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Glasses design: compromise between resistance requirements and aesthetic needs

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1 Introduction and objectives

There are some objects that, being part of our daily life, are under estimated for the importance they have in our lives. I refer principally to that objects relatively small and built with elementary technologies (or commonly considered elementary), that are present in very house, offices or that we wear in our everyday life without cares of what is behind them.

I consider in this set pen, watches and, in particular, eyewear, object that since 700 years let people with visual defect, like myopia, astigmatism, etc., to "access to reality".

I focus my energy on the study of this object, to show at a large number of persons their importance and show the technological development behind it. This means to adapt the eyewear to today's world, with a more and more wide knowledge and the consequential develop of rules in order to protect the health of the wearer. The role of today's developer and design is to project an object that is fancy, that can express your own style, be emotional, but without forgetting safe and health.

In fact, eyewear is not only an object that allow to see better, but it is also "anteojos", a Spanish word that means in front of your eyes, that form a barrier in front of our eyes that are common defined as the mirror of our soul, so they have a great sociological aspect.

So, from a visual protection or corrective prothesis, they become the way to express the style and your own personality in relationship. In fact, they have a different meaning considering the different age of a person.

All of this is discussed in the first part of my thesis, that is divided in two parts.

In the first chapter, there is an introduction to eyewear world: there will be a description of the evolution of glasses from the historical point of view; then it will be analysed the production processes that allow the realization of this object; after this introduction part, it will start a more specific part focused on the technologies and norms that rules that object. As most of the industrial fields, also the eyewear industry is ruled by strict laws that are in constant update, focused on the safety of the user. Even if the glasses were developed a long time ago, first rules in Europe were developed only during 90's.

All these rules should be considered during the phase of project and design of a new model: the second part of this thesis is focused on one aspect of the ISO Standards that rules the eyewear today and its purpose is to find a way to help designer during project phase to avoid errors in dimensioning that can cause a waste of money and time in case they are not detected in time.

2 First part: introduction to eyewear

2.1 Historical and sociological analysis

2.1.1 From Nerone’s emerald until today

The history of eyeglasses is very long and, from some points of view, it is not yet completely clear. For the first references it is necessary to go back to the times of Nero, of which Plinius wrote, in his opera “Historia naturalis”: *Nero princeps gladiatorum pugnas spectabat in smaragdo*, which gave rise to fantastic interpretations.

The reality is that it was conviction of those times that in the green light of the emerald the eye rest and preserve the sight. However, it cannot be excluded hat the special cut of that stone acquired the advantage of a corrector of myopia, but in a casual way.

Before going into the true history of glasses, it is necessary to stop our focus on known magnifying means in antiquity, which marked the first step towards realization eyewear as we know it.

2.1.2 Lens invention

In the search for the first eyewear inventor, it was undoubtedly done a certain confusion because we could not distinguish with precision what is meant by lens, or other means, of magnification or glasses.

This difference appears for the first time in 1300 in the “Capitulars Venetians” where it was distinguished between "roidi da ogli", lenses for glasses, and "Lapides ad legendum", the magnifying glasses, without making themselves account of the big difference from the optical point of view.

We must wait until XVII century for this misunderstanding to be scientifically noted by Daça de Valdes, a Portuguese scientist that was the first to spread the work about lens classification, started by Keplero that was the first to develop a scientific method to do that classification.

This system did not have to be very different from today's dioptres if Daca advised cataract operations to use two pairs of glasses: one of 10-11 degrees, for distance, and one of 10-16 degrees for near.

Today's international dioptre, proposed by the French Monoyer, was made official at the Medical Congress of Brussels in 1874.

Before the XII century, it was known those means of enlargement derived from the knowledge of the phenomenon of light reflection, phenomenon known in ancient times long before that of the refraction.

Concave mirrors were used as first magnifying devices, which allowed to see significantly enlarged and overturned pages of manuscripts through the reflection mechanism of the light.

Much later appeared the lenses that substitute the use of the mirror, until Roger Bacon studied the refraction’s laws of the light through the lenses and perhaps applied the use of convex lenses like magnifying glasses in presbyopia.

This was the first important step to move from using lens to enlarge, to use lenses for the correction of visual defects; it was a preliminary degree to reach the glasses.

But where and when therefore were made the first glasses with corrective lenses?

The first eyeglasses were made in northern Italy at the end of the XII century, but depending on different literal evidence, there is no certainty of the city: some sermons say Pisa and other Venice. For sure from Venice started their regulation and their diffusion through business relations and commercial route that started from that city.

We must then consider the historical sources, not strictly literary, which can greatly contribute to providing a clearer vision on the birth of this optical instrument.

A fundamental contribution is given by the paintings in the church of S. Nicolò in Treviso. This monumental church was built by Nicolò Boccassini, elected Pope with the name of Benedict XI in 1200, in honour of his own patron saint, the Saint of Bari.

Near this church stands a monastery of Dominican friars who in 1352 they wanted to paint a room with a kind of figurative catalogue of men of the most exemplary order for holiness e for doctrine. Thus, in this room, the most ancient figure with glasses appears in the world. In the painting by Tomaso da Modena, 40 preachers are represented illustrious, accompanied by an identifying writing: each one of these figures, in their own cell, is sitting at the desk, busy meditating, reading, compose or transcribe. Among these scholars are Cardinal Nicolò of Rouen with a reading lens in his hand, the ancestor of the glasses and the cardinal Hugh of Provence with the glasses resting on the nose.

Figure 1 Detail of a portrait of the Dominican Cardinal and renowned biblical scholar Hugh of Saint-Cher painted by Tommaso da Modena in 1352

Other evidences of the first glasses, as said before, comes from the Chronicles of the Convent of S. Caterina di Pisa. In this book are transcribed the lives of the preaching friars who were part of this convent after the foundation, at around 1200. Among these, appears friar Alessandro Della Spina which was exultated for the ability to correctly reproduce every object he can see, including glasses, invented by someone else but freely disseminated by the friar.

Indeed, Della Spina, living in a convent, was relieved of problems of money and food; according to the thought of some scholars, for this reason he was ready to generously disclose what he had learned, or discovered.

It is therefore evident to associate, in the mid-1300s, the Dominican friars with the developing of books and their accessories, including glasses; even if, according to some studies, the inventor some glasses were probably a layman, Simone Nerucci who lived in Pisa.

Not wanting to lose his job, he intended to draw a good gain from the invention; for this he tried to keep the secret. The bond of secrecy is expressly mentioned in one deed stipulated in Pisa between three goldsmiths. Simone Nerucci undertook to teach the art to make glasses with glass and bones to the two colleagues, also procuring the equipment necessary, and for the time of the agreement (four and a half years) he would not teach others how to make glasses. The two partners, in turn, assumed the obligation not to betray the secret by creating students and future competitors.

During 14 century, monopoly of glasses' production was suppressed in Venice: in fact, it was permitted to everyone who was part of the guild of the glass' craftsman to build glasses with the purpose of reading; and some years later it was also permitted to some people that wasn't part of that guild.

Some studies say that it was due to the fact that production of glasses was less complicated and was no more a secret; in this way, it was possible for everybody to produce it, as long as it was done loyally.

Eyewear art raised to a very high level in Venice at that time and factories were rooted and flourishing.

It is easy to imagine why this art raised in a city like Venice: they were skilful in glass production and they knew all the secrets.

Frequent trips of the Venetian merchants with Asian territories help them discover the importance of glass industry, that was completely abandoned in Europe since Roman Empire fall. They export that knowledge from Asia to Venice and during 13 century there were a lot of glass factory that let Venice become the most important centre of that art and all the European cities buy it from Venice.

Subsequently all the factories were moved to Murano, where they exist until today.

2.1.3 Eyeglasses development

The first glasses were packaged, as can be deduced from the pictorial works, with round, biconvex lenses, to improve the view of the farsighted.

They were mainly used by scholars, above all from those monks who in the Middle Ages who devoted themselves not only to the transcription of religious texts, but mainly to transmit that complex literary and historical heritage of Greek, Roman and Arabic civilization.

Concerning materials, there are some evidences that describe emery and tripol.

Grinding and cleaning technique of glass has arisen in connection with the grinding of the precious stones and was known already at the time of the Romans.

The first lenses were probably made by hand rubbing the glass against spherical cups sprinkled with sand or emery powder of Naxos until the surface had reached the cup shape.

Finer grinding and cleaning were done by rubbing the lenses with tripol and tin ash. This lens processing system was used for hundreds of years and today modern processing methods have not changed so much.

Eyeglasses frames, in the early days, were made with metal or beaten leather rings to which the two handles were fixed in order to join them in pairs with a pin. Naturally they were kept in front of the eyes with one hand.

Only later it was found, from what one can see in pictorial representations, a way to build up frames made up of a single piece, to replace the pin with a bridge with torsion spring to tighten the two rings on the sides of the nose. It was developed a type of eyewear very close to the so-called "pince-nez", which was painful and could easily fall off.

For these reasons various systems were designed to fix the glasses firmly in front of the eyes: first of all, it was sought a system to make the glasses bridge adhere to the edge of the cap and then pass-through string were inserted behind the pavilion headset.

In 1450 the invention of the printing by Johann Gutenberg increased the use of glasses to facilitate reading, that now it did not happen only inside the monasteries or done by the scholars, but also in a part of the people, thanks to the greater diffusion of books. But the print in small characters also contributed to the spread of myopia.

In the second half of the 15 century the first glasses to correct those faults related to vision from afar appeared: biconcave lenses, for myopic, were produced. Subsequently, in the first half of the 16 century the oval lenses appeared; for those rectangular and square we must wait 1570, in England.

Figure 2 Jean Collaert, "Spectacles seller", 1582

Measurement of sight was done in an empirical way, trying one after the other a series of myopic and farsighted glasses, graded according to different ages, it was possible to try glasses for people aged 10, 20 or 30. In 1585 Tommaso Garzoni introduced the gradation through focal values, which were probably set for the first time in a scientific manner by Kepler.

In 18 centuries, glasses appear in the sumptuous and decadent Venetian environment ed at the Court of France used as fashion object. These were real masterpieces, made of gold, adorned with precious stones and someone even in gold porcelain and the lens was often made of a pure sapphire.

During this period, there was a large increase in the number of glasses factories in Venice because the hand glasses became an object in fashion that could not be missing to complete the clothing.

There was no lady, no young and old man, that did not have it with him when he left the house and, it seems, could be used as a means of mute communication. Casanova tells in fact that the nun of Murano used three pairs of glasses, different only for the material of the handle: gold meant "I love you", silver "you are indifferent", turtle "attention, we are supervised ".

Meanwhile, the eyewear industry raised abroad too, important factories were established in France, Spain, in Holland, Germany, Czechoslovakia, England and even in the United States, while in Italy this art fell into oblivion just in the century of the most important discoveries in the optical field and eye.

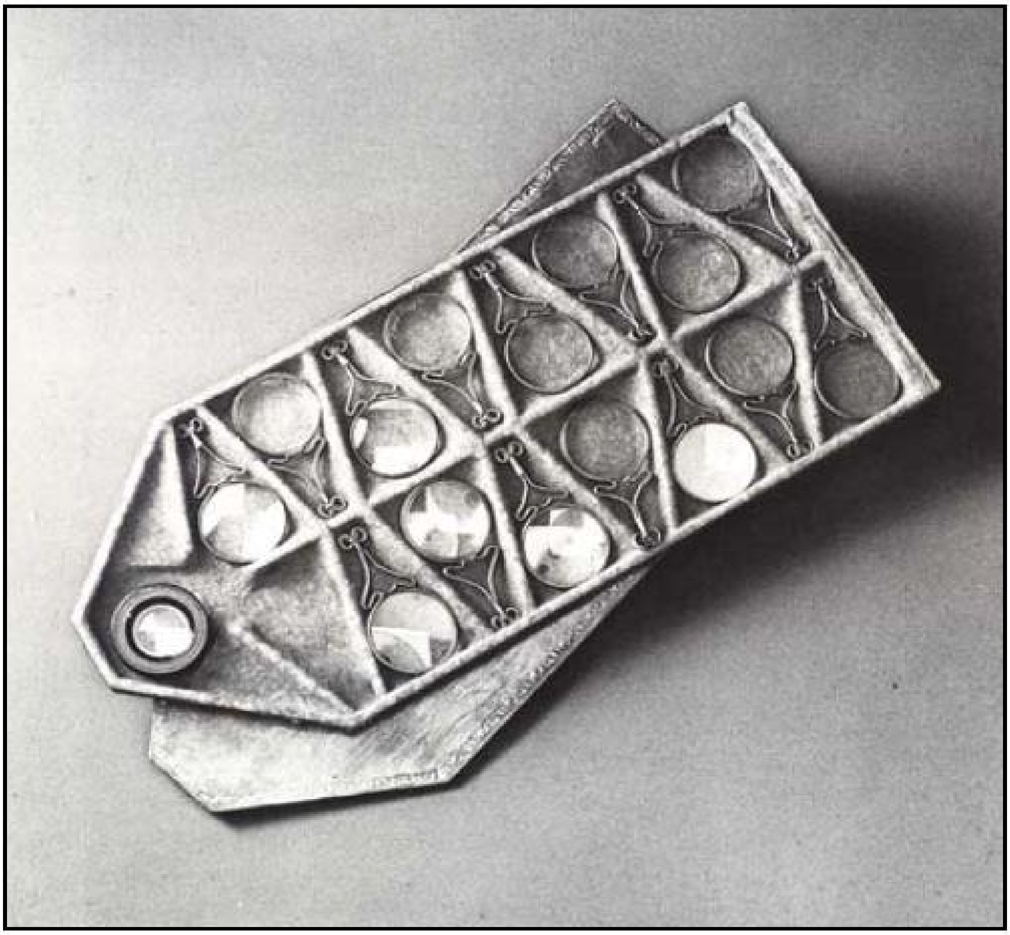


Figure 3 Box with test lenses for clients, 1780

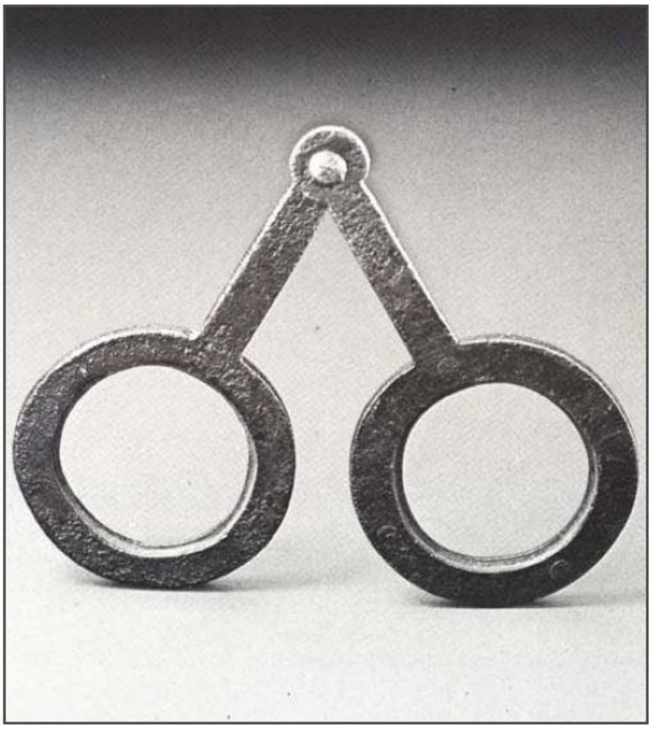


Figure 4 Iron pin glasses, XIV Century

Figure 5 Pince-nez glasses made of horn or brass

The first studies on astigmatism date back to the 1800s of the Dutchman Cornelius Donders, preceded by the design of eyewear bifocal by Benjamin Franklin. He considered unbearable the typical gesture of the short-sighted people that have to remove or change constantly glasses, for close up view and from afar, and thought to use for each eye two broken lenses in half, one half lighter to put in the lower part, and a stronger one to put in the upper one, suitable to see from afar.

Also in this period, periscopic lenses were studied and realized, so call because they have a larger useful surface compared to normal lenses and reduce peripheral alteration; toric lenses (conceived by the Roman optic Suscipi) constituted by two circular curvatures to correct astigmatism; and finally prismatic lenses used for strabismus.

But the innovations applicable to eyeglasses do not end only from the point of view of lenses, in fact, even the frame has suffered remarkable transformations.

The first materials used were leather, various metals, including silver and gold, ivory, bone, horn and turtle. Turtle scales came mostly used for bar glasses, and they were a lot of requests in the nineteenth century. But the reserves of this precious material were gradually decreasing, and the same problem was detectable for ivory, so there was the need to find some different materials to fill the market.

In this circumstances, Alexander Parkes began a series of experiments for fabricating the celluloid and succeeded in producing a substance called "Parkesina", obtained by dissolving the fulmicotone in methyl alcohol with the addition of appropriately treated vegetable oils, which he tried to use to make waterproof clothes, and in the manufacture of pipes. Parkes' research was carried out by one of his employees, Daniel Spill who founded the first factory in England in 1877 of celluloid.

Meanwhile, in America, other researchers were trying to find out a plastic material that has the requisites of ivory. So John Wesley Hyatt, who was unaware of Parkes and Spill' research, became interested in the subject and after numerous experiments he succeeded in obtaining a printable and thermoplastic compound through the use of camphor. The discovery of celluloid was patented in 1873 and in 1879 Hyatt succeeded in producing it in industrial quantities for the manufacture of printing cylinders, billiard balls, dental plates, plates, wires, sticks and coils; and it did not take long for it understand that this new product was usable for different purposes.

One of these purposes was the use of celluloid for glasses frames, which, suitably coloured, was used above all, replacing the turtle, since it lends itself very well to a perfect imitation. The process for making celluloid frames was patented in 1879 in the United States, while in Europe it is necessary to await the 1906, year in which Eichengrün made glasses in Cellon, a plastic material similar to celluloid.

Figure 6 Chinese glasses made of tortoise, XIX Century

Instead in Italy the discovery of this material took place in 1910 made by Ulysses Cargnel, who was already part of the eyewear industry; while it was in a certain workshop in Naples, he saw a pair of tortoise-shell glasses done and he got the inspiration to use celluloid for this type of application. Without waste time Cagnel immediately set up the right equipment for the manufacture of the new article and, seeing that the first experiments gave good results, gave birth to the first department used to the manufacture of glasses in celluloid in Italy.

Following the outbreak of the First World War, this kind of processing was immediately abandoned, only to be restarted in 1920 in Cadore by the Lozza brothers, who dedicated themselves exclusively to the manufacture of frames made of plastic materials. It was started like this the largest Italian factory of celluloid frames for glasses from sight and sun highly specialized in this field.

XII century, magnifying glass was used, also known in antiquity

XIII century, Magnifying glasses are made on a large scale in Venice. Maybe two magnifying lenses joined together with a pin at the end of their handles were the first eyewear.

XIV century, pin glasses spread in the Veneto and Tuscany.

XIV century, goggles, painted by Tomaso da Modena on the nose of friar Ugone from Provence, in the Church of S. Nicolò in Treviso, represent the first model of pince-nez.

XV century, pivot armor is softened and ornamental motifs appear above all in the eyewear paintings in works of art of the Veneto region.

XV century, pivot armature is replaced by a torsion spring mount.

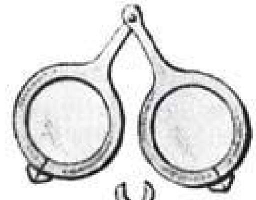
XV century, it slowly appears the bridge type arc frames.

XVI century, it was developed the arch spring bridge.

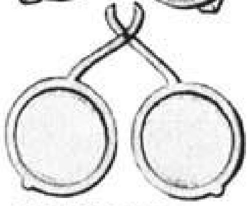
XVIII century, pince-nez with circular or oval lenses became common.

XVIII century, pince-nez with oval lenses spread.

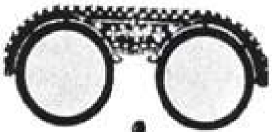
XIX century, pince-nez, with oval lenses, were perfected inserting in the armour spring plates that grip the nose.



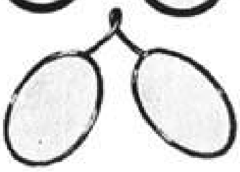
XIV century, The Italian-made pin glasses appear widely in Italian and foreign works, painting and sculpture, supported with one hand before the eyes.



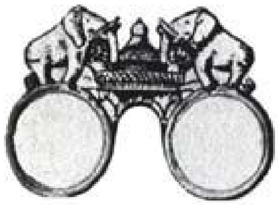
XV century, eyewear with pin, with spring inserted in a groove of the two handles.



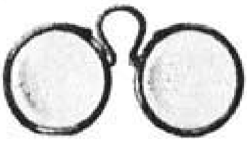
XVI century, ornamental patterns appear on the armour of the glasses. This type was built by the masters of Nuremberg.



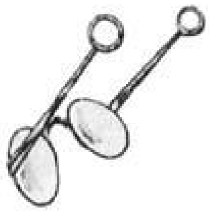
XVI century, first oval lenses appear and the frame is perfected so that the glasses remain fixed on the top of the nose



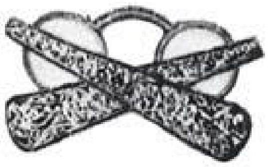
The ornamental motifs of the armor are particularly treated in Asia. This type was used by some character lndù (Greeff) and is made of sandalwood, precious and fragrant.



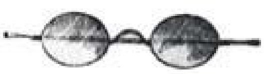
XVII century, type of pince-nez with large and round lenses



XVIII century, after many centuries since the invention of eyeglasses, the system to support them appears with the temples. It was tried to fix glasses on cap and in the Seventeenth century with a string passing behind the ear pads.



Eyewear with silver frame and finely worked temples with ornamentation in filigree.



XIX century, frames with metal temples, straight or curly, of French origin or German, are commonly used.

XX century, with the discovery of plastic materials, frames in celluloid started being manufactured. Cadore has the pride of being the first country in the world to achieve large scale and to spread celluloid frames by a group of ingenious and enterprising men, who created the first machines for processing of this, now widespread, type of eyewear.

Figure 7 (in previous and current pages) scheme of frame evolution

2.2 Productive process

After seeing how glasses were born and how they evolved, this chapter is dedicated to the analysis of processing processes that lead to the realization of this object. To make the processes clearer I decided to distinguish two moments different: the manufacture of the lens, and that of the frame.

2.2.1 Ophthalmic lens construction

The first step for the realization of an ophthalmic lens is constituted from mixing different raw materials that will be introduced in the oven to obtain a glass paste. The basic components like silica and alumina are introduced respectively in the form of sand and feldspar, then mixed with sodium, potassium, lime and magnesium, as well as other products present in smaller quantities. The composition thus obtained is transferred to the melting furnaces and mixed with glass powder, glass of the same composition recovered from the waste of other processing cycles and ground, useful for facilitate the merger of the composition. It is thus introduced in an oven brought to a temperature such as to transform the glass bath into a liquid state; this temperature varies from 1000 to 1500 ° C, a depending on the type of glass.

The next phase consists of refining, so to increase the glass temperature to make it more liquid, to eliminate gases still present at the time of the merger, an operation that takes place in a second part of the furnace, called the refining chamber. Into this stage the glass is at a temperature too high to be used as it is for moulding, because it is too fluid and insufficiently homogeneous. That's why, out of the area of refining, the temperature of the glass must be lowered for make the material more viscous and at a homogeneous temperature throughout its mass.

The material thus obtained exits from the constant delivery casting tubes and it is cut by special steel shears, to supply the presses with quantities of glass of constant weight, these quantities come called "drops". At this point the glass drops fall in the moulds that are located on a rotating disk of the press, in which each position of the same corresponds to a precise one processing phase: loading, moulding, cooling, demoulding. The moulding phase takes place by means of a bending punch concave that compresses the mass of glass against a plane with curvature convex. This continuous system allows one to get one production of thousands of blanks per hour.

When the blank comes out of the press it is transported by means of a conveyor belt in an annealing tunnel, where the temperature it is equal to 500/700 ° C, to significantly reduce stress or internal tensions of thermal origin that may be present in these parts and be able to treat them superficially without breaking.

This leads to the need to carry out a series of processes on the glass superficial useful to obtain a corrective lens with precise characteristics optics required. The first three steps consist of roughing, grinding and polishing.

The first is to consume the glass with a crown cutter diamond, to give it the final thickness and the precise bending radius corresponding to the desired correction power. The grinding refines, by grinding, the two sides of the rough-hewn glass without modify the radius of curvature; the principle is to rub the glass on a counter form, having the same radius (or the same rays) of curvature of the blank, in cast iron where a film is fixed abrasive composed of very fine diamond grains drowned in a binder of sintered bronze. Glass and counter frame are equipped with a rotation movement.

At the end of the grinding, the diameter, the curves and the thickness of the glass have all the required precision; the two faces of the lens are smooth but opaque, it is therefore necessary to polish them to make them transparent. This operation is very similar to grinding only that the counter form is covered with a felt for polishing or a film made of special plastic, however even finer abrasive materials than those previously used, in such a way as to render perfectly smooth the surface of the lens.

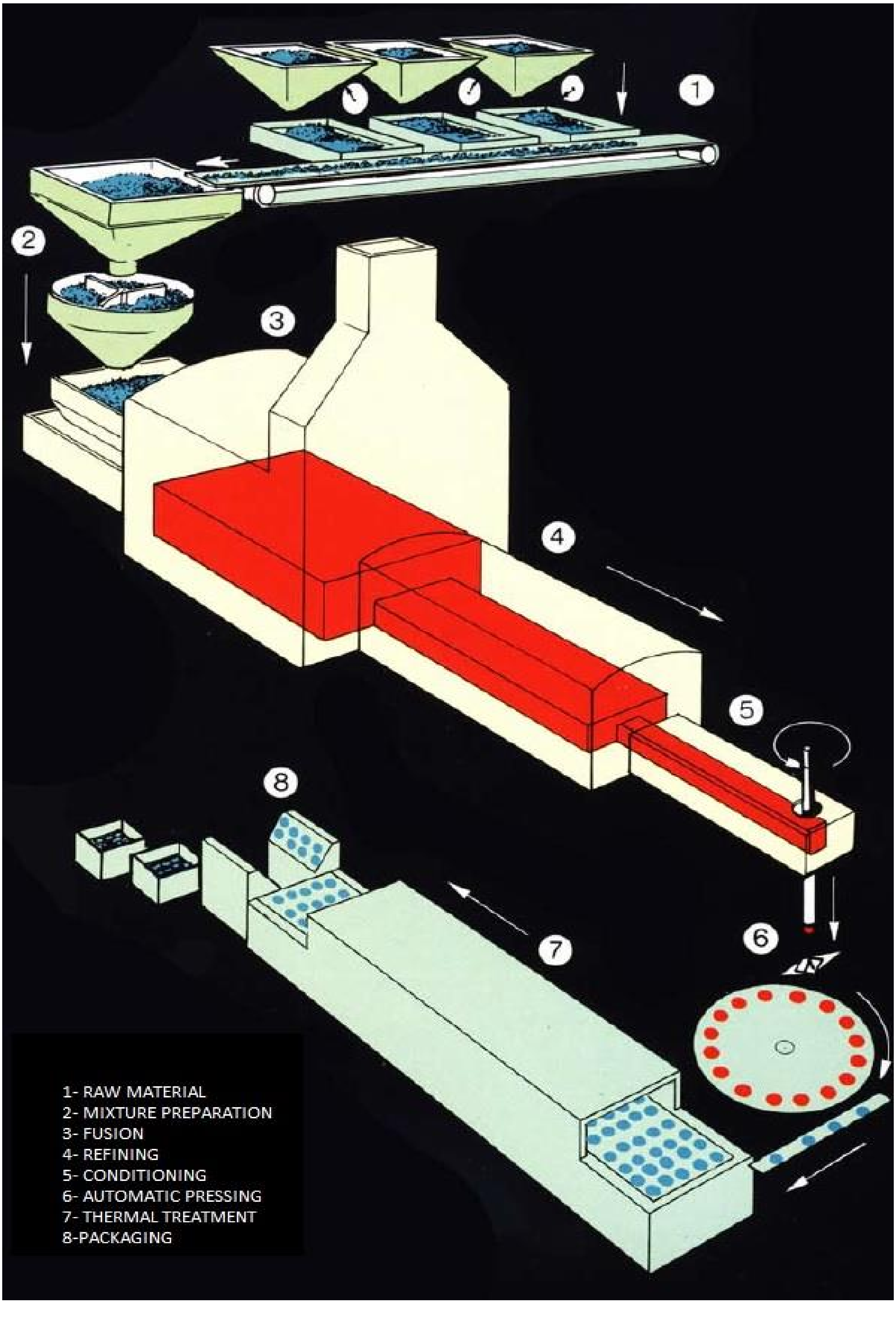


Figure 8 Scheme of the production line for raw lenses

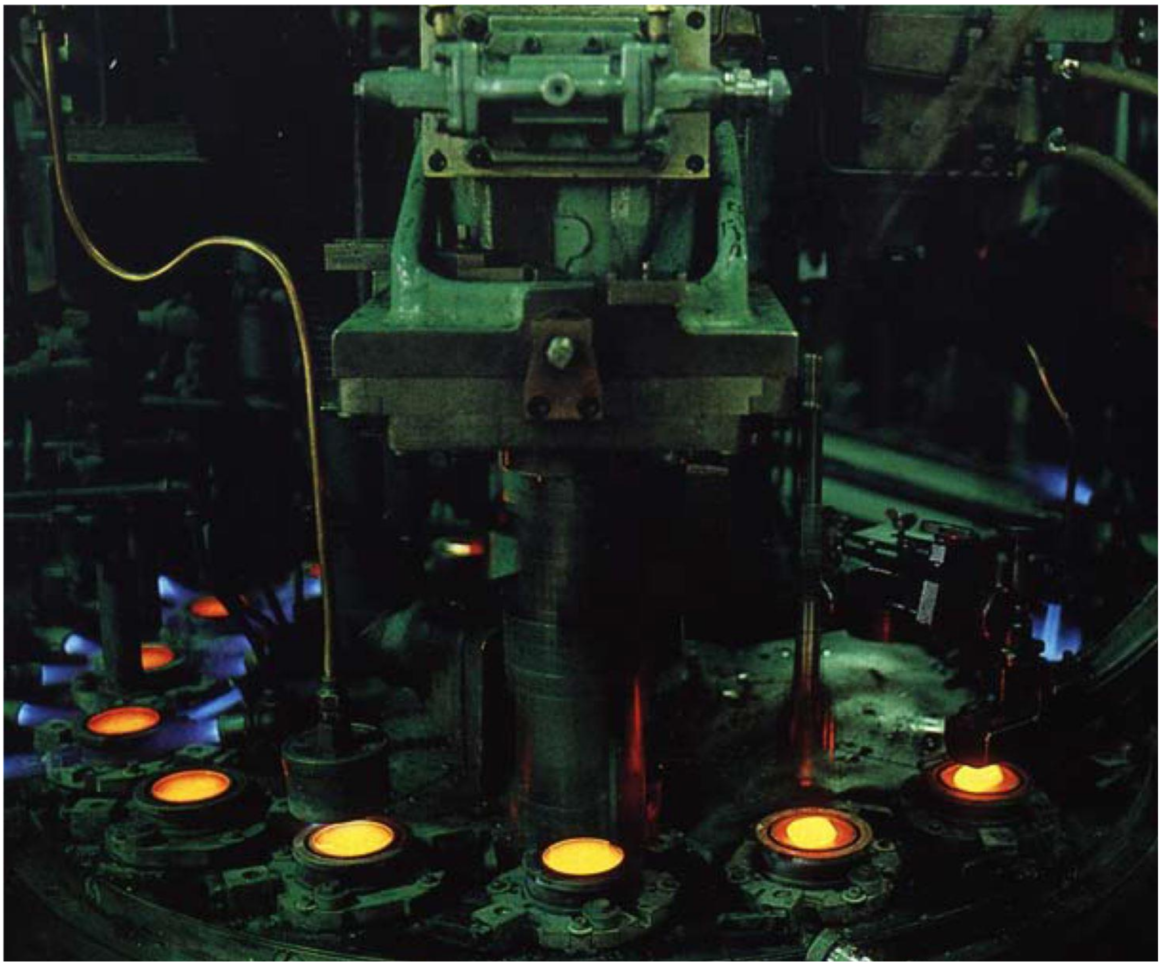


Figure 9 Overall view of a press machine for ophthalmic lenses

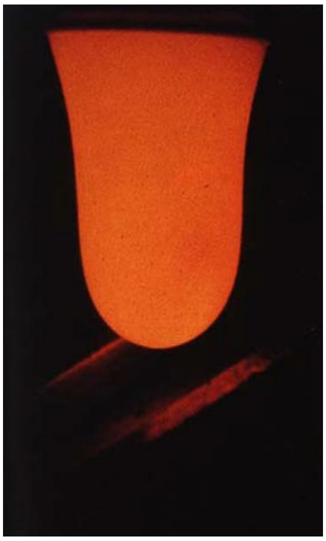


Figure 10 Glass "drop"

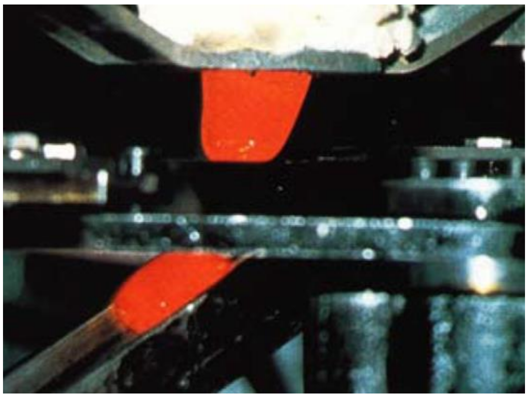


Figure 11 Glass "drop" cutting

For bifocals lenses, processing also includes some additional steps. First of all, the raw lens must be prepared following these operations:

- roughing of the concave face of the blank;
- roughing of the hollow of the convex face;
- grinding of the hollow;
- cleaning of the hollow;
- pressmark on the hollow of the parting line of the lens for the near vision.

Then the lens used for near vision is processed, this process will consist of two parts: a segment realized of the same glass as the corrective lens and another segment with greater power. To assemble these two segments and prepare the assembly it takes six consecutive operations:

- roughing of the welding lines of the two segments;
- grinding of the lines;
- welding for heating and softening of the two welding lines;
- roughing of the faces to be welded of assembled segments;
- grinding of the faces to be welded;
- cleaning of the same faces.

The two segments obtained are then positioned in the hollow of the lens and melted in a tunnel oven and then subjected to leveling and grinding of the prominent part of the segment.

Finally, both the concave and convex faces of the lens will be cleaned, the piece thus obtained will be subjected to quality control.

When the processing of any type of ophthalmic lens is finished, it is possible to use some surface treatments that they allow an increasing of the wearers' comfort. The treatment which is now carried out for any lens is the anti-reflective one which consists of depositing on the convex surface layers of magnesium fluoride. This operation is performed for evaporation of the material to be deposited, in a vacuum chamber to make the layers adhere to the glass and make sure that the treatment is successful.

Last paragraph is focused on the description of the realization of a polycarbonate lens. This thermoplastic material is usually made up of small pellets, which are processed by injection molding, so that it will blend these pieces together. Liquid polycarbonate thus obtained is quickly injected into a mold, which has the shape of the lens we want to obtain, compressed to high pressure, and finally cooled to obtain the product desired.

2.2.2 Frame construction

Today there are many different types of frames on the market. A simple first distinction can be made between frames made of metallic material and plastic frames. As for the first type of frames, the simplest it is called "pince nez", consisting of a spring clamp that holds the lenses tightening the base of the nose. The lenses can be contained within a metallic armour or can be attached to clamp using a small hole.

Then there is the metal frame with temples which consists of an armour simply resting on the base of the nose but firmly held in place by two sticks that end at the temples. The temples are hinged and rotated by means of a pin or a hinge at the end glasses, in order to allow the user to close the object when it is removed from the face and stored away without occupying it too much space.

The materials necessary for the manufacture of a pair of glasses are: nickel silver wires of different diameters, screws for hinges, fins plastic nose rests and ends for the temples. All these parts are cut and drawn or printed with well-polished tools and then subjected to a first polishing performed with wheels of felt sprinkled with black soap. Subsequently they are welded different parts through electric or induction resistance welding machines. The glasses thus formed therefore pass to a first control phase. The glasses are then immersed for one hour in a cyanide solution of potassium and from there subsequently in the pickling baths and of brightening, here begins the processing phase called of "Cleaning" comprising the brushing of all the heated zones and oxidized, polishing with felt wheel and black soap, brightening final with cloth wheel and white-chrome soap; and then suffer of washing to remove soap residues. The next treatment it is the galvanic one consisting of a galvanizing and subsequent degreasing nickel plating that prepare the piece for subsequent operations polishing, degreasing and chrome-plating. Hence the piece passes by new under a scrupulous check to verify the welds and the finishes, if passes this phase is moved to the assembly department where are assembled the various parts consisting of front, rods a where the nose pads and hinges have been previously fitted.

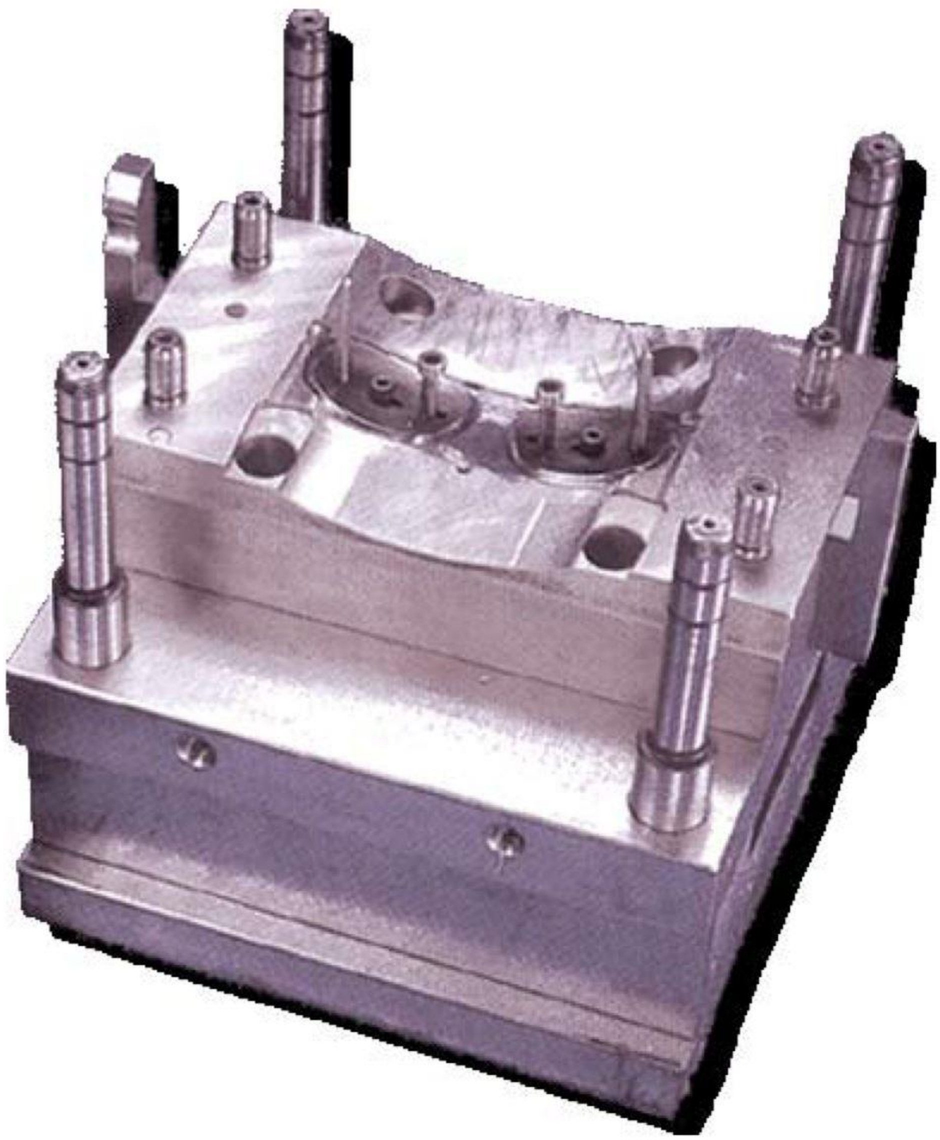


Figure 12 Mold for acetate frame

As for the plastic frames, generally celluloid or acetate, production begins with the division of the plate in two thirds, intended for the front and one third, necessary for the temples. These strips are immersed in a mixture of boiling water and oil at the temperature of 115 ° C and subsequently die-cut according to the desired shape. The pieces obtained are left to cool on plates flat to then do the external milling, useful for removing the burr of blanking and give the piece a clear and contoured profile at will. Then the internal milling is performed, which smoothes the corners and gives it to the profile a section with a corner and another milling that digs in the center of the thickness of the front a small channel that will constitute the housing of the lenses.

After the hot bending of the piece, a first cleaning is performed with a felt wheel sprinkled with black soap and a subsequent one degreasing to remove any residual soap. The front it is then polished again in all those areas that have been subjected to new milling, then degreased and passed to assembly department.

2.2.3 Italia Independent

The brand Italia Independent was founded in 2007 by Lapo Elkan, one of the heirs of Giovanni Agnelli (the most important entrepreneur of FIAT), and other Italian businessmen.

It is a company active mostly on eyewear market and some projects in lifestyle products, like clothes or collaboration to create new style object.

The brand's first product was an eyewear completely handmade in Italy made of carbon fibre; they were the first to use innovative material and shapes in eyewear market.

The philosophy of the group is to promote made in Italy 2.0, by operating in several sectors to export Italian style in a globalized world.

The brand conjugate creativity and style, fashion and design, tradition and innovation.

Figure 13 Advertising Italia Independent

LA SpA, now Italia Independent SpA, was founded on 1 August 2006. Italia Independent brand ufficialy born in January 2007, with their first product, a pair of sunglasses totally handmade in Italy made of carbon fiber, that was promoted and launched as single product with innovative features. From the beginning, the Italia Independent brand was focused on make their “philosophy” more popular with a strategy focused on differentiation, with the aim of obtaining maximum media attention.

In June 2007, the founders of the Group set up the Independent Ideas agency in order to capitalize on their expertise in communication activities. In 2007 the group acquired a part of a society specialized in production of high quality denim, supporting them with knowhow of branding and commercialization of the brand.

In 2008 the Company was set up, conceived as a holding company at the head of the Group, through which the entrepreneurial activities of Lapo Edovard Elkann, of the other founding members and top management of the Group in the field of eyewear, design and communication were rationalized. 2008 is also the first year in which the Italia Independent brand has a significant diffusion, with the launch of the first collection of sunglasses and some clothing products, as well as marking the beginning of the first collaborations with important brands such as Borsalino (hats), Arfango (shoes), Iveco (cars) and Pantofola d'Oro (shoes). The Independent Ideas agency also establishes new professional relationships with international creative partners and begins to sign agreements with third-party customers, including Breil, Fox, La Stampa, Levi's, Moschino, Meltin'Pot, Pantofola d'Oro, Film Commission Torino Piemonte . I Spirits Srl start-up activity is also launched, of which the Group owns 50% of the share capital, for the production of an Italian I Spirit Vodka brand vodka, developed with Arrigo Cipriani and Marco Fantinel and with support of the Group in defining the corporate identity and the brand.

In 2009, the Group decided to focus on the core business of eyewear and licensed the production of clothing to the Brama Sportswear company. In the eyewear sector, the Group introduces the first models of optical frames and the beginning of an integrated and direct management of the organizational model. The distribution reaches about 220 customers in Italy and distribution abroad is also started; in Saint Tropez was opened a temporary store. At the same time, to the collaborations with Arfango and Borsalino, which went on, the group added collaboration with Spy (a manufacturer of ski masks) and Alfa Romeo.

Also in 2009, the Group constitutes to an agency specialized in communication projects based on music.

Independent Ideas continues its development by acquiring new customers, including Virgin Radio (with the campaign "Rock Save Italy") and Fiat, with which it realizes the project "Fiat 500 by Diesel", thanks to which it obtains visibility on a national level and international.

In 2010, the range of Italia Independent products was expanded through the presentation of the first velvet glasses (I-velvet). The distribution network reaches around 650 customers in Italy and expansion continues abroad. New collaborations are also started with Dinh Van (a company that produces men's jewelry), Meritalia (active in the field of furniture), Diesel (jeans) and Vans (footwear company).

Figure 14 Velvet frame made by Italia Independent

The Group continues to pay great attention to communication aspects, with the restyling of the website www.italiaindependent.com and the further expansion of the structure of Independent Ideas, which acquires, among others, customers Vogue Italia, Skitsch and La Rinascente . On a commercial level, the Group signs a license agreement that provides for the possibility of using the historic brand "Fiat 500" c.d. "Vintage" for the development of specific design appliances and furniture.

In 2011, the Group further extended its product offering by introducing the I-thin family of glasses to the market and expanding the range of models and colours available. The distribution reaches around 1,000 customers in Italy. New collaborations are also developed with Orciani (belt manufacturer), bStripe / Blossom (ski manufacturers), Toy Watch (watches) and Meritalia (furniture collection inspired by the historic Fiat 500). In 2011 the first single-brand franchised stores were opened in Alassio, Alessandria and Courmayeur and the communication campaign with historical figures and the “Be Independent. Everywhere" in

Japan and Scandinavia. The growth of Independent Ideas continues, whose customer portfolio expands to Bic, Gucci, Caffè Vergnano, Unicredit and Pinko.

The development of the Group continues in 2012, thanks to the introduction of the I-cons eyewear family and the I-teen family, the first family specifically designed for children and teenagers. The Group's distribution network has about 1,400 customers in Italy and its presence is consolidated abroad.

During 2012 new collaborations are started with important partners, including Juventus (concerning the creation of glasses for the victory of the Serie A football championship in 2012, repeated in the 2012/2013 season), Eclectic (men's jackets), Invicta (bags), K-way (sports jackets), Bear (costumes), Mark Mahoney (dedicated glasses line), Victoria's Secret (dedicated glasses line), Smeg (refrigerators), Vertu (mobile phones) and Able to enjoy (wheelchairs for Disabled).

The “shop in shop” project also starts, namely the preparation of Italia Independent corners at selected opticians, with the aim of attracting people and at the same increasing sales of glasses. In addition, 5 new single-brand franchised stores were inaugurated in Bergamo, Porto Montenegro, Bologna, Turin and Sestriere, as well as the first outlet at the Turin headquarters. At the end of 2012, the license granted to the company Brama Sportswear for the production of lifestyle products ended and the Group started production internally.

The Group begins the process of internationalizing the brand: in September 2012, Italia Independent USA Corp. was established with headquarters in Miami for the management of the American market and local units in France and Spain; some distribution contracts are also concluded in the Middle East, Japan and other countries.

In 2017 the results of his efforts were in fact below expectations, strongly impacted by the ongoing restructuring and relaunching process.

All the markets (except for the United States), which have discounted an excess stock and past aggressive commercial policies, are significantly down. A new management was set; it has intervened to reduce the cost base (closure of stores and non-performing branches, staff reduction), rationalize distribution and the brand / product portfolio, strengthen some managerial positions and improve credit control.

The relaunch work is still in progress, but new partners joined the society and this will strengthen the asset and let the definitive consolidation on the market.

3 Second part: ISO Standards

3.1 Introduction to ISO Standards

The International Organization for Standardization is an international standard-setting group made by representatives from different national standards organizations.

It was founded on 23 February 1947, the organization promotes worldwide proprietary, industrial and commercial standards. Geneva host the headquarter of this organisation and it is recognised and work with 164 countries.

The United Nations Economic and Social Council granted it as one of the first general consultative representative.

The International Organization for Standardization is an independent, non-governmental organization, the members of which are the standards organizations of the 164 member countries. Its purpose is to promote and facilitate world trade by giving different counties the same standards to refer to and it is the larger organisation in the world that develop, in a voluntary way, International standard. During all the years it has developed and draw up over twenty thousand standards, covering almost everything (from manufactured products and technology to food safety, agriculture and healthcare).

Creation of products and services that are safe, reliable and of good quality in today’s world is more and more requested and necessary and it is aided by international standards. The standards help businesses increase productivity while minimizing errors and waste. They create fair basis that allow the comparison between products from different markets and, consequently, they facilitate companies in entering new markets and assist in the development of global trade. Right and safety of consumers and the end-users of products and services are protected by standards because they certified, sometimes also affixing a mark (for example CE logo), products conform to the minimum standards set internationally.

Figure 15 ISO organization

The term "ISO" is not an acronym (in English the ISO is also called the International Organization for Standardization, in French is Organisation Internationale de Normalisation, and in Russian, Международная организация по стандартизации (Mezhdunarodnaya organizatsiya po standartizatsii; this are the three official languages of the organization), but instead derives from the Greek ἴσος (pronounced: isos), whose meaning stands for "equal". The choice of a term of Greek origin rather than an acronym was dictated by the search for an abbreviation that had the character of universality (the acronym is instead usually linked to the language with respect to which it is used).

The organization known today as ISO was born in 1926 as the International Federation of National Standardization Associations (ISA). Because of the World War II, in 1942 it was suspended, but after the war the United Nations Coordinating Committee of Standards (UNSCC) was proposed to form a new body of global standards. In 1946, just after the end of the Second World War, ASA, AFNOR and the British Standards Institute (BSI) in London participated with the standardization institutes of 22 other countries in the creation of the International Organization for Standardization. It is officially created on February 23, 1947.

ISO is an organization whose members decides to join in voluntary way and members, each one representing one country, are chosen between experts of each field of competence and delegate as representative of the standards. Central Secretariat based in Geneva is the system that coordinate all the projects and organise annual meetings at a General Assembly to discuss ISO's strategic objectives.

A Council is formed by a rotating membership of 20-member bodies; this council provides guidance and governance, definition of projects groups and setting the Central Secretariat's annual budget.

The Technical Management Board is responsible for over 250 technical committees, who develop the ISO standards.

ISO develop and publish international standards. They include technical reports, technical specifications, publicly available specifications, technical corrigenda, and guides.

ISO Standards express criteria, parameter and rules that should be applied in a uniform and coherent way by everyone and they are internationally valid.

In this way it is possible for factory far one from the other, or that comes from different country, or have different culture, to use same rule and same parameters.

Application field of these norms are all the elements that are considered “interesting” from each factory.

In order to understand if something is “interesting” for a factory, they have to analyse the application method: it is not subjective, it should refer to objective and shared values; method couldn’t change in the same system, function to test should not be methodologically different; it could only vary quantitative (if applied to element that differs in quantity) and qualitative (according to different characteristic of tested or testing tool) references; but the method could improve according to a better knowledge of the reality.

3.2 ISO Standards in eyewear sector

First distinction that should be done in eyewear sector is the difference between 2 kind of product that are commercialize:

- Sunglasses: these kinds of devices are defined as a personal protective equipment (PPE), which main role is to protect the eye from sunlight;
- Spectacle frame: these kinds of devices are defined as medical devices and allow to mount a corrective lens to improve the quality of vision of a person.

These different products are ruled by different norms, but some tests are in common, like mechanical resistance tests.

3.3 Sunglasses

Sunglasses are a form of protective eyewear whose main purposed is to prevent damaging or discomforting the eyes from bright sunlight and high-energy visible light. They are characterized by lenses that are coloured, polarized or darkened; they can also mount these lenses with function of visual aid.

If you want to protect eyes from ultraviolet radiation (UV) and blue light, it is recommended to wear sunglasses because that radiation can cause several serious eye problems. After some surgical procedures, like LASIK (laser vision correction) or LASEK (laser eye surgery technique), it is mandatory an immediate usage after them and it is recommended in dusty area to prevent infiltration of small particles or in front on screens.

It is very important to wear dark glasses that in the meantime block UV radiation, because it can be more damaging since the pupil tends to open, due to the darker vision insured by sun filters, and this opening allow more UV rays into the eye; so it is more damaging than not wearing eye protection at all.

According to international standards, they are defined as Personal Protective Equipment

But sunglasses are no more only a PPE; in fact during 20th century, sunglasses have become more and more popular as a fashion accessory, especially on the beach.

Today, while glasses with transparent lenses are very rarely used with different purpose with respect to correct eyesight or protecting eyes from external particles, sunglasses have been popular as fashion object: it is an accessory that have been worn even indoor or at night, especially with cosmetic lenses.

Sunglasses can be used for social reason: in fact, the can hide user eyes. They can establish a wall between two persons making eye contact impossible, which can be intimidating to those not wearing sunglasses; it can also be considered “cool” due to the fact that they can demonstrate detachment of the wearer; mirrored lenses improve this effect of detachment, because they completely hide eyes. Professional poker players, for example, used to worn sunglasses during competitions because they help hiding emotions; emotions can range from happiness to sadness, in fact they can hide blinking and weeping (with consequent red eyes); thus, it avoid (complicating it) nonverbal communications.

3.3.1 PPE (personal protective equipment)

Regulation (EU) 2016/425 lays down requirements for the design and manufacture of personal protective equipment (PPE) which is to be made available on the market, in order to ensure protection of the health and safety of users and establish rules on the free movement of PPE in the Union.

It repeals the Directive 89/686/EEC in April 2019.

The regulation says:

"For the purposes of this Regulation, the following definitions apply: 'personal protective equipment' (PPE) means:

- equipment designed and manufactured to be worn or held by a person for protection against one or more risks to that person's health or safety;
- interchangeable components for equipment referred to in first point which are essential for its protective function;
- connection systems for equipment referred to in first point that are not held or worn by a person, that are designed to connect that equipment to an external device or to a reliable anchorage point, that are not designed to be permanently fixed and that do not require fastening works before use."

Sunglasses meet the first definition, so they must respect all the norms requested by this regulation.

Norms to be satisfied by sunglasses are collected in following ISO standards:

- ISO 12312-1:2013/Amd 1:2015 "Eye and face protection—Sunglasses and related eyewear — Part 1: Sunglasses for general use"

In this standard, different other ISO Standards are specified in order to test the effectiveness of the PPE:

- ISO 12311 “Personal protective equipment – Test method for sunglasses and related eyewear”
- ISO 8624 “Ophthalmic optics – Spectacle frame – Measuring system and terminology”
- ISO 4007 “Personal protective equipment – Eye and face protection – Vocabulary”
- ISO 8950-5 “Ophthalmic optics – Uncut finished spectacles lenses – Part 5: Minimum requirement for spectacle lens surface claimed to be abrasion-resistant”

While if a factory decides to export products in North America or in Australia, they have to satisfy the following Standards:

- ANSI Z80.3-2015 “Ophthalmic – Non-prescription Sunglasses and Fashion Eyewear – Requirements”;
- AS/NZS 1067:2003/Amdt 1:2009 “Sunglasses and fashion spectacle.

Sunglasses are a form of protective eyewear designed primarily to prevent bright sunlight and high-energy visible light from damaging or discomforting the eyes. They can sometimes also function as a visual aid, as variously termed spectacles or glasses exist, featuring lenses that are coloured, polarized or darkened. They can improve visual comfort and visual clarity by protecting the eye from glare. The lenses of polarized sunglasses reduce glare reflected at some angles off shiny non-metallic surfaces, such as water. They allow wearers to see into water when only surface glare would otherwise be seen and eliminate glare from a road surface when driving into the sun.

Sunglasses offer protection against excessive exposure to light, including its visible and invisible components.

The most widespread protection is against ultraviolet radiation, which can cause short-term and long-term ocular problems such as photokeratitis, snow blindness, cataracts, pterygium, and various forms of eye cancer. Medical experts advise the public on the importance of wearing sunglasses to protect the eyes from UV; for adequate protection, experts recommend sunglasses that reflect or filter out 99% or more of UVA and UVB light, with wavelengths up to 400 nm. Sunglasses that meet this requirement are often labelled as "UV400". This is slightly more protection than the widely used standard of the European Union (see below), which requires that 95% of the radiation up to only 380 nm must be reflected or filtered out. Sunglasses are not sufficient to protect the eyes against permanent harm from looking directly at the Sun, even during a solar eclipse. Special eyewear known as solar viewers are required for direct viewing of the sun. This type of eyewear can filter out UV radiation harmful to the eyes.

More recently, high-energy visible light (HEV) has been implicated as a cause of age-related macular degeneration; before, debates had already existed as to whether "blue blocking" or amber tinted lenses may have a protective effect. Some manufacturers already design glasses to block blue light; the insurance company Suva, which covers most Swiss employees, asked eye experts around Charlotte Remé (ETH Zürich) to develop norms for blue blocking, leading to a recommended minimum of 95% of the blue light. Sunglasses are especially important for children, as their ocular lenses are thought to transmit far more HEV light than adults (lenses "yellow" with age).

There has been some speculation that sunglasses actually promote skin cancer. This is due to the eyes being tricked into producing less melanocyte-stimulating hormone in the body.

3.3.2 ISO 12312-1:2015 and ISO 12311

These Standards are applicable to all afocal sunglasses and clip-on whose scope is the protection against solar radiation.

All the test’s methods are described in ISO 12311, in ISO 12312 there are present general principle to be tested.

The first thing to be tested is construction process, that must ensure no dangerous defects on frame and filters, and materials that compose the frame.

For safety reasons, the frame should be smooth and must not have any sharp projection in areas that can be in contact with the wearer; incidental scratches or wound, that can come from everyday use, should be avoided. Sunglasses filters should not have any defect, spots, dot that could create a discomfort of the vision in an area with 30mm diameter around the reference point; the reference point is described in ISO 8624. Test method to detect surface defects is made of visual inspection without any magnification; while test method to detect filter's defects needs a lamp and a black background: eyewear should be kept at a distance of around 30cm from eye and looking at the light source inspect the filter.

Materials should not be dangerous for the wearer, they should be physiological compatible; they must not be dangerous for health and safety of the user when used for the purpose they are intended for; special attention must be paid on material of the part of the eyewear that are in contact with the skin: they must not be allergenic, carcinogenic, mutagenic or toxic to reproduction; substances leaking is regulated by REACH: it is an European regulation adopted to improve knowledge on chemical substances on human health and regulate it. It is up to the manufacturer to ensure the respect this regulation; specialized laboratory can test substances leaking.

Main purpose of sunglasses is to protect eye against sun glare and the result is obtained by using obscuring filters that absorb a part of the light. The characteristic that is evaluated and tested is the transmittance of the filter.

Transmittance, in optics and spectroscopy, is the fraction of incident light at a given wavelength that passes through a sample; its opposite is the absorbance: it is the opposite of the transmittance's logarithm. The general formula of the transmittance is:

$$\tau_v = \frac{I_1}{I_0}$$

Where I0 and I1 are, respectively, luminous irradiance that the source light emits and the one that passes through the sample. It is expressed as a percentage (usually it does not overcome 100%).

Filters should filter visible light as well as UV and infrared light.

Consumer label	Technical label	Requirements			
Descriptive label	Filter category	Ultraviolet spectral range		Visible spectral range	Enhanced infrared absorption[a]
		Maximum value of solar UV-B transmittance τ_{SUVB} 280 nm to 315 nm	Maximum value of solar UV-A transmittance τ_{SUVA} 315 nm to 380 nm	Range of luminous transmittance τ_V 380 nm to 780 nm	Maximum value of solar IR transmittance τ_{SIR} 780 nm to 2 000 nm
Light tint sunglasses	0	0,05 τ_V	τ_V	τ_V > 80 %	τ_V
	1	0,05 τ_V	τ_V	43 % < τ_V ≤ 80 %	τ_V
General purpose sunglasses	2	1,0 % absolute or 0,05 τ_V, whichever is greater	0,5 τ_V	18 % < τ_V ≤ 43 %	τ_V
	3	1,0 % absolute	0,5τ_V	8 % < τ_V ≤ 18 %	τ_V
Very dark special purpose sunglasses	4	1,0 % absolute	1,0 % absolute or 0,25 τ_V, whichever is greater	3 % < τ_V ≤ 8 %	τ_V

NOTE The upper limit of UV-A at 380 nm coincides with that taken in ophthalmic optics and in ISO 20473, *Optics and photonics — Spectral bands.*

[a] Only applicable to sunglass filters recommended by the manufacturer as a protection against infrared radiation.

Figure 16 Transmittance for sunglasses filters for general use

Luminous transmittance, for International standards, is calculated with the following formula, a percentage from the spectral transmittance:

$$\tau_v = 100x \frac{\int_{380}^{780} \tau(\lambda) * S_{D65}(\lambda) * V(\lambda) * d\lambda}{\int_{380}^{780} S_{D65}(\lambda) * V(\lambda) * d\lambda}$$

Where the limit of the integral is the range of the visible light, λ is the wavelength of the light [nm], V is the spectral luminous efficiency, SD65 is the spectral distribution of radiation and it is standardized by ISO 11664-2. Annex of ISO12311 gives values for $S_{D65}(\lambda) * V(\lambda)$, so it remains just to evaluate the transmittance with special detectors.

Category of filters is very important: according to the value of transmittance, they are part of one category or another one; 2 and 3 are the most common category of sunglasses, they are considered for general use and their usage condition is suggested for category 2 with cloudy or not fully sunny conditions and category 3 for sunny day; 0 category usually are lens for medical devices while 1 category is for tinted lens (usually used for fashion reasons); 4

category is for special purpose (for example working with welding machine or travel across desert or glacier) and do not permit driving vehicle.

Filters, to be worn during road use, have to let the wearer distinguish the colours of the traffic signals and traffic light (red, yellow, green and blue).

A structural test is the evaluation of the optical power: D1 and D2 are the powers in the two principal meridians od the sunglasses. Optical power refers to the degree of the lens to deflect the light; it can be convergent (positive optical power) or divergent (negative optical power).

Sunglasses for general use should have lens with no optical power in order to be sold to customer; if they need also corrective lenses, they could be substituted, but only later on.

Spherical power	Astigmatic power
Mean value of the optical power values (D_1, D_2) in the two principal meridians. (D_1+D_2)/2 dioptres	Absolute difference between the optical power values (D_1, D_2) in the two principal meridians. ID_1-D_2I dioptres
± 0,12	≤ 0,12

Figure 17 Optical power values for ISO Standards

They should allow values lower than the one indicated in the lower part of the table.

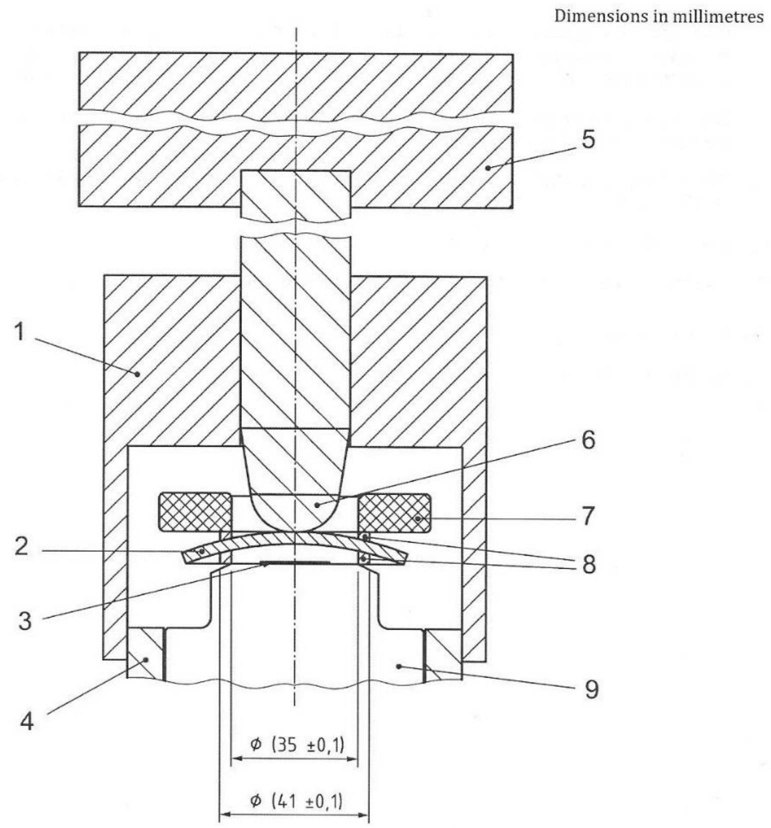
Frames should also guarantee a minimum robustness; tests are developed in order to simulate everyday use.

The robustness of the filters must allow safety for the wearer: after a collision against an object they should not have damage; there exists minimum robustness that all the filters must have and 3 more levels of resistance that are at the discretion of the company that commercialize sunglasses.

Minimum robustness of the filters test require that filters do not have any of the following defects when a static load of 100N (uncertainty of 2N) is applied:

- Filter fracture: a crack across the entire filter appears or a person, with no magnification, can find any piece of the material that has become detachable;
- Filters deformation: the filter is considered deformed if during deformation, a mark appears on the carbon paper or white paper placed under the filter.

Test procedure consist in using a steel ball with 22mm of nominal diameter that load the filter with the force of 100N.



Key

1 guiding block
2 filter (can be curved)
3 carbon paper on white paper
4 centring ring
5 loading mass (100 ± 2) N
6 steel ball
7 pressure ring (250 ± 5) g
8 silicone seating rings (35×3×3)
9 support system

Figure 18 Apparatus for minimum resistance of filters test

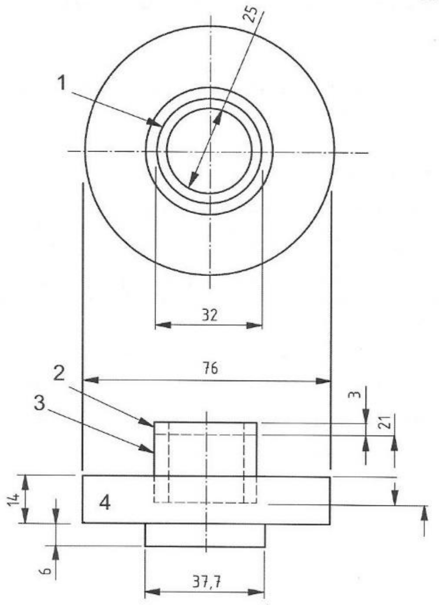
Other 3 tests methods are impact tests: a steel ball is used to hit the filter:

- Strength level 1: a steel ball of 16[g] is dropped from a high of $1,27^{+0.03}_{-0}[m]$

- Strength level 2: a steel ball of 43[g] is dropped from a high of $1,27^{+0.03}_{-0}[m]$
- Strength level 3: a steel ball of 6mm nominal diameter and 0.86g must hit the filter at the speed of $45^{+1,5}_{-0}\left[\frac{m}{s}\right]$

The test apparatus has a pipe where the ball can be directed and a neoprene basket to support the filter.

Dimensions in millimetres



Key
1 neoprene gasket
2 neoprene gasket
3 support tube
4 test block

NOTE Modification of the support tube may be made to accommodate non-spherical filter surfaces.

Figure 19 Support tube and test block for filter's impact test

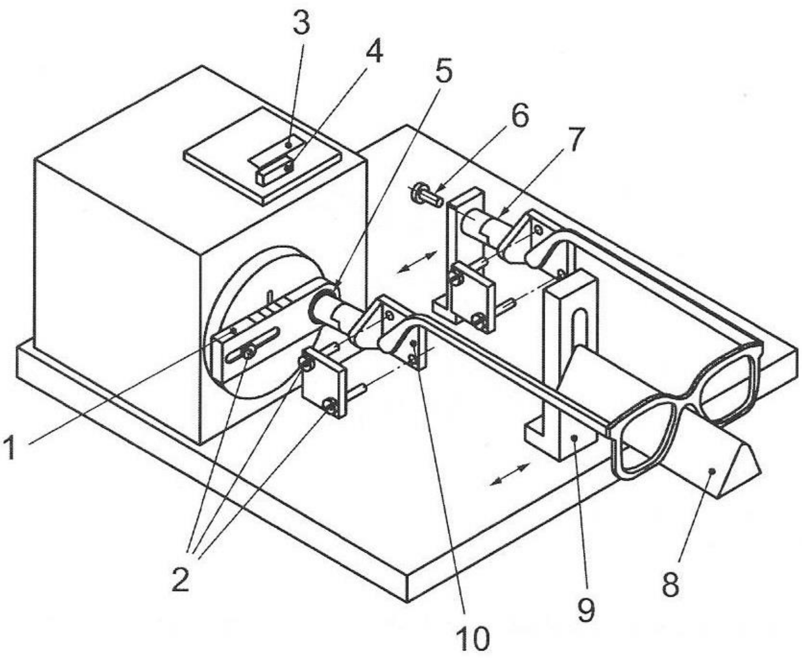
As for the minimum robustness filter must not have deformations, cracks or the ball mustn't pass through the filter to pass the test.

If a filter is tested for a certain level of strength, previous level cannot be tested.

The frame deformation and filter retention are tested by using a clamping device that hold one lens and a punch apply a force on the other deforming the frame; to pass the test the frame should return to its initial displacement and do not have to lose filters from the groove.

This test will be described in detail in the next chapter and it will be the argument of analysis of this thesis.

The endurance of the frame is tested to simulate its strains, and in particular of its joints, by reproducing the gesture of putting sunglasses on and off.



Key

1 frame displacement amplitude scale
2 finger screws
3 counter window
4 control switch
5 ball bearing
6 lockscrew
7 universal joint
8 adjustable sunglass bridge support
9 adjustable bracket to match various sunglass frame sizes
10 clamping point

Figure 20 General test arrangement for endurance test showing clamping devices

The end of one temple is clamped to restrain movement in lateral direction, but it is free to rotate; the other temple is attached to a device that rotate it for a circle of 60mm of diameter; the bridge is held by an artificial nose that support the frame without constrain it.

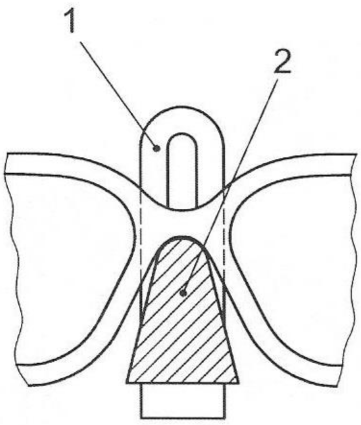
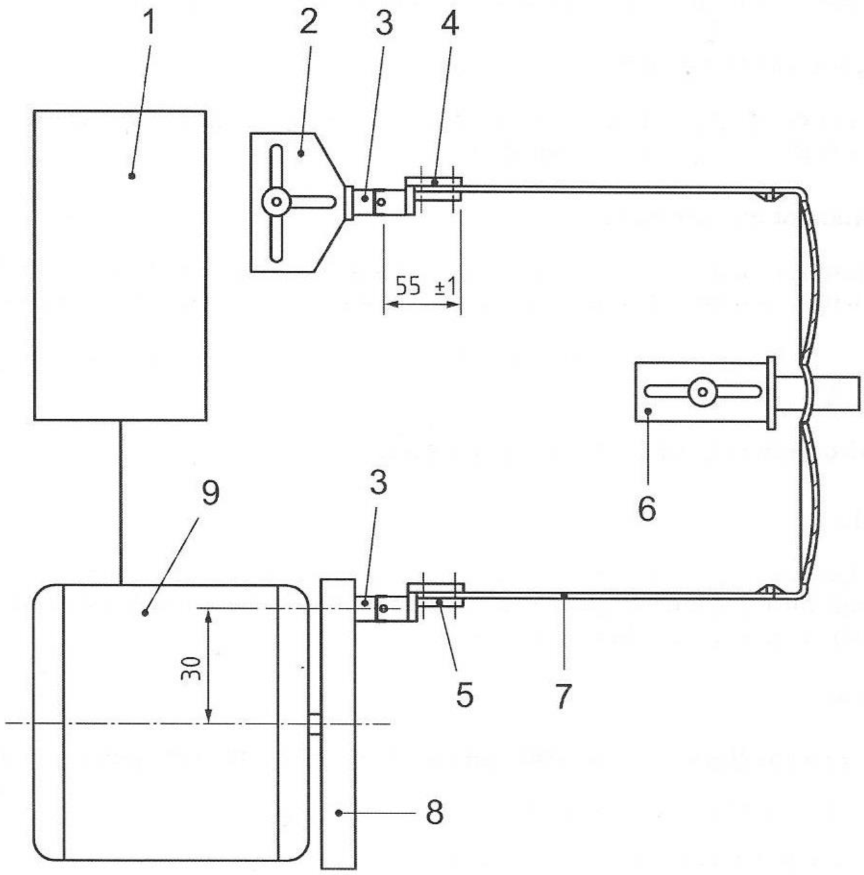


Figure 21 Adjustable bridge support for endurance test

Before the test, the distance between the sides of the frame are measured; then the frame is stressed by the device at a frequency of 40 cycles/minute for a cycle of 30mm movement up and down and of 60mm out; the device allow this movement continuously and smoothly.



Key

1 control panel and counter
2 side clamp adjustment
3 universal joint
4 fixed clamp
5 rotating clamp
6 adjustable sunglass frame bridge support assembly
7 test sample
8 rotating disc
9 geared motor

Figure 22 Diagram for test apparatus

After 500 cycles completed, the frame is removed and the distance between the sides is measured again; the difference between the two measures must not exceed 5 mm to succeed the test; then the frame passes a visual inspection: there must be not cracks or fracture.

Resistance to ignition is tested by using a steel rod heated at 650°C and pressed on the surface of the frame for at least 5s; if the frame continues to glow the test is passed, while if it ignite and burn the test is fail.

Resistance to perspiration is tested by corroding with artificial sweat in a controlled environment the frame; the glasses at the end of the test should not change colour and no corrosion should appear on the surface.

Solar radiation is tested for filters to determine their resistance to fading: the artificial irradiation, which the filter is subjected to, should not decrease the transmittance more than the scheduled value.

Filter category	**Relative change in the luminous transmittance** $\Delta\tau_V / \tau_V = (\tau_V' - \tau_V) / \tau_V$
0	±3 %
1	±5 %
2	±8 %
3	±10 %
4	±10 %
NOTE τ_V' is the luminous transmittance after irradiation.	

Figure 23 Uncertainty for category range

Lamp should be xenon ozone free lamp with power of 450W and the test duration should be in between of 10 and 50 hours.

According to the filter category, the sunglasses have a different usage and they are scheduled.

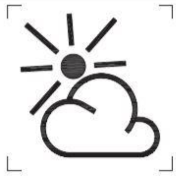
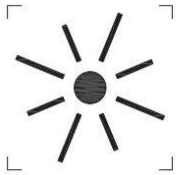
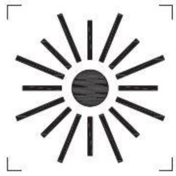
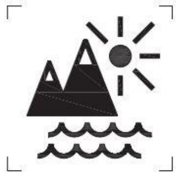
Filter category	Description	Usage	Symbol
0	Light tint sunglasses	Very limited reduction of sunglare	 IEC 60417-5955
1		Limited protection against sunglare	 ISO 7000-2948
2	General purpose sunglasses	Good protection against sunglare	 ISO 7000-2949
3		High protection against sunglare	 ISO 7000-2950
4	Very dark special purpose sunglasses, very high sunglare reduction	Very high protection against extreme sunglare, e.g. at sea, over snowfields, on high mountains, or in desert	 ISO 7000-2951
NOTE The wording and/or the pictograms may be used.			

Figure 24 Filter's category suggested use

3.4 Glasses

Glasses are external prostheses composed of a frame and two lenses designed to correct visual changes due to refractive defects (such as myopia, astigmatism, hypermetropia and presbyopia) or insufficient ocular function.

According to the characteristics of the lenses mounted, they can protect eyes from different kind of light radiation, like blue light that today's screen emits (phones, laptops, tv…).

They are defined by inferential standards as medical devices and they are subjected to different parameter with respect to sunglasses; for example to pass the Italian border, sunglasses need to have attached a booklet that specify characteristics, while glasses do not need it, but they need a medical "nulla osta" and the conformity to international standards as an auto declaration.

Iso organization apply the standards described in ISO 12870.

3.4.1 Medical equipment

Medical Device Directive (council directive 93/42/EEC) is a document that reports general rules to be used in projecting and realizing of category of medical equipment, valid in EU country.

It is mandatory to have the marking CE; to obtain this mark they have to satisfy some essential requirement.

The definition od medical equipment is: "any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or other similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purpose(s) of:

- diagnosis, prevention, monitoring, treatment or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of or compensation for an injury,
- investigation, replacement, modification, or support of the anatomy or of a physiological process,
- supporting or sustaining life,
- control of conception,
- disinfection of medical devices
- providing information by means of in vitro examination of specimens derived from the human body;

and does not achieve its primary intended action by pharmacological, immunological or metabolic means, in or on the human body, but which may be assisted in its intended function by such means."

According to Italian regulation, they are medical device with I class, because they are not invasive devices.

International regulation that determine standards is ISO 12870.

3.4.2 ISO 12870

These Standards specified requirements for unglazed frame whose purpose is to be used with prescription lenses. It is applicable to frames made of any material.

As for the ISO 12312 for sunglasses, some tests are the same.

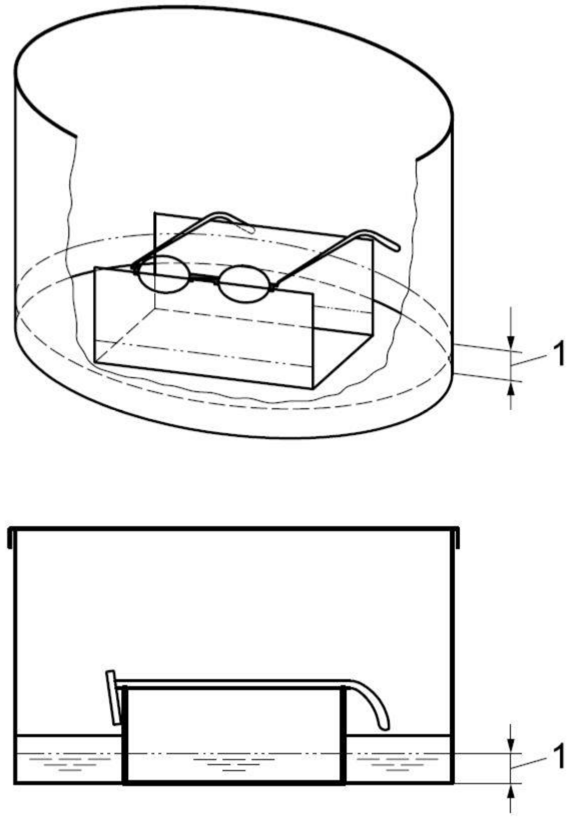
Mechanical stability is tested clamping one lens and using a punch to deform the frame.

A force of 5 N is applied by the punch and after releasing, the frame should return to its initial position, with no permanent deformations or cracks.

Endurance test on the temples is standardised as for sunglasses.

The frame is mounted on a device that lock one temple and constraint the nose of the frame; the other temple is moved in vertical and horizontal direction: up and down of 30mm and out of 60mm; it is not moved in because the hinge will do this movement and do not stress the frame. It is tested for 500 cycles. After the test the frame should perform as before the test and the tip to tip distance and general dimension should not be changed.

Perspiration of the frame is tested using an artificial sweat and test the frame at 55°C for 8 hours; after the test the frame should stay 16 hours at rest and then visually inspected: it should have no corrosion and colour changing.



Key
1 artificial sweat

Figure 25 Diagram for frame support for corrosion test

Resistance to ignition and resistance to optical radiation are tested as before.

Other tests are different or done with more detail and attention.

Physiological compatibility is very important for spectacles frames, they are usually used every day for many hours and they should not compromise wearer health; due to the prolonged contact with the skin, migration (leaking) of substances should be reduced to a practical minimum that is requested by any existing regulation.

Substances that are known to be allergenic, carcinogenic, mutagenic or toxic for reproduction should be detected and manufacturers should control them with special attention.

Nickel release is tested only in metal part that can be in touch with the skin of the wearer; release should be lower than 0,5 µg/cm2/week. Parts that are testes include:

- Both rims’ rear surface
- Bridge’s rear and lower surface
- Sides and metal collet (not joint)
- Metal decorative trims

Test for nickel release include a prior treatment of corrosion simulation; only after that test, the sample can be analysed for nickel release.

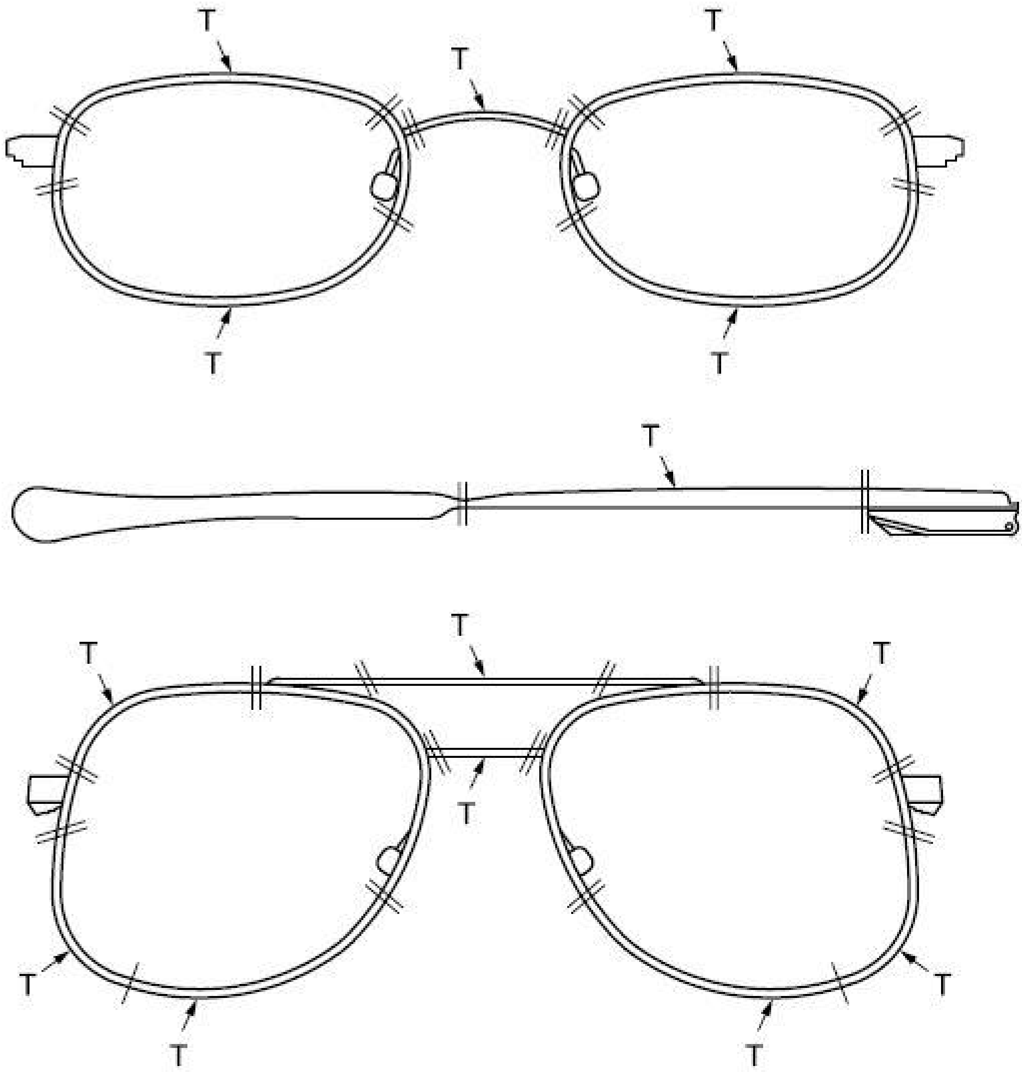


Figure 26 Examples of locations for cutting metal spectacles frames before testing for nickel release

Sample’s part that don’t have to be tested are masked (typically: pad arm, external parts of rims and bridge, joints, threads); cutting is needed in some parts to save masking.

The sample is so tested and it does not have to overcome the value of 0,5 µg/cm2/week.

It is tested the resistance at elevated temperature: sample is put in an oven at 55°C; when the sample has reached the temperature, leave it for 2h. the distance between the tips should be the same as before the heating.

3.5 Eyewear terminology

Even if eyewear is a very common object and used every day by millions of people, most of them usually do not need to know all the name of the parts that compose it.

For this study is helpful to distinguish different parts.

Figure 27 Glasses' parts

1- Rims: hold lenses in their right positions and characterize the most your frame; depending in the material, customized lenses can have a different thickness: plastic frame can hold thicker lenses with respect to metal one, that can support thinner one;
2- End pieces: connect the rims with the temples; they enlarge the frame in order to have a better fit;

3- Bridge: it connects the two rims, it is central in the frame and remains on wearers nose; it can have different shapes: keyhole bridge, that lighten the frame, saddle, if the frame is heavier, double bridge, more resistant;
4- Hinges: they connect frame and temples, allowing closure of temples by folding them inward, in order to be stored in their appropriate case; frames can have a traditional, or regular, hinge, but there are special hinges called flex (or spring loaded) that allow an extra external movement to fit better;
5- Lenses: they are the most important part of the eyewear; they correct visual defect by deflecting images or protect from sun glare if the filter is darkened; they are usually made of plastic, sometimes of glass, for safety reasons, plastic resist better to shocks avoiding damages to wearer's eyes;
6- Screws: they fasten hinges and, in case of metal rims, close the rims to hold lenses; they are of metal material and usually have a rubber gasket to reduce unscrewing;
7- Nose pads: 90% of eyewear weight is supported by the part under the bridge, nose pads keep glasses comfortable while holding them in position; they can be made in silicone or metal: silicone ones give a better comfort while metal are more fashionable;
8- Pad arms: they allow nose pads to be adjusted to fit better with wearer's face; they are not always present, for example if they are moulded in the frame, for acetate usually;
9- Temples: they are the "arms" of the frame that fit over wearer's ears; they are on the sides of the frame; their end is called tip, usually made of plastic to ensure plastic and it is bent to avoid glasses falling off.

4 Third part: analysis on frame deformation test

This test, that is required both for personal protective equipment and medical devices, serves to guarantee a safety object to the wearer; in fact, it stresses in particular two parts of the eyewear that should resist to everyday use:

- Lens retention: it tests if the rims of the eyewear are strong enough to retain lenses when a force is applied; the groove that hold the lens should be deep enough and, in case the rim is closed with a screw, the screw should not unscrew and release the lens;
- Bridge deformation: the weakest part of a front of a frame is the bridge; it should guarantee not to crack during this test and when the force is removed to return to the same displacement that the frame had at the beginning of the test.

This test simulates everyday use, because in using eyewear even simple acts, that no one pat attention on, it is normal to bend it: when you clean lenses, when you remove eyewear with just one hand, when glasses are stored in soft cases and put in bags or backpack.

Having glasses that maintain always their displacement is very important: if the lenses are no more in their right position, the non-coplanarity of the lenses creates a discomfort in the wearer, due to the fact that right and left eye receive different information (especially if the lens has gradient filter, so the colour is darker on the top and brighter on the bottom); this effect is magnified if the glasses have graduated lenses and so the focus point is changed.

That’s why during project phase is very important to know how to sizing in the right way all the part of the glasses in order to satisfy Standards; being a fashion object, in every factory that produce and commercialize eyewear, the design part is developed by designer, that create shapes and use different material according to marketing instruction and their own aesthetic.

During this part is very important to have technicians that support the designers in order to prevent future failure or failure to tests, that are mandatory for commercialize glasses.

Project development consist in different phases:

- Marketing strategy: marketing is the interface between factory and client; they research and elaborate market opportunity, study market sector where sell the product and identify client expectations
- Design of the glasses: when guidelines are defined, designers start projecting shapes, colours, dimensions… of future collections, using CAD software;
- Test on samples: when the design is settled, the drawings are analysed by technicians that will prepare samples with simple technologies to show the final aspect; this is the first time that the final object can be seen and touched; this phase is more focused on aesthetic, not on structural properties, because glasses are handmade; if they are approved, factory starts building up all the technologies to construct the final object (mould, extrusion die, press,…); only when the final production system is finished, the first glasses with the characteristics of the product that will be commercialized can be done; if some details were neglected, some defects should emerge;
- Start of production: when all the details are defined, the production can start.

According to this development process, the sooner a possible defect is detected, the cheaper and the faster it is for the factory to solve the problem.

It is due to the fact that if a problem is discovered during a certain phase, the project team have to change all the previous steps and, for example, a mould has been already constructed, modifications are slow and expensive.

That’s why I decided to develop an easy tool to dimension the bridge to help designer during project phase.

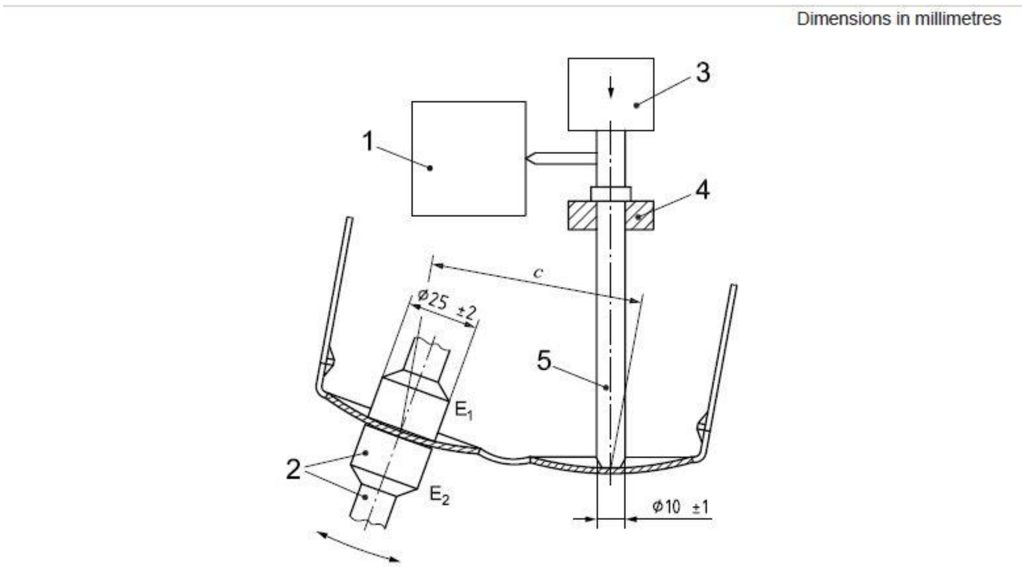
4.1 Test description

The test consists in applying a force through a pressure-peg that act on a lens and a holding device that clamp the other lens. The apparatus consists in:

- a measuring device that have to measure the movement of the pressure peg, with an accuracy at least of 0.1mm;
- an annular clamp that have to block one lens, it should avoid any slip or twist of the sample and it should have a diameter of 25mm with uncertainty of 2mm; the material of the two

surfaces that clamp the object are made of firm elastic material in order to adapt to the surface that is not flat;

- a pressure-peg that operate in downward direction should provide a maximum force of 5N and have a diameter of 10mm with 1mm of uncertainty; it has a hemispherical contact surface.



Key
1 measuring device
2 annular clamp
3 direction and point of application of force (maximum 5 N)
4 travelling ring
5 pressure peg

Figure 28 Scheme of frame deformation and filter retention test

The distance between clamping device and pressure-peg could be adjusted according to the frames that are tested; in fact, the distance between the clamping system and the pressure-peg is standardised by ISO 8624; in fact, the distance "c", also called boxed centre distance, that separate the two devices is defined as:

$$c = \frac{a}{2} + d + \frac{a}{2}$$

With "a" the dimension of the lenses and "d" the distance between them.

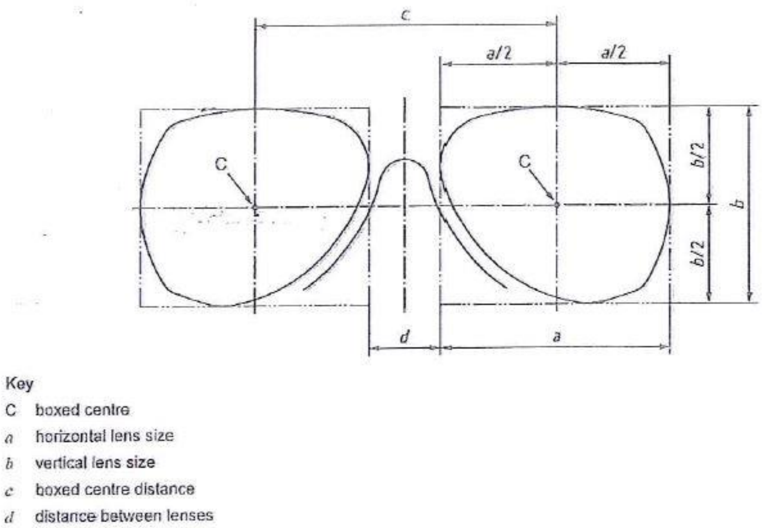


Figure 29 Reference points for filters (frontal view)

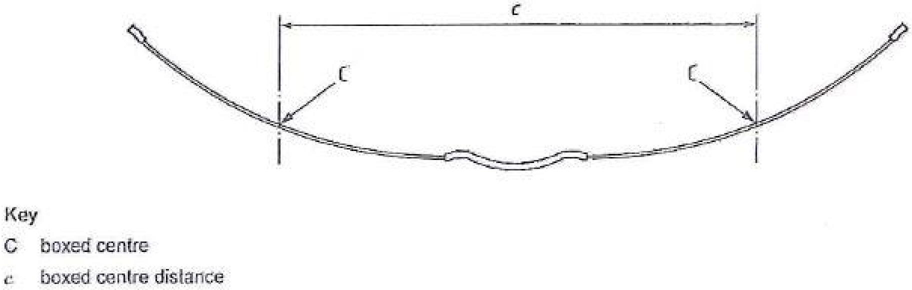


Figure 30 reference points for filters (top view)

The test consists in applying a force of 5 N by the pressure peg for a period of 5 seconds and then removing it and check that there are no cracks on the frame and that lenses have not been dislodged from their original location in the groove or mount.

The deformation of the front is evaluated as the ratio between the movement of the pressure-peg and the boxed centre distance multiplied by 100 to have a result in percentage.

In this test the loaded lens is the right lens and the clamped lens is the left one (right and left are determined watching the frame from the point of view of the wearer).

4.2 Bridge with rectangular section

The analysis of this test starts from the need to have an easy device to easily understand if the frame that designers are projecting will pass it; in order to do that the analysis was divided into two parts: the first was to study the behaviour of a frame with a Finite Element Model simulator, Hypermesh, it consists of evaluating the stresses inside an object by applying the right boundary conditions and forces; while the second was to study the frame according to the beam theory outlining the frame as two plates connected by a beam.

The final step will be the comparison between the results of the two analysis in order to find a possible correlation.

4.2.1 FEM model

As a first step, it was developed a FEM model to simulate the behaviour of the test.

A very simple shape eyewear was used to do it, designed with Solidworks software; the simplicity of the model allows to go in deeper study of the test and to change easily dimension of the rims and of the bridge in order to compare them before applying to the reality.

The first sample developed had rectangular rims with a bridge that can be represent as a beam with rectangular section.

Lenses are made starting by a sphere, so rims should follow that shape; base of the lens define its radius: typical bases are even number between zero and 8 (base 0, base 2, base 4…) and the radius is defined as the following formula:

$$radius = \frac{523}{base}[mm]$$

In the next figure you can see the drawing of the sample designed with base 2 rims.

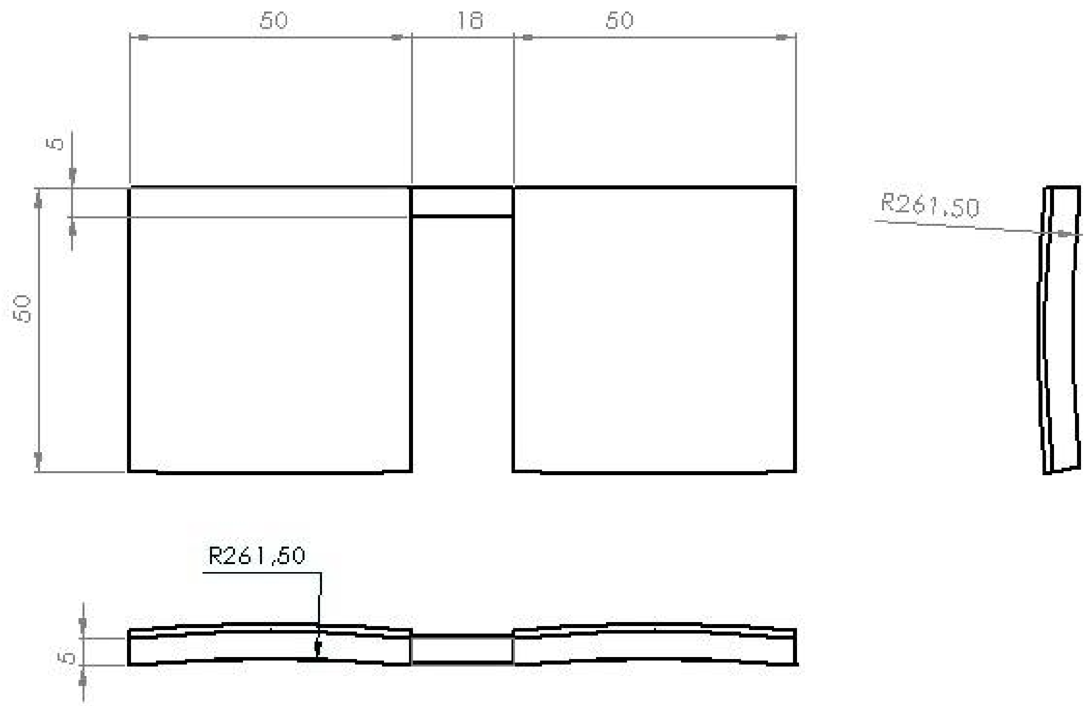


Figure 31 Scheme of the eyewear for FEM model

For a lens that should not have any optical power, external radius and internal radius of the lens should be the same; base 2 and 4 are the most used for everyday glasses; for sport eyewear, usually it is used base 8 because it is needed to protect eyes from lateral glare or wind in order to not compromise the sport competition; while the trend of the front is up to the designer (it could be flat, common glasses, or it can envelop along the face, for example as masks for sport, for the same reasons as before).

Temples are not represented in the model because they do not interfere with this kind of test and so they can be eliminated from the sketch.

According to the test, on the right lens was applied a boundary condition, while on the left lens it was applied a force of 5N perpendicular to the lens.

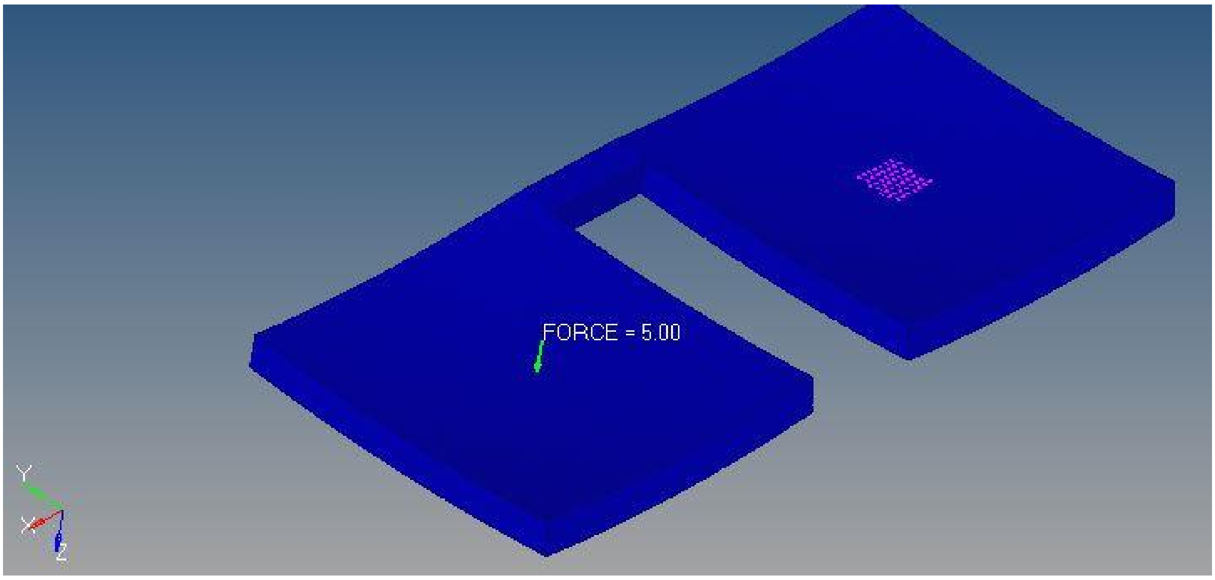


Figure 32 Force application to FEM model

A first results of the test showed that the bridge is the most solicited part and, in particular, the two sections connected with the rims, where it can be seen a peak of stress.

Figures 33, 34 and 35 show stresses according to Von Mises model.

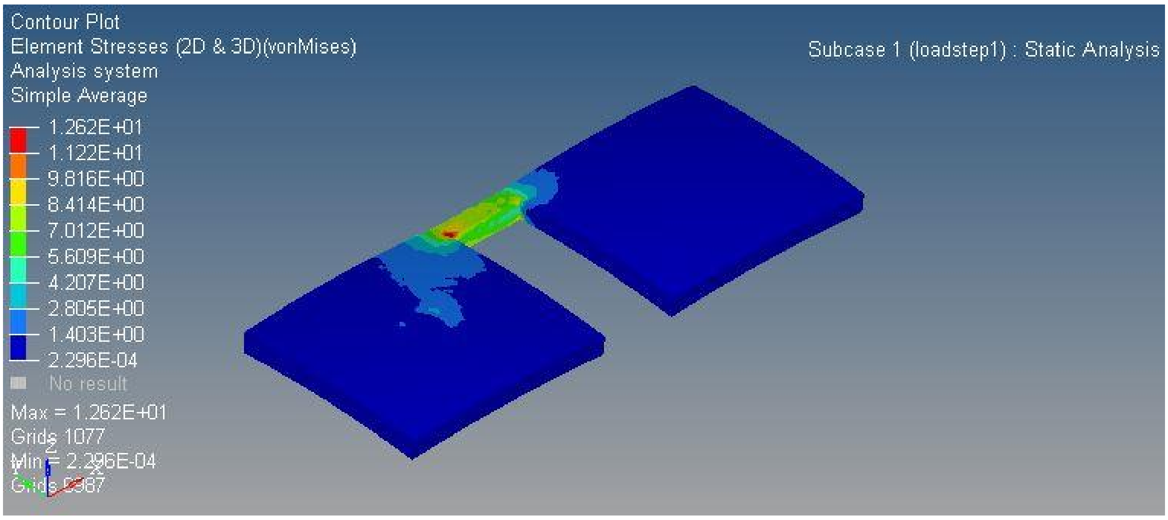


Figure 33 Stresses on the frame according to Von Mises model

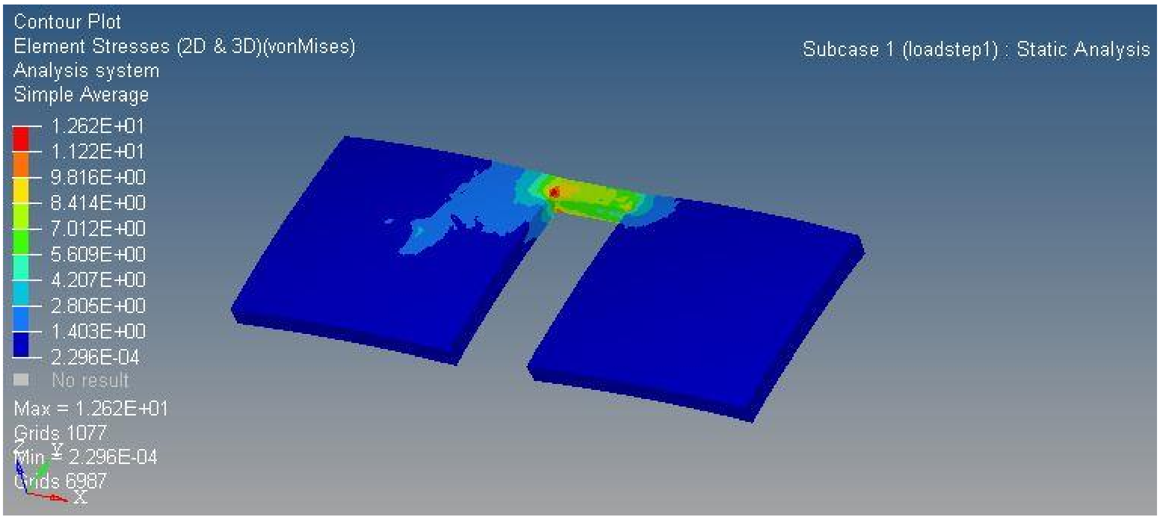


Figure 34 Stresses according to Von Mises model

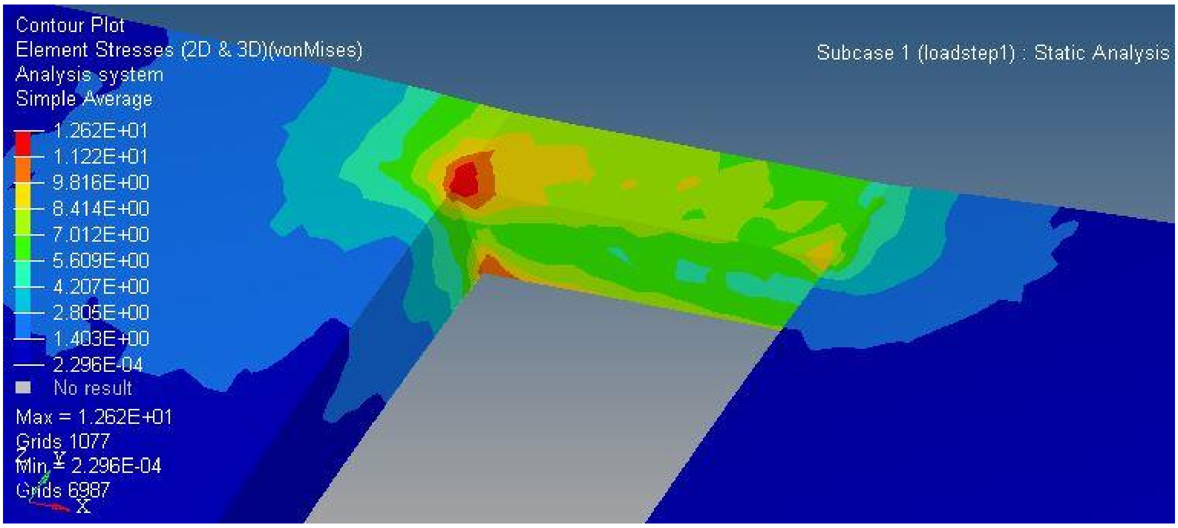


Figure 35 Detail of stresses according to Von Mises model

While fidure 36 show stresses according to Tresca model.

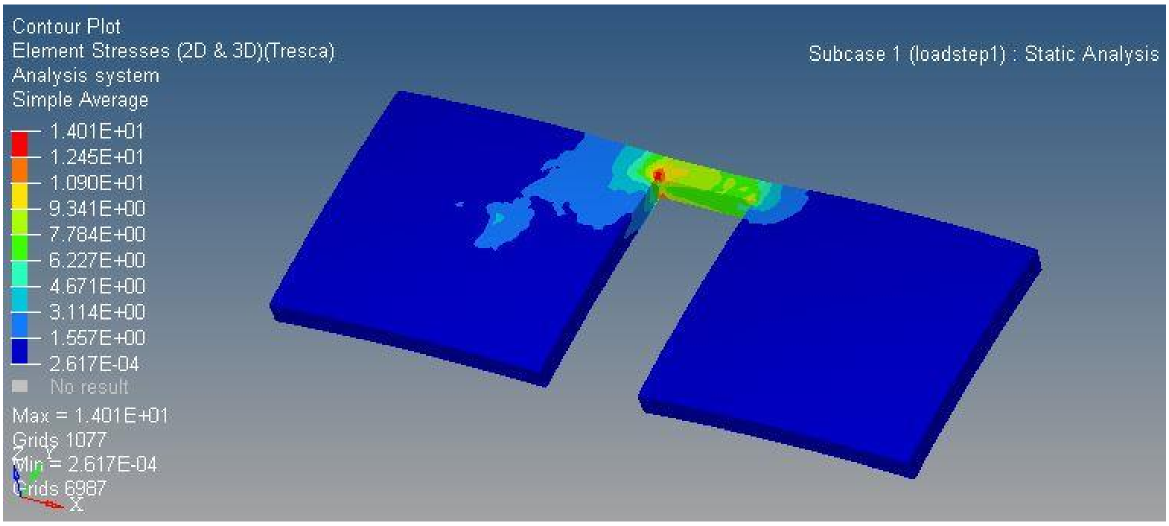


Figure 36 Stresses according to Tresca model

And the shear is showed in figure 37.

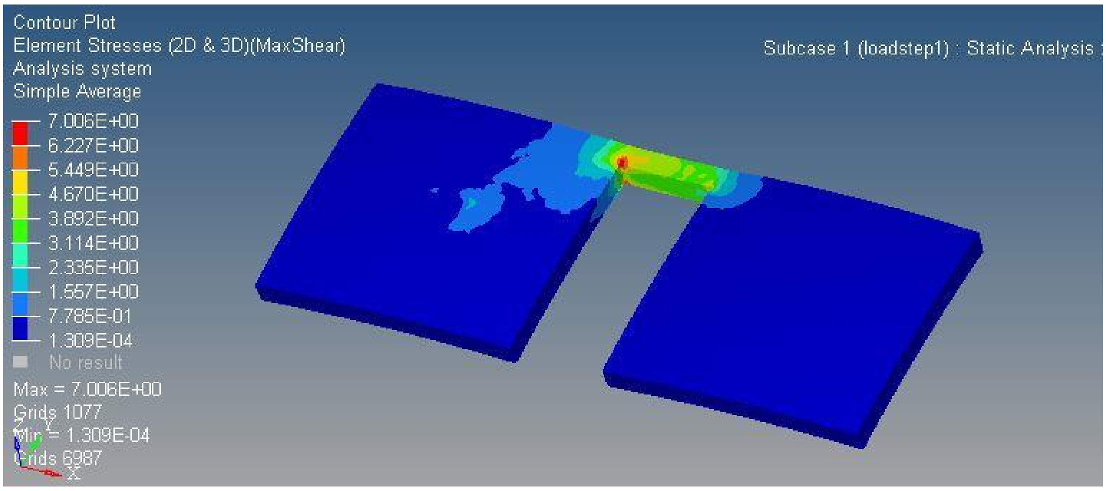


Figure 37 Shear stresses

Studying in detail results of FEM simulation, it is easy to see that the most solicitated section of the eyewear is the junction between the bridge and the right rim (the one clamped). A cross cut of the section shows in detail the stresses that affect the part.

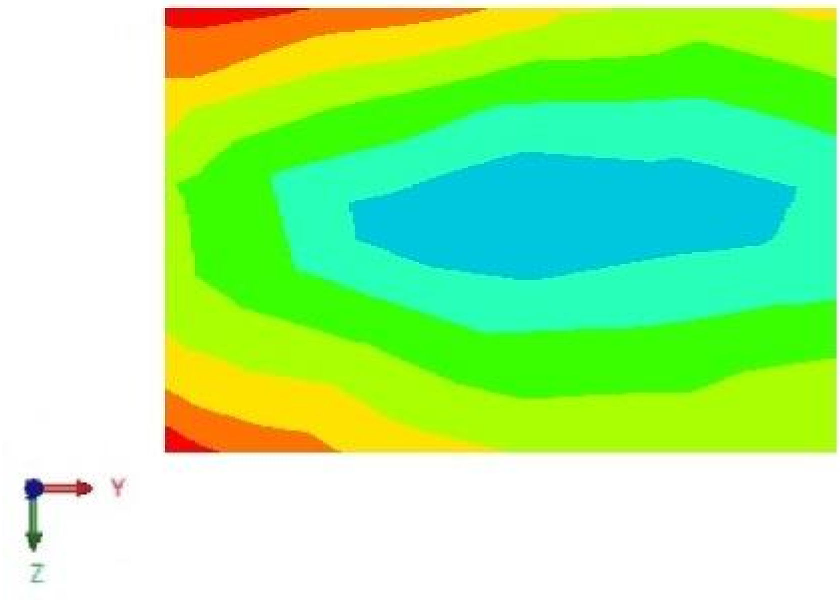


Figure 38 Most stresses section detail

According to the axis, the top of the section is the part of the bridge in front of the eyewear, while the rightest part is the part of the bridge that is closer to the nose of the wearer.

In order to study in detail the stress trend and to have an easier view of the section, it was selected on the most solicited section 8 points where to record the value of the stress.

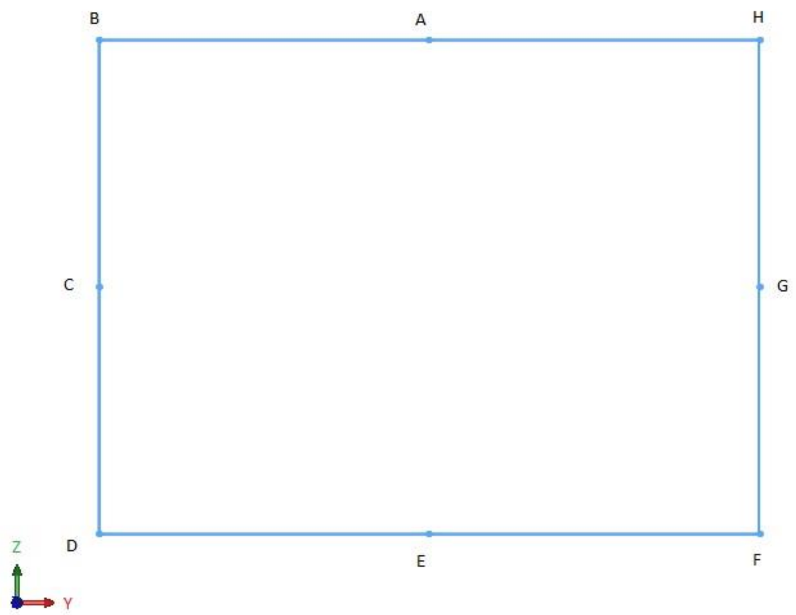


Figure 39 Section's most relevant points

The points B and D are the most solicitated; another detail of this section is that the most solicitated edge is the BH edge, that correspond to the part of the eyewear were the force is applied; finally, we can notice that the inner part of the beam is almost unstressed.

This was a preliminary study of the phenomenon that appears in a frame, but in order to develop an easy model, all the variables that could be done in projecting phase were studied to find a possible correlation between them and the stresses that are caused by this test.

All the following tests are performed maintaining the bridge dimension always constant and varying one at a time the variable considered.

The comparison between the variables are made comparing points on the most solicitated edge, so point B, A and H.

Lens radius:

The first step was to analyse the behaviour of the stress when the base of the lenses was changed, maintaining a flat bridge.

The radius of the sphere was changed according to previous formula and it vary from a rim with lens radius of 523mm, so almost flat, to a rim with radius 65.375 mm, always maintaining a rim dimension 50x50 mm. the figure shows the changing of the lens with respect to the base viewed on the top plane.

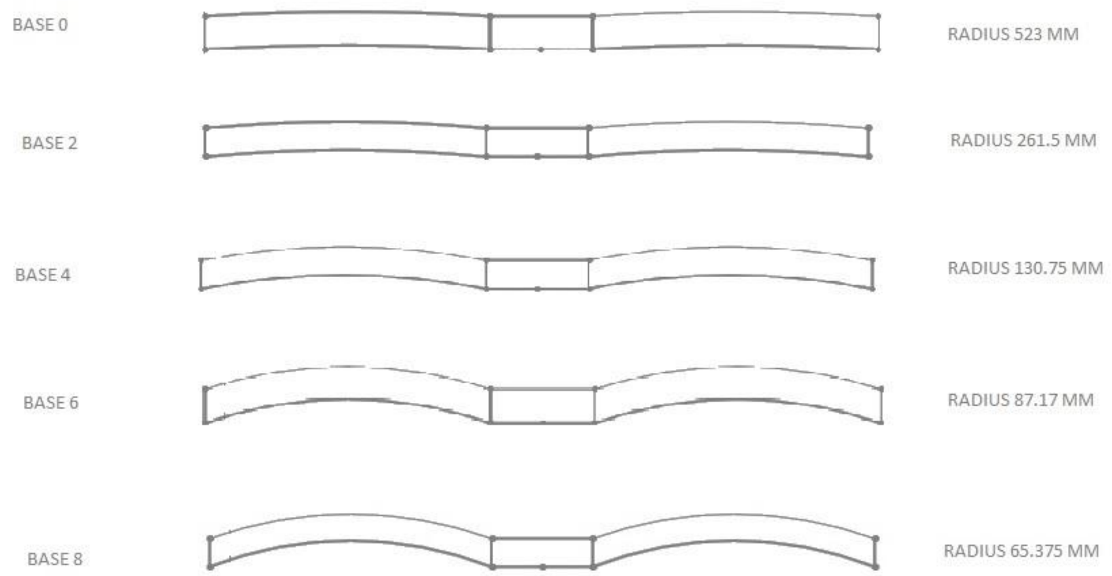


Figure 40 Different lens radius

The result showed in the next table are evaluated with a bridge with square cross section and dimensions of 5 mm of height, 5 mm of width and 18 mm length. They show that the stresses evaluated in the same points have comparable values, they float around the mean value of 6%; decreasing the dimension of the bridge, the stresses increase and the difference between values decrease in percentage; the conclusion is that the base lens do not interfere with the stresses in the bridge.

LENS BASE	MAXIMUM STRESS [Mpa]		
	POINT B	POINT A	POINT H
0	12,2	10	7
2	12,6	9,8	7,2
4	13	9,6	6,9
6	13,5	9,5	7
8	13,7	9,3	7,6

Frame radius:

The same study was made to see the stress trend if also the bridge had a curvature, always according to the base lens dimension.

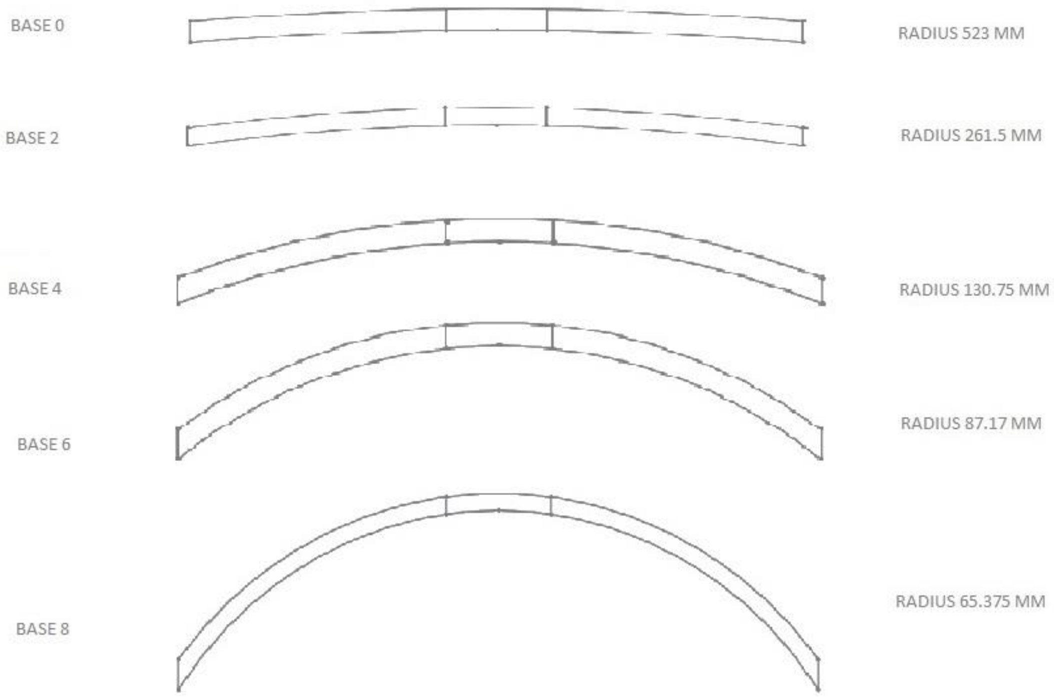


Figure 41 Different frame radius

The result, as before, show little changes in stress in the bridge and so for the sample it needs only one shape.

LENS BASE	MAXIMUM STRESS [Mpa]		
	POINT B	POINT A	POINT H
0	13	9,6	7
2	13,5	9,8	7,2
4	13,7	10	6,9
6	13,9	10,3	7
8	14,5	10,6	7,6

Bridge shape:

Another variable analysed was in changing the shape of the bridge, like making it bend in frontal direction or in vertical one.

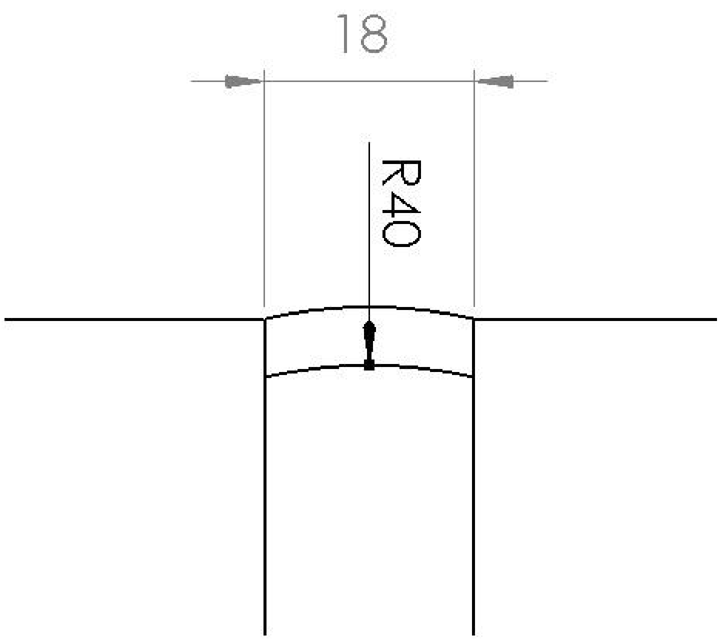


Figure 42 Frontal view of bridge displacement

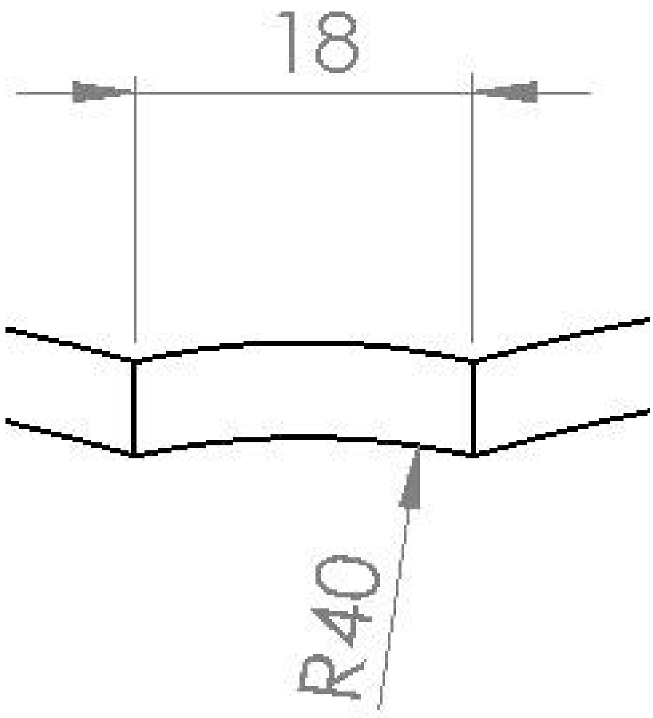


Figure 43 Top view of bridge displacement

The results shows that increasing the deflection of the bridge (keeping the distance between rims equal) stresses decreases of 5% in the edges of the bridge that different from 90°, while the other remains almost constant; having an edge different from 90° in the bridge creates a fillet radius between bridge and rims and this decreases the local stresses; so we can assert that, to be on the safe side, stresses do not change if the shape of the bridge is different from linear one.

Bridge position:

This time the test performed was done comparing results obtained by varying the position of the bridge with respect to the rims, using the standardized point of application of the force and the bond, with results of a “standard” sample where the point of application of the force and the bond had the same distance with respect to the bridge of the previous glasses.

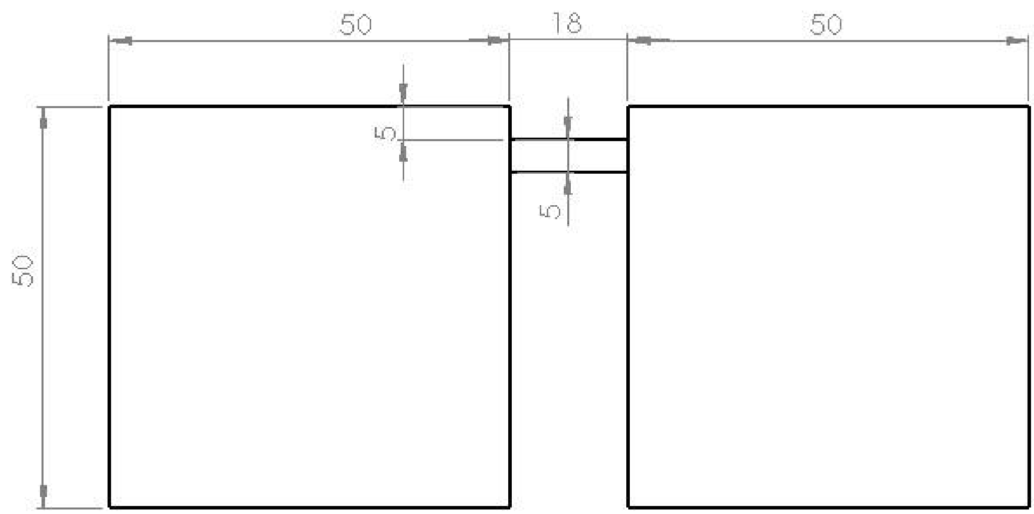


Figure 44 Lower position of the bridge in a frame

The maximum stress of the configuration of the frame with bridge position different from the top one is the same of a configuration with same distance of force and clamp with respect to the bridge; it increases stresses on the edges on the top of the bridge, because it creates a right angle that create a local stress increase.

Frame material:

Last, but no less important, is the behaviour of the frame changing material. The most used materials today are plastic (acetate, Grilamid, injected plastic…) and metal (stainless steel).

With FEM simulation is very easy to simulate the different behaviour of materials, just specifying the main characteristics (Young modulus and Poisson's ratio) and the results show the different behaviour; stresses of frames with same dimensions are comparable, in general plastic have a lower maximum value, but the biggest difference in the two materials is the deformation: in fact the deformation evaluated in the point of force application show a trend of the plastic to have a deformation 10 times bigger then metal one.

In conclusion, this FEM simulation helps in finding the real stresses that occurs during the frame deformation test and it is has demonstrate that these stresses are just function of the dimension of the bridge and the position of the forces. All other variables (lens shape, frame shape, bridge position, frame material) do not affect in a remarkable way, so the simplest model can be accepted as a good representation of the reality.

4.2.2 Beam model

In parallel, it was developed a case that analyse the problem according to beam theory: the most important part to analyse is the bridge, because it is the part that have the higher stresses; the model developed consider the bridge as a beam, constrained on one side and loaded on the other side.

The scheme used to represent the glasses is very simple and can be seen as 2 plate (one constrained and one loaded) connected by a bar; the force, according to the convention is along Z direction.

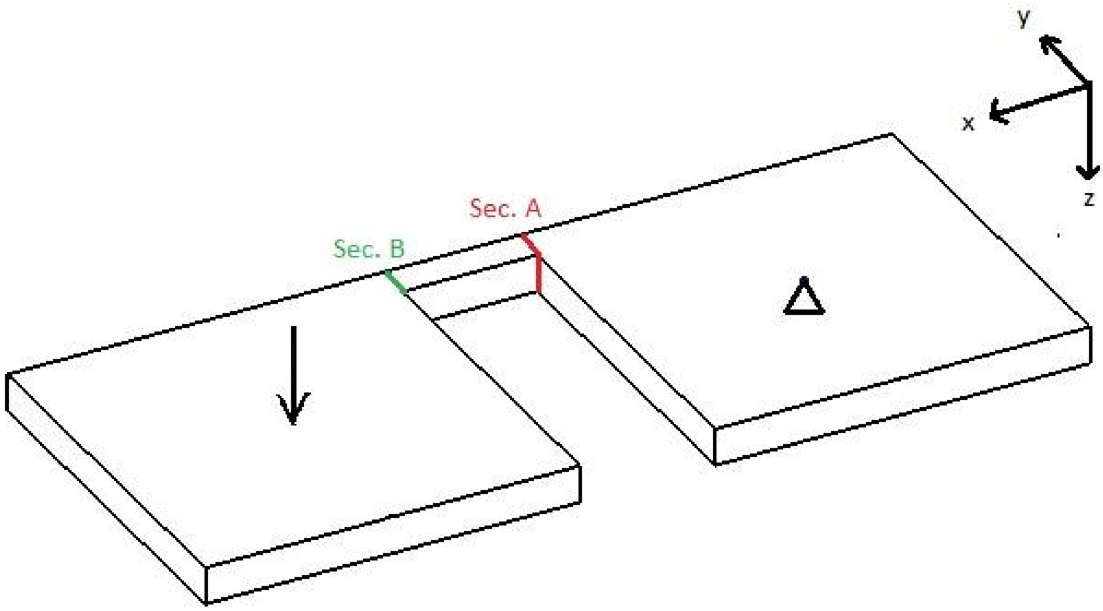


Figure 45 Frame model for beam theory

The distance between the bridge and the force is standardized by Standards, as seen for FEM model.

The bridge can be schematized by a bar with length L and section H*S; A-A is the hinged section while B-B is the free end section.

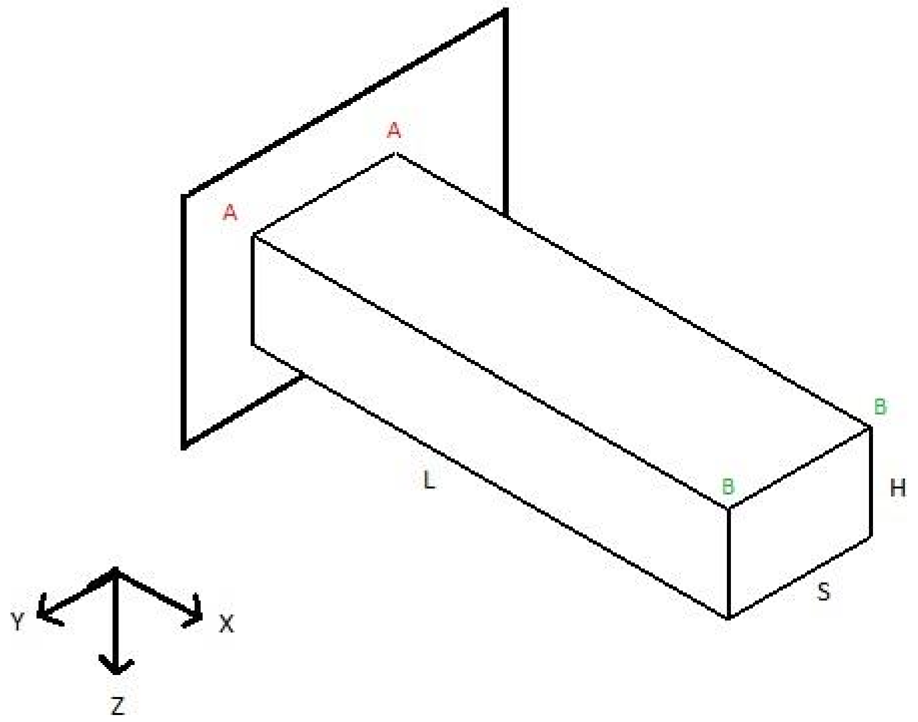


Figure 46 Bridge scheme

According to beam theory, the bridge is loaded by a concentrated force applied distant in X and Y direction with respect to the end of the beam; so by translation of the force it emerge that the beam is loaded by a concentrated force equal to the one that load the lens plus a bending moment that is obtained by multiplying the force by the distance in x direction and a torsion moment (or a torque) obtained by multiplying the force by the distance in y direction.

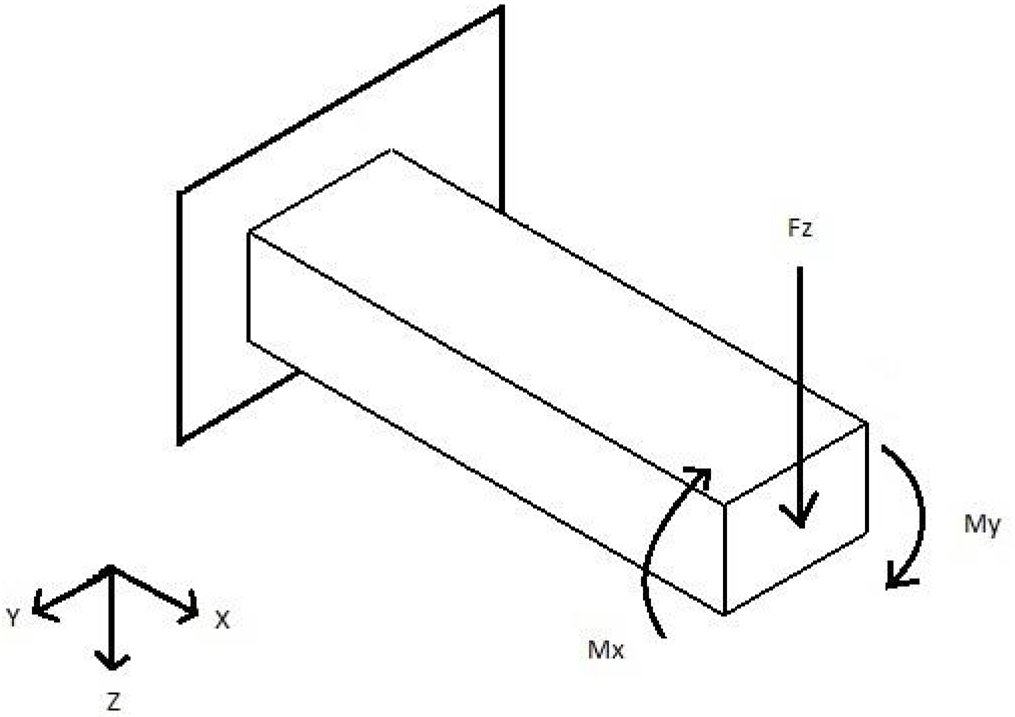


Figure 47 Resultant force on bridge

$$\begin{cases} F_z = 5[N] \\ M_y = F_z * \frac{a}{2}[N * m] \\ M_x = F_z * \frac{b}{2}[N * m] \end{cases}$$

“a” and “b” are the values evaluated according to ISO 8624.

According to these loads, on the beam we will have stresses due to cutting forces T, bending moment Mb and torque Mt; the bending moment will produce σ stresses, while cutting forces and torque will produce τ stresses.

$$\begin{cases} N = 0[N] \\ T = F_z[N] \\ M_b = M_y + F_z * (L - x)[N * m] \\ M_t = M_x[N * m] \end{cases}$$

With “x” the distance of the section with respect to the hinged part.

According to these formulas, the most solicitated section is the A-A section, the hinged one because it has the higher bending moment, while all the other stresses are constant along the bar.

Trends of the loads are described in the following figures.

Figure 48 Cutting force trend along the bridge

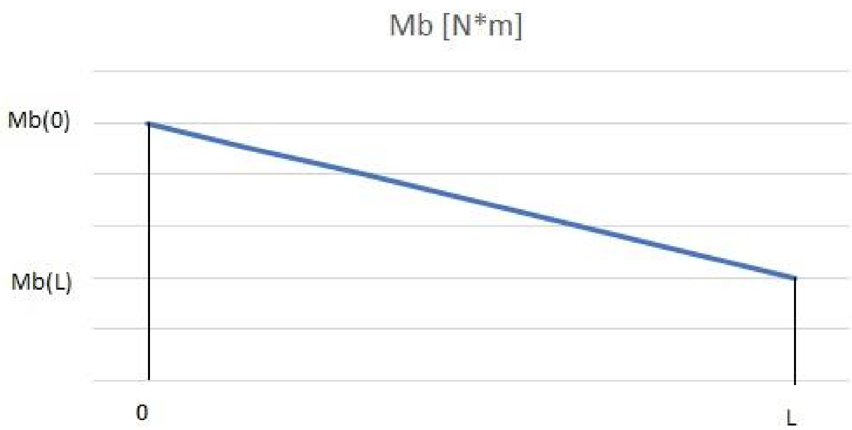


Figure 49 Bending moment trend along the bridge

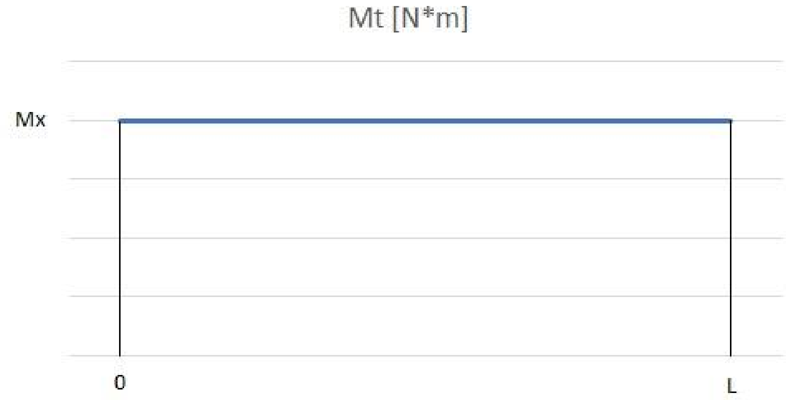


Figure 50 Rotational moment trend along the bridge

Once evaluated the loads on each section, we can evaluate the stresses:

$$\begin{cases} \sigma_x = -\dfrac{M_b}{J} * z[MPa] \\ \tau_{torsion_{MAX}} = \left(3 + 1.8 * \dfrac{H}{S}\right) * \dfrac{M_t}{S * H^2} [MPa] \\ \tau_{cut} = \dfrac{F_z}{2 * J} * \left(\dfrac{H^2}{2} - z^2\right) [MPa] \end{cases}$$

With J the moment of inertia and "z" the distance in z direction from the centre of gravity of the section.

$$J = \frac{S * H^3}{12} [m^4] \quad (for\ rectangular\ section)$$

As for FEM model, some points of section A-A have been detected were to evaluate the stresses.

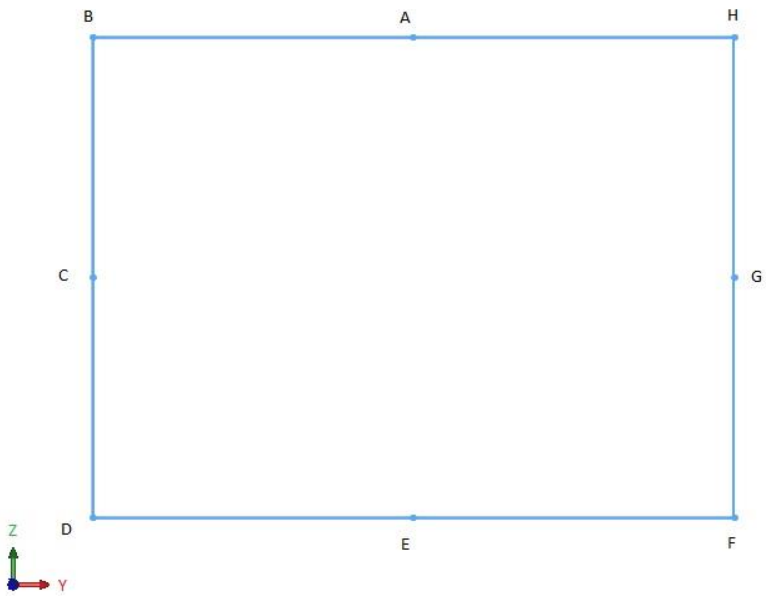


Figure 51 Section's most relevant points

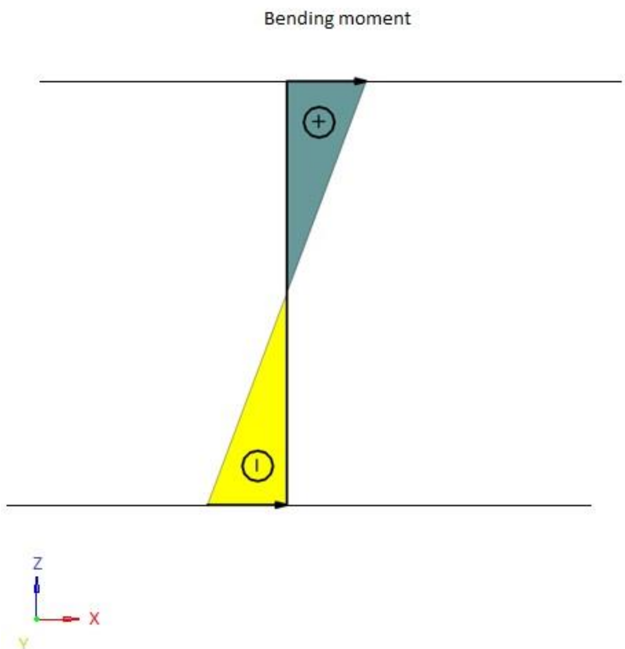


Figure 52 Sigma due to bending moment

Sigma due to the pure bending moment are like in the figure and they are constant along y direction and x direction. Then bending moment due to force F in Z direction, increases stresses along the x direction, with the maximum at the bounded section.

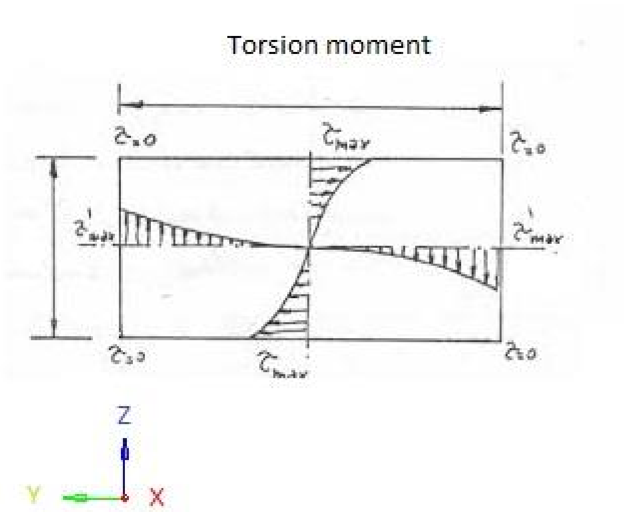


Figure 53 Tau due to torsion moment

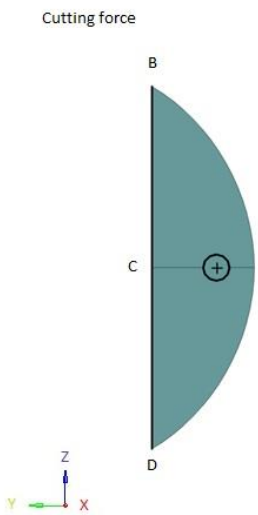


Figure 54 Tau due to cutting forces

Tau due to torsion moment are constant along x direction and maximum in point A and E; while tau due to cutting moment are maximum on point C and G and constant along Y direction.

And the resultant stresses are the following, evaluated for a beam 18mm long, 2.5mm high and 5mm width.

Known the sigma and tau in each point, the equivalent stresses can be evaluated as:

$$\sigma_{1,3} = \frac{\sigma}{2} \pm \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_{eq,Von\,Mises} = \frac{1}{\sqrt{2}} * ((\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_3 - \sigma_2)^2)$$

$$\sigma_{eq,Treasca} = \sigma_1 - \sigma_3$$

point A (traction)	sigma 1	26,1	Mpa
	sigma 3	-2,8	Mpa
	sigma eq Tresca	28,9	Mpa
	sigma eq Von Mises	27,6	Mpa
point B (traction)	sigma 1	23,3	Mpa
	sigma 3	0	Mpa
	sigma eq Tresca	23,3	Mpa
	sigma eq Von Mises	23,3	Mpa
point C	sigma 1	9,2	Mpa
	sigma 3	-9,2	Mpa
	sigma eq Tresca	18,4	Mpa
	sigma eq Von Mises	15,9	Mpa
point D (compression)	sigma 1	0	Mpa
	sigma 3	-23,3	Mpa
	sigma eq Tresca	23,3	Mpa
	sigma eq Von Mises	23,3	Mpa
point E (compression)	sigma 1	2,8	Mpa
	sigma 3	-26,1	Mpa
	sigma eq Tresca	28,9	Mpa
	sigma eq Von Mises	27,6	Mpa
point F (compression)	sigma 1	0	Mpa
	sigma 3	-23,3	Mpa
	sigma eq Tresca	23,3	Mpa
	sigma eq Von Mises	23,3	Mpa
point G	sigma 1	9,2	Mpa
	sigma 3	-9,2	Mpa
	sigma eq Tresca	18,4	Mpa
	sigma eq Von Mises	15,9	Mpa
point H (traction)	sigma 1	23,3	Mpa
	sigma 3	0	Mpa
	sigma eq Tresca	23,3	Mpa
	sigma eq Von Mises	23,3	Mpa

According to this result, the point A is the most solicitated according to beam theory, because it has the maximum equivalent stresses and they cause a traction, so if the beam will break, it will happen in that point.

4.2.3 Beam theory

According to structural mechanics, beam theory is a simplification of the linear elasticity theory for the analysis of the mechanical behaviour of beams. In particular, it is a simplification of the De Saint Venant problem, thanks to the fundamental hypothesis of conservation of the flat sections, according to which the sections are bound not to hunch out of their plane and therefore, I note the rotation angle of the section with respect to the axis of the beam, it is possible to know the displacements of each point of the known section the displacements of the average line.

The internal stresses are linked to the internal continuity constraint that acts at each section of the beam. This constraint requires that the two sections (right and left) in which the generic section S ideally divides the beam remain mating. Due to the principle of constraint reactions, this continuity constraint is expressed on the section by a punctual system of stresses (internal tensions) that the two parts of the body exchange with each other through the two faces of the section. The vectors of the resulting forces and the resulting moment of this punctual distribution define the stress characteristics of the beam in the considered section.

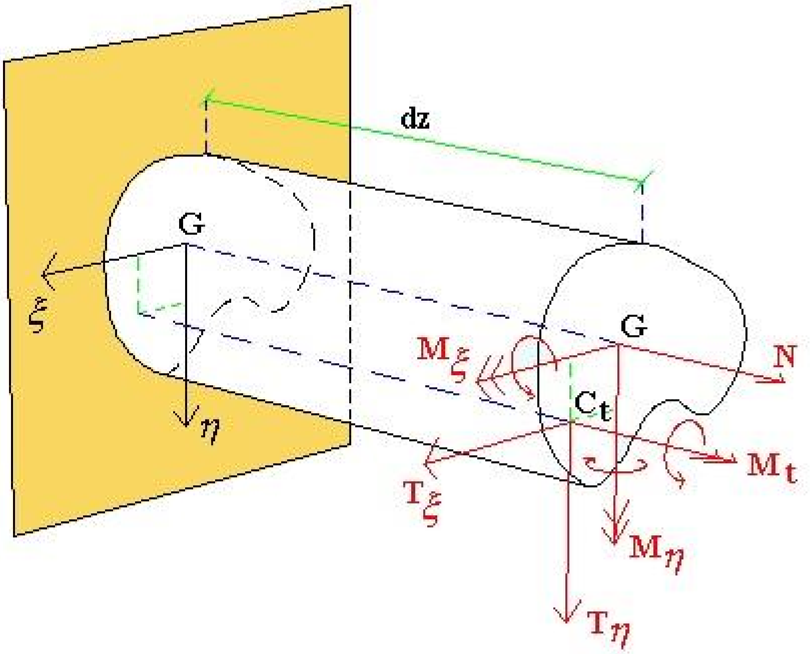


Figure 55 Beam theory

The relative components in a reference system (x, y, z) with axes (y, z) in the section plane and axis (x) normal to it, are:

- Normal stress N: resultant of forces along (x) axis
- Shear stress Ty or Tz: resultant of forces along (y) or (z) axis
- Bending moment Mb: resultant of moment around (x) axis
- Twisting moment My or Mz: resultant of moment around (y) or (z) axis

Normal stress (generally referred to as σ {sigma}) is an stress that acts perpendicular to a given surface. Like any effort, it is physically defined as a force per unit area, therefore it is measured with the same units of pressure, for example in Pascal (Pa) = N/m^2. In general, it is defined considering the component of the force perpendicular to the surface and dividing this value by the surface area.

This concept is intuitively easy to apply on flat surfaces (for example the face of a cube), since the direction perpendicular to these surfaces is uniquely identified over the entire surface area; in case the surface has instead a curvature in the space (for example the surface of a sphere), in every point we can define a different direction perpendicular to the considered surface. For non-flat surfaces, therefore, normal effort is necessarily defined in a precise manner, making use of the mathematical theory of limits.

The composition of more than one normal effort can result in:

- compression: when the forces are opposite and directed towards the inside of the material;
- traction: when the forces are opposite and directed towards the outside of the material.

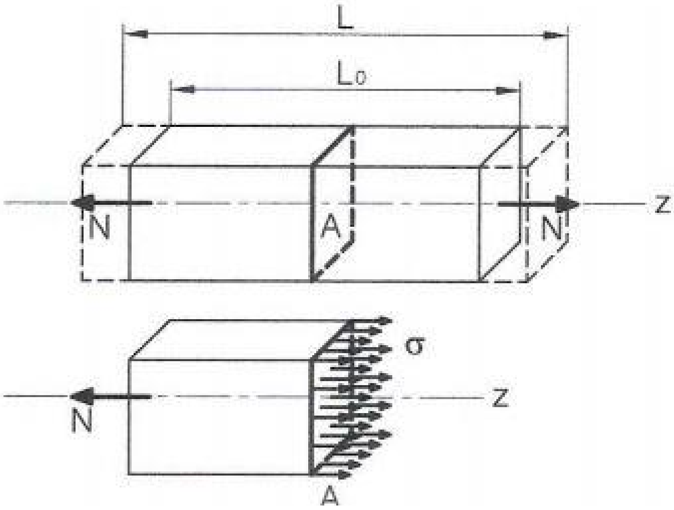


Figure 56 Normal stresses on a beam

Shear stress is an elemental stress which a body may be subjected to and is measured in Pascal [Pa]; it is indicate generally with letter τ.

The composition of shear stresses and normal stresses can give rise to bending, while the composition of more shear stresses can cause torsion.

In solid materials, shear stress is a state of tension in which the shape of a material tends to change (usually due to internal transverse sliding forces) without changes in volume (in the case of elastic-linear and isotropic materials). The change in shape is quantified by measuring the relative variation of the angle between the initially perpendicular sides of a differential element of the material (shear deformation). A simple definition of shear stress represents this as components of the tension at a point that acts parallel to the plane on which they lie.

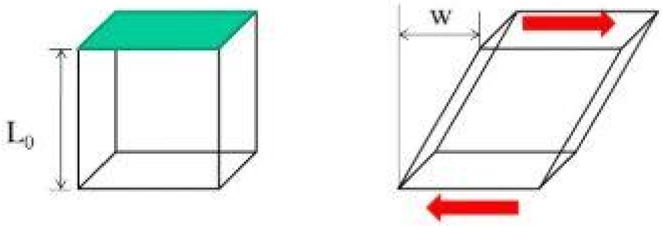


Figure 57 Shear stress on a beam

The bending moment is a pair of two force vectors, parallel and having opposite directions, having application points at a distance that is not zero.

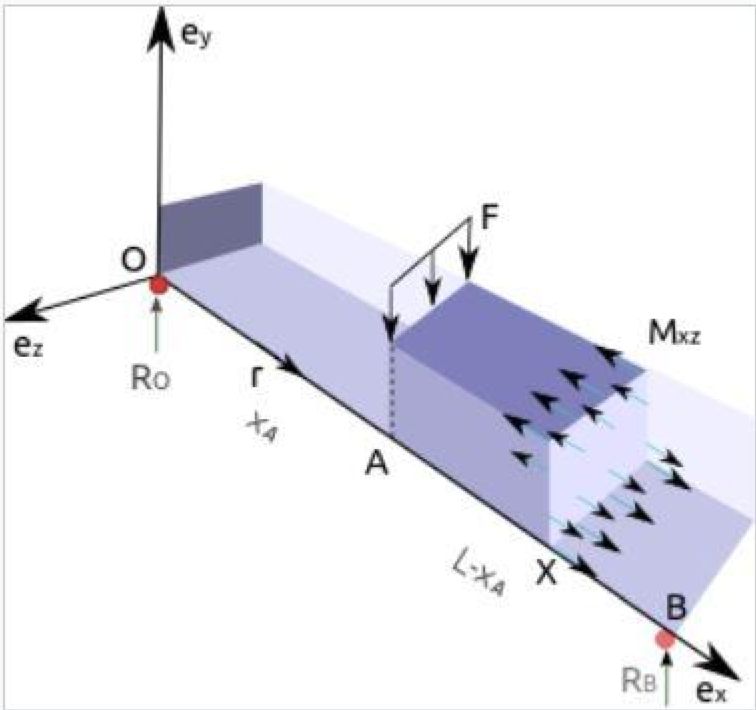


Figure 58 Stresses due to bending moment

In mechanics the twisting moment of a section is a pair of mechanical moments applied perpendicularly to two opposite faces with respect to any section. The stress it causes is called twisting. If there are no other types of stress, each of the two moments is a pair of forces, since it is equivalent to the application of two distinct and equal forces, each with a module equal to the ratio between the torque moment and the distance between their lines of action and acting on two points exactly opposite to its fulcrum.

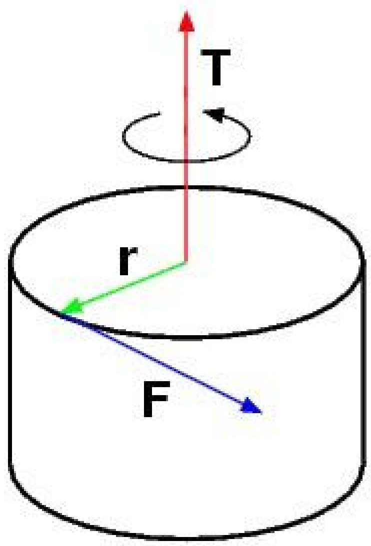


Figure 59 Torsional moment

4.2.4 Comparison of results

Once fully developed the two models, it is necessary to compare them in order to validate the theory that rules the behaviour of the glasses.

Analysing in detail the two methods, they indicate the same section as the most solicitated so the analysis is focalised on that part; they indicate the same edge as the most loaded, the one on the rear of the frame, but while the beam theory assert that the point A is the most loaded, the FEM model assert that is B point, so the stresses in these two points were compared: equivalent stresses of the beam theory and total stresses of the FEM model coincide in point A, they are comparable in term of dimensions, while on point B they are very different: in fact the FEM model indicate higher values on this point.

Analysing the behaviour of the stresses on B point, it is evident that in those points there is a phenomenon of intensification of stresses.

From theory, we know that in every structure, when is present a change in geometry there is an intensification of the stresses.

In order to understand the difference between the two theories, it was evaluated a parameter, Kt, that is defined as:

$$K_t = \frac{\sigma_{FEM}}{\sigma_{beam}}$$

This equation gives a relation and can be used for predicting stresses with different dimensions.

Dimension of rectangular bridge			FEM	Beam model	Kt
Hight [mm]	Width [mm]	Lenght [mm]	Sigma eq [MPa]	Sigma eq [MPa]	
10	2,5	18	32	24	1,33
10	5	18	9	6	1,50
5	2,5	18	63	47	1,34
2,5	2,5	18	115	93	1,24
5	5	18	17,5	12,3	1,42
10	5	15	8	5,5	1,45
5	7	15	8	6	1,33
5	1,5	15	170	125	1,36

The values of Kt flow around the value of 1,35 and it can used as a intensification factor of the stresses in the point B, that is the most solicitated.

In this way by using the beam theory, just evaluating the stresses in one point and applying the stress intensification factor, we can quickly know if the design is sufficient to pass the test: in fact, the frame should return to its initial displacement, so knowing the yield strength of the material, it is possible to predict the behaviour of the frame.

4.2.5 Analysis of intensification factor

The previous analysis highlights that there is an increasing of the stress in the junction of the bridge with the rims; in order to study it, it was developed a new model in FEM with a fillet radius in between the junction of the bridge and the rims.

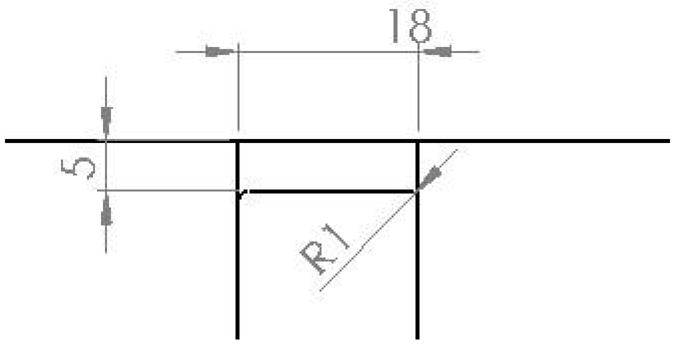


Figure 60 Fillet radius between bridge and rims

It is possible to see a trend of the stresses that is inversely proportional to the fillet radius; in fact the fillet radius decreases the local stresses and they tend to the beam theory model.

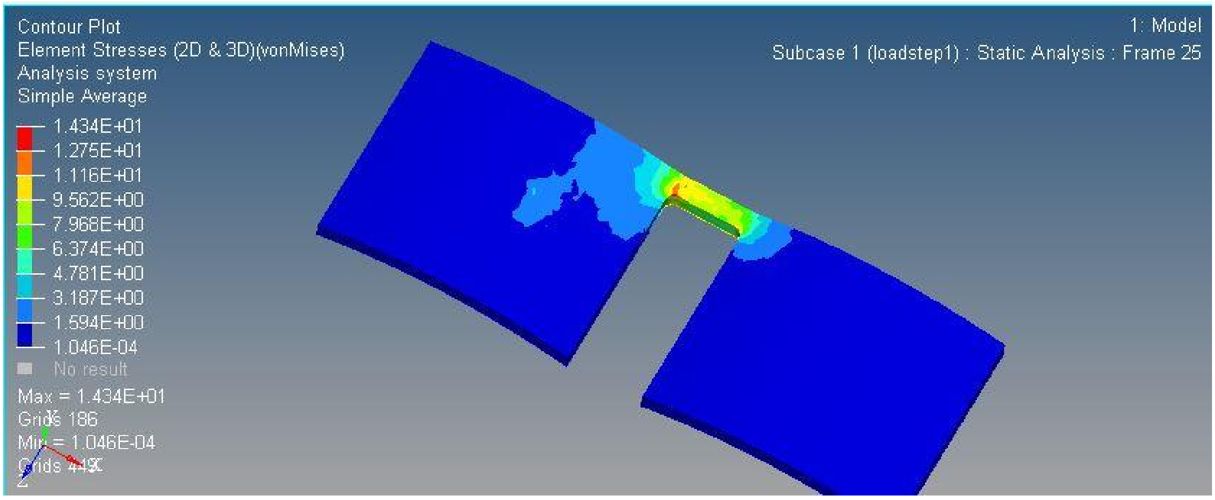


Figure 61 Stresses with FEM model with frame with fillet radius

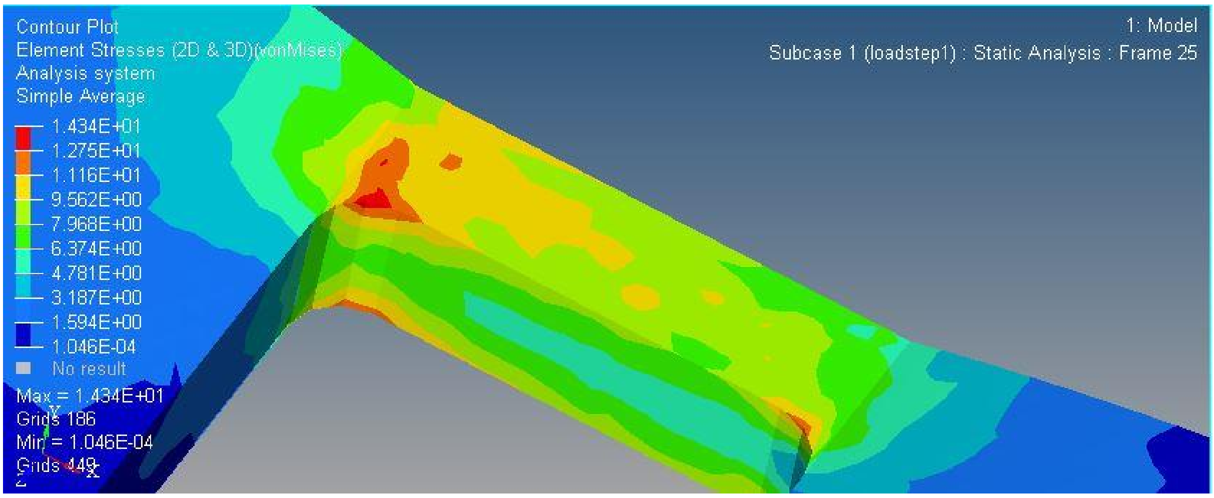


Figure 62 Deatil of stress on the fillet radius

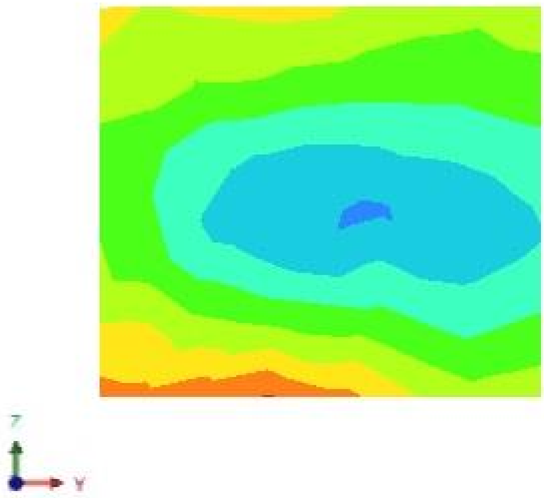


Figure 63 Most silicitated section detail of frame with fillet radius

As it is possible to see from the upper figure, the stresses in the lower edge is more constant along the edge, with no more a peak of stress in the D point, so increasing the fillet radius is decreases the maximum stress.

Fillet radius [mm]	Stress FEM [Mpa]	Stress beam model [Mpa]
0	124	93
0,5	122	93
1	119	93
1,5	118	93
2	118	93
4	110	93
6	108	93

As for the previous test, it is possible to find a correlation between fillet radius and the stress concentration factor; in fact, increasing the fillet radius maximum stress become closer to the one evaluated with beam theory. It was possible to find a correlation of Kt with the fillet radius, even if with a rough approximation.

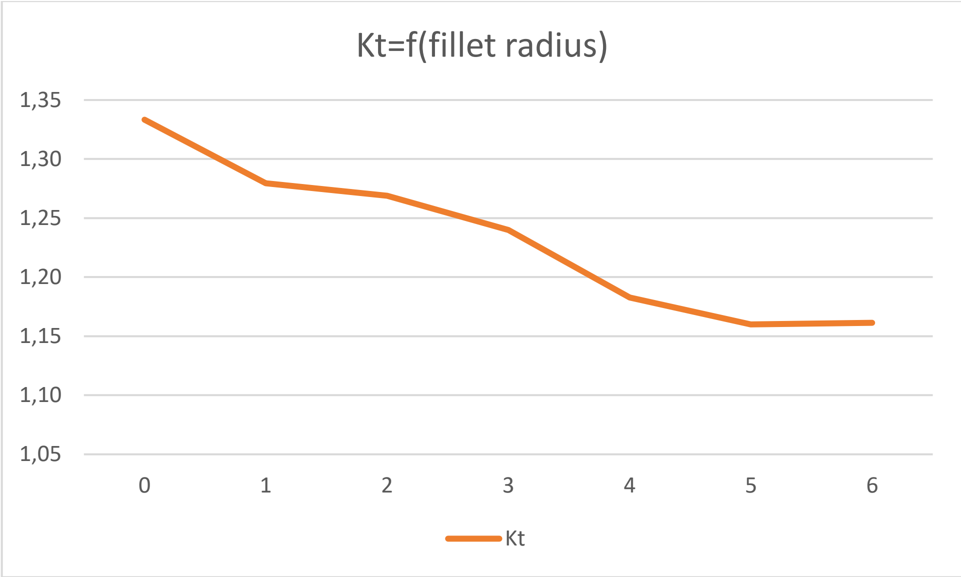


Figure 64 Stress concentration factor in function of the fillet radius

The second test to reduce the stresses was to increase the angle between the bridge and the rims; this modification helps also to have more ergonomic eyewear.

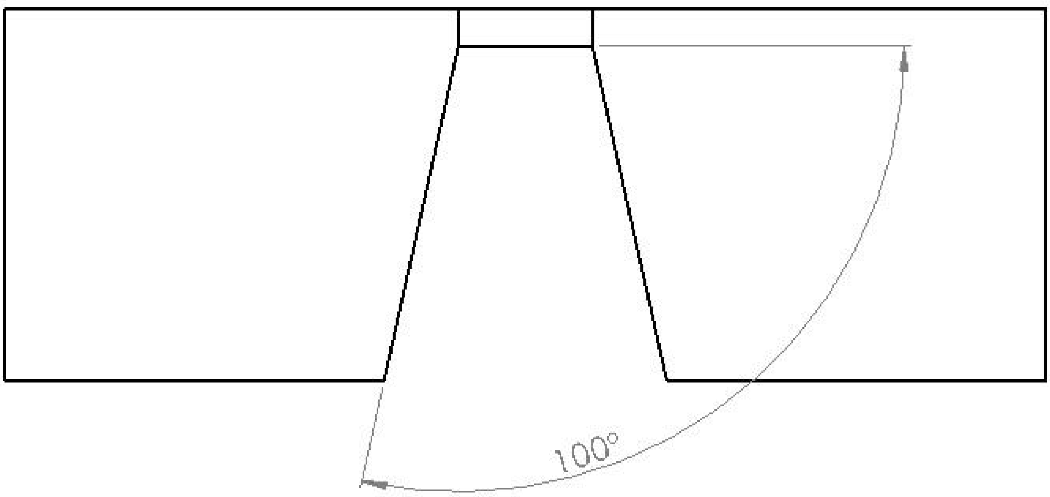


Figure 65 Frame with larger angle between rims and bridge

As it is possible to see in the next figures, the stresses are more constant also in this case.

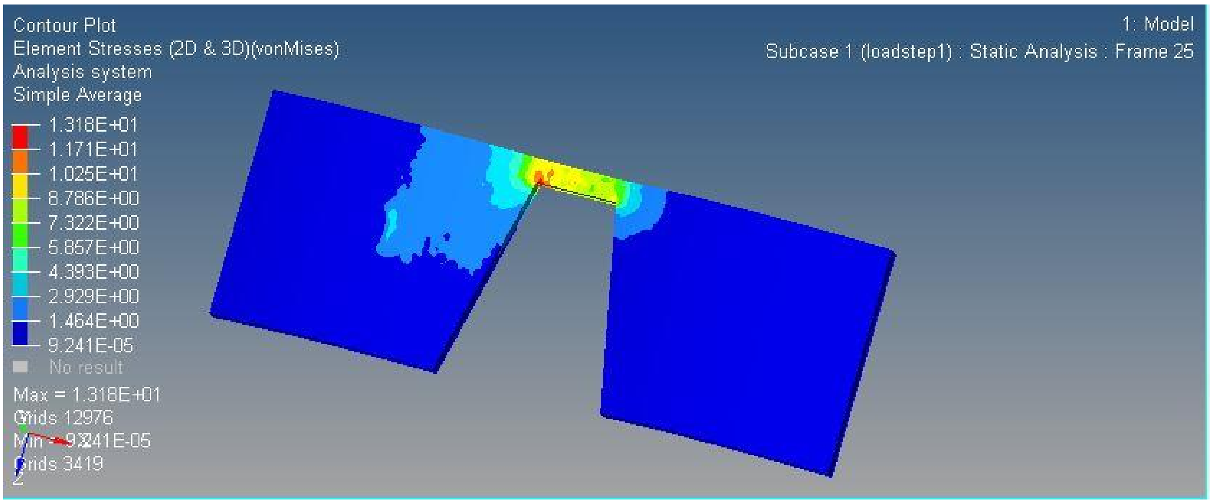


Figure 66 Stresses for FEM model with larger angle

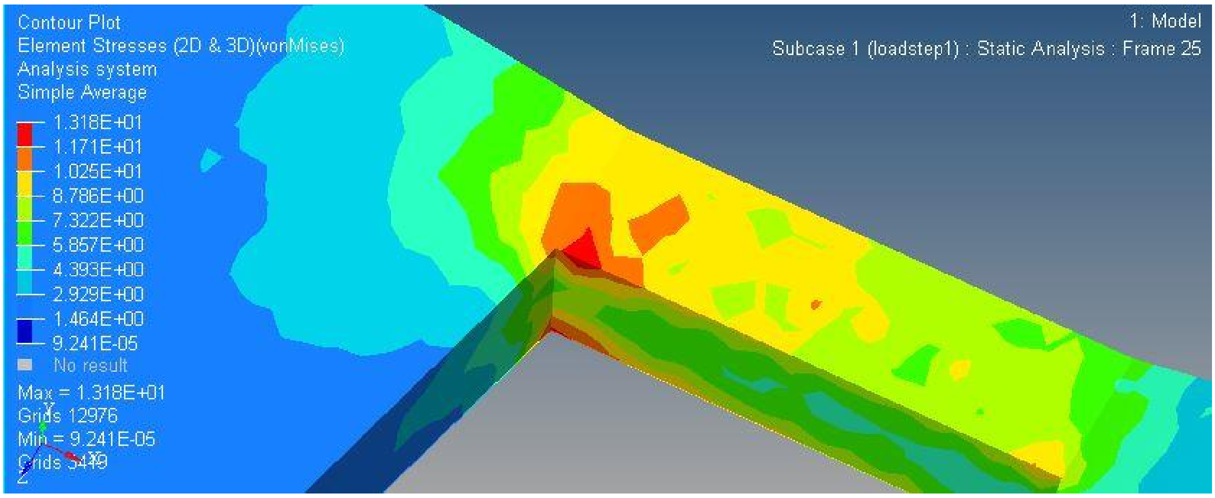


Figure 67 Close up to most solicitated section of frame with larger angle

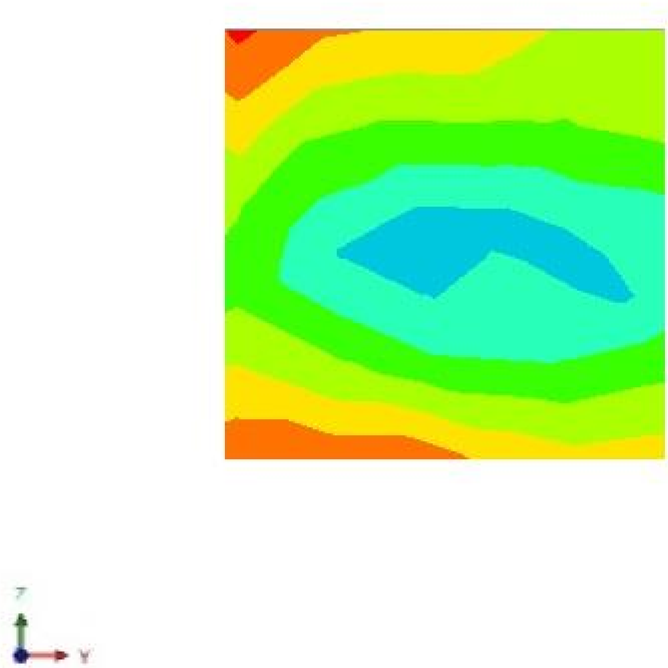


Figure 68 Most solicitated section of frame with larger angle

This new shape helps in decreasing the local stresses, in smaller percentage with respect to the previous case.

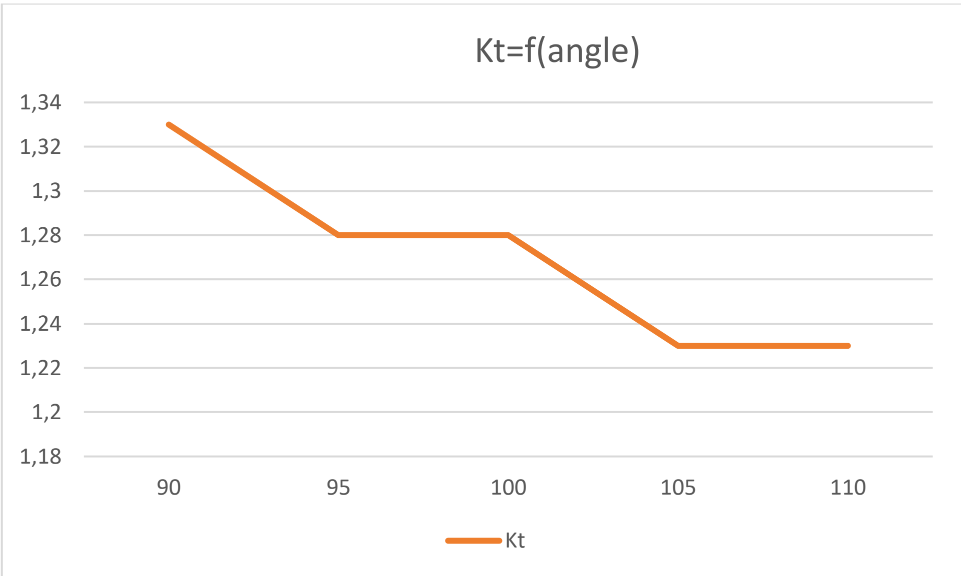


Figure 69 Stress concentration factor in function of the angle

4.2.6 Stress concentration factor

For any mechanical piece, a notch effect is defined as a change in the piece section, obtained through drilling, shoulder or unloading groove, which modifies the flow pattern of the effort. The modification involves an over-stressing of the effort in the section affected by the carving. In the structural elements subjected to tension, which present discontinuities (such as holes or sudden variations in the section), stress concentrations occur: the maximum stress differs from the nominal stress calculated with the normal methods.

The notch effect is mathematically shown with a multiplicative stress coefficient, the so-called stress concentration factor (or notch coefficient), which expresses the ratio between the maximum tension present near the discontinuity (the maximum effective stress caused by the incision) and the nominal voltage calculated in the critical section (the stress in the absence of notch):

$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

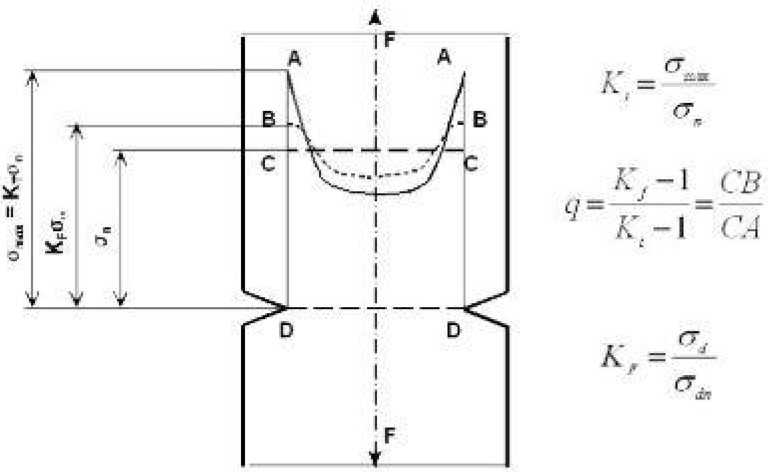


Figure 70 Stress concentration factor in a rod

4.3 Conclusions

In conclusion, it can be asserted that it is possible to predict the stresses in the bridge of a frame by means of the beam theory.

This beam model with the classical stress intensity factor is useful to represent the real behaviour of the bridge of eyewear. In particular, the calculated stresses may be compared to the material yield stress.

For us concerns the security test of frames, as requested by general ISO Standards, it has to be paid attention that the maximum stresses are lower than the yield value.

5 Bibliography

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