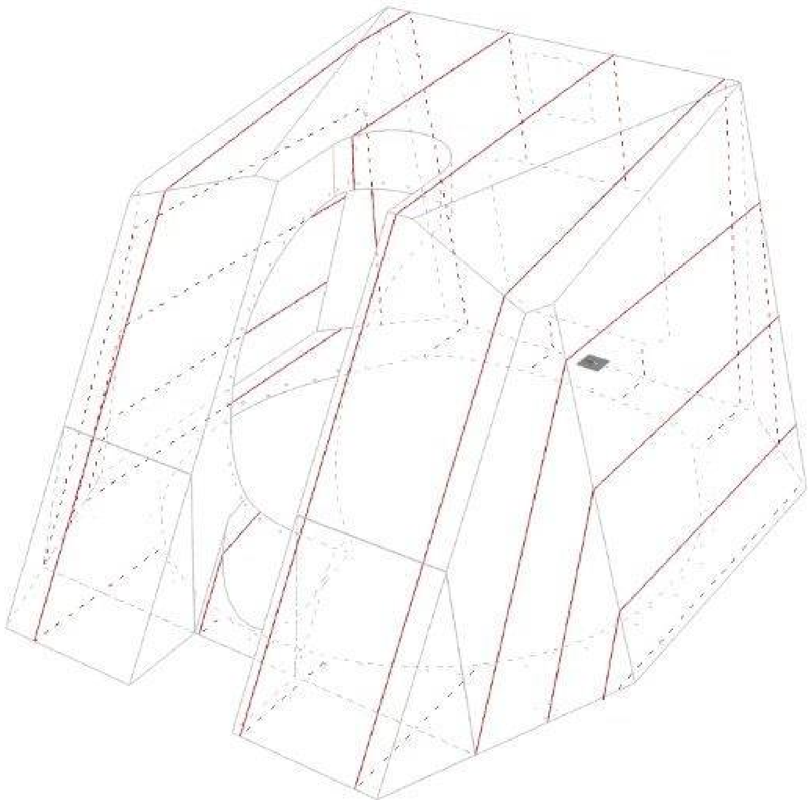
<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td colspan="6" rowspan="2">Fase: 4 - Sesta Laminazione
Operazione: Laminazione QE 2 LONGITUDINALE</td></tr>
<tr><td>4</td><td>2</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="7">LAM-6-T-QE</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="7">FIBRA DI VETRO QE</td></tr>
<tr><td>Spessore (mm)</td><td>0.7</td><td>Angolo (deg)</td><td>0</td><td>Tipo Ply</td><td>-</td><td>Ripetizioni</td><td>1</td><td></td></tr>
<tr><td colspan="2">Note operative:
3. Stendere il tessuto QE in senso longitudinale (vedi disegno) su tutta la superficie interna dello stampo
4. Le ply dovranno essere laminate affiancate e non sovrapposte</td><td colspan="7"></td></tr>
</table>

<table>
<tr><td>Fase</td><td>Operazione</td><td></td><td rowspan="2">Fase: 4 - Settima Laminazione
Operazione: Laminazione QE 4 TRASVERSALE</td></tr>
<tr><td>4</td><td>3</td><td></td></tr>
<tr><td colspan="2">Nome Ply</td><td colspan="2">LAM-7-L-QE</td></tr>
<tr><td colspan="2">Materiale</td><td colspan="2">FIBRA DI VETRO QE</td></tr>
</table>

Spessore (mm)	0.7	Angolo (deg)	0	Tipo Ply	-	Ripetizioni	1

Note operative:

3. Stendere il tessuto QEin senso trasversale (vedi disegno) su tuttala superficie interna dello stampo
4. Le ply dovranno essere laminate affiancate e non sovrapposte



CURING CYCLE

The definition of the care cycle for materials of the E-PREG QE family was obtained through targeted cooking tests on the samples made for the characterization of the materials in addition to NCN's decades of experience in the use of the chosen **materials.**

The technical data sheet of the material used (E-Preg QE) provides precise notes on the timing of care of the materials that have been further verified and optimized considering the masses of the materials and mold in addition to the performance of the equipment used.

After the first ramp, from room temperature to 60°, 10°C/h ascent phases alternate and stasis of 1 h until reaching 80°C, temperature maintained for another 16 hours.

The final cooling will be carried out naturally, until the product returns to room temperature and is workable for subsequent finishing activities.

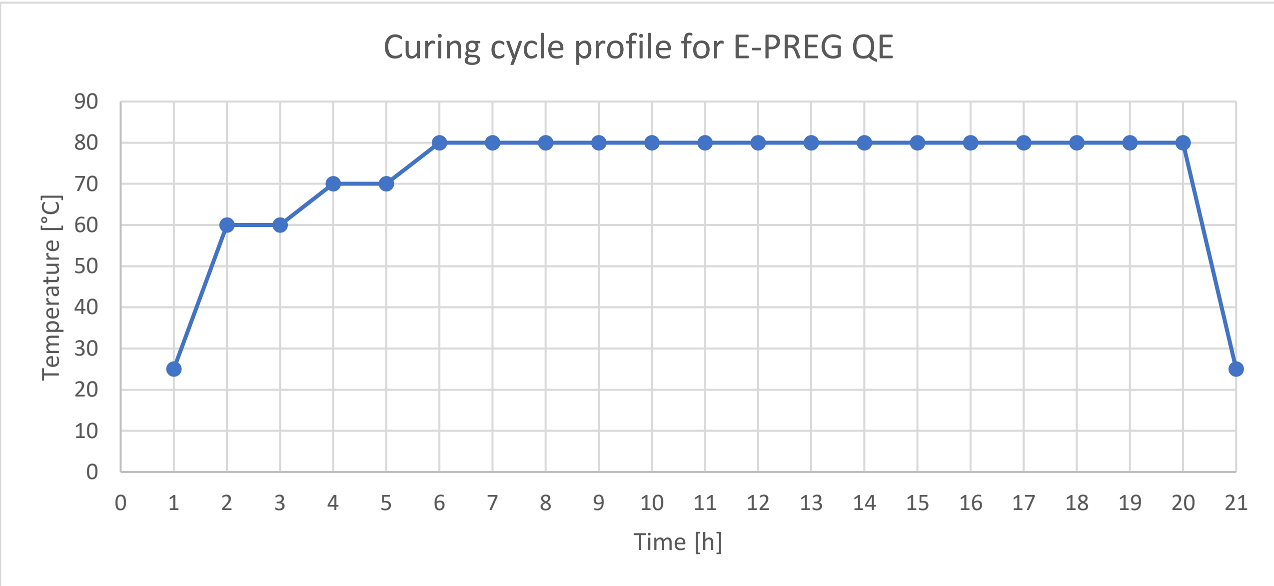
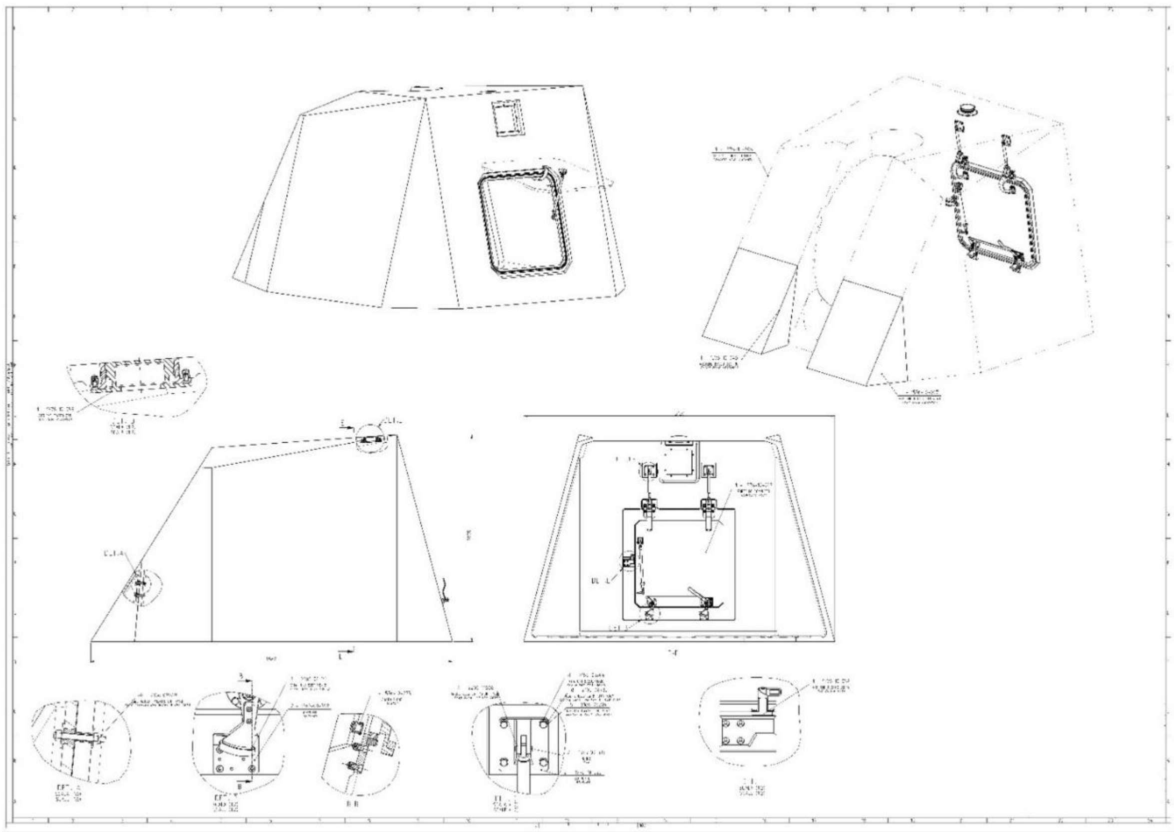


Figure 27: curing cycle for E-PREG QE

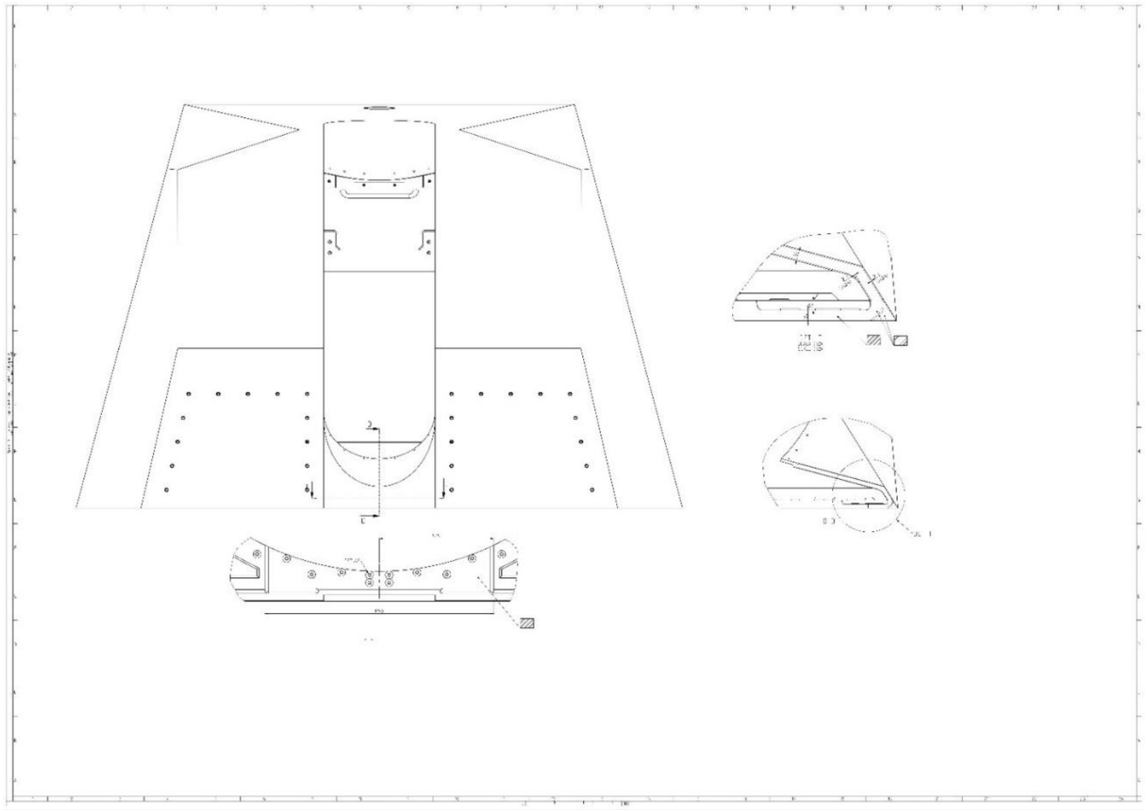
1. General and constructive assembly drawings

The entire package consists of about 250 drawings. We will only present the following designs that we consider to be the most important:

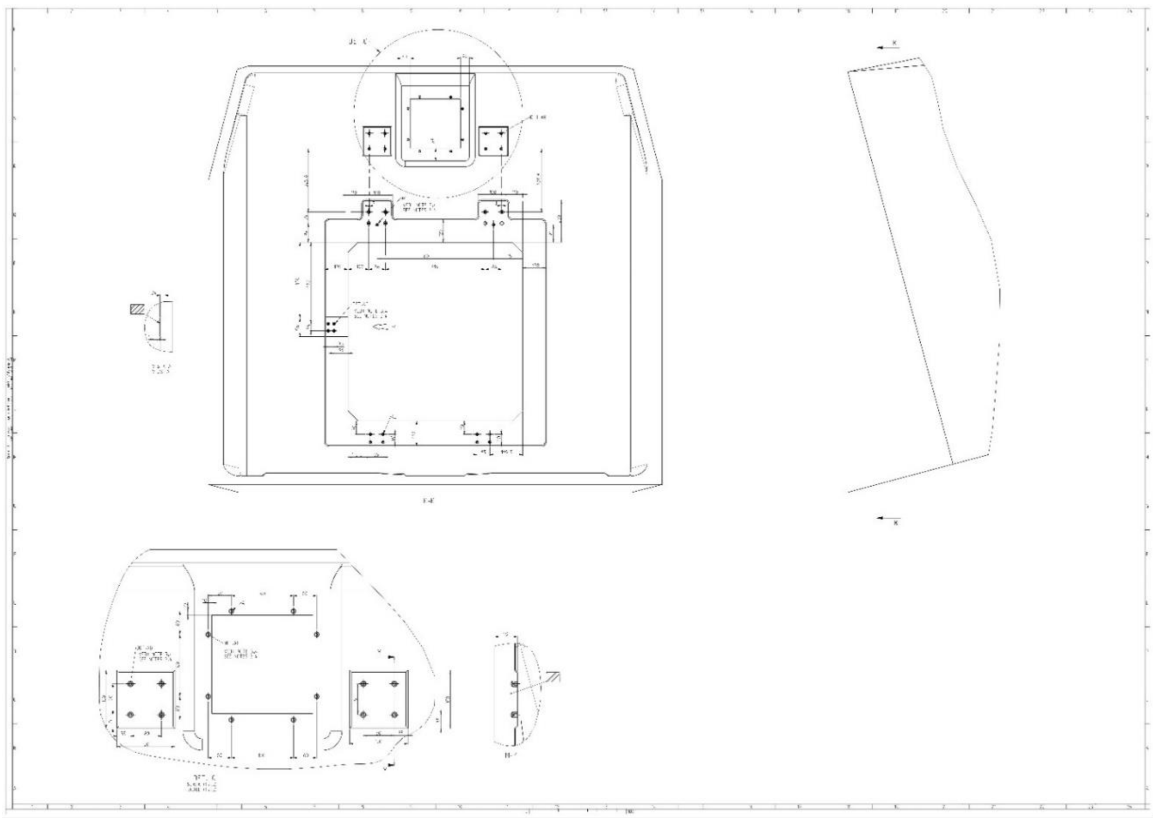
- general assembly
- shield detail drawing



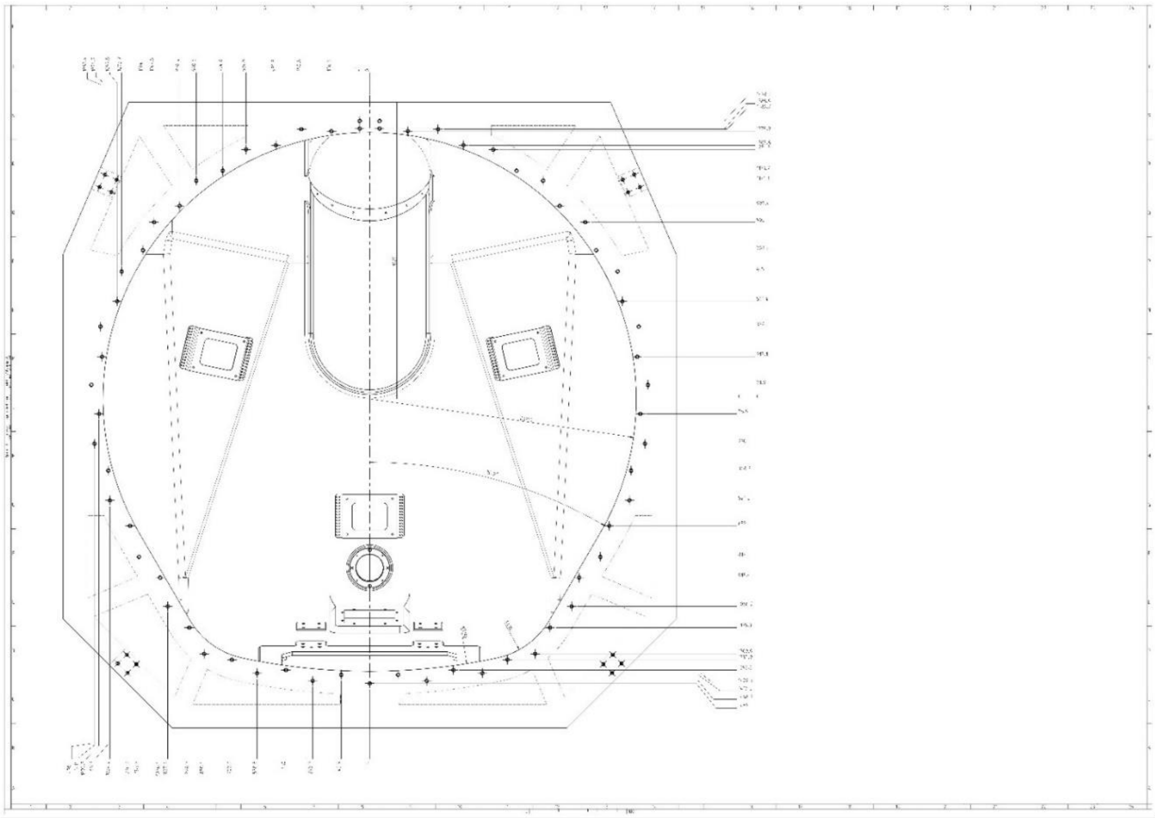
Drawing 1



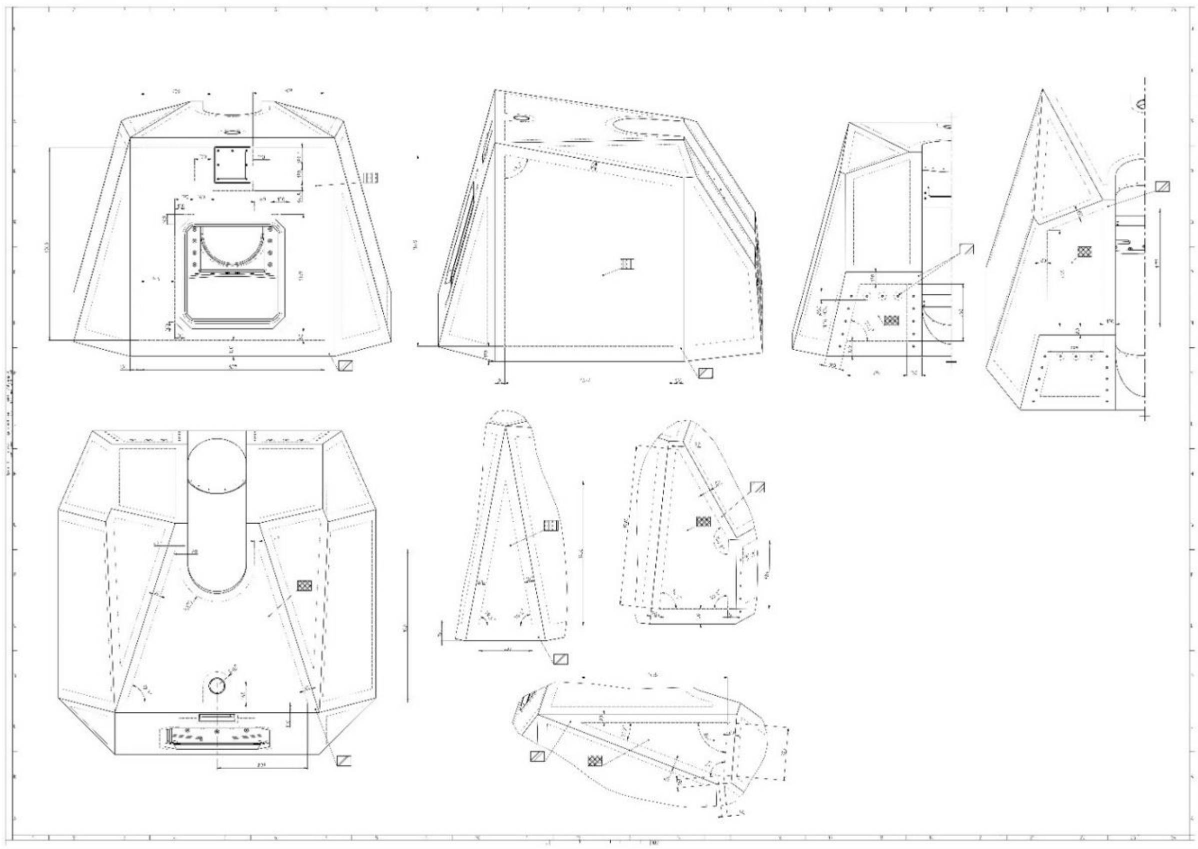
Drawing 2



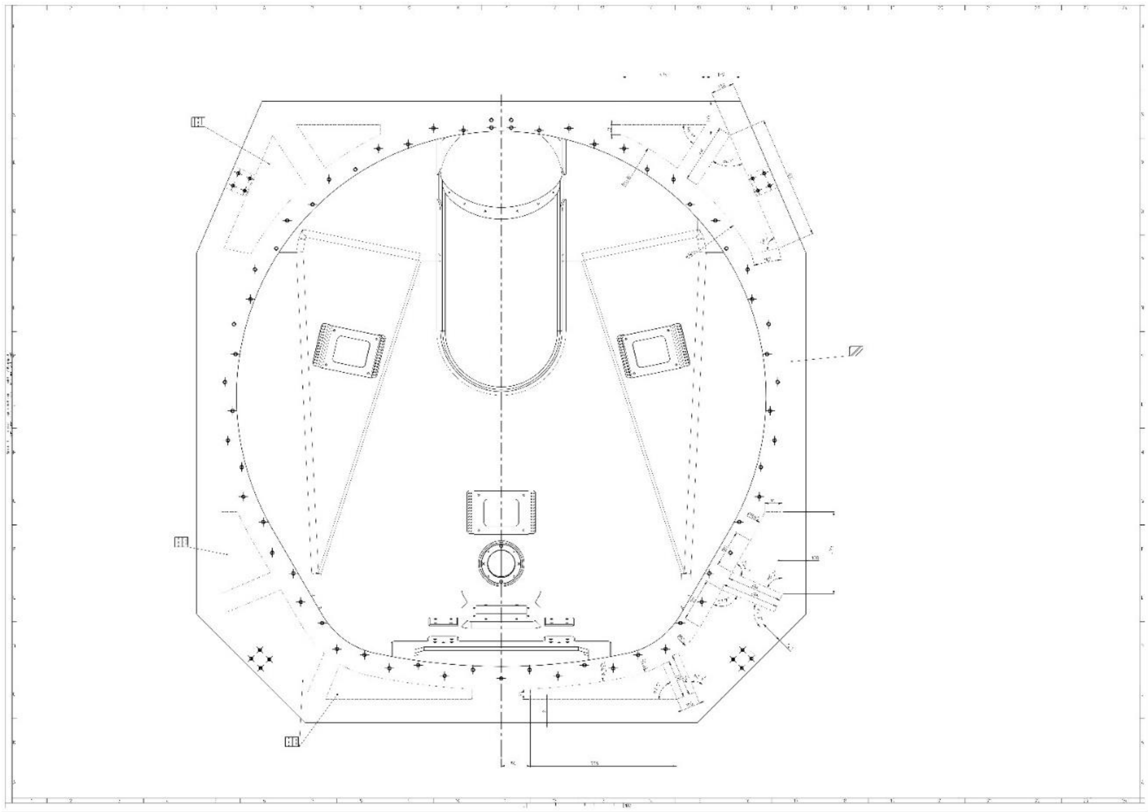
Drawing 3



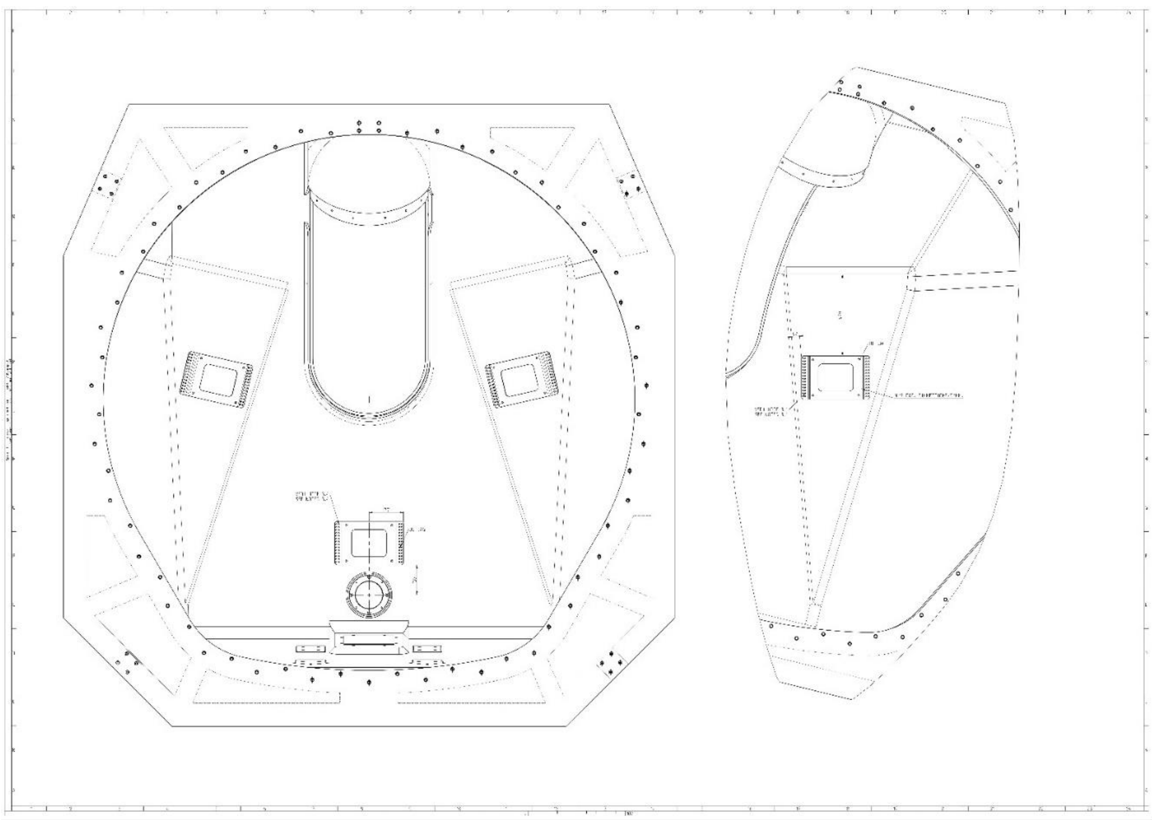
Drawing 4



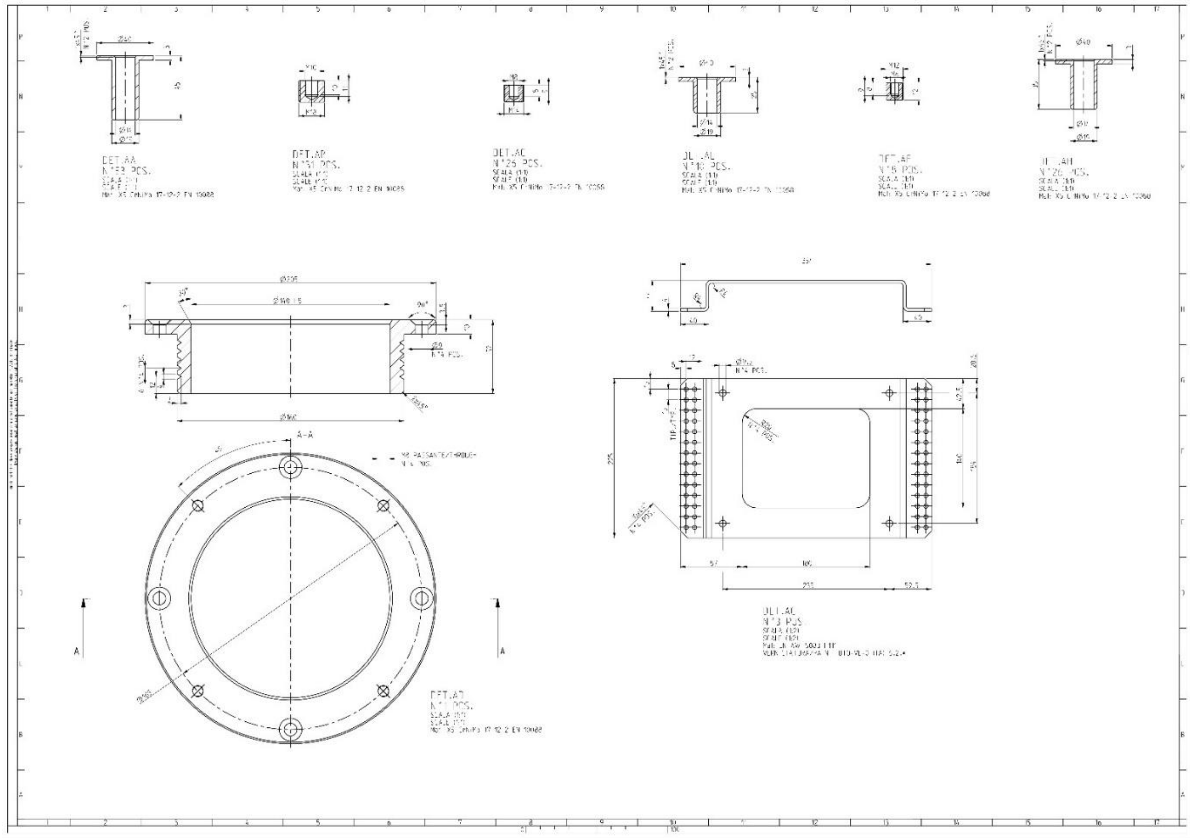
Drawing 5



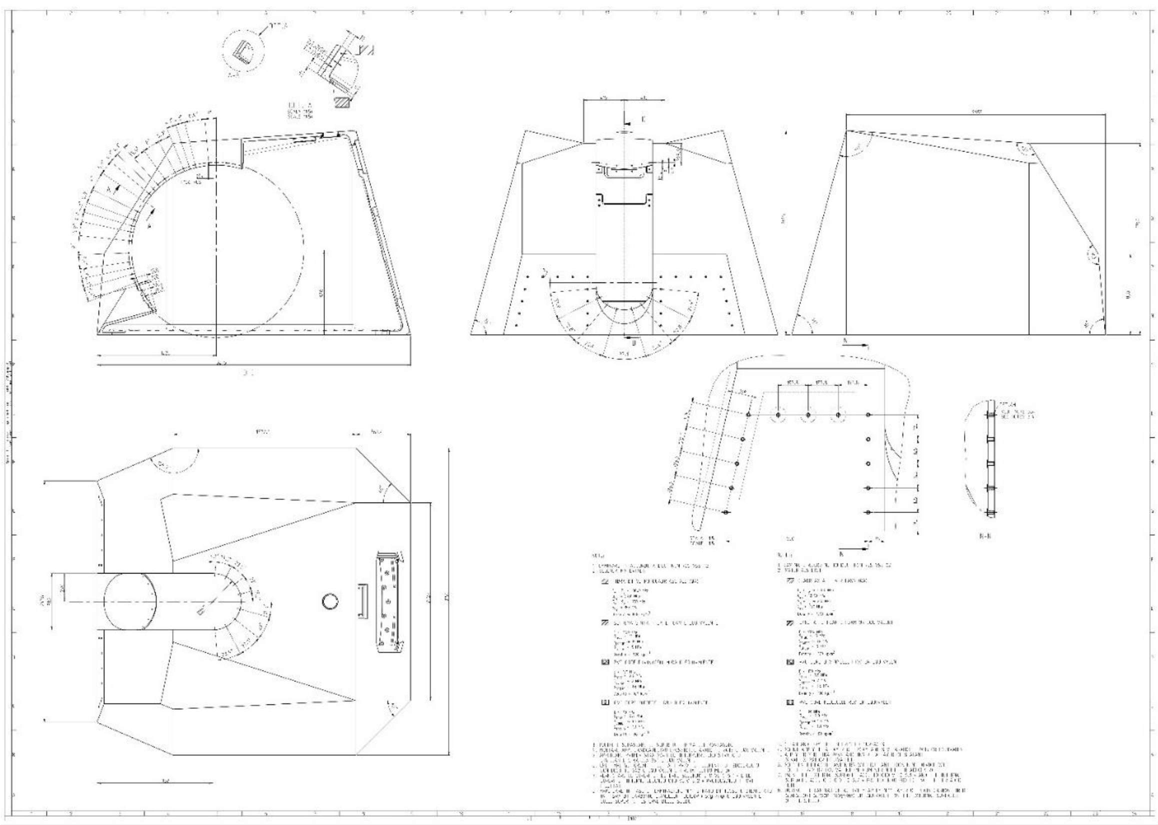
Drawing 6



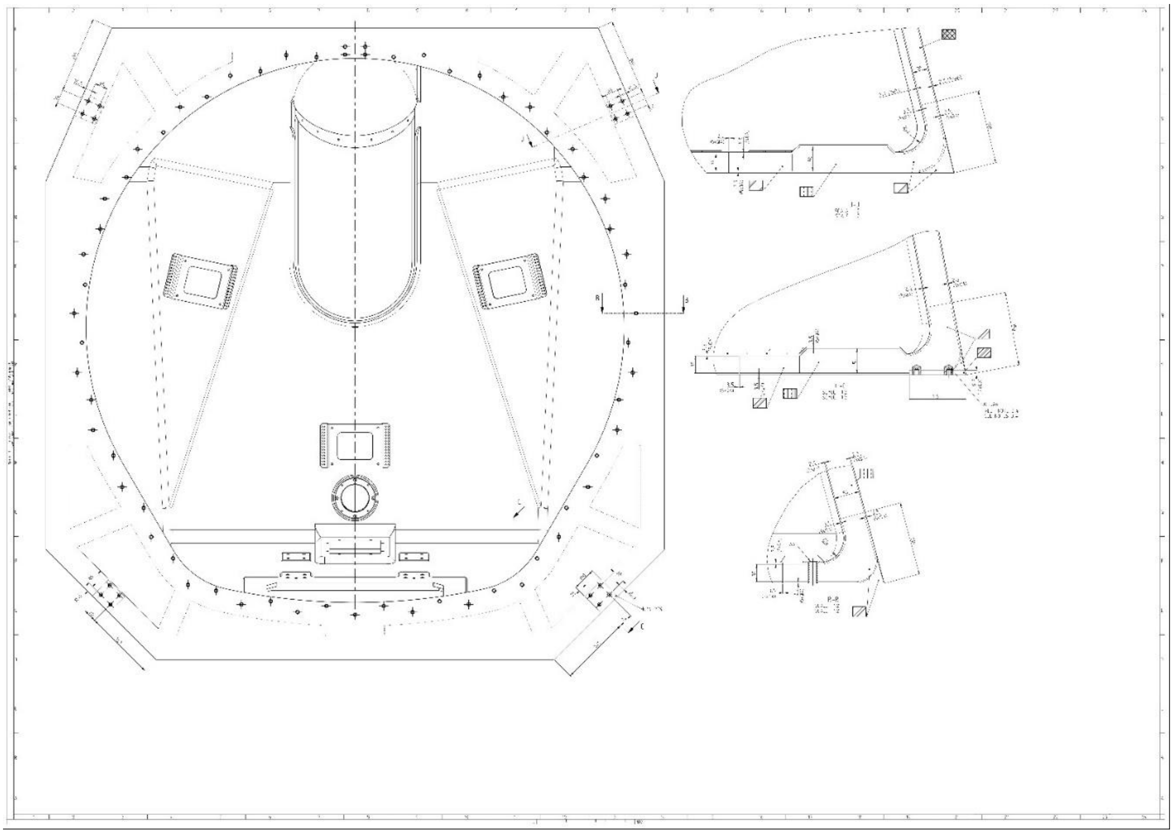
Drawing 7



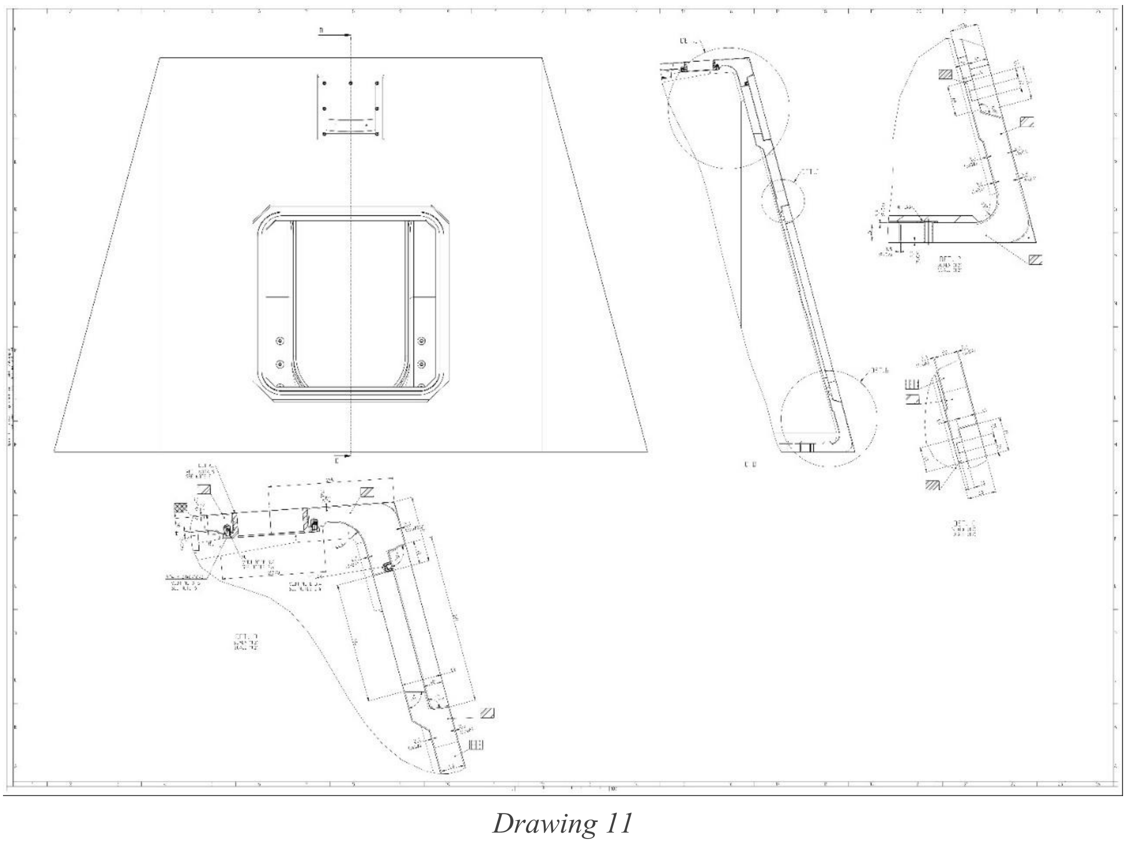
Drawing 8



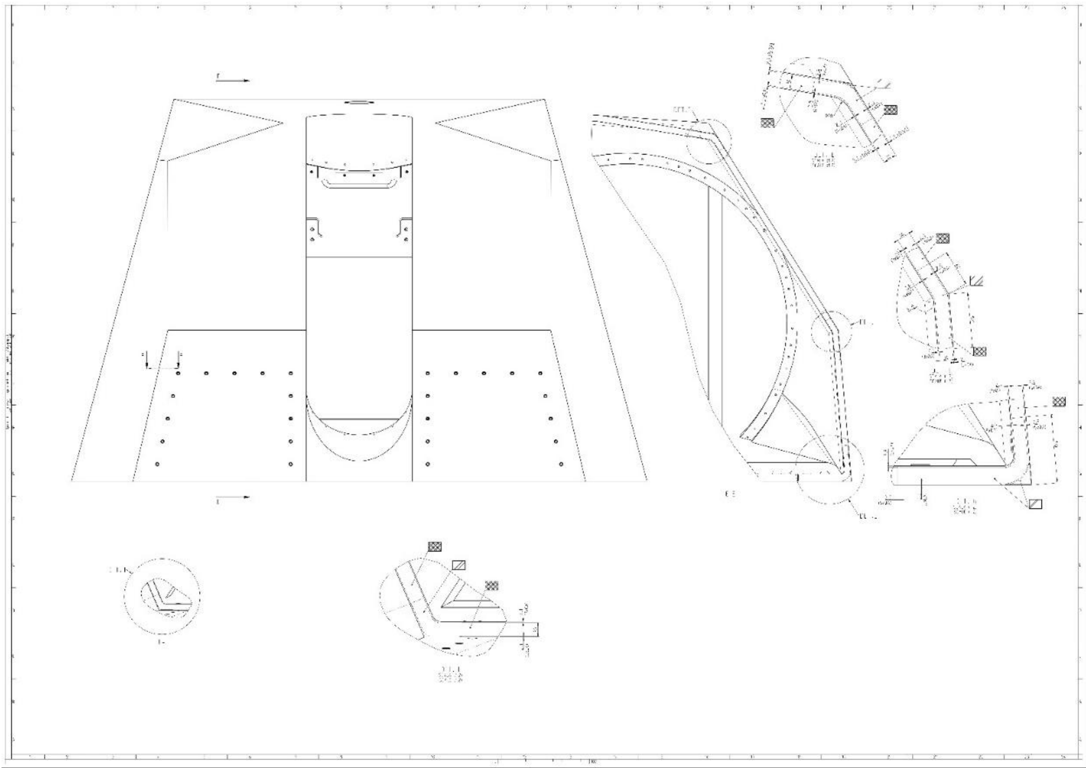
Dreawing 9



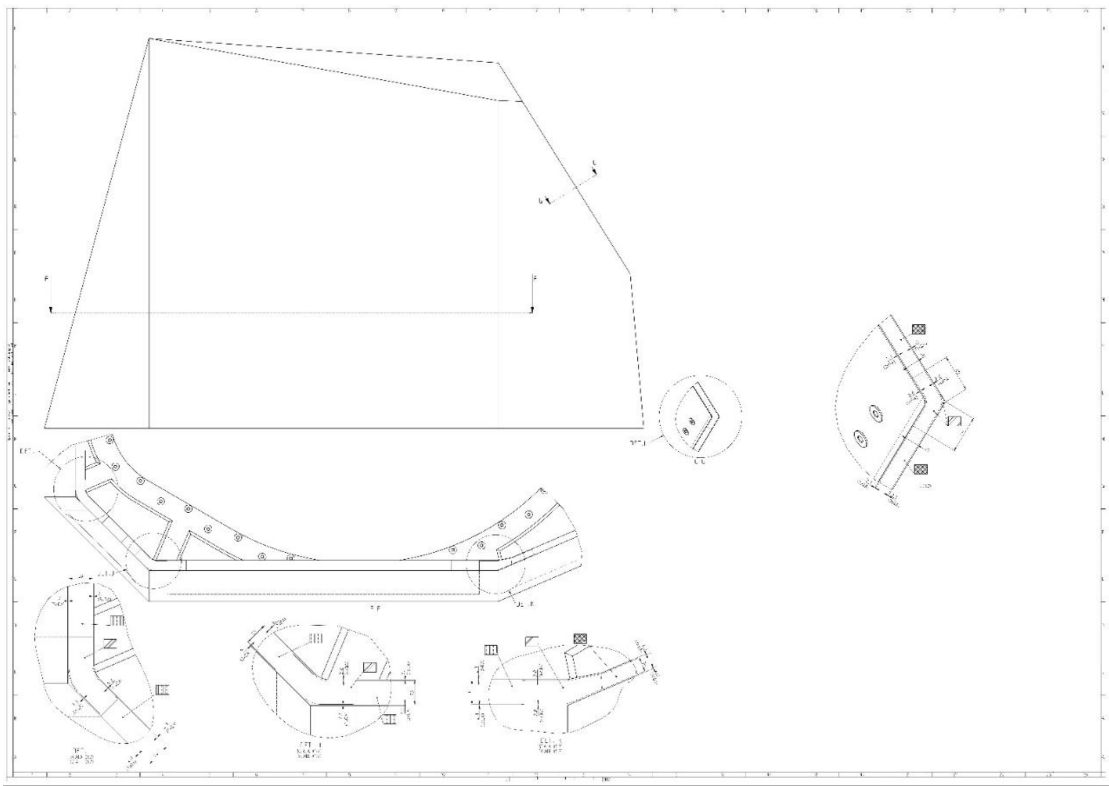
Drawing 10



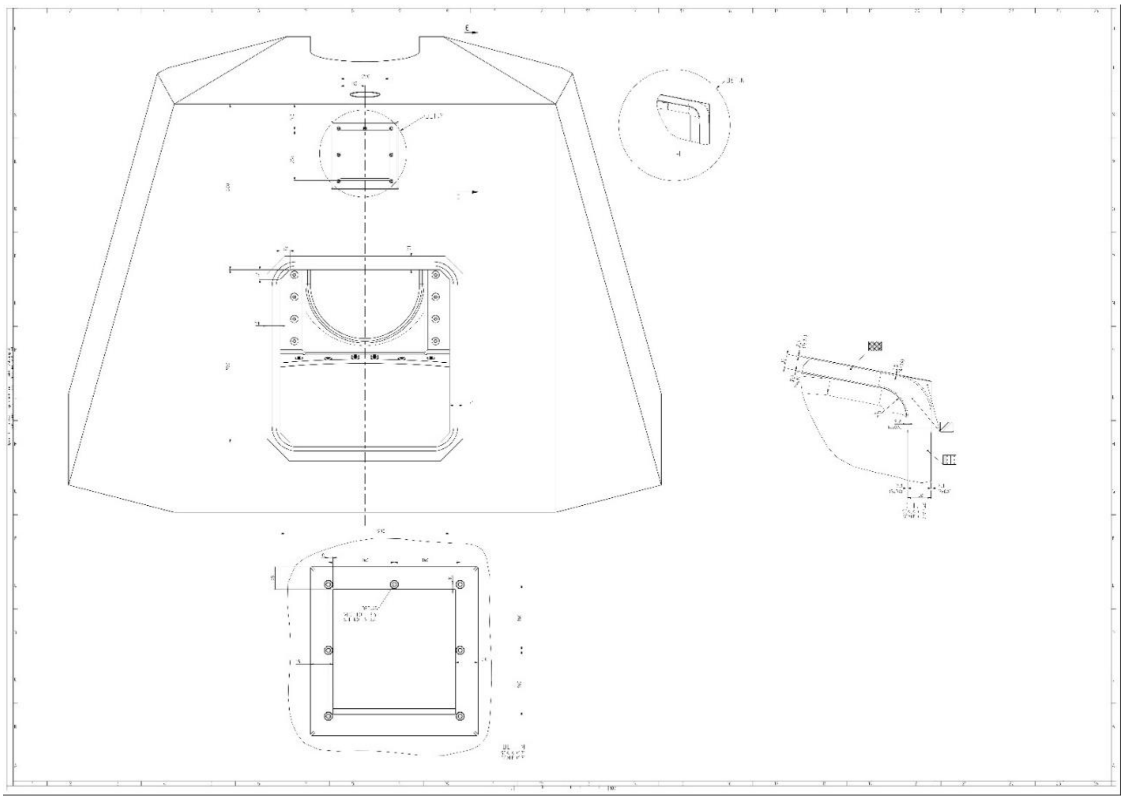
Drawing 11



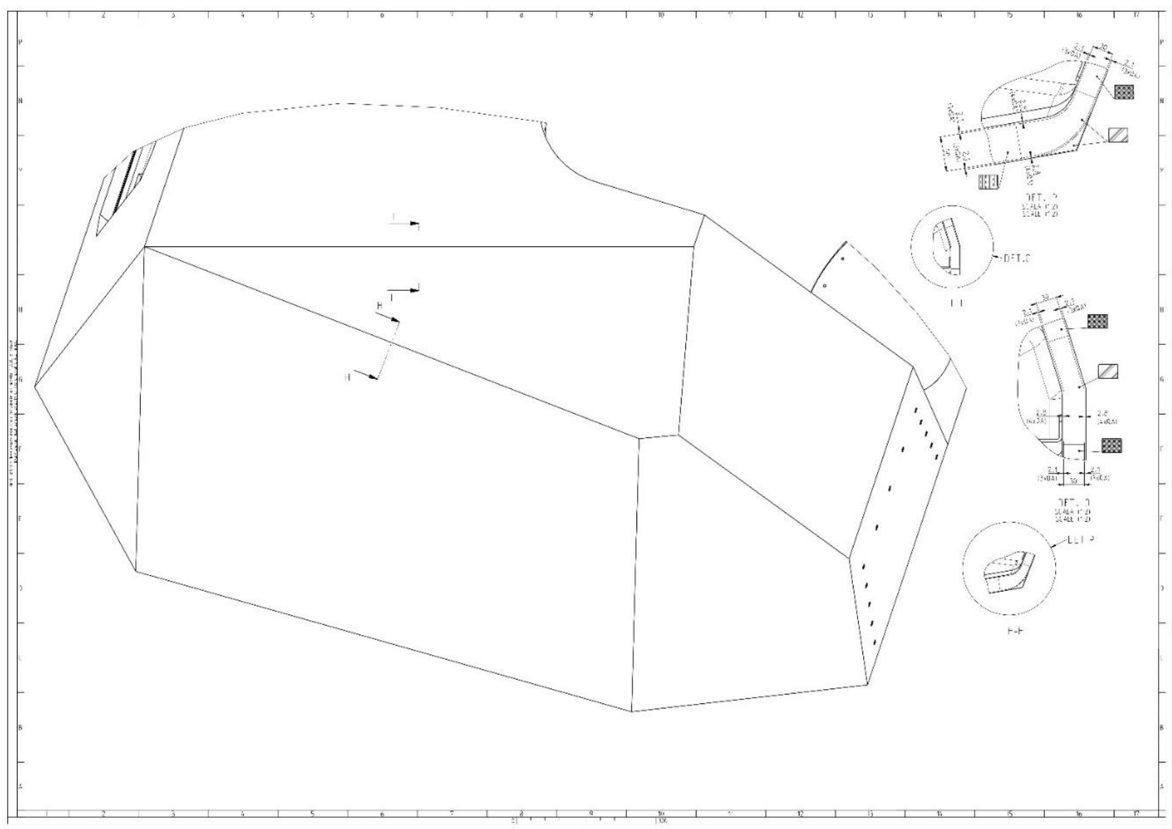
Drawing 12



Drawing13



Drawing 14



Drawing 15

ATTACHMENTS

Procedura di collaudo

La procedura di collaudo dello scudo per MK 71 MOD 2 è stata elaborata in accordo coi requisiti di cui al capitolo X Technical Requirement Specification of Composite Shield for Naval Gun System MK 71 MOD 2 e i parametri dettati dal sistema qualità della Nuova Connavi descritti nella procedura “ Prove controlli e collaudi I SQP 04-01”.

1. DOCUMENTAZIONE APPLICABILE

Questa procedura fa riferimento al Piano di Qualità della fornitura, alla scheda di lavorazione e controllo della fornitura e ai documenti standard:

SQP-04 – Gestione Del Processo;
IST-084- Costruzione Scudi del MK 71 MOD 2.

2. CONTROLLI INTERMEDI SUL CICLO DI PRODUZIONE

Tutti questi controlli verranno effettuati per ogni fornitura e dovranno essere registrato su PFC (Piano Fabbricazione e Controllo) dedicato.

2.1 Verifica delle attrezzature/materiali

Prima dell’inizio delle lavorazioni deve essere effettuata una verifica del corretto funzionamento delle attrezzature di lavoro, della conservazione degli stampi e delle aree di lavoro.

I materiali da impiegare per la produzione degli scudi del MK 71 MOD 2 saranno controllati per verificare il loro corretto stato di conservazione e di rispondenza ai requisiti.

2.2 Controlli intermedi in produzione

Verificare in accordo con la IST-084, la corretta preparazione delle superfici dello stampo (prova distacco gelcoat), la stesura delle pelli di rinforzo (carbonio, E-Preg, della schiuma sintattica, core, della stuccatura angoli e del posizionamento dei relativi particolari (portello, becchi, presa fumi ecc...) .
Detti controlli vanno effettuati anche per la costruzione del portello e dei becchi se previsti dai disegni.Il presente controllo verrà ripetuto per ogni fornitura e dovrà essere registrato su PFC dedicato.

2.3 Controllo del ciclo di cura/indurimento

Il ciclo di cura/indurimento dello scudo, dei becchi dovrà essere eseguito rispettando i seguenti parametri impostati sul PLC:

- Salita dalla temperatura ambiente fino a 80°C con un gradiente di 0,5 gradi al minuto;
- Stabilizzazione a 80°C e mantenimento della temperatura per 16 ore.
- Spegnimento dello stampo e raffreddamento naturale per circa 24 ore.

2.4 Controllo della superficie dello scudo

Verrà eseguito un controllo della superficie dello scudo secondo i parametri dettati dalla ASTM 2563D ed eventuali difettologie minori dovranno essere risolte ripristinando il corretto trattamento superficiale dello scudo.

2.5 Controllo verniciatura scudo

Verrà eseguito un controllo della verniciatura dello scudo concordata con il Cliente secondo i parametri riportati sulla scheda tecnica dei materiali impiegati. Eventuali difettologie minori dovranno essere risolte ripristinando il corretto trattamento superficiale dello scudo.

3. COLLAUDO FINALE DELLO SCUDO FAT (Factory Acceptance Test)

3.1 GEOMETRY (5.1.1)

Il test sarà condotto misurando la compatibilità fra i dati rilevati ed i disegni di progetto.
Verranno controllati gli spessori tipici della flangia di base e della cannoniera oltre ad un controllo della posizione dei fori sulla flangia della cannoniera.

Il dettaglio dei controlli da effettuare e l’evidenza delle misurazioni saranno riportate in Allegato.01 al presente documento dove verranno anche indicate le relative tolleranze e gli estremi della strumentazione dimisura impiegata.

L’esito della verifica e gli eventuali commenti / remark / riserve saranno riportati nel modulo Rapporto di Collaudo.

Il controllo degli spessori tipici della flangia di base, della cannoniera e della foratura di interfaccia dellacannoniera verrà ripetuto per ogni fornitura.
Lo spessore richiesto per la flangia di base è di 22 mm ± 2.2 mm e quindi un range compreso fra 21.8 ÷ 24.2mm.
Lo spessore richiesto per la flangia di base è di 14 mm ± 1.4 mm e quindi un range compreso fra 12.6 ÷ 15.4mm.
Ulteriori dettagli sono disponibili nell’Allegato.01 al presente documento.

Un controllo delle dimensioni generali verrà svolto solo per la prima fornitura.

5.2 MASS (5.1.2)

Il test sarà condotto misurando la compatibilità fra i dati rilevati ed il requisito di progetto.
Verrà controllato il peso delle varie parti (scudo, portelli, becchi, bulloneria, packing list etc) dello scudo del MK 71 MOD 2 con apposita strumentazione.

L'evidenza del controllo misurazioni sarà riportata in Allegato.01 al presente documento dove verrannoanche indicate le relative tolleranze e gli estremi della strumentazione di misura impiegata.
Il peso dello scudo come espresso nel Requisito 5.1.2 è di 600kg e considerando una tolleranza del 5%,dovuta ai materiali impiegati. e quindi un peso massimo ammissibile di 630 kg.
Ulteriori dettagli sono disponibili nell'Allegato.01 al presente documento.

L'esito della verifica e gli eventuali commenti / remark / riserve saranno riportati nel modulo Rapporto diCollaudo.

5.3 SOLAR RADIATION (5.3.8) / TEMPERATURE (5.3.1)

Il test sarà condotto misurando la compatibilità fra i dati rilevati ed il requisito di progetto testando gli scudi del MK 71 MOD 2 provenienti dalla produzione.

La rispondenza dello scudo al requisito contrattuale verrà verificata sottoponendo la superficie dello scudo aduna radiazione solare equivalente a 1120 W/m² generata dal pannello per irraggiamento solare (vedi Figura 1).
L'irraggiamento genererà sulla superfice dello scudo una temperatura di circa 65° che dovrà essere mantenuta per almeno 10 minuti. La temperatura verrà monitorata con una sonda posizionata sul perimetrodell'area testata e potrà essere monitorata anche con termometro laser o termocamera.

La prova avrà esito positivo se, dopo esposizione a tale radiazione, sulla superficie dello scudo non saranno visibili difetti (es. inclusioni d'aria, cricche…) di entità superiore 'Livello III' dettagliato nell'ASTM- D2563-08.

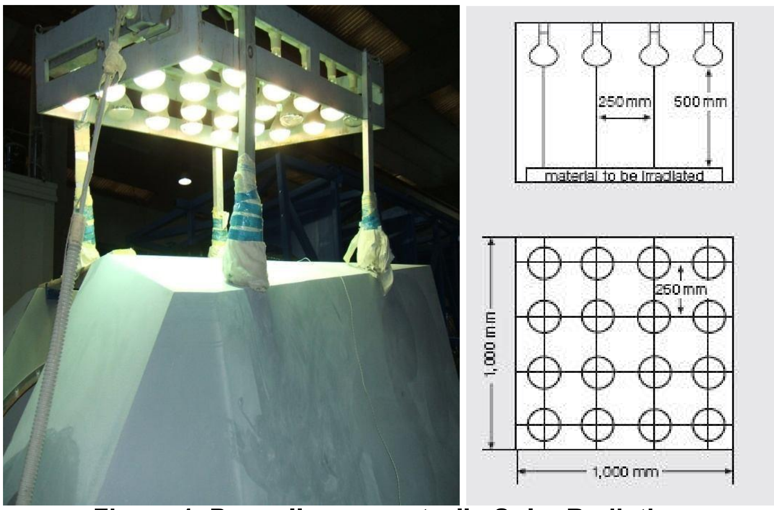


Figura 1- Pannello per controllo Solar Radiation

L’evidenza del controllo misurazioni sarà riportata in Allegato.01 al presente documento dove verrannoanche indicate le relative tolleranze e gli estremi della strumentazione di misura impiegata.

Considerata la severità del presente test, in cui le temperature generate raggiungono circa 70°C, la provaverrà considerata valida anche per l’accettazione del requisito Temperature (5.3.1).

L’esito della verifica, gli eventuali commenti / remark / riserve saranno riportati nel modulo Rapporto diCollaudo.

5.4 DEGREE OF ENCLOSURE (5.1.9) / PROVA FUNZIONALE PORTELLO

Il test sarà condotto misurando la compatibilità fra i dati rilevati ed il requisito di progetto.
Verrà controllata la tenuta del portello dello Scudo 76N e sarà svolta una prova funzionale di apertura, chiusura e stazionamento del portello onde verificare che non vi siano interferenze nell’interfaccia scudo/portello e nei meccanismi portello.
Il test verrà effettuato trattando con una pressione di 6 bar generata da un getto d’acqua, con un diametro di12mm, da una distanza di 3 metri per una durata minima di 15 minuti.

L’evidenza del controllo sarà riportata in Allegato.01 al presente documento dove verranno anche indicate lerelative tolleranze e gli estremi della strumentazione di misura impiegata.

L’esito della verifica e gli eventuali commenti / remark / riserve saranno riportati nel modulo Rapporto di Collaudo.

Il presente collaudo verrà ripetuto per ogni fornitura.

5.5 PROVE DISTRUTTIVE

Se richiesto dal Cliente, durante la costruzione dello scudo, dovrà essere realizzato un pannello con gli stessi materiali e tempistiche impiegate per la produzione dello scudo.
Le dimensioni del pannello dovranno essere di 500x500 mm

Realizzare 3 provini con lunghezza pari a 20 volte lo spessore e larghezza di 50 mm ed eseguire prove di flessione con metodo a tre punti secondo UNI EN ISO 14125.
Per tale prova è necessario produrre idonea certificazione.

Il presente controllo verrà ripetuto per ogni fornitura e sarà essere registrato su PFC dedicato.

5.6 APPRONTAMENTO FINALE

Ogni scudo verrà controllato visivamente per escludere la presenza di eventuali difettologie superficiali dovute alle precedenti lavorazioni o danneggiamenti durante le movimentazioni.

Verrà inoltre verificata la corretta integrazione di tutte le parti dello scudo (portello, becchi, staffe di sollevamento, etc.)

5.7 COLLAUDO/SPEDIZIONE

Per ogni scudo prodotto verrà controllata la redazione e la completezza della documentazione di produzionegenerata (PFC, SLC, Packing List, Rapporto di Collaudo e CoC).

4. ALLEGATI

- Allegato.01 Test Report FAT scudo MK 71 MOD 2

5. MATRICE REQUISITI

Di seguito viene una riportata tabella con tutti i requisiti espressi nella specifica di riferimento e la metodologia di controllo degli stessi.

Codice requisito	Identificazione	Metodologia controllo	Documentazione di riferimento
5.1.1	Geometry	Test	Allegato.01 PC-033 Test Report
5.1.2	Mass	Test	Allegato.01 PC-033 Test Report
5.1.3	Structure, materials, manufactoring process	N/A	N/A
5.1.4	Thermal trasmittance	Analysis	NCN-76N-VSS-01 (§ 8, pg 73)
5.1.5	Shielding	N/A	N/A
5.1.6	Electrical resistance	N/A	N/A
5.1.7	RCS reduction	N/A	N/A
5.1.8	Painting	N/A	N/A
5.1.9	Degree of enclosure	Test	Allegato.01 PC-033 Test Report
5.1.10	Ageing	N/A	N/A
5.2.1	Shock	Analysis	NCN-76N-VSS-01 (§5, pg 30)
5.2.2	Vibrations	Analysis	NCN-76N-VSS-01 (§10, pg 77)
5.2.3	Green water load	Analysis	NCN-76N-VSS-01 (§4, pg 22)
5.3.1	Temperature	Test	Allegato.01 PC-033 Test Report
5.3.2	Pressure	N/A	N/A
5.3.3	Icing	Analysis	NCN-76N-VSS-01 (§7, pg 72)
5.3.4	Salt fog	N/A	N/A
5.3.5	Fungus	N/A	N/A
5.3.6	Wind	Analysis	NCN-76N-VSS-01 (§6, pg 54)
5.3.7	Rain	N/A	N/A
5.3.8	Solar radiation	Test	Allegato.01 PC-033 Test Report
5.3.9	Humidity	N/A	N/A
5.3.10	Ship motion	Analysis	NCN-76N-VSS-01 (§9, pg 75)
5.4.1	Reliability	N/A	N/A
5.5.1	Safety	N/A	N/A
5.5.2	Flammable materials	N/A	N/A
5.5.3	Poisonous gas, normal operation	N/A	N/A
5.5.4	Health hazards	N/A	N/A
5.5.5	NBC protection	N/A	N/A

Piano di qualifica

Tutti i requisiti contrattuali da verificare nell'ambito delle qualifiche (analisi, test, dimostrazioni ed ispezioni) necessari al processo di Accettazione dello scudo del MK 71 MOD 2 verranno elencati di seguito.

1.1 Documento di riferimento

ID	Riferimento/Numero	Titolo.Doc
R1	S ST 1827 8369	Technical Requirement Specification of Composite Shield MK 71 MOD 2 LW Vulcano Naval Gun System
R2	NCN-127-TS-06	Technical Specification Scudo MK 71 MOD 2
R3	-	Ordine 5100006877 del 02/01/17
R4	GRT143_01	Dimensionamento e Verifiche Strutturali Scudo in Composito – 127/64 LW Vulcano

2. STRUTTURA DEL QUALIFICATION PLAN

L'identificazione dei requisiti applicabile e delle normative

Una volta individuati i requisiti applicabili recepiti dalla Specifica Tecnica Technical Requirement Specification of Composite Shield MK 71 MOD 2 (S ST 1827 8369 Rev.05, Rif. R1) è stata strutturata una lista (Allegato.01) contenente le seguenti informazioni:

- Una colonna denominata 'Trial Code' identifica il codice univoco della prova (codice requisito);
- Una colonna denominata 'Identification' riporta il titolo generico della prova;
- Una colonna denominata 'Requirement Reference' identifica la categoria generica del requisitoin oggetto;
- Una colonna denominata 'TP Link' riporta il riferimento alla procedura di prova/documentazione giustificativa;
- Una colonna denominata 'Trial Short Description' riporta una breve descrizione della prova;
- Una colonna denominata 'Note' dove all'occorrenza saranno riportate informazioni genericheinerenti la prova e le prove più significative;
- Una colonna denominata 'MIL' dettaglia la norma MIL di riferimento per la prova in oggetto;
- Una colonna denominata 'Method' specifica il metodo di prova ('Test, Analysis, Inspection, Demonstration);

- Una colonna denominata ‘Occ.’ specifica l’occorrenza della prova in oggetto (T: Prova di Tipo - effettuata solo sul primo esemplare, R: Prova Ripetitiva - effettuata su ogni esemplare);

- Una colonna denominata ‘Sup. Res.’ specifica l’attrezzatura relativa alla prova procurata dal fornitore;

- Una colonna denominata ‘Cus. Res.’ specifica l’attrezzatura relativa alla prova fornita dalcliente.

Le informazioni sopra descritte sono inserite in dettaglio nell’Allegato.01 NCN-127-QP-07‘Qualification Plan’.

2.1 TEST ED ISPEZIONI

Per i requisiti il cui soddisfacimento è previsto tramite **test** od **ispezione**, verrà sviluppata apposita Procedura di Collaudo (PC-030).

Per comodità i requisiti in oggetto vengono riportati nella seguente tabella:

Trial Code	Identification	Site	Riferimento alla relativa procedura di prova	Method	Occ.
4.1.1	GEOMETRY	FAT	PC-030	INSPECTION	R
4.1.2	JOINTS	FAT	PC-030	INSPECTION	T
4.1.3	MASS	FAT	PC-030	TEST	R
4.1.6	SHIELDING	FAT	PC-030	TEST	R
4.1.7	ELECTRICAL RESISTANCE	FAT	PC-030	TEST	T
4.1.10	DEGREE OF ENCLOSURE	FAT	PC-030	TEST	T
4.3.3	SALT FOG	FAT	PC-030	TEST	T
4.3.6	RAIN	FAT	PC-030	TEST	T
4.3.7	SOLAR RADIATION	FAT	PC-030	TEST	T
4.3.8	HUMIDITY	FAT	PC-030	TEST	T
4.4.4	INTERNAL REINFORCES	FAT	PC-030	TEST	T
4.4.5	SPARES AND TOOLS LIST	FAT	PC-030	INSPECTION	T
4.5.2	FLAMMABLE MATERIALS	FAT	PC-030	TEST	T

Tabella I - Test ed Ispezioni

2.2 DIMOSTRAZIONI ED ANALISI

I metodi di verifica e le giustificazioni per tutti i requisiti il cui soddisfacimento è previsto tramite **analisi** sono stati soddisfatti con calcoli FEM per la definizione/dimensionamento dello scudo. Per comodità i requisiti vengono elencati di seguito.

Trial Code	Identification	Riferimento alla relativa procedura di prova /documentazione giustificativa	Method
4.1.5	THERMAL TRASMITTANCE	GRT-143-01	ANALYSIS
4.2.1	SHOCK	GRT-143-01	ANALYSIS
4.2.2	VIBRATIONS	GRT-143-01	ANALYSIS
4.2.3	GREEN WATER LOAD	GRT-143-01	ANALYSIS
4.3.2	ICING	GRT-143-01	ANALYSIS
4.3.5	WIND	GRT-143-01	ANALYSIS
4.3.9	SHIP MOTION	GRT-143-01	ANALYSIS

Tabella II - Analisi

Le giustificazioni per i requisiti il cui soddisfacimento è previsto mediante **dimostrazione,** oltre a **test** (**soltanto per il requisiti 4.3.1 e 4.3.3**) sono elencate in Tabella III e nell'Allegato.02 al presente documento sono inoltre disponibili le giustificazioni ottenute.

Trial Code	Identification	Riferimento alla relativa procedura di prova /documentazione giustificativa	Method
4.1.4	STRUCTURE, MATERIALS AND MANUFACTURING PROCESSES	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.1.8	RCS REDUCTION	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.1.9	PAINTING	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.1.11	AGEING	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.3.1	TEMPERATURE	Allegato.02 NCN-127-QP-07	TEST
4.3.4	FUNGUS	Allegato.02 NCN-127-QP-07	ANALYSIS
4.4.1	RELIABILITY	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.4.2	MAINTAINABILI TY	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.4.3	TRANSPORTABILITY	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.4.6	TOOLS STANDARD	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.4.7	HUMAN FACTOR	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.5.1	SAFETY	Allegato.02 NCN-127-QP-07	DEMONSTRATION
4.5.3	POISONOUS GASES, NORMAL OPERATION	Allegato.02 NCN-127-QP-07 – GRT-143-01	DEMONSTRATION
4.5.4	HEALTH HAZARDS	Allegato.02 NCN-127-QP-07 – GRT-143-01	DEMONSTRATION
4.5.5	NBC PROTECTION	Allegato.02 NCN-127-QP-07 – GRT-143-01	DEMONSTRATION

Tabella III - Dimostrazioni e Test

3. ALLEGATI

- Allegato.01 NCN-127-QP-07 ‘Qualification Plan’;
- Allegato.02 NCN-127-QP-07 ‘Documentazione Giustificativa Scudo MK 71 MOD 2’.

Allegato.01 NCN-127-QP-07 ‘Qualification Plan’;

Trial Code Codice Prova	Identification Titolo	Requirement Reference Riferimento a requisiti	TP link Riferimento alla relativa procedura di prova / documentazione	Trial Short Description Descrizione della prova	Note	Site Sito delle prove	S/S Sotto Sistemi Coinvolti	Method Metodo di verifica	Occ.	Mil..	Sup. Res. Descrizione delle attrezzature relative alle prove di qualifica	Cus. Res. Descrizione delle attrezzature relative alle prove di qualifica
4.1.1	GEOMETRY	GEOMETRY AND PHYSICAL REQUIREMENTS	PC-030	Inspection will demonstrate that the shield’s main dimensionsare coherent to the project drawings.		N/A	P/N 1828-11-001	INSPECTION	R	-		Tools per controllo forature.
4.1.2	JOINTS	GEOMETRY AND PHYSICAL REQUIREMENTS	PC-030	Inspection will demonstrate that the joints used for theshield’s assembly are internal L-joins with 2 rows of misaligned bolts.		N/A	P/N 1828-11-001	INSPECTION	T	-		
4.1.3	MASS	GEOMETRY AND PHYSICAL REQUIREMENTS	PC-030	Test will demonstrate that the measured mass of the shielddoes not exceeds 1600 kg.		FAT	P/N 1828-11-001	TEST	R	-		
4.1.4	STRUCTURE, MATERIALS AND MANUFACTURING PROCESSES	GEOMETRY AND PHYSICAL REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the shield structure has been realized in accordance to Table 3 and 4 of S ST 1827 8369Rev.05.		N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-		
4.1.5	THERMAL TRASMITTANCE	GEOMETRY AND PHYSICAL REQUIREMENTS	GRT-143-01	Analysis will demonstrate that the thermal trasmittance of theshield is not higher than 1,5W/m2K.		N/A	P/N 1828-11-001	ANALYSIS	N/A	-		
4.1.6	SHIELDING	GEOMETRY AND PHYSICAL REQUIREMENTS	PC-030	Test will demonstrate that the whole surface of the shield guarantees a minimum shielding effectivnmess of 40dB inthe frequency range 2 MHz ÷ 18 GHz	Prova con supporto di SDI	FAT	P/N 1828-11-001	TEST	R	IEEE -299-2006		
4.1.7	ELECTRICAL RESISTANCE	GEOMETRY AND PHYSICAL REQUIREMENTS	PC-030	Test will demonstrate that the electrical resistance of the conductive layer of thre shield is less than 0.1 Ohm.		FAT	P/N 1828-11-001	TEST	T	-		
4.1.8	RCS REDUCTION	GEOMETRY AND PHYSICAL REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that RCS (Radar Cross Section) ofthe shield has been properly minimized by the use of propergeometry and material.		N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-		
4.1.9	PAINTING	GEOMETRY AND PHYSICAL REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the shield has been properly painted in accordance to OTO-VE-0.		N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-		
4.1.10	DEGREE OF ENCLOSURE	GEOMETRY AND PHYSICAL REQUIREMENTS	PC-030	Test will demonstrate that the shield is dust-tight, able to withstand temporary immersion in water in accordance with international standard IEC 60529, protection class IP67.		FAT	P/N 1828-11-001	TEST	T	-		
4.1.11	AGEING	GEOMETRY AND PHYSICAL REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the shield shall be insensitive to ageing for all the service life of the gun mount (30 years) andthat the shield shall not be affected by osmosis problems.		N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-		
4.2.1	SHOCK	STRUCTURAL REQUIREMENTS	GRT-143-01	Analysis will demonstrate that the shield will withstand a vertical shock of 500 m/s2 (static load) and an horizontal of 300 m/s2 (static load) without compromising it’s integrity andfunctionality.		N/A	P/N 1828-11-001	ANALYSIS	N/A	-		
4.2.2	VIBRATIONS	STRUCTURAL REQUIREMENTS	GRT-143-01	Analysis will demonstrate that the shield can withstand vibrations in accordance to Mil-STD-810G.		N/A	P/N 1828-11-001	ANALYSIS	N/A	-		

Trial Code Codice Prova	Identification Titolo	Requirement Reference Riferimento a requisiti	TP link Riferimento alla relativa procedura di prova / documentazione	Trial Short Description Descrizione della prova	Note	Site Sito delle prove	S/S Sotto Sistemi Coinvolti	Method Metodo di verifica	Occ.	Mil..	Sup. Res. Descrizione delle attrezzature relative alle prove di qualifica	Cus. Res. Descrizione delle attrezzature relative alle prove di qualifica
4.2.3	GREEN WATER LOAD	STRUCTURAL REQUIREMENTS	GRT-143-01	Analysis will demonstrate that the shield can withstand a static pressure of 0.7 bar with a maximum deflection of 100mm.		N/A	P/N 1828-11-001	ANALYSIS	N/A	-		
4.3.1	TEMPERATURE	ENVIRONMENTAL REQUIREMENTS	Allegato.01 NCN-127-QP-07	Test will demonstrate that the shield can operate in the and survive without compromising it's functionality and integrity inthe temperature range of -40°C ÷ 75°C.	Prova con supporto di SDI	FAT	P/N 1828-11-001	TEST	T	MIL-STD-810G		
4.3.2	ICING	ENVIRONMENTAL REQUIREMENTS	GRT-143-01	Analysis will demonstrate that the shield can withstand an ice increase of: 25mm/h, up to 70 kg/m2 for horizontal surfaces and an ice increase of 6.4mm/h, up to 24 kg/m2, for vertical surfaces. The shield can also survive an ice load up to 125 kg/m2 without compromising its integrity and functionality		N/A	P/N 1828-11-001	ANALYSIS	N/A	-		
4.3.3	SALT FOG	ENVIRONMENTAL REQUIREMENTS	PC-030	Test will demonstrate that according to MIL-STD-810G. and AECTP 300, the shield survives an environment with a salt fog concentration of 5% with the salt solution atomized in thetest chamber with at a temperature of 35° for a period of 24 hours with the shield dried at standard temperature and a RH of 50% or less. The procedure can be repeated at least twice with an overall salt fog trial with a duration of at least 96 hours.	Prova con supporto di SDI	FAT	P/N 1828-11-001	TEST	T	MIL-STD-810G AECTP 300		
4.3.4	FUNGUS	ENVIRONMENTAL REQUIREMENTS	Allegato.01 NCN-127-QP-07	Test will demonstrate that the shield complies the fungus requirement in accordance with MIL-STD-810G.		N/A	P/N 1828-11-001	ANALYSIS	T	-		
4.3.5	WIND	ENVIRONMENTAL REQUIREMENTS	GRT-143-01	Analysis will demonstrate that the shield can withstand, without compromising its integrity and functionality, wind of75 knots with gusts up to 135 knots in operative conditionsand wind of 100 knots with gusts up to 175 knots in non- operative conditions.		N/A	P/N 1828-11-001	ANALYSIS	N/A	-		
4.3.6	RAIN	ENVIRONMENTAL REQUIREMENTS	PC-030	Test will demonstrate that the shield when installed can withstand a water jet pressure of 6 bar with a diameter of 12 mm, from a distance of 3 m and a duration of 15 min, with noinfiltrations inside the shield.		FAT	P/N 1828-11-001	TEST	T	-		
4.3.7	SOLAR RADIATION	ENVIRONMENTAL REQUIREMENTS	PC-030	Test will demonstrate that the shield can withstand a solar radiation of 1120 W/m2 without compromising its integrity.		FAT	P/N 1828-11-001	TEST	T	MIL-STD-810G		Pannello per irraggiamento
4.3.8	HUMIDITY	ENVIRONMENTAL REQUIREMENTS	PC-030	Test will demonstrate that the shield can withstand an humidity cycle as reported in MIL-STD-810G.	Prova con supporto di SDI	FAT	P/N 1828-11-001	TEST	T	MIL-STD-810G		
4.3.9	SHIP MOTION	ENVIRONMENTAL REQUIREMENTS	GRT-143-01	Demonstration will show that the shield can withstand a ship motion up to a roll of ±22.5 for a period of 10 s, a pitch of ±7.5 for a period of 5 s. During the specified motions, the parts of the shield (modules, junctions, hatches, etc.) will remain connected to each other and to gun system and thedeflection of the surfaces of the shield will not exceed the one indicated in 4.2.3.		N/A	P/N 1828-11-001	DEMONSTRATION	T	-		

Trial Code Codice Prova	Identification Titolo	Requirement Reference Riferimento a requisiti	TP link Riferimento alla relativa procedura di prova / documentazione	Trial Short Description Descrizione della prova	Site Sito delle prove	S/S Sotto Sistemi Coinvolti	Method Metodo di verifica	Occ.	Mil..	Cus. Res. Descrizione delle attrezzature relativealle prove di qualifica
4.4.1	RELIABILITY	LOGISTIC AND SAFETY REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the shield has a MTBF (MeanTime Before Failure) greater than 150000 hours	N/A	P/N 1828-11-001	DEMONSTRATION	T	-	
4.4.2	MAINTAINABILITY	LOGISTIC AND SAFETY REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the shield can be replaced within 4 hours in the harbour with a crane and a specific lifting device by a team of 3 people (including the operator ofthe crane), that each module is removable independently from the others.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	
4.4.3	TRANSPORTABILITY	LOGISTIC AND SAFETY REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the shield's inserts for transportability are integrated and properly reinforced in theupper parts of the modules with the use of eye bolts.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	
4.4.4	INTERNAL REINFORCES	LOGISTIC AND SAFETY REQUIREMENTS	PC-030	Test will demonstrate that on the internal surface of shield proper interfaces are implemented for the handling of heavyitems (≤ 150 kg).	FAT	P/N 1828-11-001	TEST	T	-	
4.4.5	SPARES AND TOOLS LIST	LOGISTIC AND SAFETY REQUIREMENTS	PC-030	Inspection will demonstrate that it will be possible to replacethe shield at module level.	FAT	P/N 1828-11-001	INSPECTION	T	-	
4.4.6	TOOLS STANDARD	LOGISTIC AND SAFETY REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that the transportation, installation tools and STTE comply with Directive Machinery 2006/42 CEand that they are delivered with proper operative and maintenance manuals.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	
4.4.7	HUMAN FACTOR	LOGISTIC AND SAFETY REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that shield complies with MIL-STD-1472 G.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	MIL-STD-1472G	
4.5.1	SAFETY	SAFETY-RELATED REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that shield can be exposed to fire or corrosive environment without representing	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	

				hazards to personnel and any parts of the gun mount and onboard equipment.						
4.5.2	FLAMMABLE MATERIALS	SAFETY-RELATED REQUIREMENTS	PC-030	Test will demonstrate that it is impossible to ignite the shieldwhen exposed to sparks or heat).	FAT	P/N 1828-11-001	TEST	T	-	
4.5.3	POISONOUS GASES, NORMAL OPERATION	SAFETY-RELATED REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that shield does not contain materials that can emit poisonous gases or hazardous materials to the touch in normal operation and storage.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	
4.5.4	HEALTH HAZARDS	SAFETY-RELATED REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that shield does not containmaterials representing health hazards during normal operation and storage.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	
4.5.5	NBC PROTECTION	SAFETY-RELATED REQUIREMENTS	Allegato.01 NCN-127-QP-07	Demonstration will show that shield can withstand the damaging effect of nuclear, biological and chemical contamination agents and of decontamination agents andrelative procedures.	N/A	P/N 1828-11-001	DEMONSTRATION	N/A	-	

	SISTEMA		
NUOVA CONNAVI s.r.l.	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.4	1

REQUISITO: STRUCUTURE, MATERIALS AND MANUFACTORING PROCESSES

The **modules** and **hatches** shall be built with a with a self-supporting sandwich structure (**except the gunport**) with external skins and internal core, and with the possibility of using local reinforcements. The material and the manufacturing processes shall be selected in accordance with Table 3 and Table 4.

As anticipated, the only part which shall not be a sandwich structure is the **gunport** (which is included in the forward module). The gunport shall be a solid laminate composed by pre-preg E-glass balanced woven with epoxy resin, made in autoclave (vacuum pressure 6 bar) at 110°C-130°C. The gunport shall be designed to withstand the requirements listed in this document.

All the materials used must be commercial, not built in house, and easily available on the market.

COMPONENT		CHARACTERISTIC	M.U.	SOLUTION
PRE-PREG	REINFORCEMENT	Type	-	E-Glass, Multiaxial or Balanced Fabrics
		Specific weight	g/m^2	270 ÷ 630
	RESIN	Type	-	Epoxy
		Tg	°C	110°C ≤ Tg ≤ 150°C [Ref. 18]
CORE		Type	-	PVC Foam HT/HP
		Density	kg/m^3	70 ÷ 130

TOPIC	M.U.	SOLUTION
Production Process	-	Lamination with Vacuum Bag
Vacuum pressure	bar	~ 0,9
Curing system	-	Temperature-controlled oven
Curing temperature	°C	110 ÷ 130
Trimming and Drilling	-	CNC
Molds	-	• *Type*: female • *Material*: metallic (INOX) or composite • *Duration* > 40 pieces.
Models	-	• If molds metallic -> not necessary • If molds composite -> CNC milled, epoxy paste

IPOTESI ASSUNTE

I manufatti sono stati progettati e dimensionati in accordo a quanto riportato nel requisito della specifica tecnica (vedi GRT143_01) e con i materiali identificati nella stessa (fibre di vetro, resine e core).

GIUSTIFICAZIONI ACQUISITE	**DOC. DI RIF.**
Per tutti i dettagli di realizzazione consultare il ply-book (NCN-127-PB-09) relativo alla presente commessa. Ulteriori dettagli sulle lavorazioni saranno disponibili nei disegni 2D dell'assieme Scudo 127 (NCN-127-SD-14) e relativi Piani Di Fabbricazione e Controllo.	1) GRT143_01 2) Ply-Book Scudo 127 NCN-127-PB-09 3) Shield Drawings NCN-127-SD-14

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	DOC. DI RIF.	№ PAR.	№ SCHEDA
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.8	2

REQUISITO: RCS REDUCTION

The RCS (*Radar Cross Section*) of the shield shall properly be minimized by shaping, according to geometry requirement as by par 4.1.1, and using proper materials.

RAM (*Radar Absorbent Material*) should not be used, if they comport a not negligible cost increase.

IPOTESI ASSUNTE

I manufatti saranno realizzati geometricamente in accordo a quanto riportato nella specifica tecnica del Cliente con geometrie appropriate per le riduzione RCS.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
Le geometrie generali dello scudo sono state rese disponibili con l'invio del doc. ID 6 del TDP (Shield Drawings:1828-11-001.stp) e saranno ulteriormente dettagliate nei disegni dell'assieme Scudo 127 (NCN-127-SD-127). Si ricorda inoltre che le geometrie non sono state sostanzialmente modificate rispetto alla versione in alluminio dello Scudo 127. Non è previsto l'uso di materiale radar assorbente (Vedi Ply Book).	1) 1828-11-001.stp 2) Shield Drawings Scudo 127 NCN-127-PB-09 3) Ply-book Scudo 127 NCN-127-PB-09

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	DOC. DI RIF.	№ PAR.	№ SCHEDA
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.9	3

REQUISITO: PAINTING

The shield in general (in particular the exposed surfaces of the shield) should be painted according to [Ref. 9] and according to customer requirements (typically RAL 7xxx). The internal surfaces of the shield should be painted with a light color, to be agreed with SDI Technical Department. All the painting procedures shall be quoted, discussed and approved by SDI Purchasing, Engineering and Quality departments before the delivery of the first shield.

IPOTESI ASSUNTE

Gli Scudi 127 saranno verniciati in accordo a quanto richiesto dal Cliente.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.

Tutti i dettagli sulla verniciatura saranno disponibili nei Piani Di Fabbricazione e Controllo. L'interno dello scudo verrà verniciato internamente di colore bianco 17875 Federal Standard, la verniciatura esterna verrà confermata dal Cliente. Saranno disponili le schede tecniche relative alla verniciature prescelte.	1) PFC Scudo 127 2) Schede tecniche vernici.

NUOVA CONNAVI s.r.l.	**SISTEMA** SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.11	4

REQUISITO: AGEING

The shield shall be insensitive to ageing for all the in service life of the gun mount, which is not less than 30 years. In addition, the shield shall not be affected by osmosis problems.

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati con una miscela di resine epossidiche e metodologie di produzione che minimizzano gli effetti dell'invecchiamento.

GIUSTIFICAZIONI ACQUISITE	**DOC. DI RIF.**
NCN ha recentemente svolto (anno 2013) una campagna di caratterizzazione del proprio materiale (E-Preg QE) utilizzato per la presente commessa che a fronte di un invecchiamento simulato di 30 anni, ha dimostrato la piena compatibilità dei manufatti con la richiesta in oggetto. Peraltro nessuno degli scudi prodotti da NCN, a partire dalla fine degli anni '70 e tutt'ora in esercizio, realizzati quindi con tecnologie e materiali meno performanti di quanto attualmente disponibile, ha mai presentato difettologie imputabili a problematiche relative all'invecchiamento dei materiali impiegati.	1) NCN-OSN-STPI-104; 2) NCN-OSN-RPISD-114.

NUOVA CONNAVI s.r.l.	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.3.1	5

REQUISITO: TEMPERATURE

In accordance with [Ref. 1], the shield shall:

- operate (without anti-icing systems) in the temperature range: -30°C ÷ +65°C;
- survive, without compromising its integrity and functionality, in the temperature range: -40°C ÷ +75°C.

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati con una miscela di resine epossidiche caricate e metodologie di produzione che minimizzano gli effetti delle temperature a cui sarà sottoposto in esercizio.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
NCN ha recentemente svolto una campagna di caratterizzazione del proprio materiale (E-Preg QE) che ha dimostrato la piena compatibilità dei manufatti con la richiesta in oggetto. Le prove sono state svolte dal laboratorio designato (CTS La Spezia) trattando i campioni secondo i requisiti di temperatura specificati.	1) Certificato CTS 165617 del 14/07/17 2) Certificato CTS 151117 del 23/06/17

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.3.4	6

REQUISITO: FUNGUS

The shield shall comply with fungus requirement, in accordance with [Ref. 1].

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati con una miscela di resine epossidiche e metodologie di produzione che minimizzano la crescita di funghi, organismi esterni o fenomeni di osmosi.

GIUSTIFICAZIONI ACQUISITE	**DOC. DI RIF.**
NCN ha recentemente (anno 2013) svolto una campagna di caratterizzazione del proprio materiale (E-Preg QE) che a fronte di un invecchiamento simulato di 30 anni ha dimostrato la piena compatibilità dei manufatti con la richiesta in oggetto. In particolare è stato provato che l'impiego di resine epossidiche sfavorisce non contiene sostanze che alimentano la formazione di funghi la crescita di funghi. E' inoltre disponibile ampia bibliografia di dominio pubblico che corrobora l'ipotesi assunta. NCN ha costruito con questo materiale più di 300 scudi nelle versioni 76 Stealth, 76 zuccotto e 127 LW che sono entrati in servizio a partire dal 1981 che mai hanno manifestato problematiche riconducibili al requisito in oggetto. Ciò per noi equivale ad una qualifica sul campo. Secondo la MIL-810 i test di questa tipologia vanno eseguito con riferimento a tipologie specifiche di microorganismi da definire in fase di progetto. Sul requisito non sono disponibili cenni più dettagliati a riguardo.	1) NCN-OSN-RPISD-114 Rev 0

NUOVA CONNAVI s.r.l.	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.4.1	7

REQUISITO: RELIABILITY

The shield shall have an MTBF *(Mean Time Before Failure)* greater than 150000 hours.

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati con un appropriato dimensionamento, utilizzando materiali e metodologie di produzione che minimizzano il rischio di guasti.

GIUSTIFICAZIONI ACQUISITE	**DOC. DI RIF.**
Un set di provini, realizzati con gli stessi materiali e modalità produttive simili a quanto previsto per gli Scudi 127, è stato sottoposto a cicli di invecchiamento tramite immersione dei campioni in acqua di mare sintetica riscaldata a circa 60°C simulando l'intero span operativo previsto per i manufatti (30 anni). Al termine dell'invecchiamento i provini sono stati confrontati con campioni non invecchiati evidenziando solamente lievi variazioni estetiche escludendo la possibilità di alterazioni della performance strutturale dell'assieme. Si ritiene inoltre che lo Scudo 127 soddisfi il requisito in oggetto in quanto manufatti molti simili sono già stato prodotti per (ed utilizzati da) OTO Melara sin dalla metà degli anni '80, senza presentare alcun problema legato al suddetto requisito.	1) NCN-OSN-RPISD-114 Rev 0

<table>
<tr><td colspan="1"></td><td colspan="3">SISTEMA</td></tr>
<tr><td></td><td colspan="3">SCUDO MK 71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td>№ SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.4.2</td><td>8</td></tr>
<tr><td colspan="4">REQUISITO: MAINTANABILITY</td></tr>
<tr><td colspan="4">The shield shall be replaceable within 4 hours in the harbor with a crane and a specific lifting device by a team of 3 people (including the operator of the crane).

Each module of the shield shall be removable independently from the others.

The number and the mean elapsed time of the preventive maintenance activities shall be minimized.</td></tr>
<tr><td colspan="4">IPOTESI ASSUNTE</td></tr>
<tr><td colspan="4">Gli Scudi 127 saranno realizzati con un appropriato dimensionamento, mantenendo adeguate clearances ed utilizzando collegamenti facilmente smontabili.</td></tr>
<tr><td colspan="3">GIUSTIFICAZIONI ACQUISITE</td><td>DOC. DI RIF.</td></tr>
<tr><td colspan="3">La disposizione degli elementi interessati alle operazioni di manutenzione dell’apparato interno allo Scudo 127 è stata studiata in dettaglio con il Cliente in modo da permettere un’adeguata ed agevole accessibilità agli items che necessitano di interventi.
Tutti i dettagli sono disponibili nel disegno dello Scudo 127 e nel doc. d’analisi delle giunzioni.</td><td>1) NCN-127-SD-14 Shield Drawings Scudo 127
2) NCN-127-VEF-04 Verifica Elementi Filettati Scudo 127</td></tr>
</table>

	SISTEMA		
NUOVA CONNAVI s.r.l.	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.4.3	9

REQUISITO: TRANSPORTABILITY

One of the target of the breakdown proposed in par 3.1 for the shield is the optimization of the shield transportability. In fact, it is very important to minimize the number of exceptional transportations (desirable: no one).

Inserts shall be integrated in the upper part of the modules themselves in order to use eye *bolts during integration/disassembly/transportation phases. The so-inserted-parts of the* shield shall be properly reinforced.

The supplier shall specify the mass for each one of the modules, in order to let SDI select the eye bolts (**NOT** part of supply). The final measured mass of each module shall not exceed the value specified by the supplier of more than the 5%.

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati tenendo conto delle criticità relative alla movimentazione e trasportabilità degli stessi.

GIUSTIFICAZIONI ACQUISITE	**DOC. DI RIF.**
Nel Manuale Tecnico dello Scudo 127 e nei disegni dello stesso vengono evidenziati il posizionamento dei punti di sospendita e dei baricentri per la movimentazione delle parti dell'assieme. Non sarà richiesto l'utilizzo di attrezzature particolari per la movimentazione e trasporto delle parti dello Scudo 127.	1) NCN-127-TM-11 Technical Manual Scudo 127 2) NCN-127-SD-14 Shield Drawings Scudo 127

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.4.6	10

REQUISITO: TOOLS STANDARD

The transportation, installations tools and STTE *(Special To-Type Test Equipment)* shall comply with Directive Machinery 2006/42 CE (when applicable) and shall be delivered with proper operative and maintenance manuals.

IPOTESI ASSUNTE

Gli Scudi 127 saranno corredati di documentazione relativa alle attività di stoccaggio, movimentazione e manutenzione degli stessi.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
Il manuale tecnico contrattualmente previsto riporterà tutti i dettagli per la messa in servizio, il mantenimento in esercizio e le attività di manutenzione necessarie per l'Assieme Scudo 127.	1) NCN-127-TM-11

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.4.7	11

REQUISITO: HUMAN FACTOR

The shield shall comply with [Ref. 8].

IPOTESI ASSUNTE

Il design dello scudo sarà realizzato in accordo con la MIL-STD-1472G

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
Forme, geometrie e spazi interni sono rimasti inalterati rispetto alla versione in alluminio dello scudo. Si ritiene quindi che il design dello Scudo 127 in composito rispetti il requisito.	1) 1828-11-001.stp 2) GRT143_01

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.5.1	12

REQUISITO: SAFETY

The shield shall be capable of being exposed to fire or corrosive environment without representing hazards to personnel and to any parts of the gun mount and onboard equipment/environment. The Materials Safety Datasheet and the REACH certification shall be provided.

IPOTESI ASSUNTE

Gli Scudi 127 finiti non rappresenteranno un pericolo per la salute del personale e per l'arma contenuta al suo interno. I materiali prescelti per la produzione hanno eccellenti caratteristiche di ignifugicità e resistenza agli agenti chimici.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
Come richiesto contrattualmente NCN ha prodotto ed inviato le schede per i materiali impiegati nella produzione dello Scudo 127 che risultano in accordo con il requisito.	1) MSDS Materiali e catalogazione REACH inviata con Prot.040-17

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.5.3	13

REQUISITO: POISONOUS GASES, NORMAL OPERATION

The shield shall not contain materials that can emit poisonous gases or can be hazardous to touch under normal operation and storage.

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati con materiali inerti una volta finite le operazioni di produzione.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
Come richiesto contrattualmente NCN ha prodotto ed inviato le schede per i materiali impiegati nella produzione dello Scudo 127 che risultano in accordo con il requisito.	2) MSDS Materiali e catalogazione REACH inviata con Prot.040-17

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.5.4	14

REQUISITO: HEALTH HAZARD

The shield shall not contain materials representing health hazards during normal operation and storage.

IPOTESI ASSUNTE

Gli Scudi 127 saranno realizzati con materiali inerti una volta finite le operazioni di produzione.

GIUSTIFICAZIONI ACQUISITE	DOC. DI RIF.
Come richiesto contrattualmente, NCN ha prodotto ed inviato le schede per i materiali impiegati nella produzione dello Scudo 127 che risultano in accordo con il requisito.	1) MSDS Materiali e catalogazione REACH inviata con Prot.040-17

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.5.5	15

REQUISITO: NBC PROTECTION

The shield shall withstand the damaging effect of nuclear, biological and chemical contamination agents and of decontamination agents and relative procedures. The external surfaces of the shield shall be smooth to avoid stagnation of contamination agents. Most of contamination agents belong to the classes as by Table 6.

AGENTS		
Choking agents	PS	(Chloropicrin)
	CG	(Phosgene)
	DP	(Disphosgene)
Blood agents	AC	(Hydrogen Cyanide)
	CK	(Cyanogen Chloride)
Blister agents	H	(Hyperite)
	L	(Lewisite)
	HD	(Mustard)
	THD	(Thickened HD
	HL	(Mustard/Lewisite)
	THL	(Thickened HL)
Nerve agents	GA	(Tabun)
	TGA	(Thickened GA)
	GB	(Sarin)
	TGB	(Thickened GB)
	GD	(Soman)
	TGD	(Thickened GD)
	VX	
	TVX	(Thickened VX)

Table 6

NBC protection shall be granted at the following conditions

- a round has to be charged into the gun's barrel;
- cartridge evacuator hatch has to be closed;
- smoke evacuators turned off;
- internal overpressure up to 1085 mbar (absolute value).

IPOTESI ASSUNTE

Lo scudo verrà dimensionato ed allestito in modo a soddisfare il requisito NBC.

GIUSTIFICAZIONI ACQUISITE	**DOC. DI RIF.**
Come già definito dal requisito 4.1.10, tutti i portelli e le giunzioni dello scudo sono stati realizzati a tenuta. Inoltre, per quanto riguarda l'eventuale shock dovuto all'esplosione di una bomba atomica tattica, i carichi presi in considerazione per il dimensionamento dello scudo per i requisiti operativi sono di gran lunga più alti. Infine le geometrie e finiture definite dello scudo (pareti inclinate e finitura superficiale) evitano il possibile ristagno di agenti contaminanti.	1) 1828-11-001.stp

Dossier di qualifica

1. Scopo

Oggetto del presente documento è la stesura del Qualification Dossier relativo allo Scudo 127.
Per ogni requisito espresso nel doc. “Technical Requirement Specification of Composite Shield for 127/64 LW Vulcano Naval Gun System - S ST 1827 8369 Rev.05’ da soddisfare tramite **Test** od **Ispezione**, la presente relazione elenca, in apposite Schede Giustificative dedicate, la documentazione tecnica, certificati o statino di prova necessaria per verificare il rispetto del requisito.
Non appena saranno disponibili ulteriori risultati sulle prove in corso, il presente documento verrà riemesso in modo da raccogliere tutti i risultati.
Le giustificazioni riferite ai requisiti già soddisfatti tramite Dimostrazione od Analisi sono state riportate nel documento NCN-127-QP-07.

2. Schede Giustificative

Per ogni requisito o gruppo di requisiti del sottosistema, le Schede Giustificative mettono in evidenza i documenti tecnici relativi alla Fase di Progettazione ed alle Test/Ispezioni già effettuate oda effettuare. In questo modo, le Schede Giustificative consentono di valutare se, al momento attuale, i requisiti siano o meno soddisfatti.

Ciascuna Scheda riporta, in appositi campi, le seguenti informazioni:

- l’identificativo del sistema a cui si riferiscono i requisiti oggetto della Scheda Giustificativa;
- l’identificativo del componente a cui si riferiscono i requisiti oggetto della SchedaGiustificativa;
- la documentazione di riferimento in cui tali requisiti sono descritti;
- il numero identificativo dei requisiti stessi;
- la descrizione dei requisiti;
- la metodologia di controllo per la verifica dei requisiti;
- i riferimenti a documenti che dimostrino la corrispondenza tra i requisiti in esame ed ilProgetto;
- le conclusioni finali relative allo stato attuale della verifica dei requisiti.

4.1.1 SCHEDA N. 1: GEOMETRY

	SISTEMA
	SCUDO MK 71 MOD 2

COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.1	1

REQUISITO
Inspection will demonstrate that the shield's main dimensions are coherent to the project drawings.

METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**
In fase di stesura della Procedura di Collaudo dello Scudo 127 (PC-030) sono state identificate più di 50 quote per verificare la geometria generale del manufatto oltre che ad un controllo dello spessore del composito delle flange di accoppiamento.	NCN-127-SD-14 Shield Drawings Scudo 127 PC-030 Procedura di Collaudo Scudo 127

CONCLUSIONI
I controlli effettuati sul primo esemplare di Scudo 127 per la verifica della geometria dello scudo hanno dato esito positivo (vedi Allegato.01 PC-030 NCN 101 127 17 352 del 17/05/18). Tutte le misure verificate rientravano nelle tolleranze previste.

4.1.2 SCHEDA N. 2: JOINTS

<table>
<tr><td rowspan="2"></td><td colspan="3">SISTEMA</td></tr>
<tr><td colspan="3">SCUDO MK 71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td>№
SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.1.2</td><td>2</td></tr>
<tr><td colspan="4">REQUISITO</td></tr>
<tr><td colspan="4">Inspection will demonstrate that the joints used for the shield’s assembly are internal L-joins with 2 rows of misaligned bolts.</td></tr>
<tr><td colspan="2">METODOLOGIA DI CONTROLLO</td><td colspan="2">DOC. DI RIF.</td></tr>
<tr><td colspan="2">In fase di stesura della Procedura di Collaudo dello Scudo 127 (PC-030) è stato identificato un controllo da eseguire per verificare la conformazione della flangia oltre che alla presenza e corrispondenza della foratura</td><td colspan="2">NCN-127-SD-14 Shield Drawings Scudo 127

PC-030 Procedura di Collaudo Scudo 127</td></tr>
<tr><td colspan="4">CONCLUSIONI</td></tr>
</table>

Il controllo effettuato sul primo esemplare di Scudo 127 per la verifica della conformazione ad‘L’ delle flange dello scudo ha dato esito positivo (vedi Allegato.01 PC-030 NCN 101 127 17352 del 17/05/18).

In seguito alla consegna dello Scudo 127, è in corso al momento una verifica presso il Cliente la corretta corrispondenza delle forature fra i diversi moduli del manufatto.
In attesa di formalizzazione del Collaudo.

4.1.3 SCHEDA N. 3: MASS

<table>
<tr><td rowspan="2">NUOVA CONNAVI s.r.l.</td><td colspan="3">SISTEMA</td></tr>
<tr><td colspan="3">SCUDO MK 71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td>№ SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.1.3</td><td>3</td></tr>
<tr><td colspan="4">REQUISITO</td></tr>
<tr><td colspan="4">Test will demonstrate that the measured mass of the shield does not exceeds 1600 kg.</td></tr>
</table>

<table>
<tr><td>METODOLOGIA DI CONTROLLO</td><td>DOC. DI RIF.</td></tr>
<tr><td>In fase di stesura della Procedura di Collaudo dello Scudo 127 (PC-030) è stato identificato un controllo da eseguire per verificare il peso dello Scudo 127 mediante pesatura.</td><td>NCN-127-TS-06 Technical Specification Scudo 127

PC-030 Procedura di Collaudo Scudo 127</td></tr>
<tr><td colspan="2">CONCLUSIONI</td></tr>
<tr><td colspan="2">Il controllo effettuato in data 08/11/18 ha riportato esito positivo (1570 kg).
In attesa di formalizzazione del collaudo.</td></tr>
</table>

4.1.6 SCHEDA N. 4: SHIELDING

NUOVA CONNAVI s.r.l.	**SISTEMA**		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.6	4

REQUISITO
Test will demonstrate that the whole surface of the shield guarantees a minimum shielding effectiveness of 40dB in the frequency range 2 MHz ÷ 18 GHz

METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**
Per verificare il soddisfacimento del presente requisito sono state realizzate due pannellature tipiche della laminazione dello scudo che sono testate in accordo a IEEE-299-2006 verificando che i valori di schermatura ottenuti raggiungano quanto indicato.	IEEE-299-2006 Certificato GSD N° xxx del xx/xx/18 Certificato GSD N°18180 del 11/04/18 PC-030 Procedura di Collaudo Scudo 127

CONCLUSIONI
Le prove eseguite hanno riportato esito positivo come da certificati indicati. I valori rilevati hanno raggiunto i target previsti.

4.1.7 SCHEDA N. 5: ELECTRICAL RESISTANCE

<table>
<tr><td rowspan="2">NUOVA CONNAVI s.r.l.</td><td colspan="3">SISTEMA</td></tr>
<tr><td colspan="3">SCUDO MK
71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td>№
SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.1.7</td><td>5</td></tr>
<tr><td colspan="4">REQUISITO</td></tr>
<tr><td colspan="4">Test will demonstrate that the electrical resistance of the conductive layer of the shield is less than 0.1 Ohm.</td></tr>
<tr><td colspan="2">METODOLOGIA DI CONTROLLO</td><td colspan="2">DOC. DI RIF.</td></tr>
<tr><td colspan="2">È stata predisposta la verifica del requisito controllando con multimetro digitale l’effettivo valore di conduttività rilevata fra le varie parti dello scudo</td><td colspan="2">PC-030 Procedura di Collaudo Scudo 127</td></tr>
<tr><td colspan="4">CONCLUSIONI</td></tr>
<tr><td colspan="4">In seguito alla consegna dello Scudo MK 71 MOD 2, è in corso al momento la verifica presso il Cliente.In attesa di formalizzazione del presente Collaudo.</td></tr>
</table>

4.1.10 SCHEDA N. 6: DEGREE ON ENCLOSURE

NUOVA CONNAVI s.r.l.	**SISTEMA**		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.1.10	6
REQUISITO			
Test will demonstrate that the shield is dust-tight, able to withstand temporary immersion in water in accordance with international standard IEC 60529, protection class IP67.			
METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**		
Vista la severità più elevata del requisito 'RAIN' (4.3.6), lo Scudo 127 verrà testato un'unica volta con accettazione di entrambi i requisiti.	PC-030 Procedura di Collaudo Scudo 127		
CONCLUSIONI			
Vedi Scheda # 9 – 4.3.6			

4.3.1 SCHEDA N. 7: TEMPERATURE

NUOVA CONNAVI s.r.l.	**SISTEMA**		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.3.1	7
REQUISITO			
Test will demonstrate that the shield can operate in the and survive without compromising it's functionality and integrity in the temperature range of -40°C ÷ 75°C.			
METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**		
	PC-030 Procedura di Collaudo Scudo		

Per verificare il soddisfacimento del presente requisito è stata realizzata una pannellature tipica della laminazione dello scudo che è testata in accordo al ciclo di trattamento termico espresso nella Procedura diCollaudo verificando il campione al termine della prova non presenti difettologie che eccedano il Livello III di ASTM-D2563-08.	127 ASTM-D2563-08 Certificato Leonardo SDI. 17-1828-R082 del 21/12/17

CONCLUSIONI

Come da certificato Leonardo SDI 17-1828-R082 del 21/12/17 i campioni testati non hanno evidenziato modifiche sostanziali al termine del ciclo cui sono stati sottoposti.
Non si sono manifestate difettologie che eccedano il Livello III di ASTM-D2563-08. Si ritiene quindi lo scudo rispondente al presente requisito.

4.3.3 SCHEDA N. 8: SALT FOG

<table>
<tr><td rowspan="2"></td><td colspan="3">SISTEMA</td></tr>
<tr><td colspan="3">SCUDO MK
71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td>№
SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.3.3</td><td>8</td></tr>
<tr><td colspan="4">REQUISITO</td></tr>
<tr><td colspan="4">Test will demonstrate that according to MIL-STD-810G. and AECTP 300, the shield survives an environment with a salt fog concentration of 5% with the salt solution atomized in the test chamber with at a temperature of 35° for a period of 24 hours with the shield dried at standard temperature and a RH of 50% or less. The procedure can be repeated at least twice with an overall salt fog trial with a duration of at least 96 hours.</td></tr>
<tr><td colspan="2">METODOLOGIA DI CONTROLLO</td><td colspan="2">DOC. DI RIF.</td></tr>
<tr><td colspan="2">Per verificare il soddisfacimento del presente requisito è stata realizzata una pannellatura tipica della laminazione dello scudo che è testata in accordo al ciclo di trattamento previsto dal requisito nella Procedura di Collaudo verificando che il campione al termine della prova non presenti difettologie che eccedano il Livello III di ASTM-D2563-08 .</td><td colspan="2">PC-030 Procedura di Collaudo Scudo 127

ASTM-D2563-08

Certificato Leonardo SDI. 17-5523-R096 del 07/12/17</td></tr>
<tr><td colspan="4">CONCLUSIONI</td></tr>
<tr><td colspan="4">Come da certificato Leonardo SDI 17-5523-R096 del 07/12/17 i campioni testati non hanno evidenziato modifiche sostanziali al termine del ciclo cui sono stati sottoposti.
Non si sono manifestate difettologie che eccedano il Livello III di ASTM-D2563-08. Si ritiene quindi lo scudo rispondente al presente requisito.</td></tr>
</table>

4.3.4 SCHEDA N. 9: FUNGUS

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">SISTEMA</td></tr>
<tr><td colspan="3">SCUDO MK
71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td colspan="2">№ SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.3.4</td><td colspan="2">9</td></tr>
<tr><td colspan="5">REQUISITO</td></tr>
<tr><td colspan="5">The shield shall comply with fungus requirement, in accordance with [Ref. 1].</td></tr>
<tr><td colspan="3">METODOLOGIA DI CONTROLLO</td><td colspan="2">DOC. DI RIF.</td></tr>
<tr><td colspan="3">N/A. (Vedi NCN-127-QP-07)</td><td colspan="2">N/A</td></tr>
<tr><td colspan="5">CONCLUSIONI</td></tr>
</table>

NCN ha recentemente (anno 2013) svolto una campagna di caratterizzazione del materiale impiegato per la produzione degli Scudi MK 71 MOD 2 (E-Preg QE) testando un set di 60 provini, realizzati con le stesse modalità produttive impiegate per gli Scudi, sottoponendoli ad un ciclo di invecchiamento tramite immersione dei campioni in acqua di mare.
A fronte di un invecchiamento simulato di 30 anni, coprendo quindi l'intero span operativo previsto per i manufatti, i test svolti hanno dimostrato la piena compatibilità dei manufatti con la richiesta in oggetto.
In particolare, è stato provato che l'impiego di resine epossidiche sfavorisce la formazione di funghi e non contiene sostanze che alimentano la crescita di funghi.
I controlli effettuati non hanno manifestato accrescimenti di microrganismi o fenomeni di osmosi.

Con l'utilizzo degli gli stessi materiali e tecnologie, Nuova Connavi ha costruito con questo materiale più di 300 che sono entrati in servizio a partire dal 1981 che mai hanno manifestato problematiche riconducibili al requisito in oggetto. Quanto sopra riportato, equivale, per Nuova Connavi ad una qualifica sul campo.

Si ricorda inoltre che i materiali impiegati per la produzione degli Scudi MK 71 MOD 2 sono stati definiti darequisiti presenti a specifica (fibra di vetro preimpregnata con resina epossidica) e che gli stessi sono ulteriormente protetti da un ciclo di pitturazione come da specifiche Cliente, realizzato con prodotti qualificati da MMI (vernice Sinco Mec Kolor Enamel Biurethane, come da NAV-00- 00B000).

Per mitigare ulteriormente la possibile crescita di microrganismi è già stato previsto un piano di manutenzione (riportato all'interno del doc. NCN-127-MPR-15) che prevede annualmente la pulizia delle superfici interne ed esterne dello scudo.

4.3.6 SCHEDA N. 10: RAIN

	SISTEMA
	SCUDO MK 71 MOD 2

COMPONENTE	DOC. DI RIF.	№ PAR.	№ SCHEDA
Scudo MK 71 MOD 2	S ST 1827 8369	4.3.6	10

REQUISITO

Test will demonstrate that the shield when installed can withstand a water jet pressure of 6 bar with a diameter of 12 mm, from 3 m distance and a duration of 15 min, with no infiltrations inside the shield.

METODOLOGIA DI CONTROLLO	DOC. DI RIF.
Per verificare il soddisfacimento del presente requisito è stato predisposto un controllo della tenuta stagna delle interfacce scudo/portelli e delle interfacce fra i vari moduli dello scudo sottoponendole ad un getto d'acqua come da requisito.	PC-030 Procedura di Collaudo Scudo 127

CONCLUSIONI

La tenuta dell'interfaccia fra scudo e portelli è stata verificata con successo in data 03-09-18 (vedi Allegato.01 PC-030 NCN 101 127 17 352).

Come da accordi intercorsi con il Cliente, la tenuta fra i vari moduli dello scudo verrà verificata dopo la consegna con lo scudo montato sull'affusto.

4.3.7 SCHEDA N. 11: SOLAR RADIATION

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.3.7	11

REQUISITO
Test will demonstrate that the shield can withstand a solar radiation of 1120 W/m2 without compromising its integrity.

METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**
Per verificare il soddisfacimento del presente requisito sono stati approntati due test verificando la rispondenza sia su campioni tipici che sugli Scudo MK 71 MOD 2 proveniente dalla produzione. Per il controllo su pannellature è stato svolto un test secondo quanto riportato al capitolo 505 della MIL-STD 810G, Procedura 2 (Steady State Test). Per il controllo sullo scudo è stato svolto un test lampade secondo quanto previsto dalla Procedura di Collaudo. Per entrambe le tipologie di controllo verrà verificato che il campione al termine delle prove non presenti difettologie che eccedano il Livello III di ASTM-D2563-08.	PC-030 Procedura di Collaudo Scudo 127 Verbale Test Lampade 05/07/18 Certificato CTS 295318 del 30.11.18

CONCLUSIONI
Controllo effettuato sullo Scudo MK 71 MOD 2 con successo (vedi Allegato.01 PC-030 NCN 101127 17 352). Non si sono manifestate difettologie che eccedano il Livello III di ASTM-D2563-08. Si ritiene quindi lo scudo rispondente al presente requisito. Controllo effettuato sulla pannellatura tipica dello Scudo MK 71 MOD 2 (NCN-PA127-001/002 Rev.1) consuccesso (vedi Certificato CTS 295318 del 30.11.18). Non si sono manifestate difettologie che eccedano il Livello III di ASTM-D2563-08. Si ritiene quindi lo scudo rispondente al presente requisito.

4.3.8 SCHEDA N. 12: HUMIDITY

	SISTEMA		
NUOVA CONNAVI s.r.l.	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.3.8	12

REQUISITO
Test will demonstrate that the shield can withstand an humidity cycle as reported in MIL-STD-810G.

METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**
Per verificare il soddisfacimento del presente requisito è stata realizzata una pannellatura tipica della laminazione dello scudo che è testata in accordo al ciclo di trattamento previsto dal requisito nella Procedura di Collaudo verificando che il campione al termine della prova non presenti difettologie che eccedano il Livello III di ASTM-D2563-08.	PC-030 Procedura di Collaudo Scudo 127 ASTM-D2563-08 Certificato Leonardo SDI 17-1828-R084 del 10/01/18

CONCLUSIONI
Come da certificato Leonardo SDI 17-1828-R084 del 10-01-18 i campioni testati non hanno evidenziato modifiche sostanziali al termine del ciclo cui sono stati sottoposti. Non si sono manifestate difettologie che eccedano il Livello III di ASTM-D2563-08. Si ritiene quindi lo scudo rispondente al presente requisito.

4.4.4 SCHEDA N. 13: INTERNAL REINFORCES

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.4.4	13

REQUISITO
Test will demonstrate that on the internal surface of shield proper interfaces are implemented for the handling of heavy items (≤ 150 kg).

METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**
La rispondenza dello Scudo 127 al requisito contrattuale verrà testata sui punti di sospendita interni assicurando una zavorra di circa 150 kg. La prova avrà esito positivo se, dopo esposizione a tale ciclo, sulla superficie dei campioni tipici e dello Scudo 127 non saranno visibili difetti (es. inclusioni d'aria, cricche…) di entità superiore 'Livello III' dettagliato nell'ASTM-D2563-08.	PC-030 Procedura di Collaudo Scudo 127

CONCLUSIONI
Come da accordi intercorsi con il Cliente il presente requisito verrà verificato dopo la consegna con scudo assiemato. In attesa di formalizzazione del collaudo.

4.4.5 SCHEDA N. 14: SPARES AND TOOL LIST

	SISTEMA		
	SCUDO MK 71 MOD 2		
COMPONENTE	**DOC. DI RIF.**	**№ PAR.**	**№ SCHEDA**
Scudo MK 71 MOD 2	S ST 1827 8369	4.4.5	14

REQUISITO
Inspection will demonstrate that it will be possible to replace the shield at module level.

METODOLOGIA DI CONTROLLO	**DOC. DI RIF.**
Verifica non ritenuta necessarie considerata la nuova geometria dello Scudo MK 71 MOD 2.	N/A

CONCLUSIONI
N/A

4.5.2 SCHEDA N. 15: FLAMMABLE MATERIAL

<table>
<tr><td rowspan="2"></td><td colspan="3">SISTEMA</td></tr>
<tr><td colspan="3">SCUDO MK 71 MOD 2</td></tr>
<tr><td>COMPONENTE</td><td>DOC. DI RIF.</td><td>№ PAR.</td><td>№ SCHEDA</td></tr>
<tr><td>Scudo MK 71
MOD 2</td><td>S ST 1827 8369</td><td>4.5.2</td><td>15</td></tr>
<tr><td colspan="4">REQUISITO</td></tr>
<tr><td colspan="4">Test will demonstrate that it is impossible to ignite the shield when exposed to sparks or heat).</td></tr>
</table>

<table>
<tr><td>METODOLOGIA DI CONTROLLO</td><td>DOC. DI RIF.</td></tr>
<tr><td>Vista la severità più elevata del requisito ‘Solar Radiation’ espresso al § 4.3.7 della Specifica tecnica, lo Scudo MK 71 MOD 2 verrà testato un’unica volta con accettazione per entrambi i requisiti con il test previsto dalla Scheda 11 del presente documento.

Il materiale impiegato per la produzione dello Scudo 127 è stato testato in passato per la resistenza alla fiamma diretta con ottimi risultati ed emissione di certificato da parte del laboratorio CTS.</td><td>N/A</td></tr>
<tr><td colspan="2">CONCLUSIONI</td></tr>
<tr><td colspan="2">Vedi test Scheda §11.</td></tr>
</table>

Humidity Leonardo

DATI IDENTIFICATIVI ATTIVITA				*Attività N°*	*46/2017*
Programma	MK 71 MOD 2	Prodotto		Sistema SCUDO MK 71 MOD 2	
				Unità /Assieme Porzione di scudo	
Oggetto dell'Attività	Cicli di Umidità			Eseguita: 31/10/2017	Presso: LPA La Spezia
	Richiedente	Qualità Pigoni Pierpaolo			

Identificazione Apparato/Elementi				
Rif.	UUT	Part Number	S/N	Identificazione
UUT[1]	Scudo composito 1	182811001	003	NCN 127LW
UUT[2]	Scudo composito 2	182811001	004	NCN 127LW

Verificata Targhetta - ☑ NO ☐ SI | Certificato PCA - ☑ NO ☐ SI | Rilasciato PDM - ☑ NO ☐ SI | Dis. Ingegneria - ☑ NO ☐ SI

Verificabilità ☑ NO ☐ SI	Note: due piastre - scudo composito

Documenti di riferimento			
Rif.	Tipo	Numero	Titolo
Doc[1]	Modulo richiesta attività	46/2017	
Doc[2]	Allegato Doc[1]		46_Allegato Scudo127 PPA CONNAVI

Elenco TEST								
Rif.	Descrizione	Standard di Riferimento	RISULTATO					Pag.
			Rif./UUT	*POSITIVO*	*NEGATIVO*	*CUSTOMER*	*ALTRO*	
Test[1]	Umidità	Altro	UUT[1] UUT[2]	☐	☐	☑	☑ (note[1])	3

Note Attività

[1] Al termine dei cicli, ad un esame visivo non risultano alterazioni delle UUT.

[2] In accordo con il richiedente, non è possibile rilasciare la "Valutazione finale dei Test" in quanto non è stata rilasciata la documentazione minima per identificare in maniera univoca l'oggetto, inoltre non è stato fornito un documento per la valutazione degli elementi al termine della prova.

- Posizionato in camera insieme a culla tm197b con piastrine

Test[1] – Umidità

Informazioni Generali

Standard	Metodo	Doc. di Rif	§	Data Inizio prova	Data fine prove	Operatore
Test[1]	Richiesta Ingegneria	Fda 46/2017	--	31/10/2017	10/11/2017	M.Fiorelli

Condizioni Ambientali

Temperatura	Umidità	Pressione	Environment	--	--
22°C	N.R.	1024 mb	Laboratorio	--	--

Test Equipment

Rif. LPA	Codice	Modello- Tipo	Data Prossima Calibrazione
50 01	H01111245	Acquisitore Graphtec GL900	02/2018
53 00	C45320	Camera Climatica Angelantoni ANYVIB 2200 – 5	11/2018
		Termocoppia K	

Valori del Profilo Test

La camera climatica è stata impostata per eseguire 10 volte ogni ciclo di 24 ore riportato in Figura 1 e in Tabella 1 come secondo ilmetodo 507.5, Procedura II, par 4.4.2.2 della normativa MIL-STD-810G.

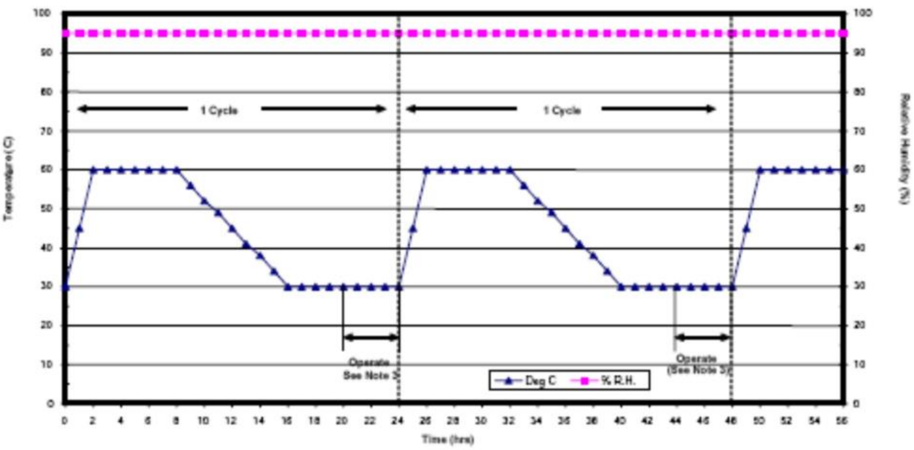


Fig. 1 – Profilo di prova 810G – met.507.5

Setup e Configurazione

Fig. 2 –EUT in camera, sensore di temperatura applicato

Grafici misura

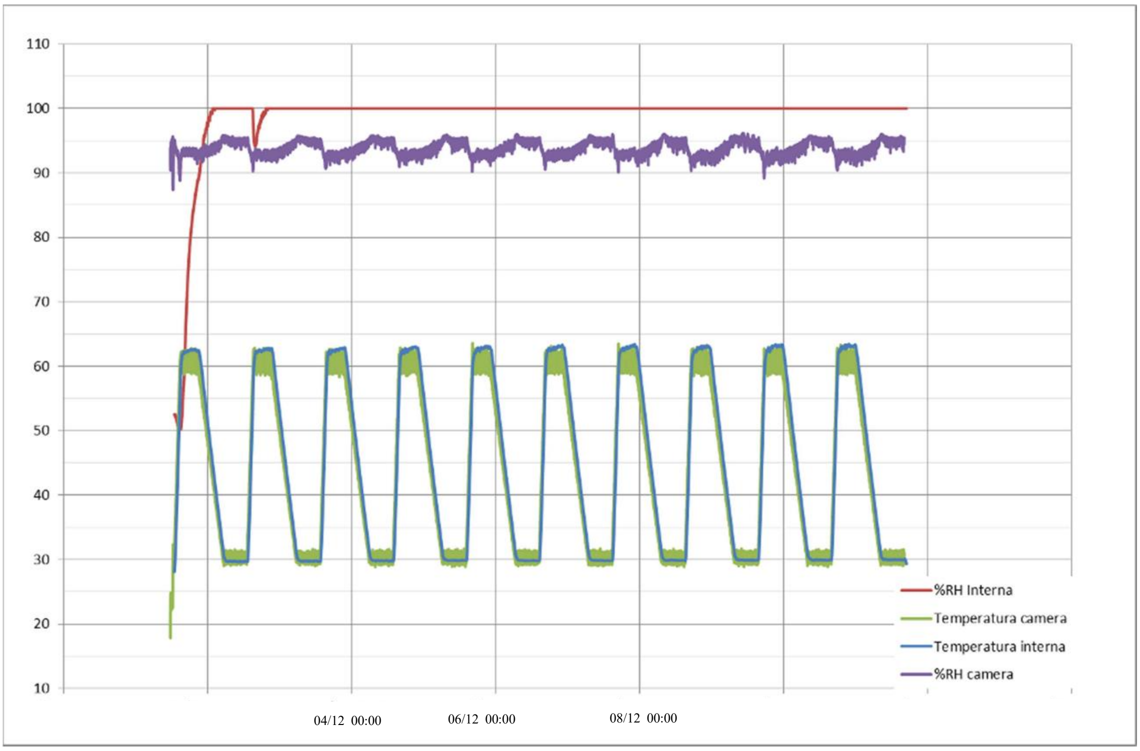


Fig. 3 – Registrazioni cicli Temperatura / Umidità

Foto UUT dopo test

Fig. 3 – EUT a fine prova

Fig. 4 – EUT a fine prova

Salt fog

DATI IDENTIFICATIVI ATTIVITA				*Attività N°*	*154/2017*
Programma	Legge Navale PPA	Prodotto		Sistema 127LW	
				Unità /Assieme PORZIONE DI SCUDO NCN 127LW 003 PORZIONE DI SCUDO NCN 127LW 004	
Oggetto dell'Attività	Salt Fog			Eseguita: dal 17/11/2017al 21/11/2017	Presso: LPA Livorno
	Richiedente	*Qualità*	Pigoni Pierpaolo		

Identificazione Apparato/Elementi				
Rif.	UUT	Part Number	S/N	Identificazione
UUT[1]	PORZIONE DI SCUDO	NCN 127LW 003	--	--
UUT[2]	PORZIONE DI SCUDO	NCN 127LW 004	--	--
Verificata Targhetta - ☑ NO ☐ SI	Certificato PCA - ☑ NO ☐ SI	Rilasciato PDM - ☑ NO ☐ SI	Dis. Ingegneria - ☐ NO ☑ SI	
Verificabilità ☑ NO ☐ SI	Note: Il disegno non rilasciato non permette la verificabilità formale dei campioni sotto test			

Documenti di riferimento			
Rif.	Tipo	Numero	Titolo
Doc[1]	Modulo Richiesta Attività	152/2017	---

Elenco TEST								
Rif.	Descrizione	Standard di Riferimento	RISULTATO					Pag.
			Rif./UUT	*POSITIVO*	*NEGATIVO*	*CUSTOMER*	*ALTRO*	
Test[1]	Salt Fog	MIL-STD-810G CHG1	UUT[1] UUT[2]	☑	☐	☐	☑ (note[1])	3

Note Attività
[1] Al termine della prova, ad un esame visivo, non risultano alterazioni delle UUT.

Valutazione finale dei Test	☐ *POSITIVO*	☐ *NEGATIVO*	☑ *Valutazione richiedente*

Compilatore	Massimo Bacci	Stato del Documento	☐ *Bozza* ☑ *Rilasciato*

Test[1] – Salt Fog

Informazioni
generali

Standard	Metodo	Doc. di Rif	§	Data Inizio prova	Data fine prove	Operatore
Test[1]	509.6	Doc[1]	--	17/11/2017	21/11/2017	Massimo Bacci

Condizioni Ambientali

Temperatura	Umidità	Pressione	Environment	--	--
22 °C	N.R.	1024 mbar	Laboratorio	--	--

Test Equipment

Rif. LPA	Codice	Modello- Tipo	Data Prossima Calibrazione
--	--	Camera per nebbia salina Angelantoni CNS 2000	07/2018

Fixture e Attrezzature

Rif.	N° di disegno	Titolo	Descrizione	sn
--	--	--	--	--

Valori dei Profili del

TestProva di Salt Fog

- ✓ Temperatura camera: +35 °C;
- ✓ Concentrazione di NaCl della soluzione salina: 5 %;
- ✓ Velocità di condensazione della soluzione salina: 1 ml / ora / 80 cm^2;
- ✓ Durata: 96 ore.

Setup

Le UUT[1] e UUT[2] sono state liberamente inserite all'interno della camera per nebbia salina.

Foto 1: le UUT all'interno della camera per nebbia salina

UUT prima della prova

Foto 2 e 3: le UUT prima della prova

UUT dopo la prova

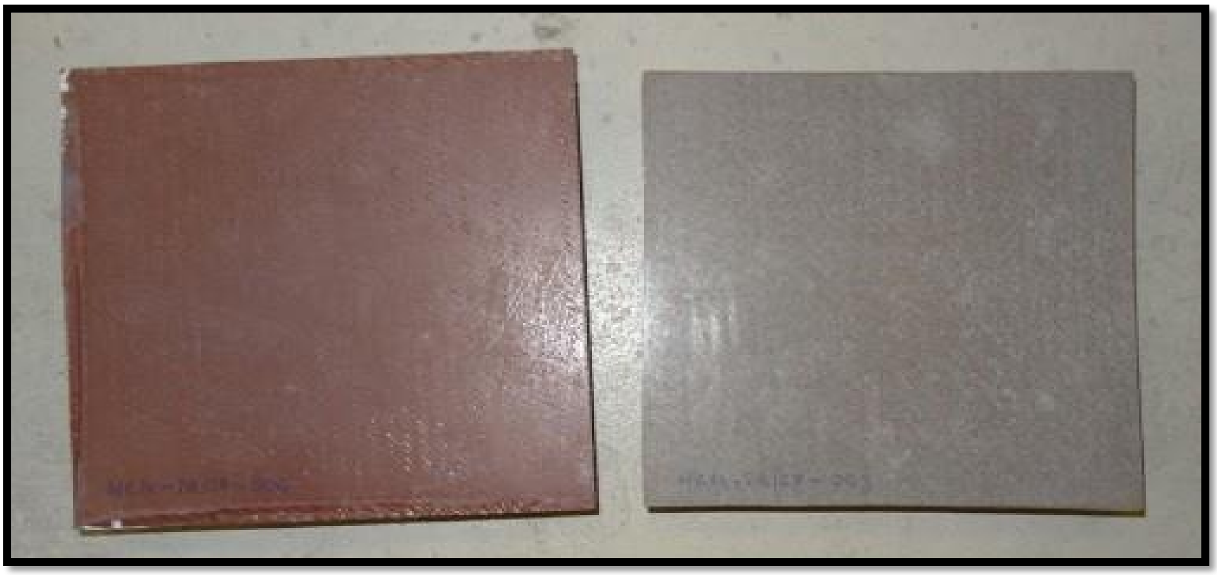


Foto 4: le UUT dopo la prova

Shielding

Laboratories	**ELECTROMAGNETIC COMPATIBILITY**	**G.S.D. S.r.l.** Certified in accordance with **UNI EN ISO 9001:2008** by **TÜV Rheinland Italia S.r.l.** **Certificate N. 39 00 1850509**
G.S.D. Srl **PISA - Italy**	***Test Report n. 18180***	Rev. 01
Manufacturer:	**NUOVA CONNAVI S.r.l.**	
	Via Lagoscuro, 107/109	
	19020 Ceparana di Vezzano Ligure (SP)	
	Italy	
EUT:	**NCN-PA127-001/002 Rev.1**	

2 Applicable Documents

The following documents are applicable and governed the preparation of the tests performed:

Standards:

Ref.	Standard / Document	Title
1.	**EN 61587-1**	Electromagnetic shielding performance tests for cabinets and subracks
2.	**CEI EN 50147-1**	Shield Attenuation Measurement
3.	**IEEE STD 299**	IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures

Acronyms:

EMC	Electro Magnetic Compatibility
EUT	Equipment Under Test
CE	Conducted Emissions
CS	Conducted Susceptibility
RS	Radiated Susceptibility

Technical personnel present during tests:

Dr. Gian Luca Genovesi G.S.D. S.r.l.

3 Conditions, Test Site, EUT Description and Tests Resume

Environmental Conditions

Temperature = (293 ± 4) K

Relative humidity = (50 ± 5) %

Test Site: Tests were performed in: G.S.D. S.r.l.

4 Shielding Effectiveness

Test Method

Measurements were performed accordingly to Ref [3].

- Acquisition of the reference value using a distance between the antennas equal to that indicated in the test bench configuration applicable (variable with frequency).
- Acquisition of the relative value of the shield using the test bench configuration applicable (variable with frequency). The measure must be carried out at panel.
- Compute attenuation level at specific frequency as difference between the value obtained in point 1 above and the value obtained in step 2 above.
- Measurements performed in the 2MHz-18GHz Frequency Range

Test Measurements:

Tests were performed on panel:

- Cut Panel

Test Equipment

Equipment Designation	*Manufacturer*	*Model, Type*	*Next Calibration*
Loop Antenna	AH System	SAS-200/551	01/2019
Loop Antenna	Singer	3301B	01/2019
Biconical Antenna	AARONIA	60700	01/2019
Biconical Antenna	AARONIA	60700	01/2019
Horn Antenna	ETS	3115	01/2019
Horn Antenna	ETS	3115	01/2019
RF Generator	Marconi	M2031	01/2019
RF Generator	HP	83620A	01/2019
Spectrum Analyzer	HP	8593E	01/2019

Test Method

Test method was in accordance with reference *Ref. [3]*.

Date Of Test	Test Location
2018 March 09-10	G.S.D. S.r.L.

Tables

The following figures show attenuation measurement

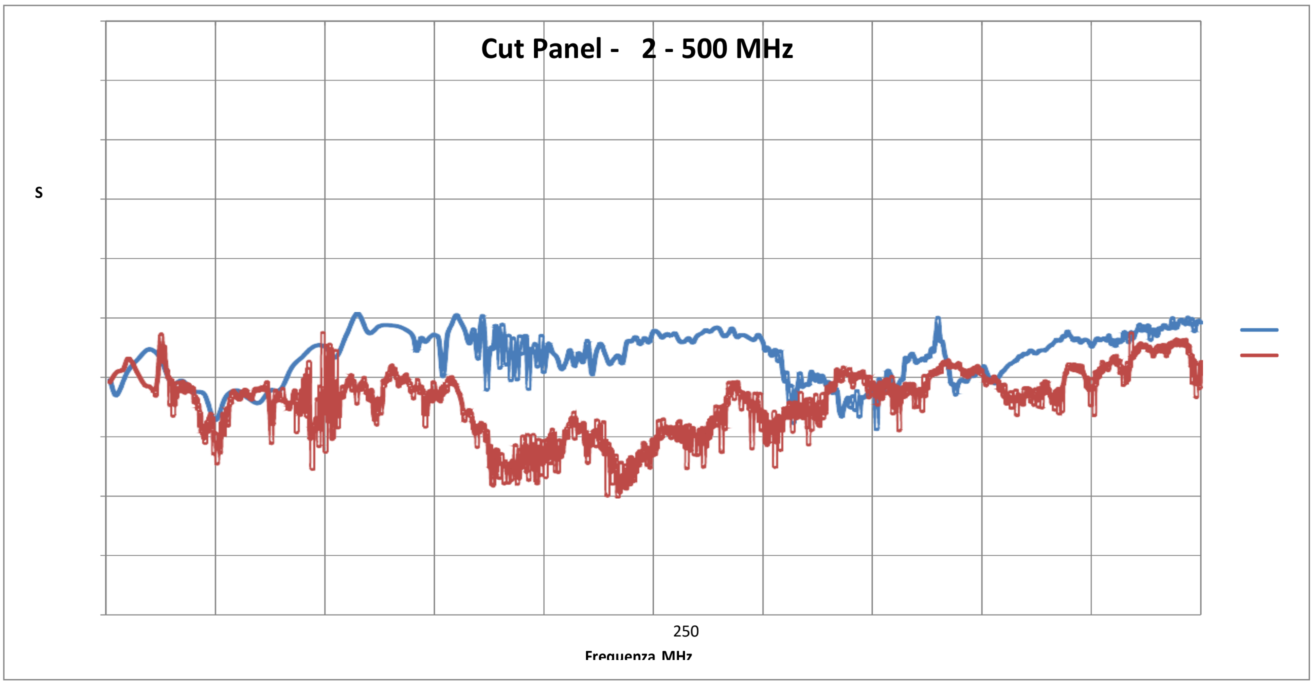

Cut Panel - 2 - 500 MHz
s
250
Frequenza MHz

Fig. 4.1

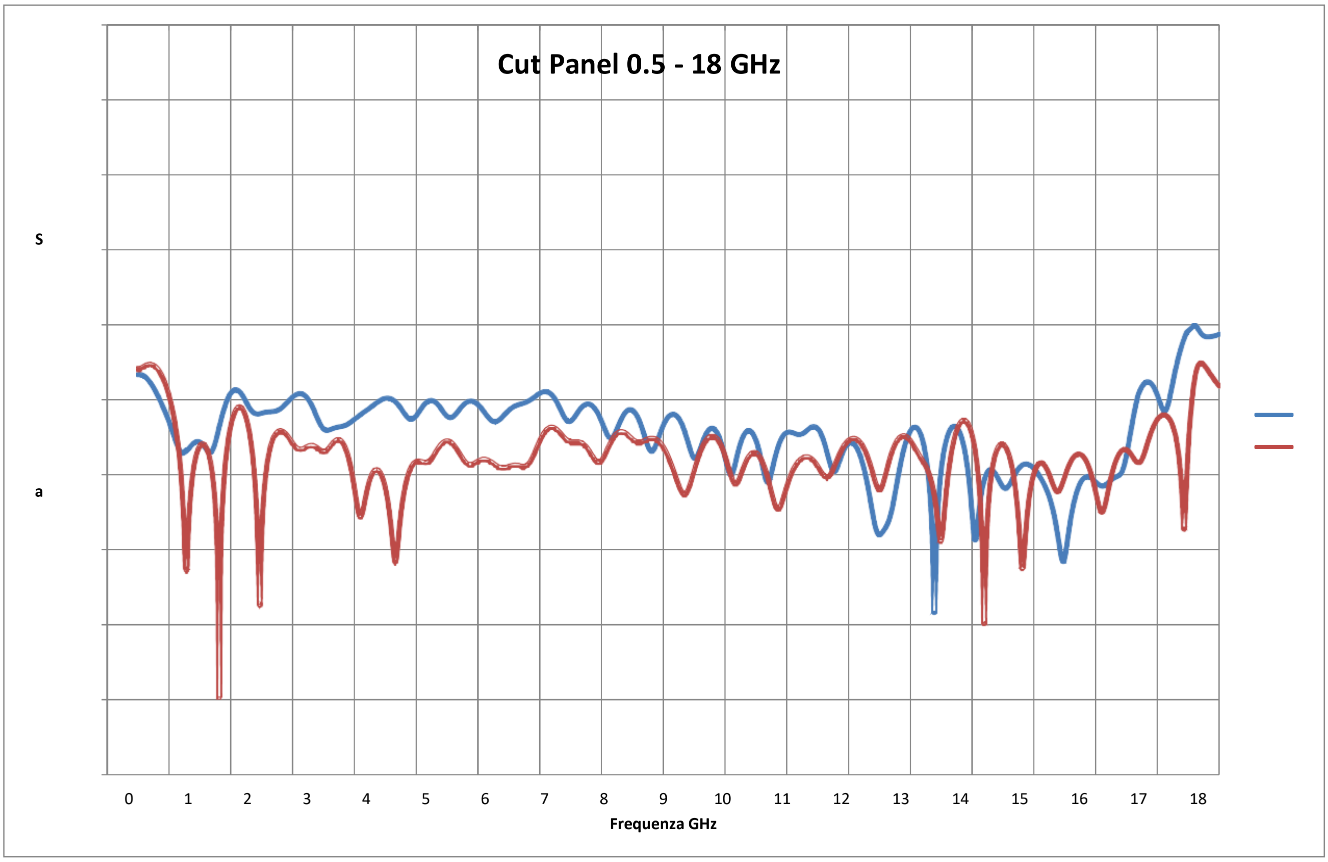

Cut Panel 0.5 - 18 GHz
s
a
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Frequenza GHz

Fig. 4.2

<table>
<tr><td colspan="2">Test Photos</td></tr>
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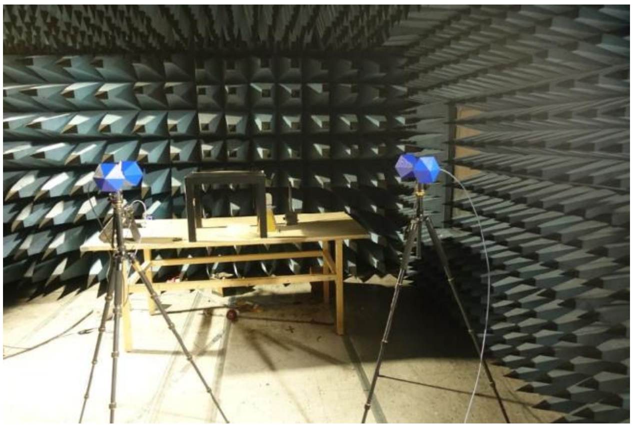
<tr><td></td><td></td></tr>
<tr><td></td><td>Intentionally blank</td></tr>
<tr><td colspan="2">Fig. 4.3 - Calibration</td></tr>
<tr><td colspan="2"></td></tr>
</table>

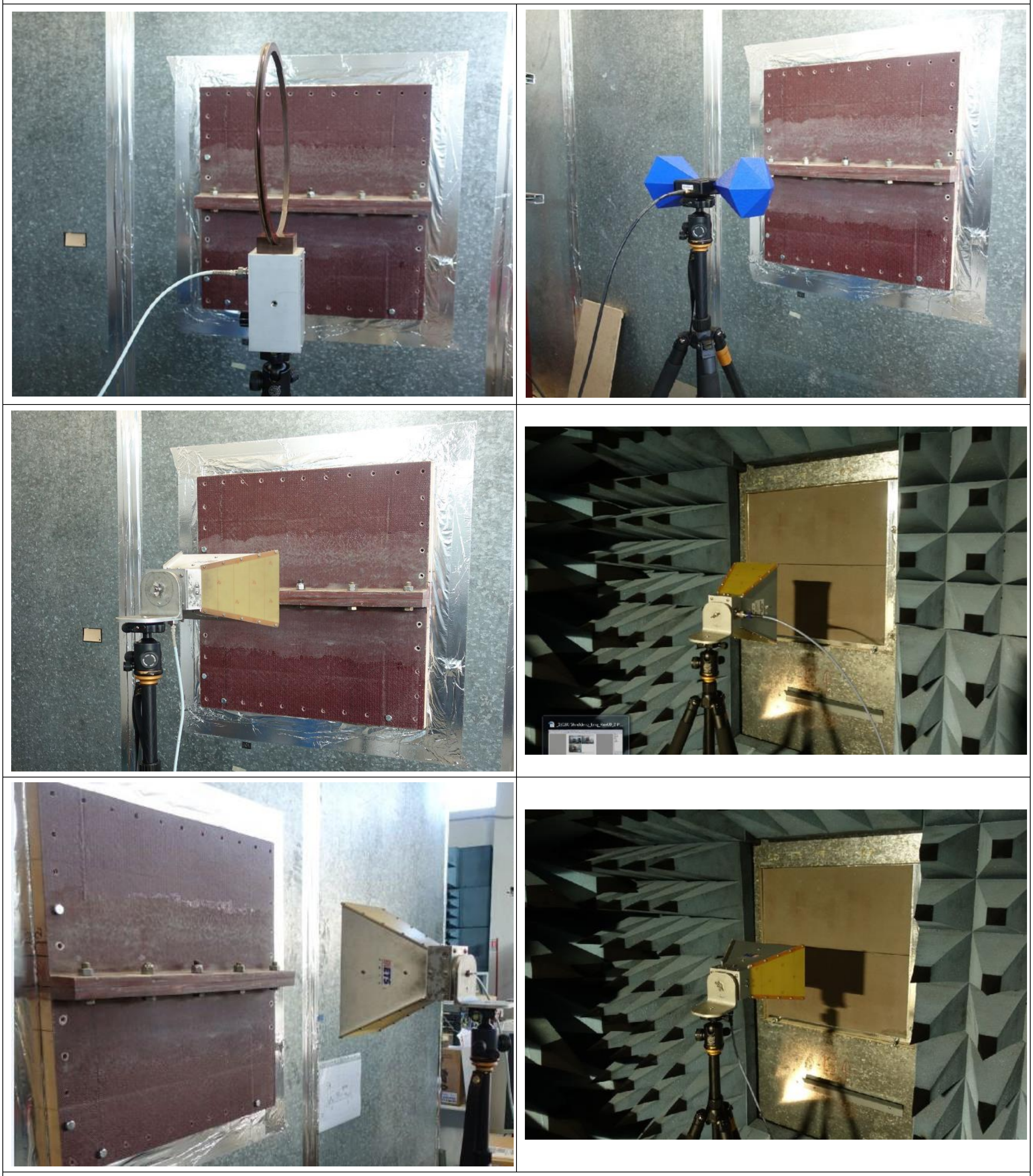


Fig. 4.4 – Cut Panel test setup

Temperature

DATI IDENTIFICATIVI ATTIVITA				*Attività N°*	*38/2017*
Programma	127 LW	Prodotto		Sistema Scudo	
				Unità /Assieme Porzioni di scudo	
Oggetto dell'Attività	Test industriali di alta e bassa temperatura di stoccaggio			Eseguita: dal 14/10/2017 al 25/10/2017	Presso: LPA La Spezia
	Richiedente	*Qualità* Rolli Massimo			

Identificazione Apparato/Elementi				
Rif.	UU T	Part Number	S/N	Identificazione
UUT[1]	Porzione di scudo	NCN 127LW 003		
UUT[2]	Porzione di scudo	NCN 127LW 004		
Verificata Targhetta - ☑ NO ☐ SI	Certificato PCA - ☑ NO ☐ SI	Rilasciato PDM - ☑ NO ☐ SI	Dis. Ingegneria - ☑ NO ☐ SI	
Verificabilità ☑ NO ☐ SI	Note: Il disegno non rilasciato non permette la verificabilità formale dei campioni sotto test			

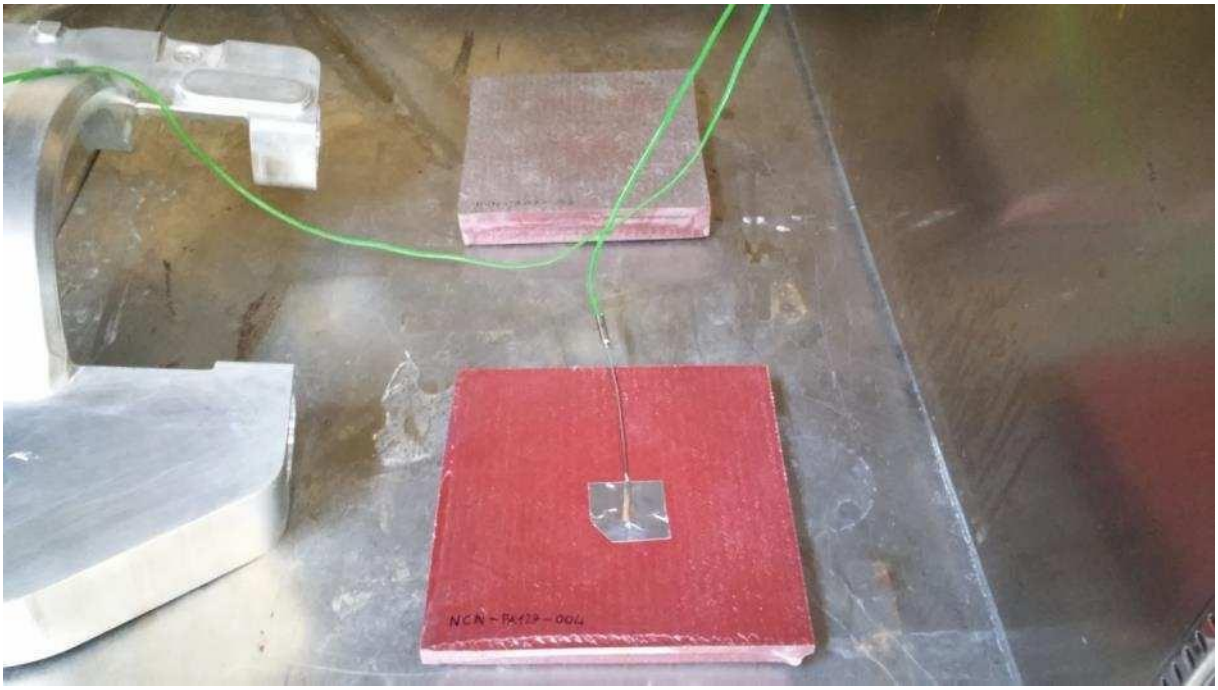
Documenti di riferimento			
Rif.	Tipo	Num ero	Titolo
Doc[1]	Modulo richiesta attività	46/2 017	
Doc[2]	Allegato Doc[1]		46_Allegato Scudo127 PPA CONNAVI

Elenco TEST								
Rif.	Descrizione	Standard di Riferimento	RISULTA TO					Pag.
			Rif./UU T	*POSITIV O*	*NEGATIV O*	*CUSTOME R*	*A L T R O*	
Test[1]	Cicli di Bassa Temperatura Storage	MIL-STD- 810G Meth. 502.6	UUT1÷2	☑	☐	☐	☑ (n o t e 1)	4
Test[2]	Cicli di Alta Temperatura Storage	MIL-STD- 810G Meth. 501.6	UUT1÷2	☑	☐	☐	☑ (n o t e 1)	5

Setup

Le UUT sono inserite in camera climatica. Una termocoppia misura la temperatura di contatto.

Picture 1 – General setup



Picture 2 – Position of the thermocouple

Test[1] - Cicli di Bassa Temperatura Storage

Informazioni Generali

Standard	Metodo	Doc. di Rif	§	Data Inizio prova	Data fine prove	Operatore
Test[2]	Met. 502.6	Doc[1]	--	14/10/2017	14/10/2017	Elisiana Cozzani

Condizioni Ambientali

Temperatura	Umidità	Pressione	Environ ment	--	--
22°C	N.R.	1024 mb	Laborat orio	--	--

Test Equipment

Rif. LPA	Codice	Modello- Tipo	Data Prossima Calibrazione
50 01	H01111245	Acquisitore Graphtec GL900	02/2018
53 00	C45320	Camera Climatica Angelantoni ANYVIB 2200 – 5	11/2018
		Termocoppia K	

Valori del Profilo Test

Tempo	Temperatura [°C]
4 ore (dopo avvenuta stabilizzazione)= 6 ore totali	-40

Grafici misura

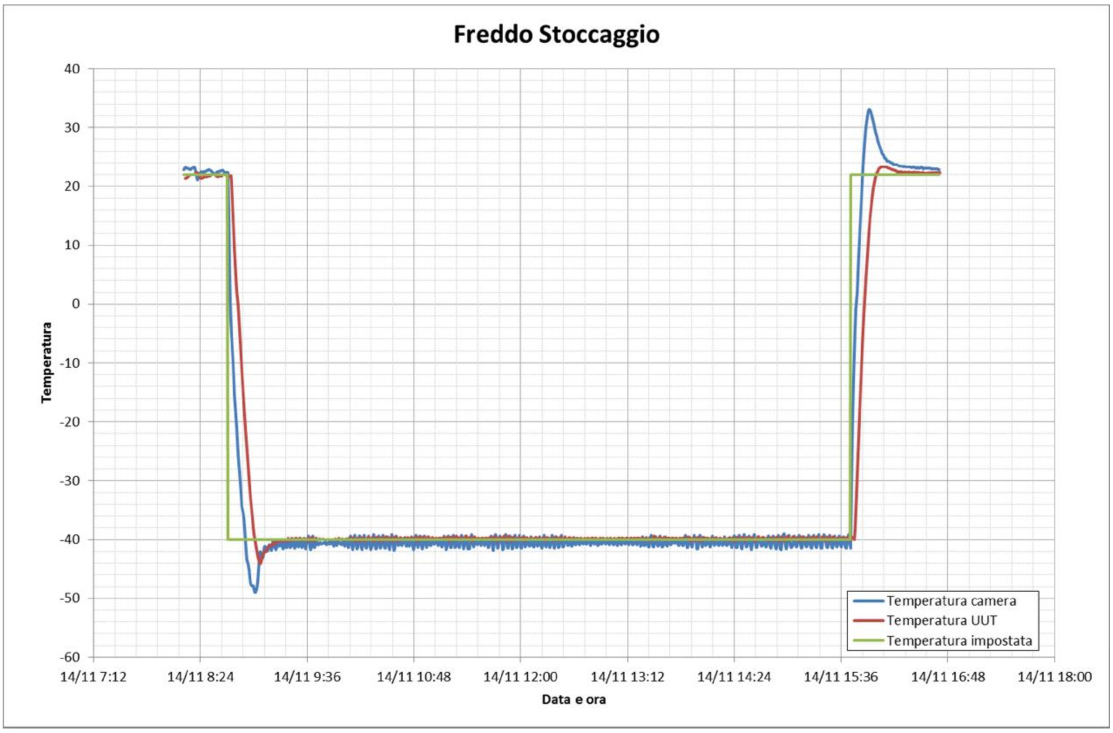


Grafico 1 – Ciclo bassa temperatura

Test[2] - Cicli di Alta Temperatura Storage

Standard	Metodo	Doc. di Rif	§	Data Inizio prova	Data fine prove	Operatore
Test[2]	Met. 501.6	Doc[1]	--	18/10/2017	25/10/2017	Elisiana Cozzani

Condizioni Ambientali

Temperatura	Umidità	Pressione	Environment	--	--
22°C	N.R.	1024 mb	Laboratorio	--	--

Test Equipment

Rif. LPA	Codice	Modello- Tipo	Data Prossima Calibrazione
5001	H01111245	Acquisitore Graphtec GL900	02/2018
5300	C45320	Camera Climatica Angelantoni ANYVIB 2200 – 5	11/2018
		Termocoppia K	

Valori del Profilo Test

Ora	Temperatura [°C]	Ora	Temperatura [°C]	Ripetizioni
0	35	13	69	
1	35	14	72	
2	34	15	75	
3	34	16	71	
4	33	17	67	
5	33	18	63	7gg
6	33	19	55	
7	36	20	48	
8	40	21	41	
9	44	22	39	
10	51	23	37	
11	56	24	35	
12	63			

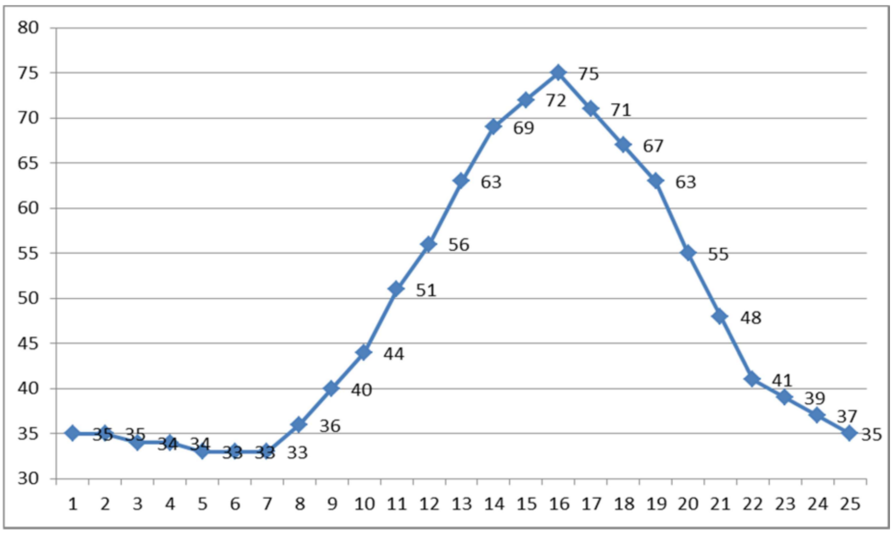


Grafico 2- Profilo di Temperature

Grafici misura

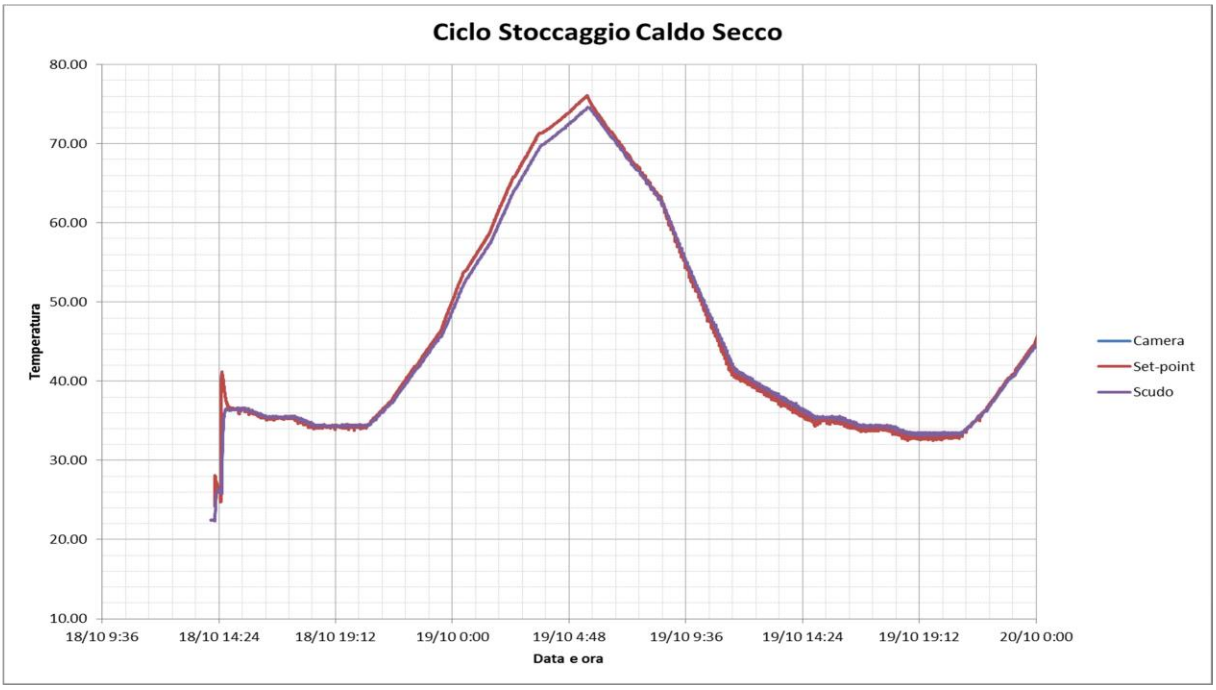


Grafico 3 – Ciclo singolo

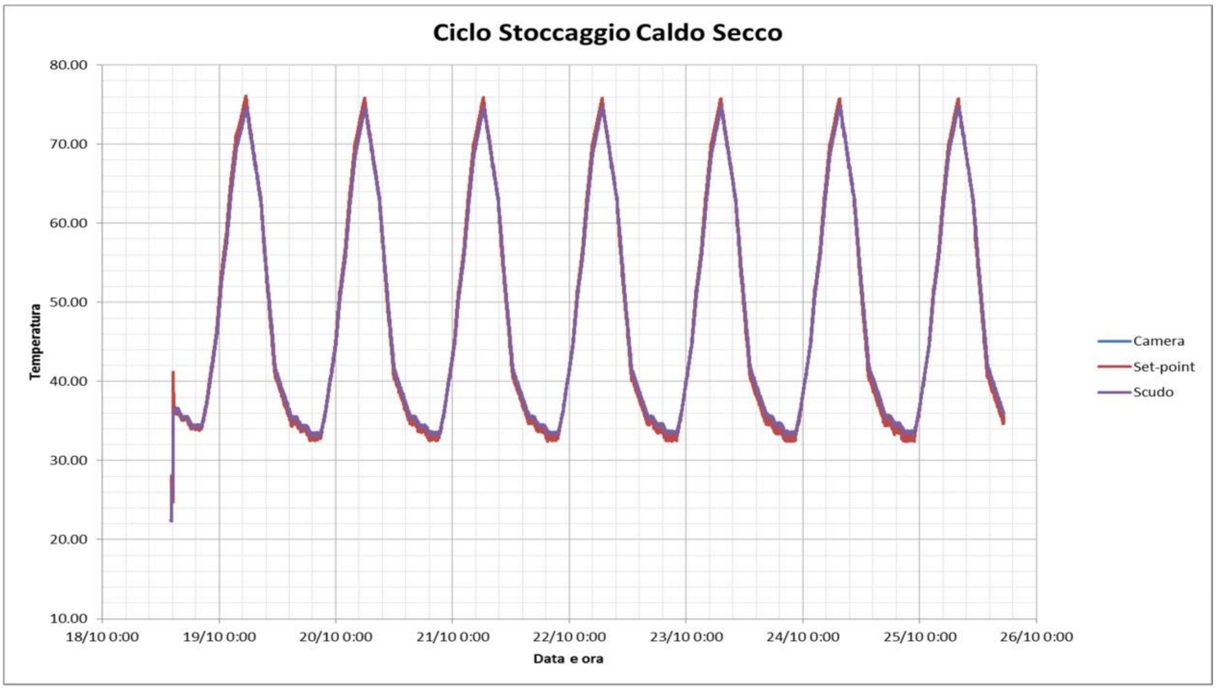


Grafico 4 – Intera prova

UUT prima della prova

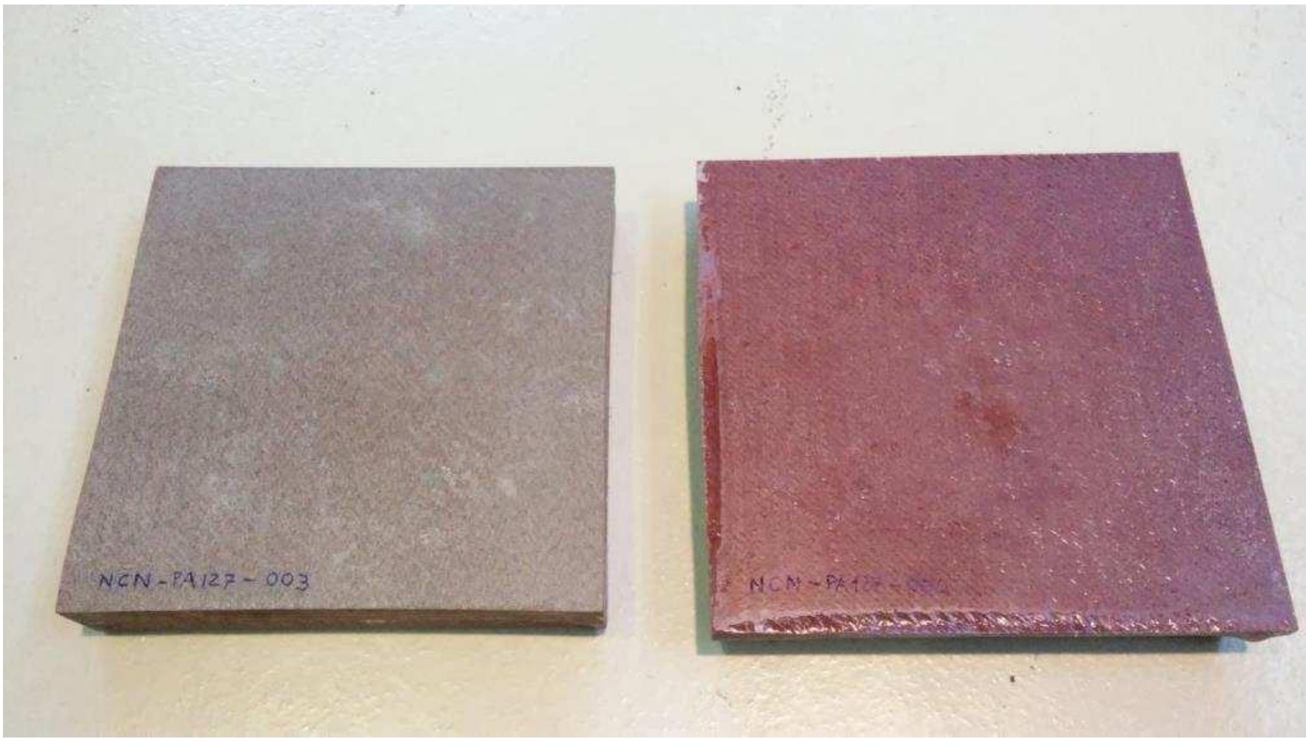


Foto 3 – UUT[1]/[2] prima della prova

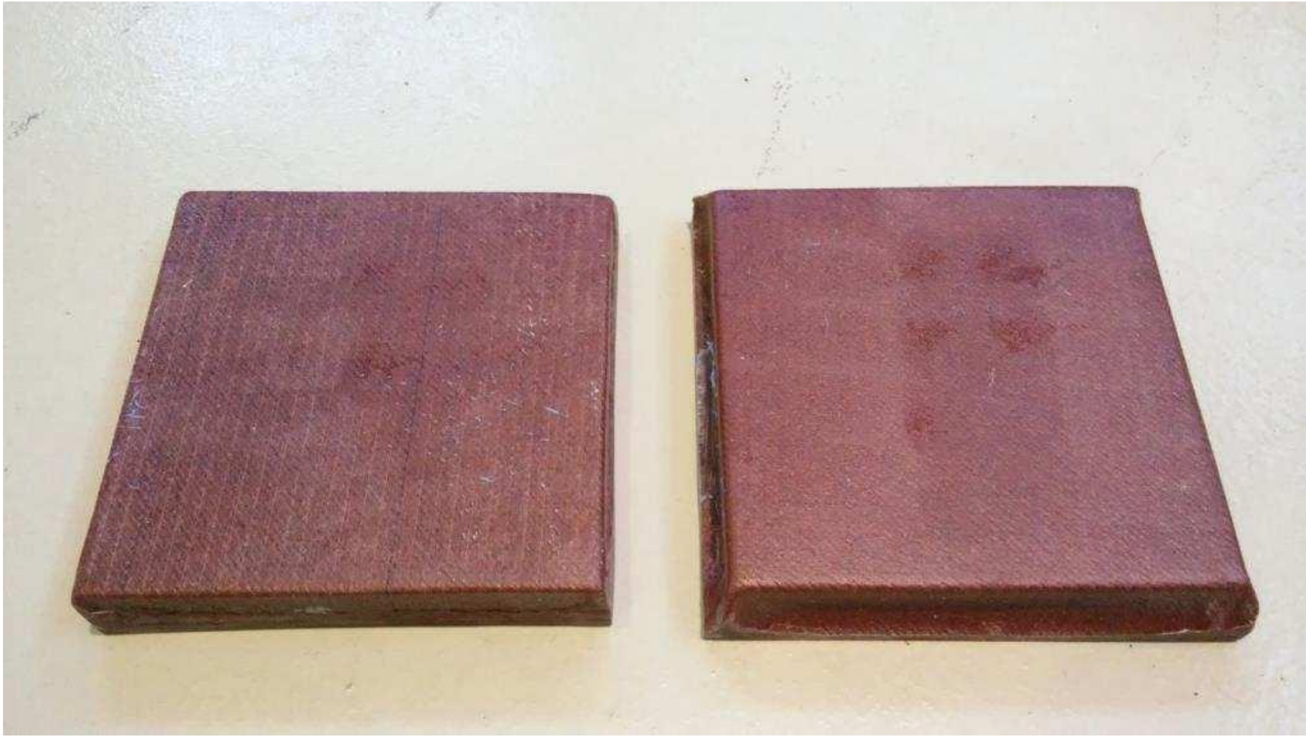


Foto 4 - UUT[1]/[2] prima della prova

UUT dopo la prova

Foto 5 – UUT[1]/[2] alla fine della prova

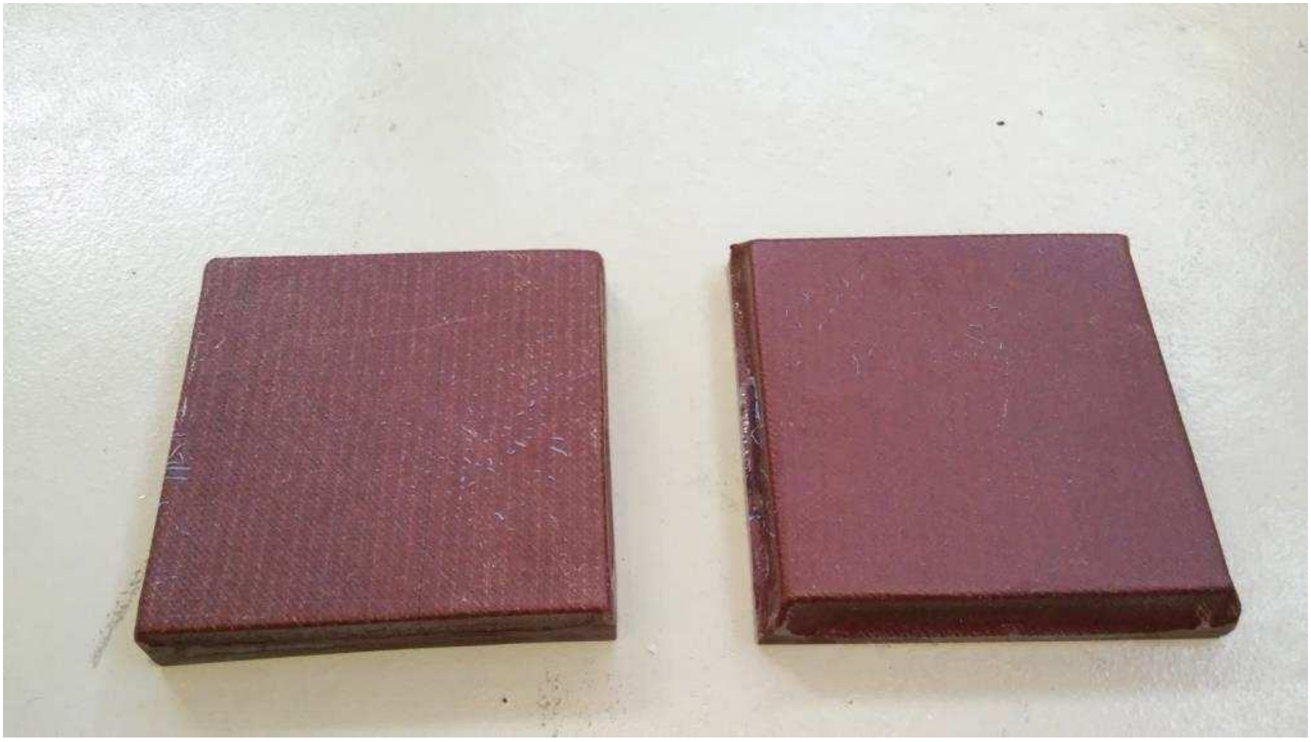


Foto 6 – UUT[1]/[2] alla fine della prova