POLITECNICO DI TORINO

Corso di Laurea Magistrale in Ingegneria Meccanica

TESI DI LAUREA MAGISTRALE

Failure mode E- coat paint runner

Testing, optimization and implementation of the blow off process after E-coating

Relatore

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Laureando

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Ringraziamenti

Ci tengo a fare i dovuti ringraziamenti al relatore della mia tesi, il prof. Lombardi che si è dimostrato di essere innanzitutto un ottimo professore, oltre che una persona di valore, paziente e comprensiva.

Inoltre ringrazio la Bosch NV che ha creduto in me dal primo momento, dall'ing. Raf Greunlinx fino all'ing. Ignace Vaincoillie che ha dato spazio alle mie idee e mi ha dato la possibilità di immergermi in una realtà completamente diversa all'estero e portare a casa degli ottimi risultati accademici e personali.

Ora penso sia giunto il momento di fare un ringraziamento a tutti coloro che hanno partecipato a quella che non può essere definito solo come un lavoro di tesi, o una laurea magistrale ma come un vero e proprio percorso di vita. Ricordo tutto di questi anni, dai primi giorni di lezione del primo anno, ai colleghi che ho ritrovato e che ho conosciuto; ai professori, e a tutte le difficoltà accademiche che mi hanno reso uno studente migliore. Ho avuto a che fare con la vita accademica, ma poi mi sono completamente immerso nella vita personale e nel dolore più profondo. Ho anche pensato qualche volta di smettere di studiare, che forse non valeva più la pena soffrire per ottenere dei risultati, che poi alla fine c'erano cose più importanti.

Ed è proprio da lì che ho ricominciato, mettendo insieme pezzo dopo pezzo, non smetterò mai di ringraziare la mia famiglia con cui abbiamo condiviso i sacrifici e che mi è sempre stata accanto nonostante le profonde differenze e i miei amici. Alessio, Marco, sapete quanto siete stati fondamentali.

Poi il salto nel vuoto e la partenza per il Belgio, con 12 mesi fantastici in cui dico grazie a me stesso per una volta, perché lì ho combattuto con la mia personalità e forse ho capito che a volte il mondo andrebbe visto con occhi diversi. Ho avuto la fortuna di incontrare poi persone splendide a cui spero di aver strappato un sorriso e di aver lasciato un buon ricordo.

Questa non vuole essere una cronaca di avvenimenti e nemmeno una pagina di freddi ringraziamenti. Quindi ne approfitto ed ora, guardandomi intorno vedo persone e famiglie speciali, come la mia fidanzata Valentina che mi accompagna e che sa prendere tutti i miei alti ma anche i bassi della mia vita, che soprattutto sa quanto sia contento di questo traguardo.

Non posso purtroppo citare tutti i protagonisti di questa avventura, vorrei soltanto trasmettere il mio profondo senso di gratitudine nei confronti di tutti.

Il giorno della proclamazione sarò contento, sereno, mi toglierò anche un incredibile peso emotivo ma credo che avrò un senso di malinconia nel non poter condividere con Voi tutto questo.

Penso che da lassù riusciate a vedermi ma per questo farò tante foto così da tenere impresso questo momento come abbiamo fatto dopo la laurea triennale. Avrò di sicuro la cravatta un po' storta e sarò emozionato ma so che ho potuto mantenere ciò che ci eravamo promessi.

Non passa giorno in cui non vi pensi o non mi manchiate.

Questa è per voi, mamma e papà

Simone

Summary

Abstract

The thesis work that I am going to introduce in this abstract, it regards one of the most common failures in automotive industry, called Paint runner.

Robert Bosch company is working since 1973 to produce wiper arms and blades for OE (Original Equipment) and AM (After Market). RBBE also deals with processes as compounding, coating, injection molding and extrusion of rubbers. Leader of this market and also promoter of new technologies and solutions.

A wiper arm is defined as the contact consisting of a conducting arm that rotates over a series of fixed contacts and comes to rest on an outlet.

The ED (Electrical Drives Division) is the main department that takes care about these products, accessories and services. The lead plant is located in Tienen, small village in Belgium. There are also other smaller sites for this production (in Mexico, Serbia and China).

Bosch Group in Belgium generated sales for 843 million euros, a substantial part of 73.1 billion euros of the worldwide.

It produced 50 milions of wiper blades, 13 millions of wiper arms and 0,8 millions of wiper rubbers. The real estate is about 129660 square meters

and there are 962 employees (February 2015).

Although there's a huge list of companies that buy these Bosch products and services, as such as Ford, VW, GM, BMW, Renault, Toyota, Fiat and so on.

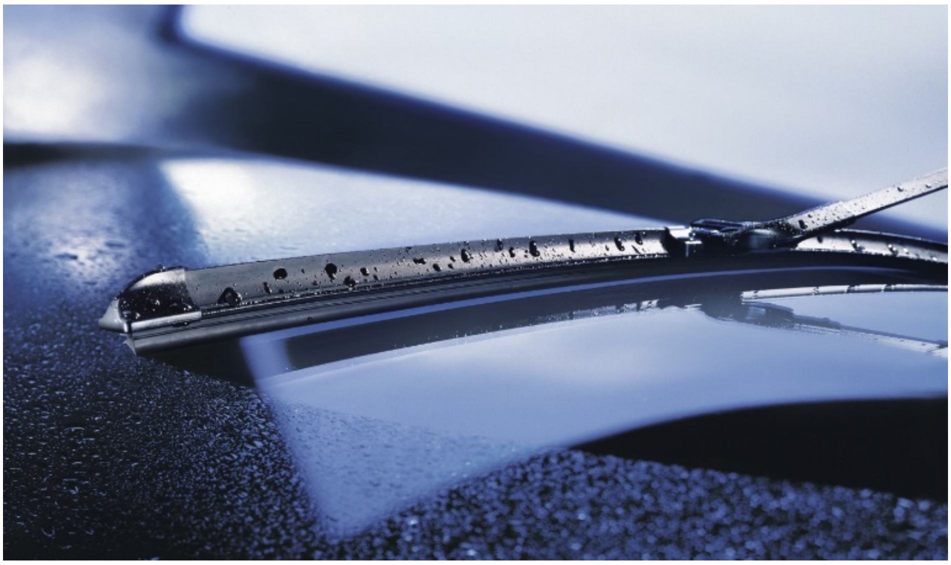


Figure 1. Windshield testing the durability

RBBE is focused to improve the main processes and has one of the most modern industrial E- coating system.

The Manufacturing Department works for both markets (OE and AM) and MSE1-OE is where I worked in these 6 months.

Its role is to improve the production processes, to implement new solutions and reduce the number of common failures under their rigorous target.

In fact, the production of wiper arms is penalized by the presence of several different kinds of errors with different causes.

Here a quick resume of them:

Type of Failures
Leverancier
Lakveschadeging
Pinholes
Schroot
Lakloper KTL BT
Lakloper KTL VE
LakfoutDekLak
Lakfout (Andere)
Stof
Montagefout
Andere

Laklоper is the Dutch term for PAINTRUNNER.

The **Lakloper KTL BT** is about the PAINTRUNNER Arm Head (BT);

the **Lakloper KTL VE** is about the PAINTRUNNER Rod/Connection Part (VE)

Paintrunner failure (both) has a percentage of 2% out of all these failures. It is noticeable to see from the bar chart that Pinhole get more errors (22%) and also similar values for Leverancier (21%) and Lakfout (Andere) about 20%.

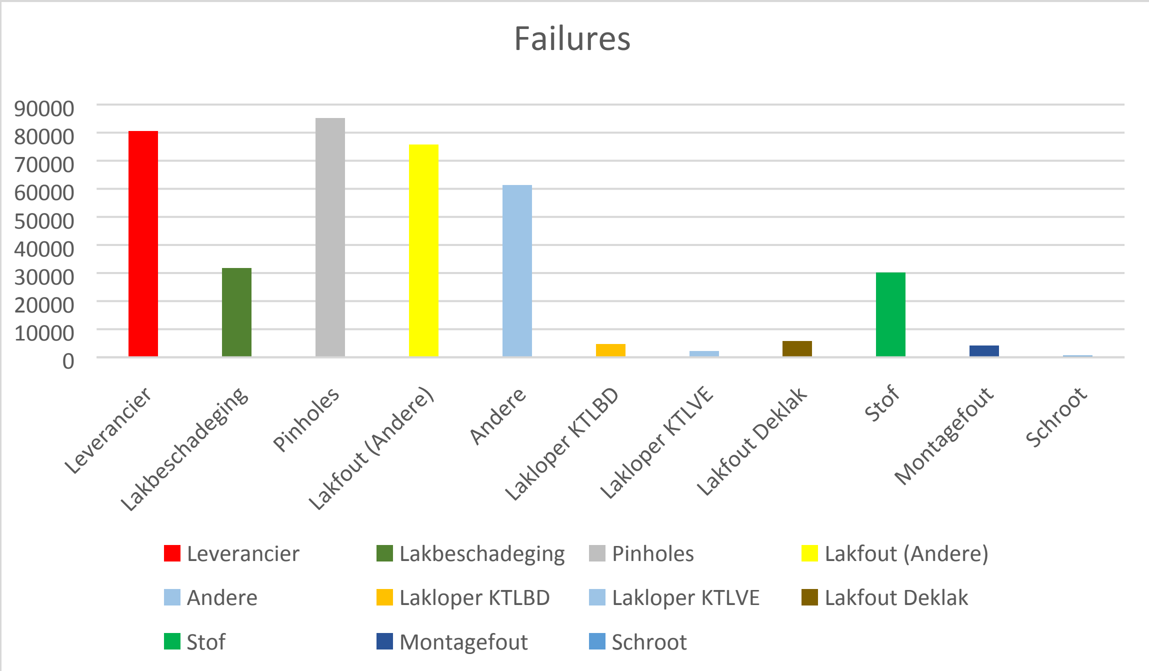


Figure 2. Bar chart with typical failures from May to August 2017

This data start from 30th of April until the 3rd of August 2017 for an amount of 5403143 FROK (first run ok parts) and the percentage of not conformed parts is 6.62% that means a quantity of 383171 wipers.

The paint runner failure is defined as a kind of spot on the top coating of the wiper arms.

Usually it is on the top part (connector) of the wiper and on the bottom as well. It depends from different parameters and causes, for example the most common is when the blow off process is not perfect or it is too quick.

These two zones on the wiper are the weak side of the process due to their position, orientation and the thickness of the metal sheet.

Here in Bosch Belgium the engineering team wants to manage this kind of failure and improve the actual techniques to reduce the issues and consequently, save a lot of money with material, internal resources, rework time, and so on.

For the other types of failure, it is not necessary a rework activity to solve the problems but they restart the complete process or, sometimes, scrap.

In fact, one of the purposes of the thesis is to work and create all the best ways to reduce these failures and improvements, not only temporary, but long lead time and feasible for the company.

We try to reduce the percentage of failures and improve the process, the quality and the product itself with all the ideas and tests done during the semester.

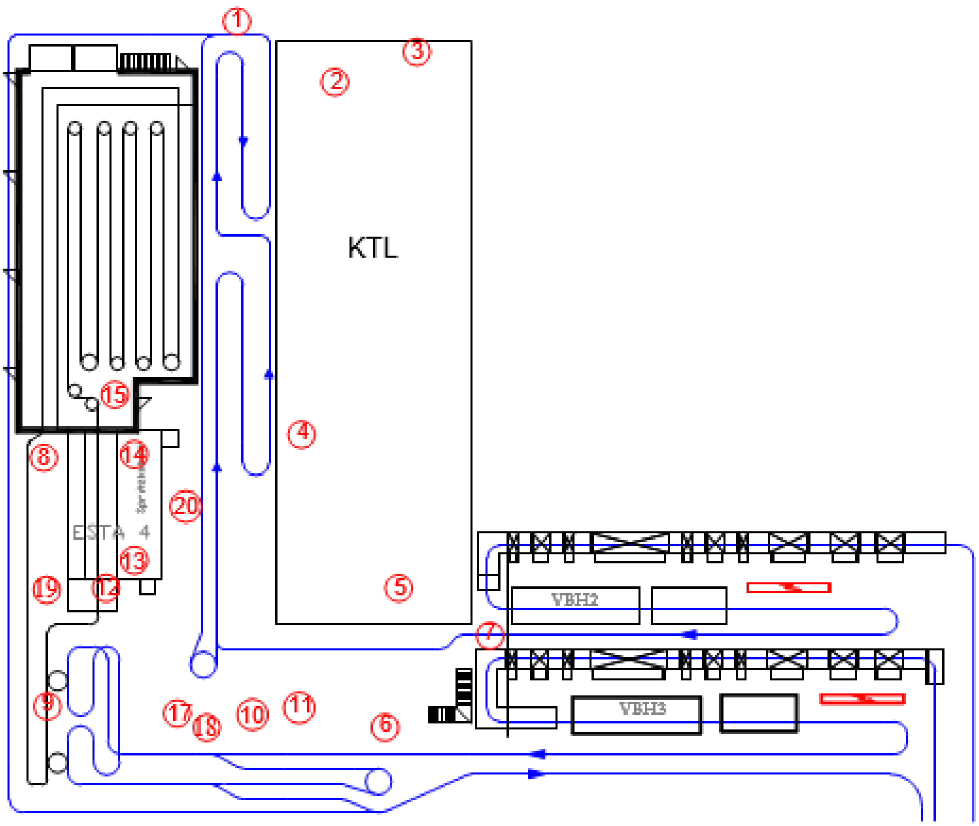
2) BLOW OFF AREA

The main division of the production is composed by:

- Assembly line;
- Pre-treatment;
- E-Coat;
- Top Coat.

We already introduced these phases into the section about the state of the art.

Here MAP of PAINTSHOP



The thesis goes in deep on the Electrocoating process for the wiper arms and fixing an important base about the blow off area.

This one is a U-shaped zone that has been added few years ago to avoid the amount of paint runners (on the connector and the arm head). Its function is to dry the wipers after Electrocoating.

The conveyor system is carrying the hangers through this area and each group of them is recognized with a Charge number (15 hangers for each one). The speed of this system is of 4 m/min.

The area is composed by 5 different stations (one is out of service) full of air nozzles that they work with different pressures and with blowers. The work environment of this zone is aggressive and rough because the temperature is around 30 °C and the general conditions are difficult.

Here some pictures of it.

Figure 3. View of blow off station

Figure 4. Overview from the first Station

The goal is to reduce the amount of paintrunners because this area works on the specific parts subject to that type of failures.

These parts are:

- Connection part;
- Arm head.

Typical examples of failures in detail (LLVE & LLBT)

The layout of the air nozzles follows this principle and they are fixed at the height of the hanger that hangs up the wipers.

This idea does not think about the several types of connectors and also arm heads that Robert Bosch Produktie NV is producing for its customers and other suppliers.

It is not possible to get the same effect for each kind of wiper arm and the developments need to be addressed to different issues.

The installation was made by experience of the technical employees and engineers in Robert Bosch Produktie NV.

Here a small list of problems:

- position of air nozzles and dis-alignment in Station 4;
- profiles and stations not cleaned;
- base of profiles is not identical for all the stations;
- Station 3 is out of service;
- Collision between hangers at the exit of the area

Anyway, the most urgent problem to solve for this area is to switch the status of it from an “unknown box” to a suitable and developable area. It is mandatory to get all the dimensions of the stations and have the chance to maintain in a good status all the components.

Since when this work started in April a lot of improvements were applied to use better the information and the production data (the results of this process).

First of all the improvement on the visual check phase that it started to split the paintrunners in two different failures:

- The first one on the VE (connection part);
- The second on the BT (arm head).

It is possible now to observe the NOK parts of each TTNR of wiper with the amount of these parts as two independent failures.

The automatic loading is the phase where the SIBOS (robot arm on the picture) are working to hang on the racks all the wiper arms produced by this way.

<u>Picture of SIBOS</u>

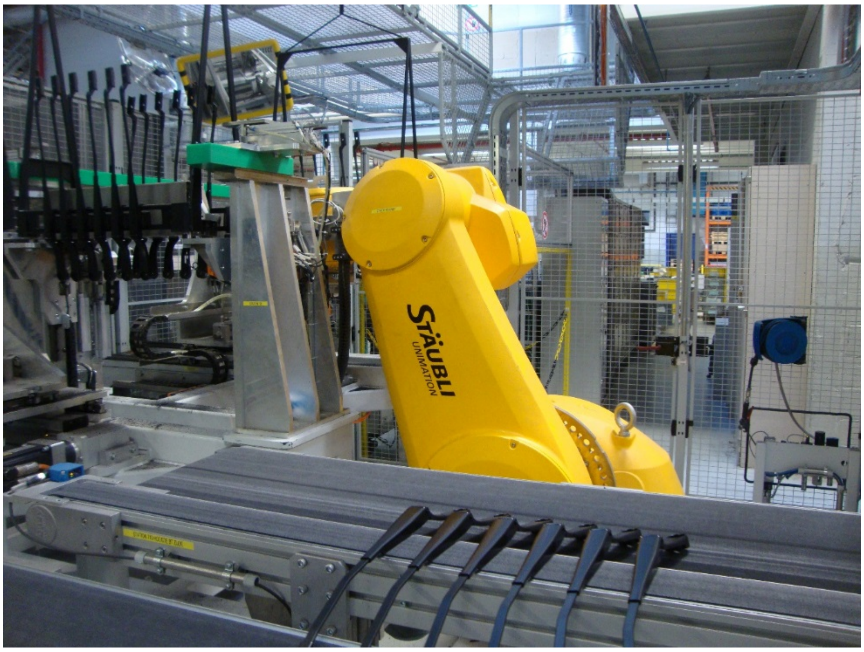


Figure 5. Sibos robot working into the plant

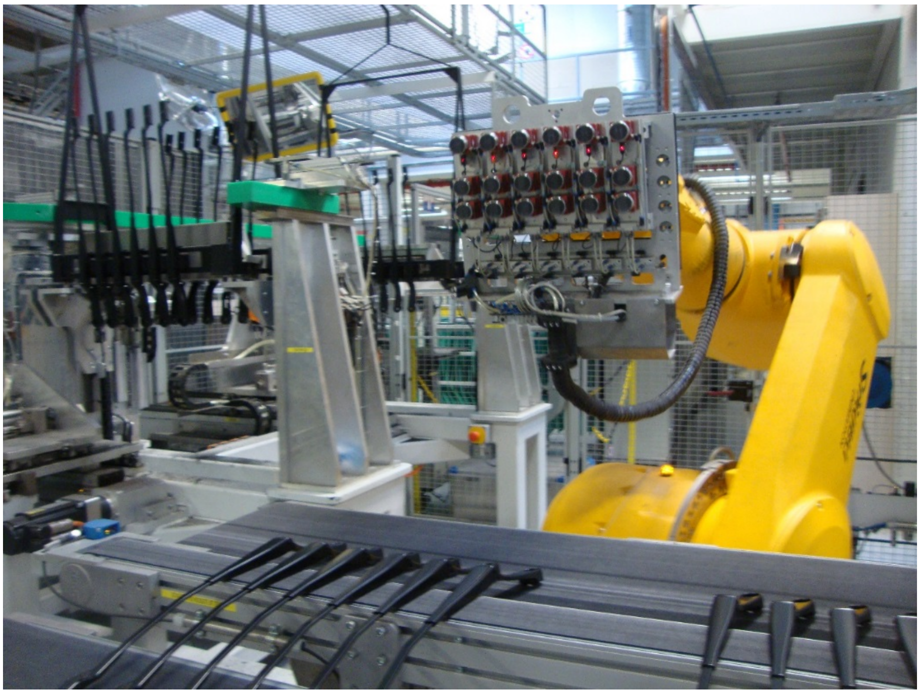


Figure 6. Automatized system to take off and get on the workflow

A huge percentage of wipers is loaded automatically by the robots and the rest is loaded manually.

This one is the previous procedure to hang the wipers and it is still used for some kinds of parts and tests. It is obvious to underline that the time cycle of the Sibos is (60 parts/min) and it can grapple 6 wiper arms for each cycle. It means an amount of 12 parts on the new frames (two movements from the robot to the rack) instead of an amount of 20 wipers for the old ones.

Picture of Old hanger

Figure 7. Old hanger with plugs

The robots are set it up with all the needs of the production lines and the particularities of the path to be completed.

This automatic loading is respecting the standard installation of wipers as the position of the clamps on the spring and the distance from the middle of the rivet (that fixes the retainer on the arm head) and the lowest point of the hanger

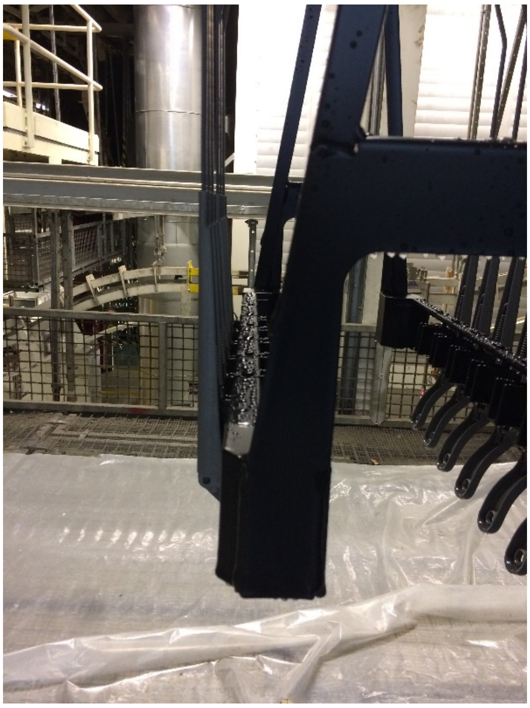


Figure 8. Side view of hanger with spring

These robots are also prepared to receive any changes during the production development window that it is always opened and rich of ideas. For example, during this work thesis, we have tested and installed several improvements about the structure of the hanger. In fact, the contact between the wiper and the rack got a big effect to one of the top failures of WAA, the pinholes.

As far as it concerned the manual loading, this allows to put on wipers and it is possible to try some setup changes like the height of the clamp on the spring. This is a good checkpoint for the job and an opened door to the adjustments. But the experience says that this is not enough.

Nowadays, all the company is following the technological revolution and it is becoming quicker to solve issues and satisfy millions of customers all over the world. All Robert Bosch factories are developing some improvements as software tools mainly to ease the work of operators, reduce the waste time on the production line and decrease the costs.

This thesis follows this important Bosch rule and it created an important first step to switch the blow off area in an automated phase.

In fact, the thesis approaches the issue splitting it in more steps to optimize each tool or model. According with the MSE-OE team and its team leader, the best way is to realize a 3D model of all the area with the possibility to change the settings and connect the failures with the root cause of them.

Starting from an installation by experience, I picked it up and measured all the dimensions, distances and angles of the area. I also had the opportunity to observe the work of the different levels of the stations, compare the different zones and find some mistakes, as dis-alignments and different kinds of waste.

This part of the work needed a lot of time observing, drawing and writing down all the characteristics of the system.

These measures are about the Lechler ® air nozzles, the blowers, the Bosch profiles used for the installation of them and so on.

One of the most important items starts from the Reverse Osmosis theory, that is applicable in different solutions as food industry (drinking water,etc.) or military use and so on. Reverse osmosis can remove many types of dissolved and suspended chemical species as well as biological ones (principally bacteria) from water, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective", this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as solvent molecules, i.e., water, H2O) to pass freely.

3) WEEKEND PAINT TEST

Robert Bosch Produktie NV is continuously improving and developing new systems to reach a better quality and less waste time. During 2014, an important study about the hangers was useful to design a new kind of rack.

The goal was to reduce the percentage of main failures and obtain a better contact between wipers and conveyor system as a Faraday gage.

Although the new type is "only" for 12 wipers instead of 20 that the old one can hang up, this hanger has reduced hugely the amount of failures. The first flow was substituted in 2014 and the second one in 2016 (100% of the hangers in production lines).

Picture of old and new hanger

Figure 9. Empty old version of hanger

Figure 10. New version with 12 wipers

Another important improvement during this experience was around second third of 2017 and it was about the clamp system that has been modified to reach a better contact.

Picture of NEW CONTACT

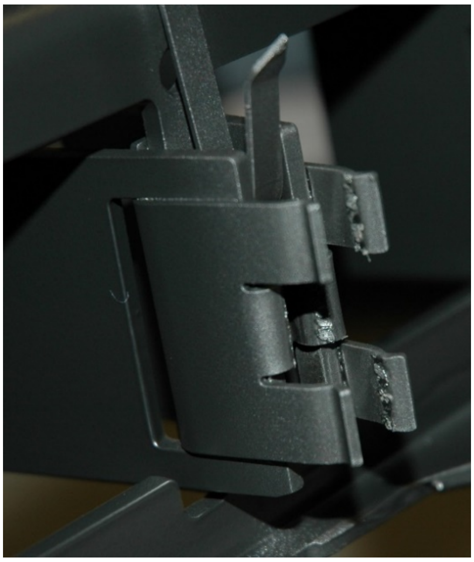


Figure 11 and 12. New type of contact

At the moment, the plant is producing 32 000 wiper arms per day, that means an average of 1333 per hour. This amount has reached from Monday to Friday, so the sum is 160 000 wiper arms.

We want to consider also the weekend production that is around 12 000 wiper arms. The percentage of wipers with old painting way is circa 7%

It is mentioned that this last WE production is using the old hangers (still into the plant) and not new ones. The purpose was to distribute the work hours of operators (in Rework Area) during the week and reduce time and costs.

This different planning started at the end of August and it will prosecute, at least, until the end of the year.

This reschedule of the production means some issues about the presence of paint runners, especially on the connector (LLVE) because it has been changed the height of wipers with the old hanger.

To prevent and avoid this possibility of failure, it has tested a full charge number in 3 different situations:

- New hanger as reference value;
- Old hanger with thread;
- Old hanger without thread.

The first was checking the presence of paintrunners (on VE and BT) with the latest method of painting and using the new hangers. It is the mode applied during the week for the 90% of the wipers.

It has to be specified that the visual check was executed using lamps and lights after the Electrocoating process, so before the Top Coating.

The TTNR of the wiper scheduled for the first weekend of September was 122 258 and it is a component for PSA B9 Berlingo / partner.

I controlled 180 wipers and here the table:

122 258								Laklopers (VE and BT) new frames (checked **AFTER** E-Coat)						
Date:	30/08/2017													
Driehoek voor								Driehoek achter						
	pos1	pos2	pos3	pos4	pos5	pos6			pos1	pos2	pos3	pos4	pos5	pos6
lakdriehoek 1	OK	OK	OK	OK	OK	OK		lakdriehoek 1	OK	OK	OK	OK	OK	OK
lakdriehoek 2	OK	OK	OK	OK	OK	OK		lakdriehoek 2	OK	OK	OK	OK	OK	OK
lakdriehoek 3	OK	OK	VE	OK	OK	OK		lakdriehoek 3	OK	OK	OK	OK	OK	OK
lakdriehoek 4	OK	OK	OK	OK	OK	OK		lakdriehoek 4	OK	OK	OK	OK	OK	OK
lakdriehoek 5	OK	OK	OK	OK	BD	OK		lakdriehoek 5	OK	VE	OK	OK	OK	OK
lakdriehoek 6	OK	OK	OK	OK	OK	OK		lakdriehoek 6	OK	OK	OK	OK	OK	OK
lakdriehoek 7	OK	OK	OK	OK	OK	OK		lakdriehoek 7	OK	OK	OK	OK	OK	OK
lakdriehoek 8	OK	OK	OK	OK	OK	OK		lakdriehoek 8	OK	OK	OK	OK	OK	OK
lakdriehoek 9	OK	OK	OK	OK	OK	OK		lakdriehoek 9	OK	OK	OK	OK	OK	OK
lakdriehoek 10	OK	OK	OK	OK	OK	OK		lakdriehoek 10	OK	OK	OK	OK	OK	OK
lakdriehoek 11	OK	OK	OK	OK	OK	OK		lakdriehoek 11	OK	OK	OK	OK	OK	OK
lakdriehoek 12	OK	OK	OK	OK	OK	OK		lakdriehoek 12	OK	OK	OK	OK	OK	OK

lakdriehoek 13	OK	OK	OK	OK	OK	OK		lakdriehoek 13	OK	OK	OK	OK	OK	OK
lakdriehoek 14	OK	OK	OK	OK	OK	OK		lakdriehoek 14	OK	OK	OK	OK	OK	OK
lakdriehoek 15	OK	OK	OK	OK	OK	OK		lakdriehoek 15	OK	OK	OK	OK	OK	OK

The results are able to be the reference values for the other settings.

- 98,33 % of the WAA are OK, 177/180;
- 1,11 % of the WAA have LLVE, 2/180;
- 0,56 % of WAA have the LLBD, 1/180.

The day after this, I planned other two tests to discover which differences there are about these failures changing the hangers (and the thread).

This second test is concerning about the same visual check with lamps and lights but with the old version of rack and within the thread.

Here the overview of the results:

122 258							Laklopers (VE and BT) with thread (checked **AFTER** E-Coat)						
Date:	31/08/2017											
Driehoek voor							Driehoek achter					
	pos1	pos2	pos3	pos4	pos5	pos6		pos1	pos2	pos3	pos4	pos5	pos6
lakdriehoek 1	OK	OK	OK	OK	OK		lakdriehoek 1	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 2	OK	VE	OK	OK	OK		lakdriehoek 2	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 3	OK	OK	OK	OK	OK		lakdriehoek 3	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	VE	OK	
lakdriehoek 4	OK	OK	OK	OK	OK		lakdriehoek 4	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 5	VE	OK	OK	OK	OK		lakdriehoek 5	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 6	OK	OK	OK	OK	OK		lakdriehoek 6	OK	VE	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 7	OK	OK	OK	OK	OK		lakdriehoek 7	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 8	OK	VE	OK	OK	OK		lakdriehoek 8	OK	OK	OK	BD	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	
lakdriehoek 9	OK	OK	OK	OK	OK		lakdriehoek 9	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK			OK	OK	OK	OK	OK	

It checked the same quantity of wipers (180) with some different results:

- 96,67% of WAA are OK, 174/180;
- 2,78 % of WAA have the LLVE, 5/180;
- 0,56 % of WAA have the LLBD, 1/180.

It is noticeable the increase of paintrunners on the connector, 150% more than the reference value. Conversely, the amount of failures on the arm head is constant (only 1).

The third and last test was similar to the second one. This means that we were still using the old hangers, all the same parameters and characteristics of the other one but removing the thread.

The results of this test are:

122 258								Laklopers (VE and BT) without thread (checked AFTER E-Coat)						
Date:	31/08/2017													
Driehoek voor								Driehoek achter						
	pos1	pos2	pos3	pos4	pos5	pos6			pos1	pos2	pos3	pos4	pos5	pos6
lakdriehoek 1	VE	OK	OK	OK	OK			lakdriehoek 1	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK				OK	OK	VE	OK	OK	
lakdriehoek 2	OK	OK	OK	OK	VE			lakdriehoek 2	OK	VE	OK	OK	OK	
	OK	OK	OK	OK	OK				OK	OK	OK	VE	OK	
lakdriehoek 3	OK	OK	OK	OK	OK			lakdriehoek 3	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	VE				OK	OK	OK	OK	OK	
lakdriehoek 4	OK	OK	OK	OK	OK			lakdriehoek 4	OK	OK	OK	VE	OK	
	OK	OK	OK	OK	OK				OK	OK	OK	OK	OK	
lakdriehoek 5	OK	OK	OK	OK	BD			lakdriehoek 5	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK				OK	OK	OK	OK	OK	
lakdriehoek 6	OK	VE	OK	OK	OK			lakdriehoek 6	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	OK				OK	VE	OK	OK	OK	
lakdriehoek 7	OK	OK	VE	OK	OK			lakdriehoek 7	OK	OK	OK	OK	OK	
	OK	OK	OK	OK	VE				OK	OK	OK	VE	OK	
lakdriehoek 8	OK	OK	OK	OK	OK			lakdriehoek 8	OK	OK	OK	OK	OK	
	OK	OK	VE	OK	OK				OK	OK	OK	OK	OK	
lakdriehoek 9	OK	OK	OK	OK	OK			lakdriehoek 9	OK	OK	OK	OK	OK	
	VE	OK	OK	OK	OK				OK	OK	OK	OK	VE	

Same sample of checked parts (180):

- 91,11 % of WAA are OK, 164/180;
- 8,33 % of WAA have the LLVE, 15/180;
- 0,56 % of WAA have the LLBD, 1/180.

Concerning the paint runners on the Connector, the percentage is surprising because it is 3 times the amount of the same failures for the wipers with the thread. Still stable and constant the number of errors on the arm head.

The test has been completed by the visual check of Bosch operators into the Packaging Area (picture) where all the amount of the wipers (100%) is inspected.

Figure 12. Workers checking the 100% of wiperarms

The results are comforting because after the last process (Top Coating), the amount of failures decreased. This means that Top Coat has a good impact on this kind of failures and it is not necessary to change settings meanwhile we are producing wipers in the weekend.

It is also noticeable that using the thread is the temporary solution for this period, respecting the necessity to change the plans for all the weekends.

4) CONCEPT OF GAUGE

The concept of gauge is an implementation that is born from the requirements and necessities of the workers and the internal team here.

The main purpose is to be able to check online (without pauses) the parameters of each station:

- Height of air nozzles;
- Orientation of nozzles;
- Distance between work levels;
- Layout of the nozzles (from the top view)

These characteristics are fundamental for the process because they can guarantee the correct operation of the area. Each station is subject to a continuous use and it is possible to discover some errors as dis-alignments of nozzles or different orientations.

This need helps to design a gauge light to handle but rigid and accurate at the same time.

First attempts

Observing the stations and the profiles, the initial attempts were going to build a specific gauge for each side of every station. This means making 8 different gauges (or 9 with the Station 3 out of service).

The top advantages of this device are the small dimensions and the light weight but not sufficient to realize it. A thorough study and a series of practical tests realized from me and some operators shows some difficulties and disadvantages.

For example, it is not possible for an operator to fix the gauge on the side and check the parameters because of the reduced space between the walls and the nozzles. It is also not feasible to move it manually because it is too rough and not accurate.

Last but not least, the operators were complaining about how to use it and where store all the gauges.

4.1) L-shape

The next step is to modify the gauge following the gripes of the operators and the advices of the engineers and it took to a different idea for the gauge, trying to improve the previous disadvantages and keeping the good skills as the weight and maneuverability at all.

It has created another kind of gauge that it is a long tool and you can use it on both sides of each station. On the faces of it, we marked:

- Number of the station;
- A range to positioning the pipes;
- An arrow for the orientation of the nozzles.

At first, the idea was to follow the shape of Bosch profile. This one is a particular structure that is easy to find in all supports or buildings made here in the plant.

It has good mechanical characteristics, it is light, not expensive, easy to assemble it and work on it.

Try to follow this profile turned out to be more difficult and complicated than expected. In fact, it is not feasible to install a gauge to check the heights and the inclinations of the nozzles because of the general conditions of the area close to the supports.

There is not enough space to manage the installation of the gauge and they did not use a standard procedure to fix the profiles. Each part has installed without a possible future change or improvement but only following the necessity of the moment.

It was a similar attempt to realize a gauge with L-shape

Indeed, the L shape can follow the Bosch profile and it is easy to fix it for a good part of it but then it is not working properly in all the stations because of the missed accuracy on the bottom part.

It was also not feasible, for the presence of air tubes, to install the gauge always on the front of the station but for some (Station 4 for example) it was mandatory to apply it on the rear.

The tests showed that the operators are confused and not confident to do their task.

Another huge disadvantage was to manage a minimum amount of 5 gauges until a max of 8/9 of them. The maintenance activity has to be clear and repeatable without difficulties.

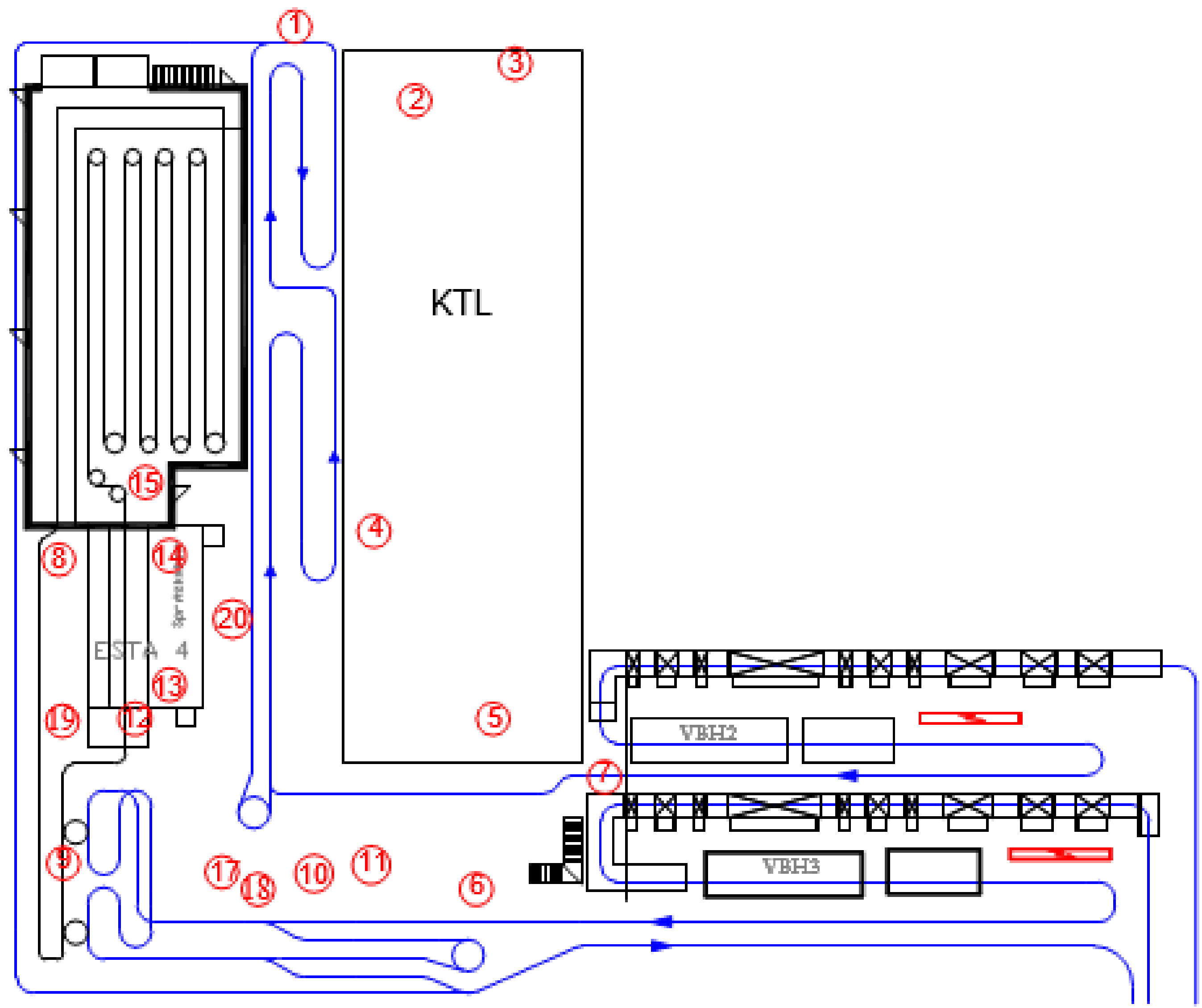
Conveyor system

The consequences of these different approaches (and practical attempts) switches the point of view of the area, trying to find a common, stable landmark in each station.

It has shown that floor, profiles and hangers are not sufficient to get the role of reference, so we decided to contrive a system able to use the conveyor on the upper part of the area.

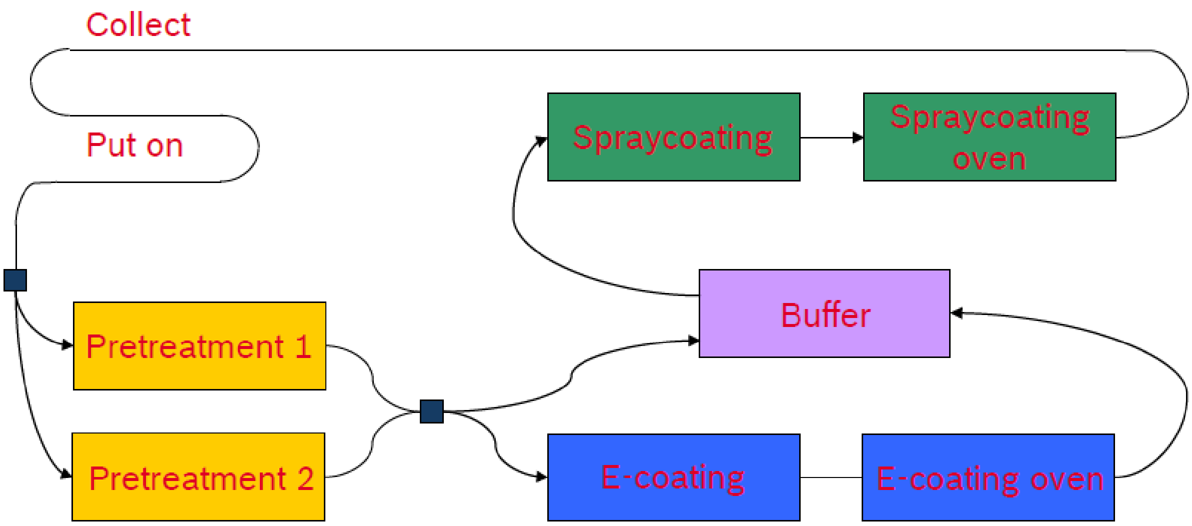
Figure 13 Sensor and conveyor

4.2) MAP of PAINTSHOP



1) Schuifdeur aan Ti-101 B → Schiebetür an Ti-101 B
2) Ingang KTL-oven → Eingang KTL-Ofen
3) Uitgang verdampingszone → Ausgang Verdampfungszone
4) Uitgang koelzone → Ausgang Kühlzone
5) Controleplaats voor KTL → Steuerungsplatz von KTL
6) Deur voor delen komende van VBH 3 → Tür bei ankommenden Teilen von VBH3
7) Deur voor delen komende van VBH 2 → Tür bei ankommenden Teilen von VBH2
8) Uitgang oven ESTA 4 → Ausgang Ofen ESTA4
9) Draaipunt ESTA 4 → Wendepunkt ESTA4
10) Onder stopper 27 → Unter dem Stopper
11) Schuifdeur richting op- en afname → Schiebetür Richtung Auf- und Abnahme
12) Ingang cabine → Eingang Kabine
13) Linkerkant cabine → ESTA-Kabine links
14) Rechterkant cabine → ESTA-Kabine rechts
15) Verdampingszone → Verdampfungszone
16) Op de rooster boven de gang → Auf dem Gitter über dem Gang
17) Uitgang borstelstation → Bürstenauslauf der Reinigungsanlage
18) ingang borstelstation → Bürsteneinlauf der Reinigungsanlage
19) Onder de toevoerlucht blazers → Unterhalb des Lüfters
20) Bediening van esta 4 → An der Steuerung zur Lackierkabine

The conveyor system has to transport parts in between different treatments for continuous processing.



The conveyor is principally formed by two parts:

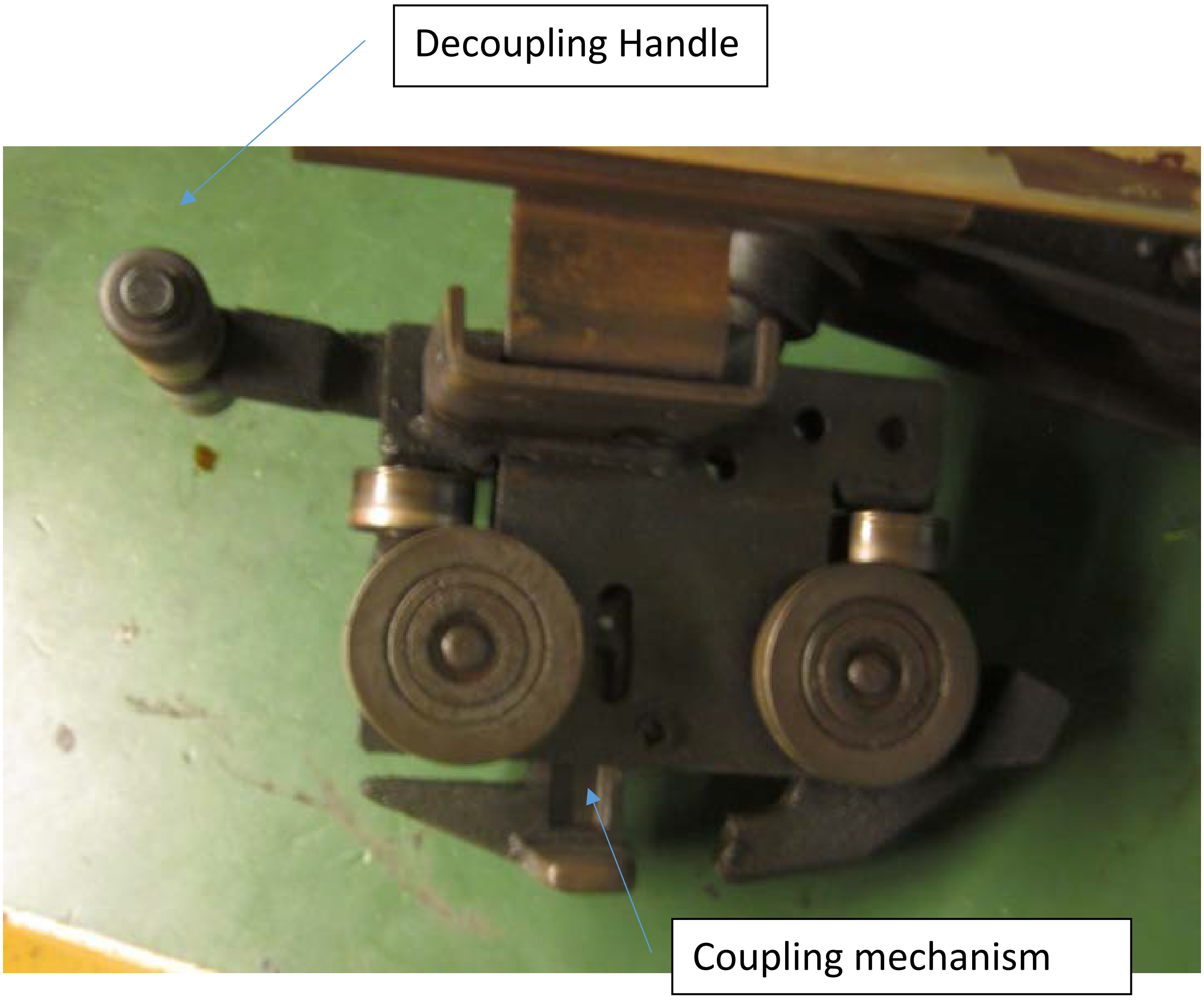
- Rail in which wheels of wagons are hung;
- Chain with moving parts that pull the wagons.

The conveyor works 24 hours each day without breaks and, to avoid the presence of dust and oil is equipped with drop panels and C shaped hook.

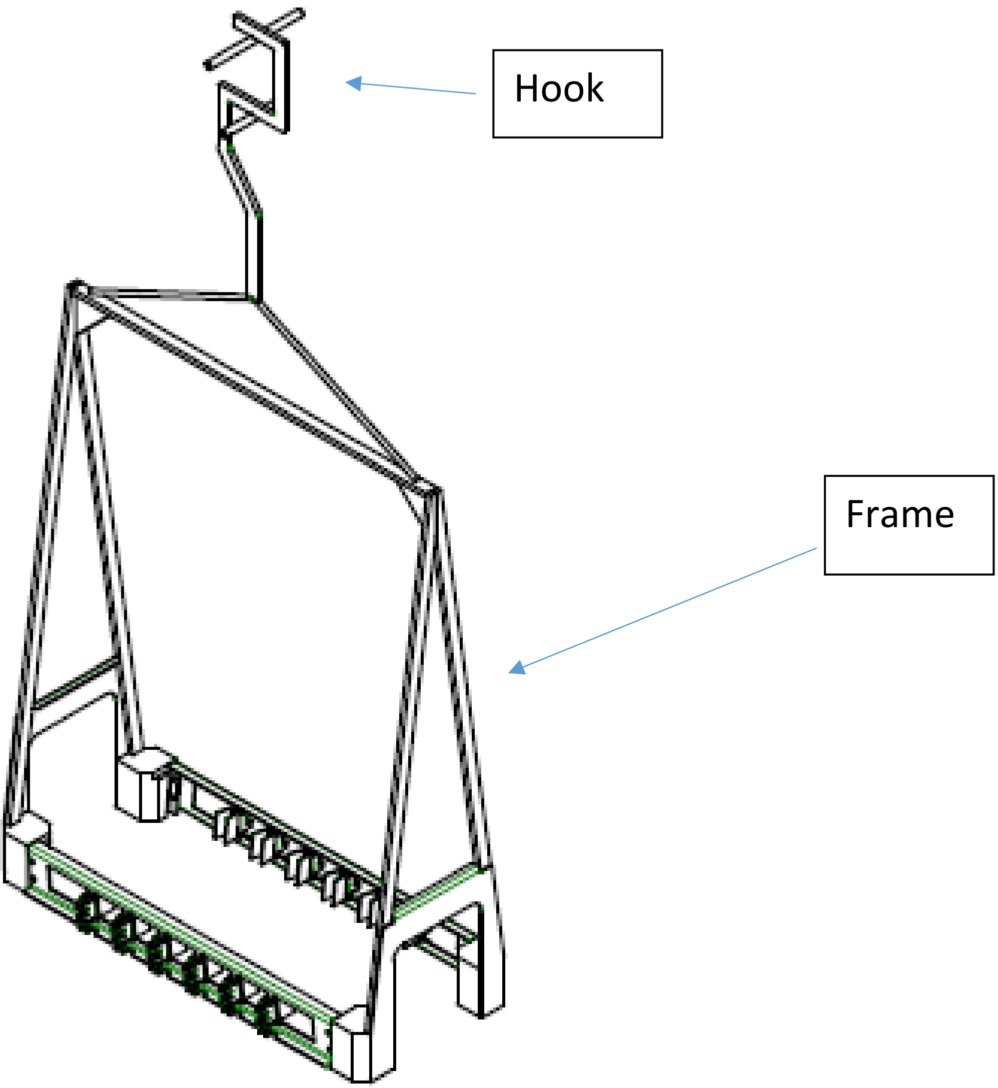
The wagons that are hanging on the rail with their wheels, have the important role to transport the frames in all the stations.

The transporting mechanism of the rail allows the wagons to move and there is a decoupling handle to uncouple it.

When the wagons are too close during the work, the next wagon is decoupled from moving part of the rail and it stops.



The wagons are connected with a hook to the frames can be hung.



Each frame transports 12 wiper arms and it can be turned of 180 ° during the process (for example in the middle of the Top Coat or at the end of the Blow Off area) when it is necessary to have a coating on both sides of the frame.

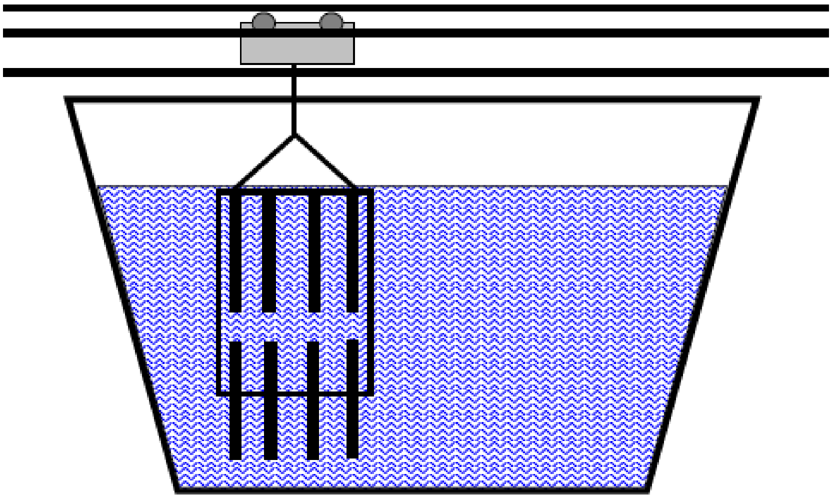
All the most important characteristics about each frame and the parts are transferred by barcode scanner. In fact, the barcode contains info about the type of parts, as the series number, the position into the paint shop and so on.

A laser reader can recognize the batch information on the conveyor path because it uses the binary code on the transportation wagon.

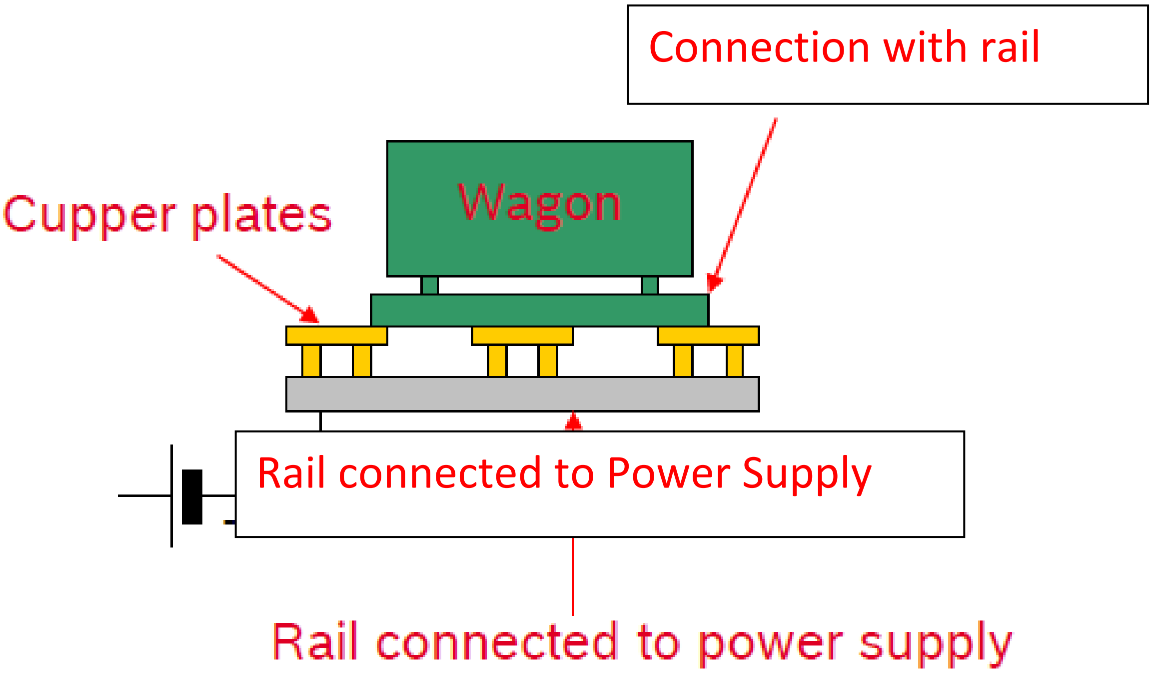
The conveyor PLC is able to control the conveyor track and also the top coat program, for example.

It is possible to track the right location of the batches by logging info of reader stations.

The painting frame is studied to act as an electrical conductor into the painting bath and it can transport electricity to the parts. This sort of electrical circuit is closed by the transporting rail on the top.



In fact, the rail is in contact with the wagons and also connected to the power supply negative pole.



5) ASSEMBLY LINE

5.1) PRETREATMENT

The pretreatment is one of the processes that concerns about Bosch Zinc phosphating. This is necessary because of the several products that contaminate the parts like flux agents, lubricants, dust and other solids that they have to be cleaned; also there will be an adhesive layer that bonds with functional coatings.

The process has 12 steps:

1,2,3: Degreasing,

4,5,6: Rinsing and Activation,

7: Zinc Phosphating,

8,9,10: Rinsing,

11: Passivation,

12: DI Rinsing.

The first three steps are about the Degreasing, a process that removes oil, grease and other contaminants products from the surface of the material.

Bosch developed a particular cascade system in 3 steps because it is more economical than one. It uses an alkalin cleaner like KOH and some surfactants (or carbonates, phosphates, silicates) for this and also there is a spray cleaning. To check the influence on cleaning efficiency, the process is controlled by important components or parameters like temperature or contamination of the bath and the titration or electrical conductivity.

It is useful to apply some expedients to maintain the bath cleaner. For example, the replenishment of chemicals or removal of contamination like filtration, ultrafiltration and so on, also the partial or complete make up.

When the process is not sufficient to clean the parts, the result is a poor phosphate coating that means porous material, poor adhesion) and painting problems (distribution, creepage resistance).

Bosch assures the quality measuring the cleaner compatibility, doing the visual check, controlling of bath concentration new bath make up.

Now it is time for Activation and Rinsing (from step 4 until the 6th). The first one is a reversible process of a molecule into a nearly identical or chemical state, that exhibits an increased propensity to undergo a specified chemical reaction. Its purpose is conditioning the surface with a faster phosphating and more finely crystalline phosphate coatings. The process is worked out by an active substance, the Titanium phosphate colloid.

The Bosch specialty in this case is about the activation baths that it starts with a rinsing zone behind the activation. The target is to remove white spots caused by Al-Zn galvanic contact, instead of the alternative one formed by an Activation zone and two consecutive rinsing zone (not necessary if the process is well controlled).

The 7th step is the Zinc Phosphating, that serves as a conversion coating in which a dilute solution of phosphoric acid and phosphate salts is applied by spraying or immersion and forms a layer of insolubile and crystalline phosphates. Its targets are to generate painting without surface defects, uniform paint coatings, improve corrosion protection of 5-10 times compared to the base metal. Furthermore the characterization of phosphate coating is based on visual assessment because it has to be closed and uniform), also the coating analysis (RFA) and paint adhesion or corrosion protection.

During phosphate process, it is noticeable to observe the formation of sludge with a stationary concentration of 0,5-2 g/l solids. When the sludge concentration is high, it is possible to find some disturbances like an increased incrustation (periodical chemical and mechanical descaling of spray pumps, tubes, nozzles and interior parts of phosphating installation) or dust on phosphate layer. Another phenomena is the Prepassivation, caused by pre-spray of phosphating solution into the intermediate zone. It can be eliminated by correct adjustments of spray nozzles, humidification and so on.

Steps 8, 9, 10 are about the Rinsing, that it is applied after each step to hinder the carry-over of chemicals components from one step to the next one. Here like in the first step, 3 rinsing tanks in cascade is much more economical than one. It used to supply fresh water with an overflow to maintain the rinse tank.

In this case to have a good measure of quality, Bosch determinates the bath concentration by titration or electrical conductivity.

Step 11: Passivation is applied after rinse and it wants to optimize the paint adhesion and protect the parts from paint creepage. Deviations in the concentrations and accumulation of contaminants have a big impact on process quality. During this step, they need to be checked and applied bath replenishment by continuous overflow.

Last step is DI Rinsing that uses dionized water after rinsing and has to remove residues of water soluble salts to:

keep E coating bath clean;

Avoid the formation of blisters in paint films in case of moisture penetration.

The quality product is influenced by salt content of the original water and its concentration of drain water (max 30-50 microS/cm) and also the water dripping from flanges and beads.

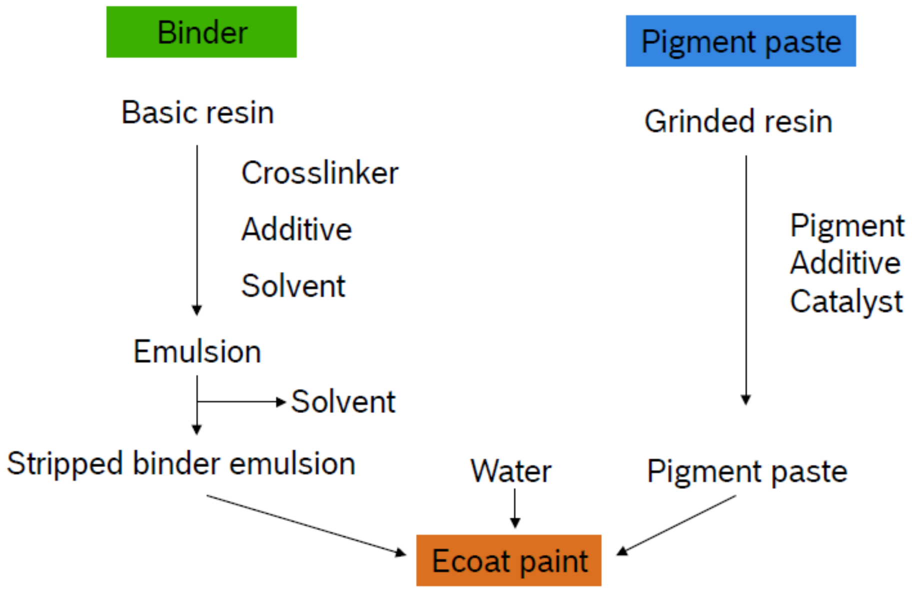
Also in this case, it is important to check the quality measuring electrical conductivity and prevent dripping by optimizing the equipment.

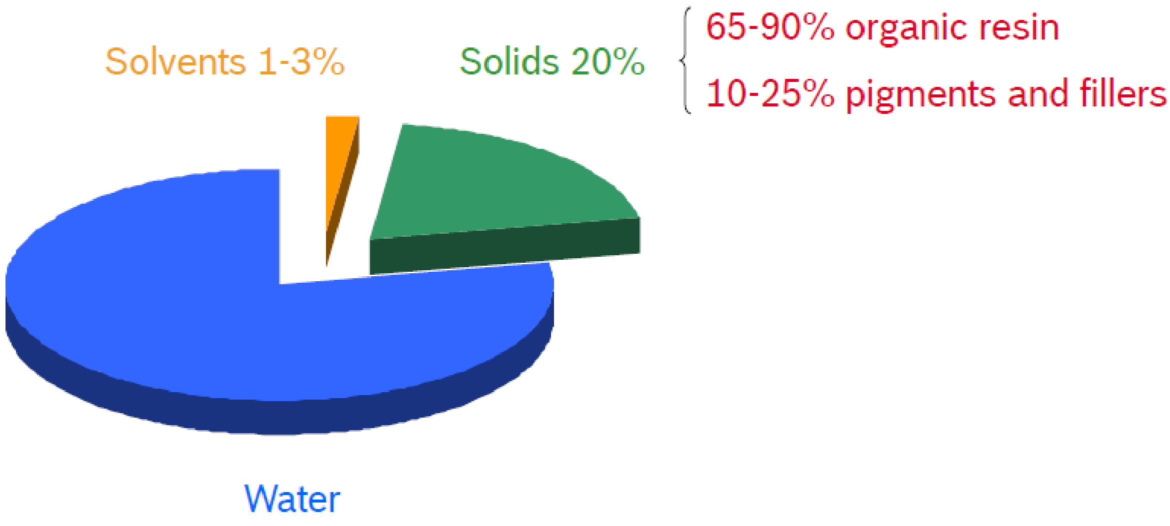
5.2) E-COATING

At the end of the pretreatment process, it starts the E-coating. This one has the purpose to cover metal substrates and protect them from corrosion and other issues.

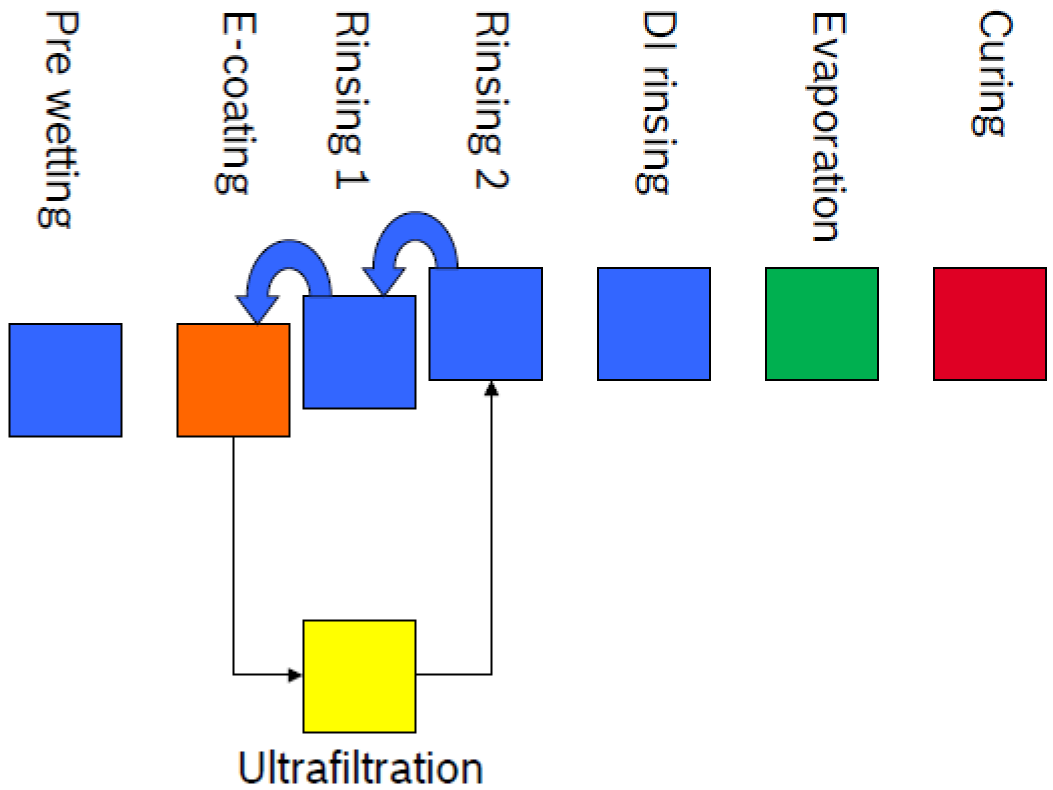
The main advantage is the water based with low solvent content, also the process is automated and reliable. E - coat paint is a mixture of binder like a basic resin where they add crosslinkers, additives and solvent, and a pigment paste (grinded resin) with pigment, additive and catalyst.

The binder is treated by emulsion process with solvent that creates a stripped binder emulsion. Mixing this with the pigment paste and the water, we obtain the E coat paint.

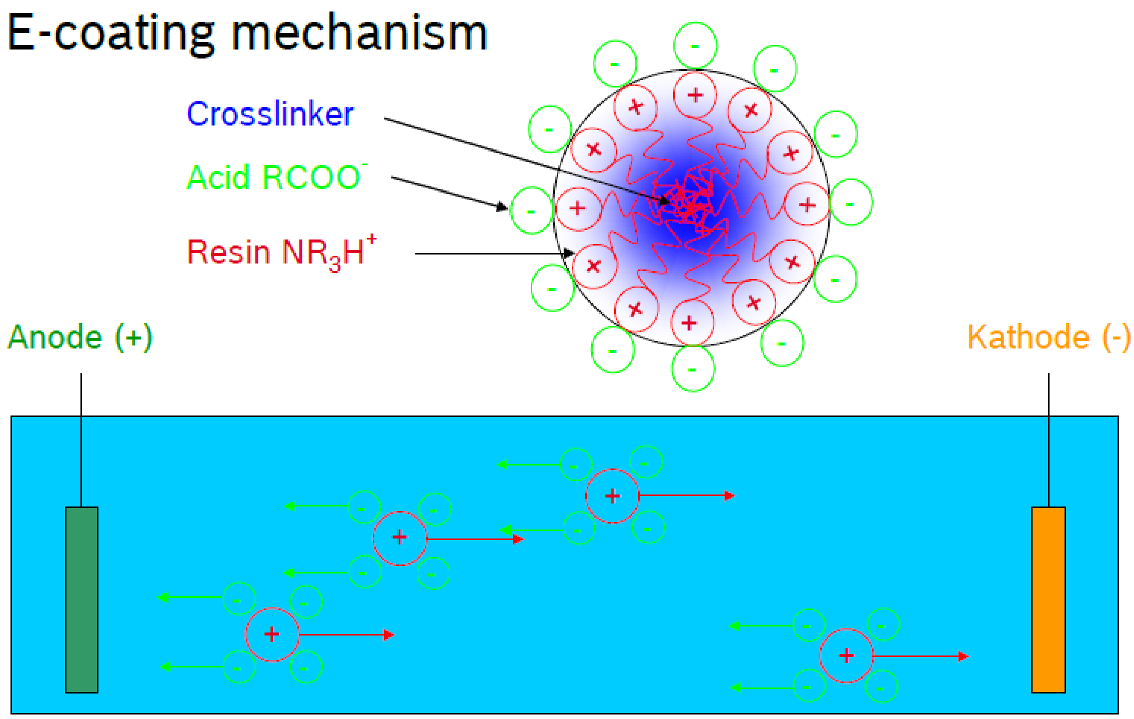




These are the steps for the Electro-coating in RBBE:



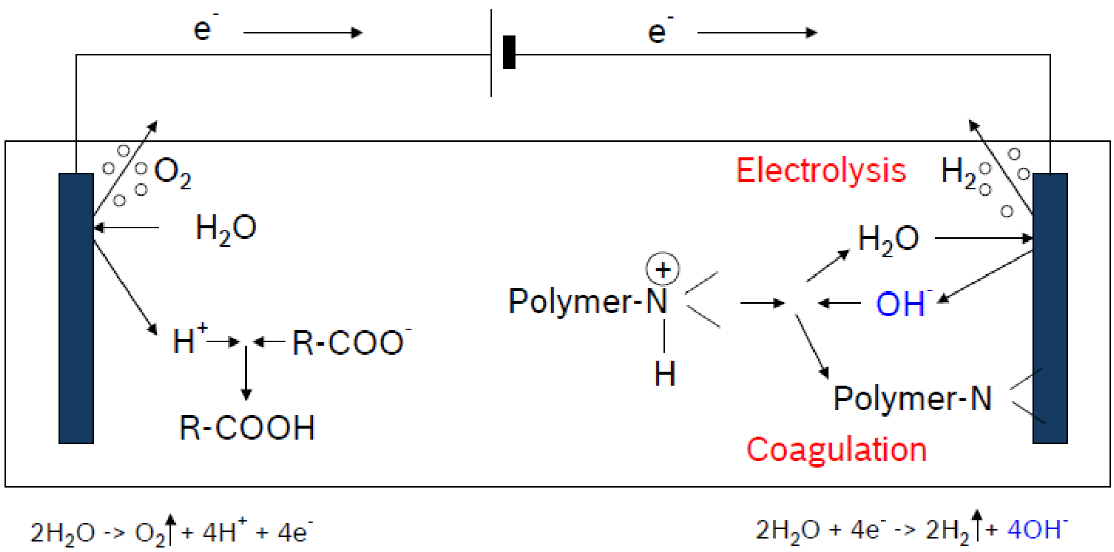
E – COATING MECHANISM



REACTION MECHANISM

This reaction starts when is applied a voltage on the parts and the electrolysis of water forms a basic layer close to them.

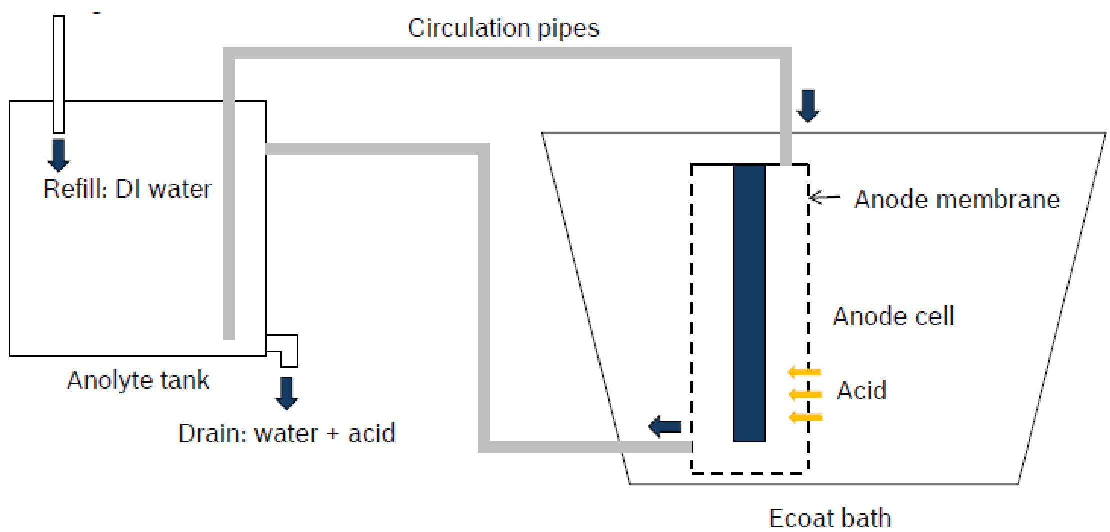
Charged paint parts move to the electrode with counter charge (electrophoresis). In this case, the particles react with OH^- and precipitate on the part.



Due to electro osmosis, water is pushed out of the paint film when it is becoming more dense.

In addition, during film formation an insulating layer builds up around the painted part, which is autoterminating the reaction because the current is blocked.

ANOLYTE CIRCUIT



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electrical contact for targeted layer thickness and uniform one.

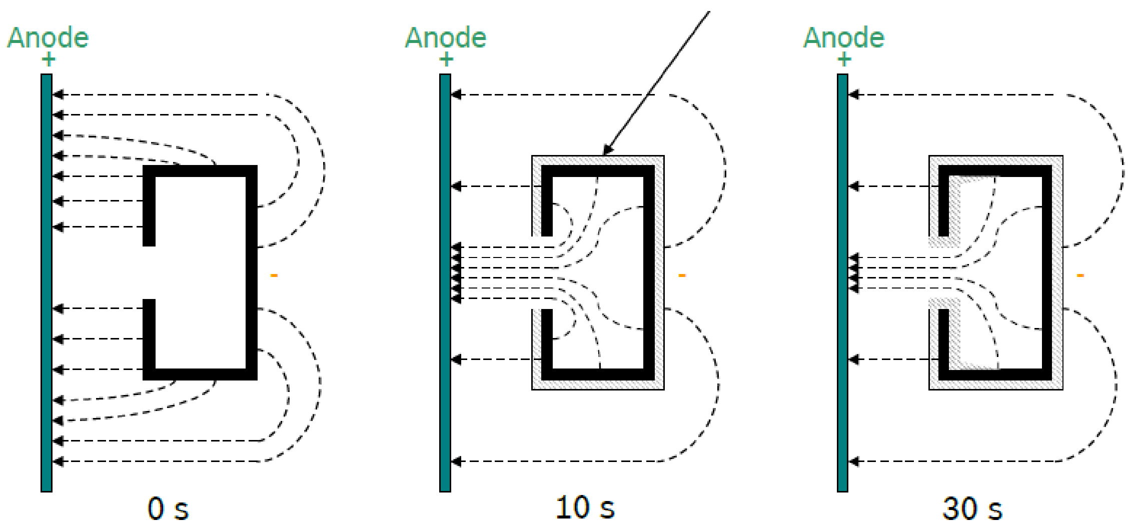
If the parts are too close to each other, due to the Faraday effect, it could create some not uniform layer thickness.

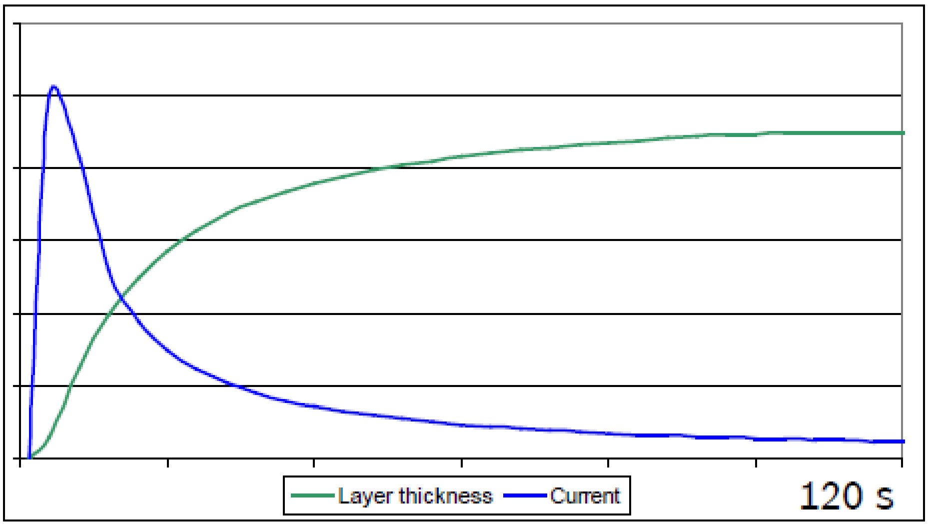
Even the total surface area of the parts in the bath is limited to avoid this.

In addition, parts with funnel will cause carry over of chemicals products.

For the pretreatment instead,

E- COATING BATH PARAMETERS

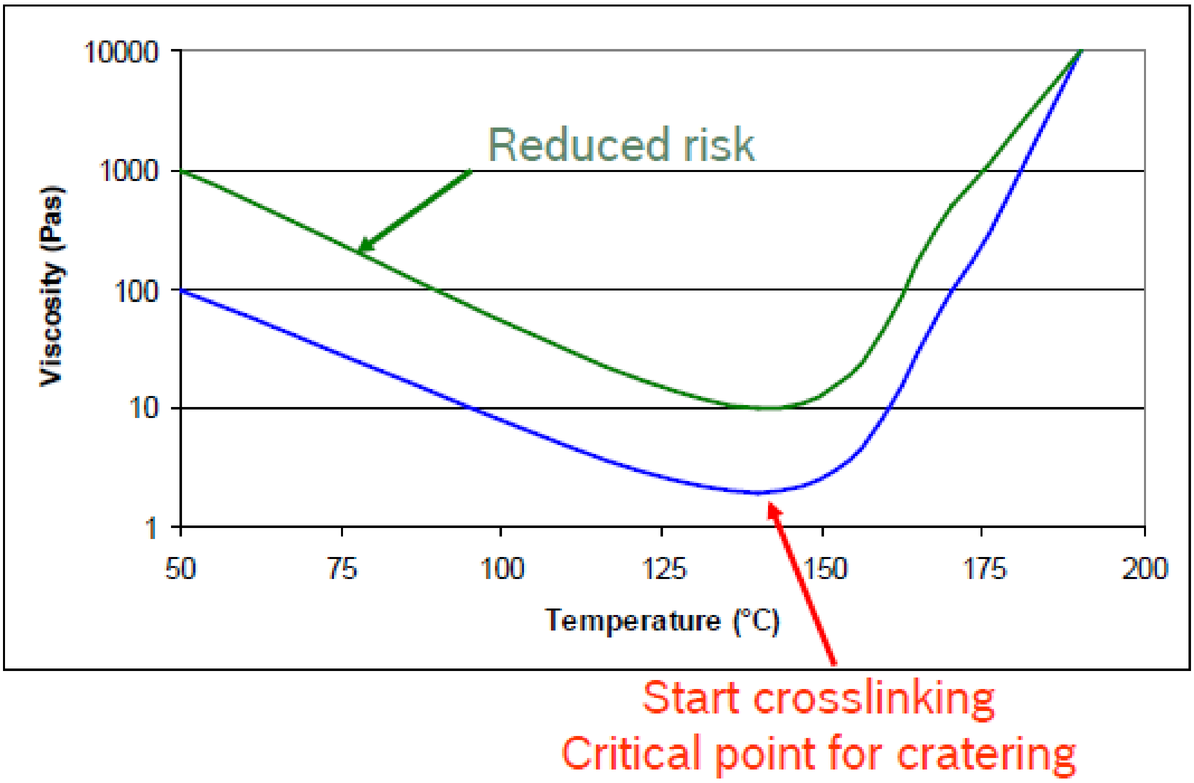




CURING PROCESS

The Curing is that kind of engineering process that can get tougher and harder a polymer material by cross linking of polymer chains. It is possible to use electron beams, heat or chemical additives. The process during the first part is going to decrease the paint viscosity.

When the cross linking starts, you have an increasing paint viscosity. Also a higher paint viscosity reduces risk of crater formation.



The process time and the temperature (as in the graph) influence the Curing result. These parameters have an important role for the adhesion (substrate and top coat); elasticity (protection against stone shipping) and finally, corrosion resistance.

We can visualize these parameters in a graph that explains clearly which it is the right baking window or in Over/Under baking.

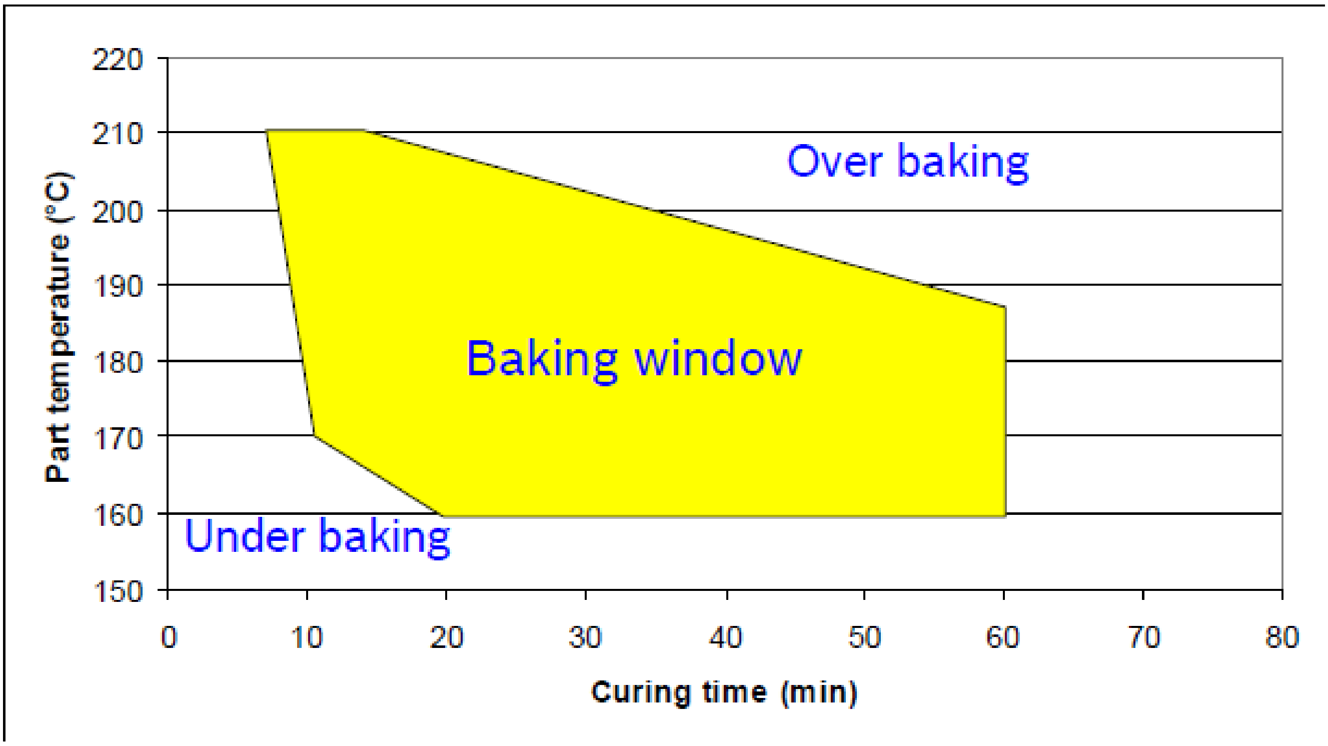


Figure 14 Curing trend

The process is controlled by a bath sample of 250 ml/5 L and they check the values of:

Conductivity;

Voltage;

Temperature;

PH;

Solid and ash content;

Solvent concentration.

Furthermore, the wiper arms are 100% visually controlled on typical paint mistakes like craters or pinholes, inclusions and too thin coating.

They have several possible causes as a high voltage, low solvent, poor contact and so on.

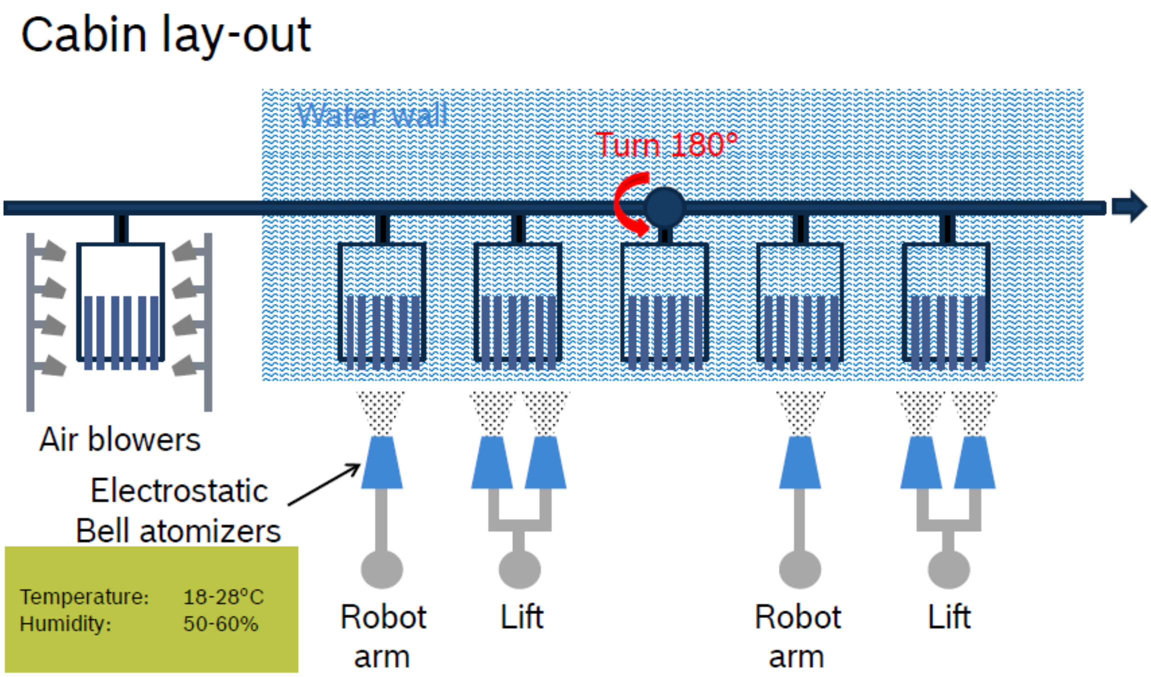
5.3) TOP COATING PROCESS

The Top Coat is a relevant process into the paint shop and it starts at the end of the E-coating.

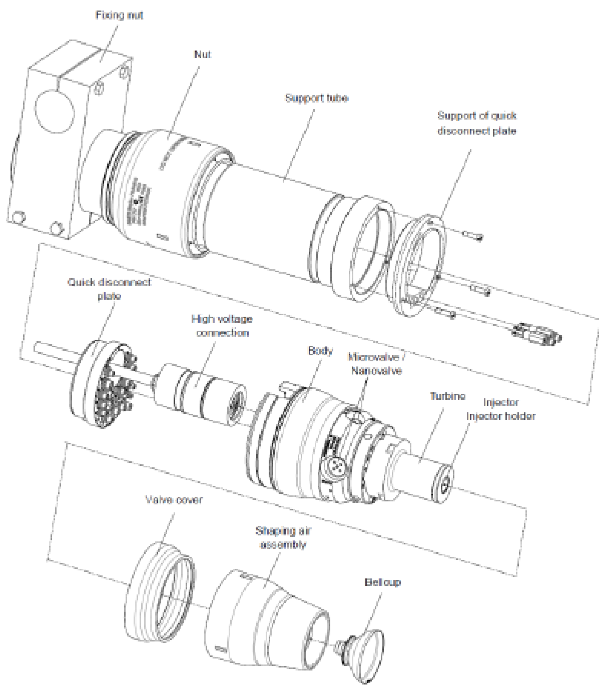
In RBBE, the top coat is applied mainly to:

- UV protection;
- Chemical resistance;
- Scratch resistance;
- Stone chip resistance;
- Edge coverage (when the electrostatic sprayers are on);
- purposes (gloss, color tone).

In paint composition we find the binder, a resin that holds the pigment and provides a good adhesion with surface. Its properties are the gloss, resistance, elasticity and hardness. The pigment is also important with other functional fillers and they improve the masking power, gloss, flow and other mechanical properties. This process requires the solvent because of flowing of paint and increasing the processability. Furthermore, it is useful adding some additives (in small quantities) to the paint composition and to obtain better properties like cross linker, catalyst and so on.



The cabin layout is important to paint the wiper arms because they use the robot arm to supply extra paint in critical zones and (for general painting) they use the lift with two bell atomizers.



The last one is a paint applicator used for high volume paint, good transfer efficiency and a low compressed air consumption if compared to a paint spray gun.

The main advantages are:

- High rotation of bell cup is in fine mist with uniform paint distribution;

- Paint (electrostatically charged) results in high yield and good penetration to side and back of workpiece.

It is useful to check some process parameters because they can show the real status of the process and if they need some adjustments:

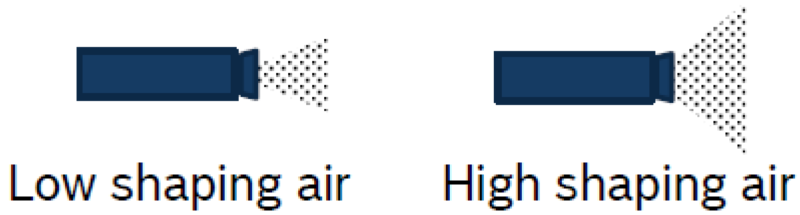
- Paint flow: quantity of paint on the piece controllable by gear pumps;

- Turbine speed: the rotation of cup defines droplet size of paint mist;

- High voltage: settles attraction force between paint and work piece;

- Robot speed: another parameter that can permit to check the amount of paint applied on the pieces;

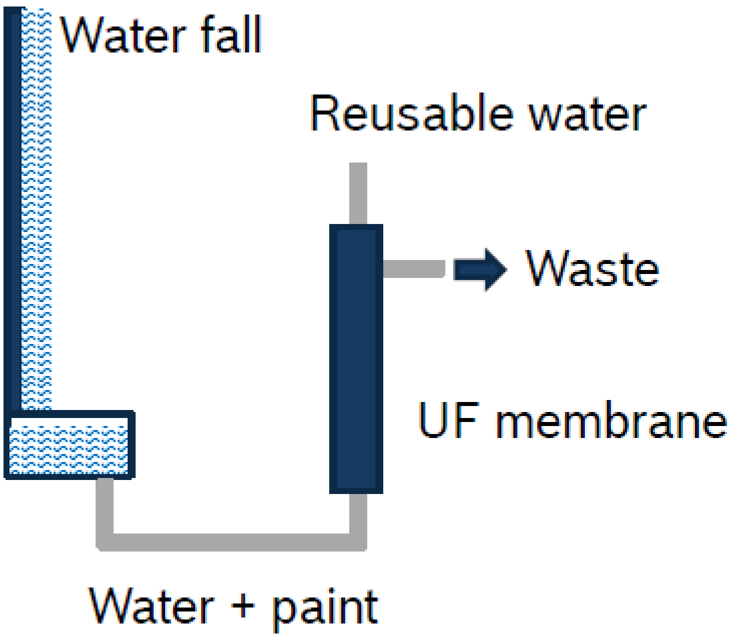
- Shaping air: defines the shape of the paint mist.



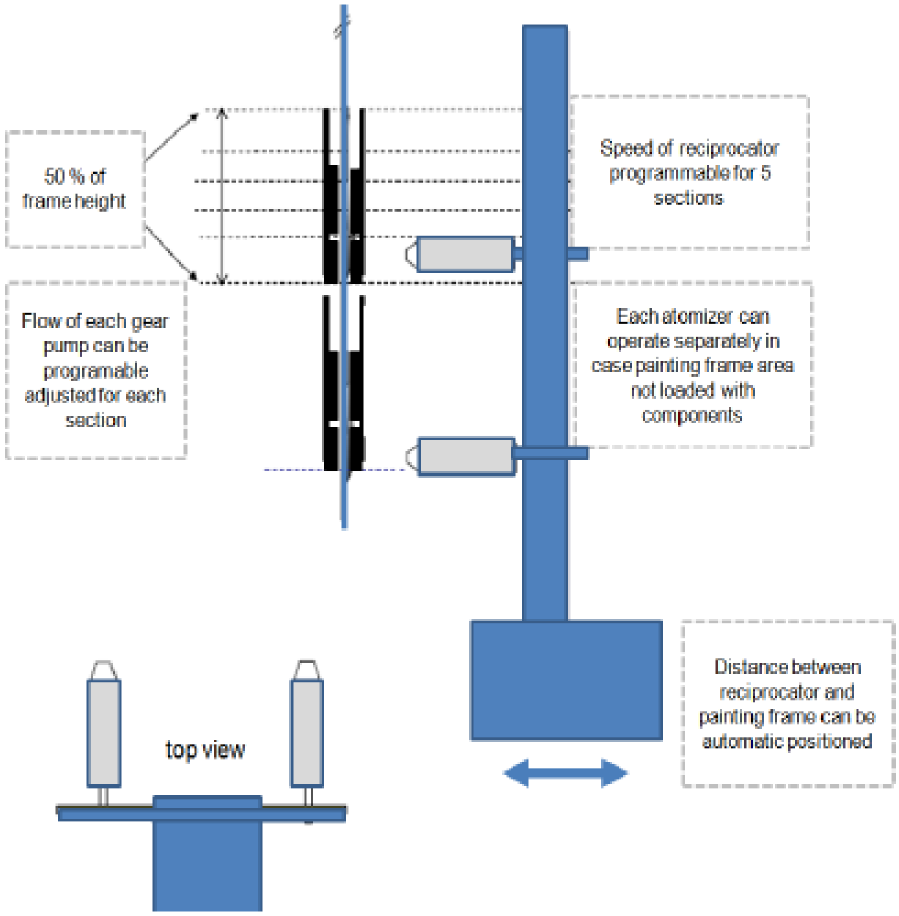
Into the cabin there is a system that turns the frames of 180 ° to paint both sides of it. Furthermore, the temperature and the humidity are, respectively, around 18-28 °C and 50-60% due to reached paint quality.

Paint preparation needs a long time and has to be prepared in advance before use because it is necessary to stir it for 6 hours, then measure viscosity with DIN cup and correct this one with DI water. After other 4 hours stirring, it is possible to control viscosity and the paint is ready to use.

The water wall has a relevant role because is used to remove overspray and do the ultrafiltration to separate paint and water.



There is also a regional programming (alternative process) where the atomizers positioned on reciprocator and they can change paint flow and reciprocator speed for different regions. Checking on the figure, it is noticeable to see one atomizer for bottom parts of paint frame and one for top parts.



Another alternative process is using dry filters because they have no risks for watermarks and they not produce waste water.

There are also some disadvantages like finding dust after filter exchange. Furthermore, this switch process needs an intensive work with a production stop of 8 hours but the cabin has to be cleaned.

The second important risk is having air blocking when filters are blocked, so it is necessary to follow up pressure over filter and planning maintenance checking weight of filters.

This preventive maintenance allows you to exchange filters, protection for robots and atomizers, protection foil for floor and walls, also for conveyors.

Every two hours is important to clean properly atomizer cups and air canals.

After the Top Coat, the process control is about the layer thickness measurement (also after the E coat), adhesion cross cut and visual inspection.

The paint layer quality is recommended by several official tests like:

- Neutral salt spray (DIN EN ISO 9227);
- Condense water constant climate (DIN EN ISO 6270-2);
- Customer specific tests;
- UV resistance (SAE J 2527);
- Stone chip test (DIN EN ISO 20567-1);
- Bucholz hardness (Din EN ISO 2815);
- Scratch resistance;
- Temperature tests.

6) 3D STUDIES AND CAD SIMULATIONS

In these paragraphs I want to introduce the 3D cad drawings and assemblies realized from myself.

They represent exactly the reality now present in RBBE blow off area and I used for this all my software skills in Solidworks to do it. Due to difficult conditions of the room, the model was created for all the stations, with complete environment (hanger, air nozzles, rack, dust avoid, etc,).

This means that each model is full of particularities and can be modified for future improvements or tests.

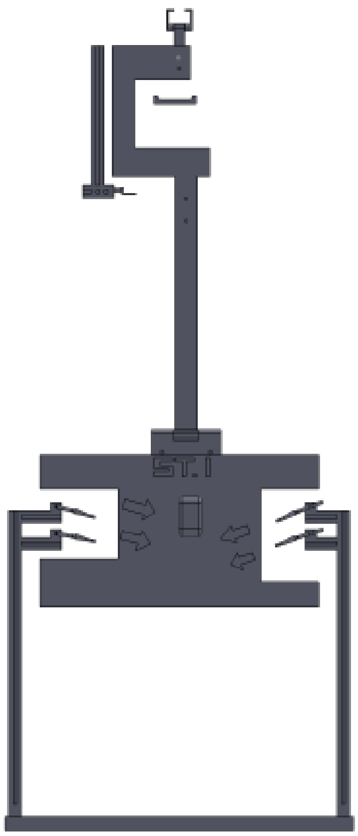
As already written before, all the distances, heights, and minimal gaps are measured by myself during my experience there.

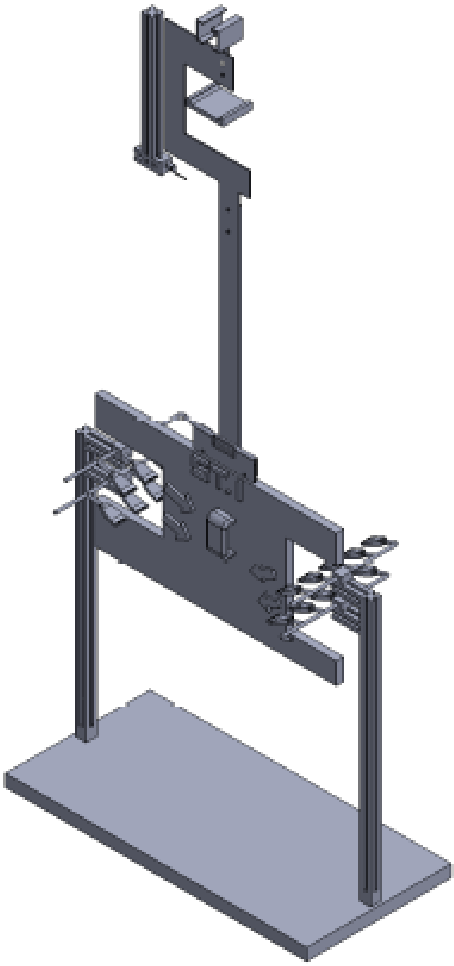
One of the purposes was to realize a concrete status of the area, including the measures, the condition of the nozzles and about the Bosch supports.

It has been useful to take some measurements of the conveyor system using the prototype into the Paintshop, once to recreate it on the 3D Assembly and then to test the first attempts of gauge, including maintenance activities and easy plug, for example.

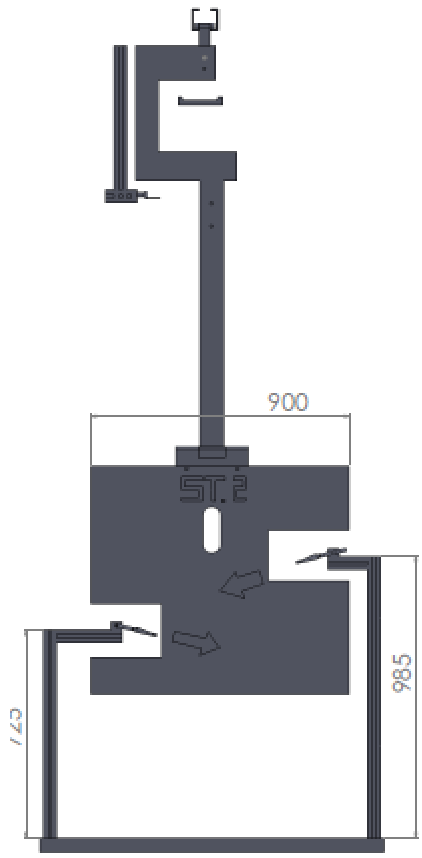
Here 3D representations for each station:

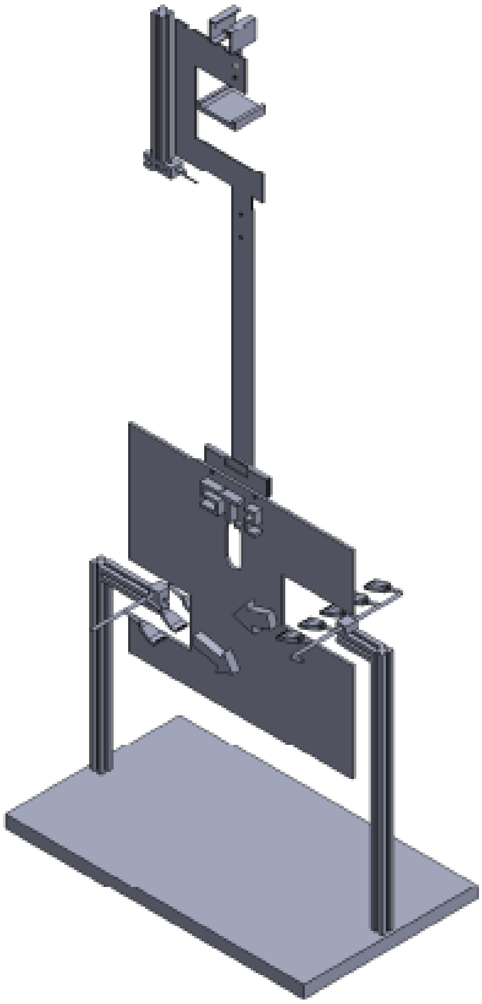
1 Station:



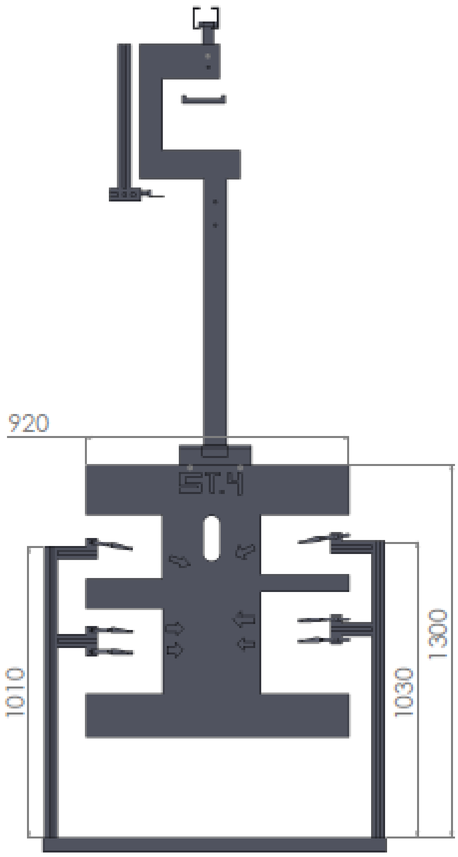


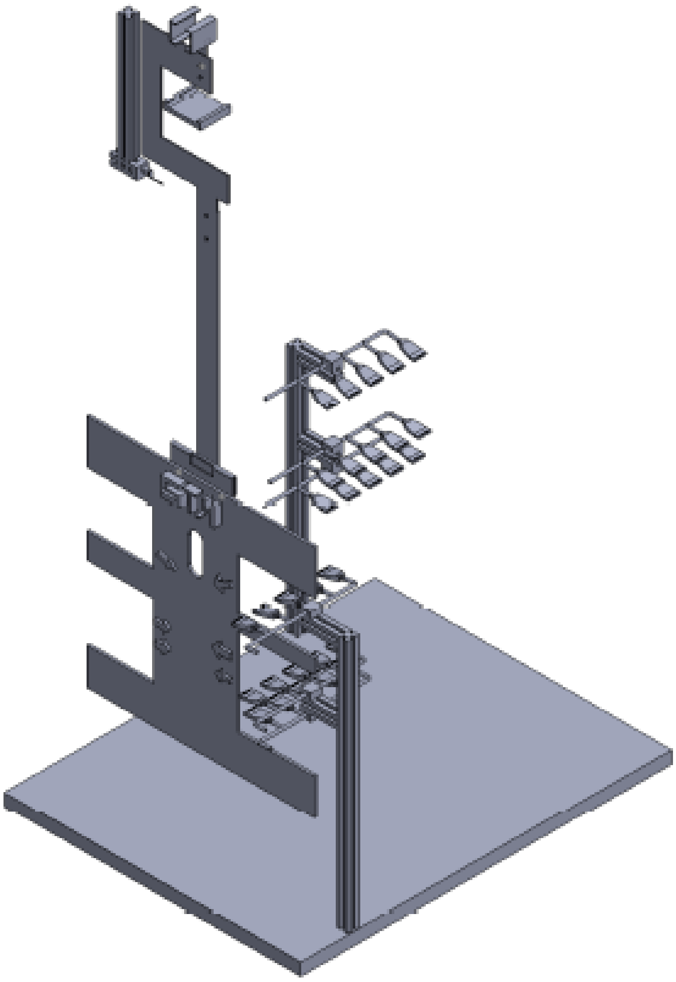
2 Station:



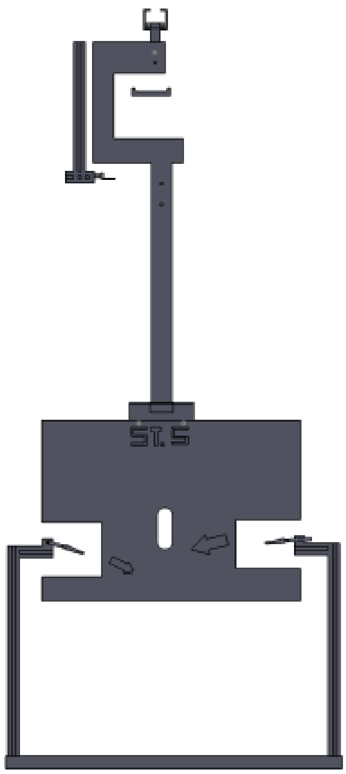


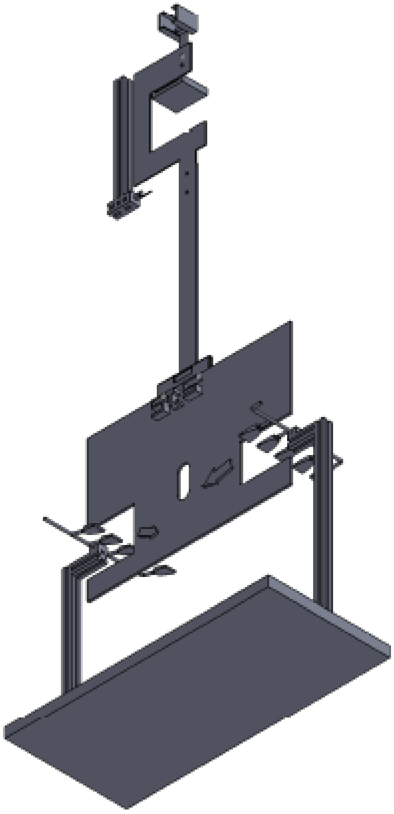
4 Station:





5 Station:





These models can explain how each station is organized and it is possible to modify some distances to keep new wipers without failures.

This work wants to be a reference point for the next activities and improvements and now you can.

Before this, it was not possible to get some changes into the blow off area because you didn't have any parameters to be modified, for example.

With these stations, I fixed a reference point with 3D Models and adding this baseline in other conditions. It is also possible to manage the differences between the wipers or the stations themselves.

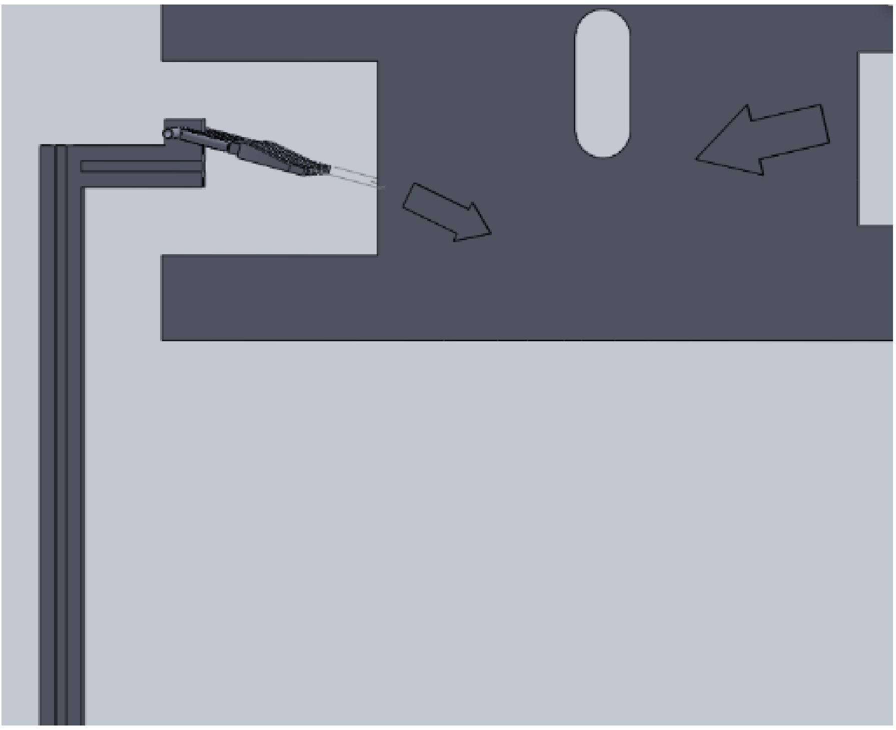


Figure 15 Orientation for nozzles from gauge

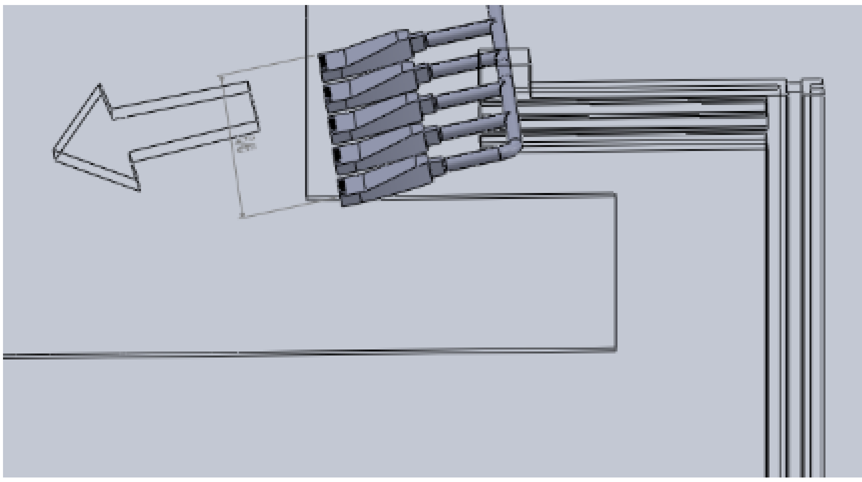


Figure 16 Detail of nozzles line

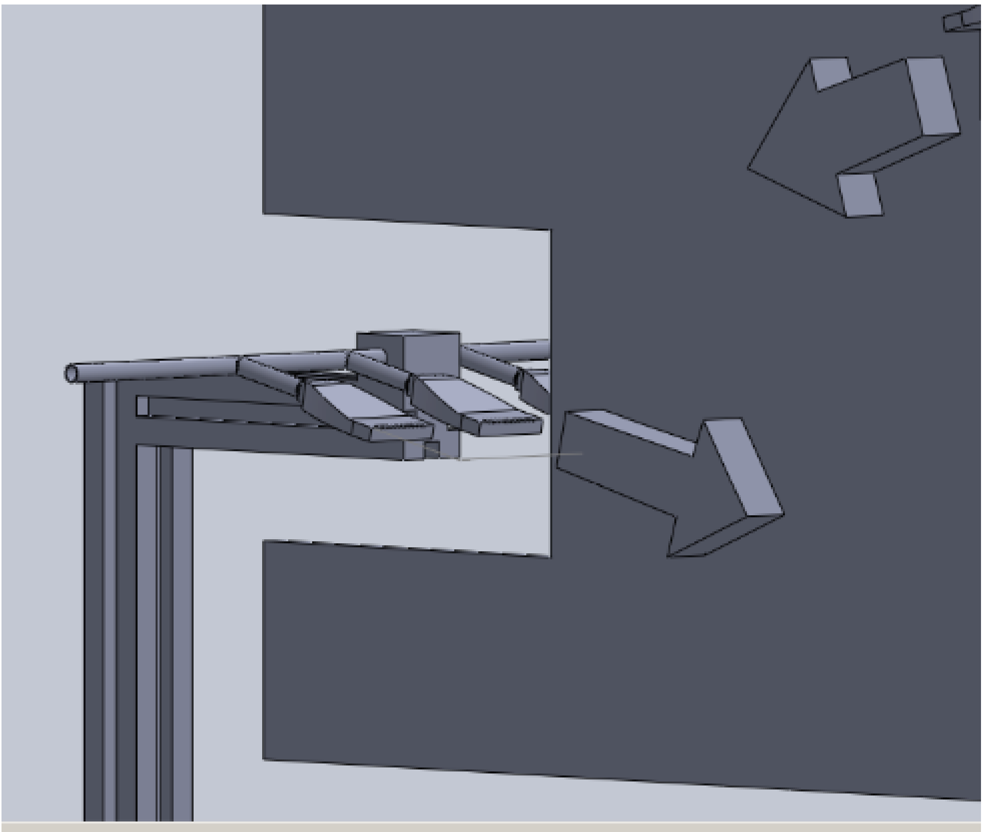


Figure 17 Another view of 3D complete station 2 doing the maintenance

After this, I created the first case of wiper into the Blow Off Area from the 3D Model.

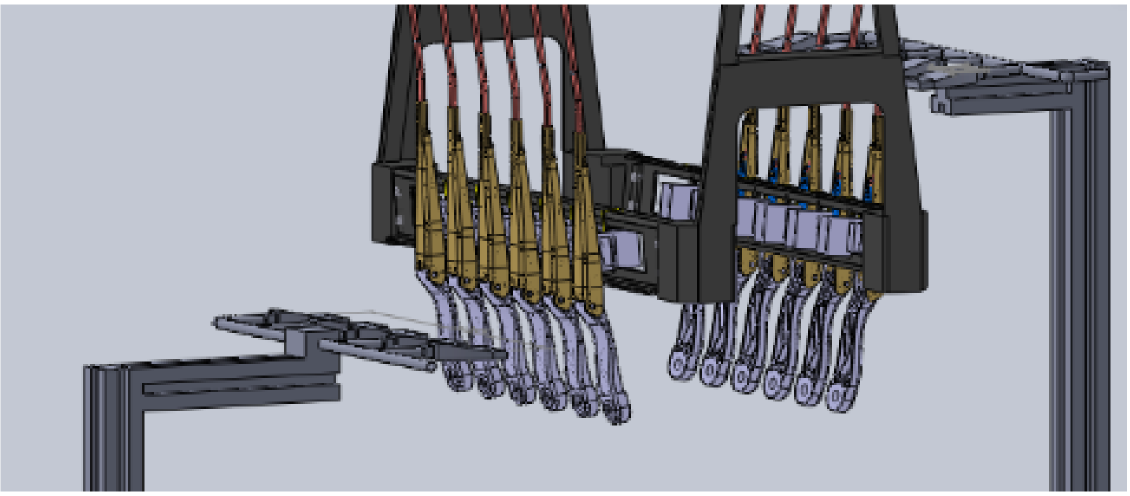


Figure 18 Airflow to Wiper

This kind of project is very helpful to check the dimensions of the nozzles, even to correct the orientations with their layout (different for each station).

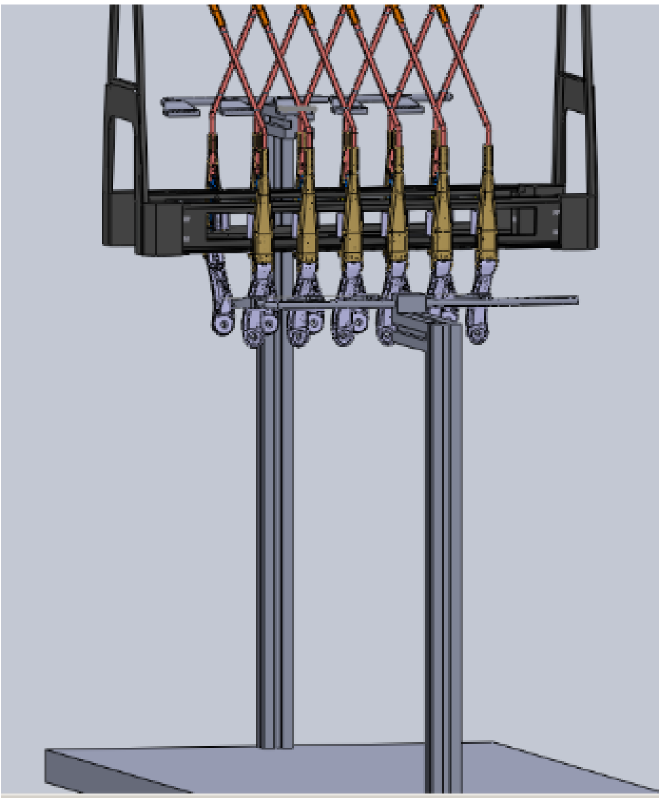


Figure 19 Side view of the system in Station 4

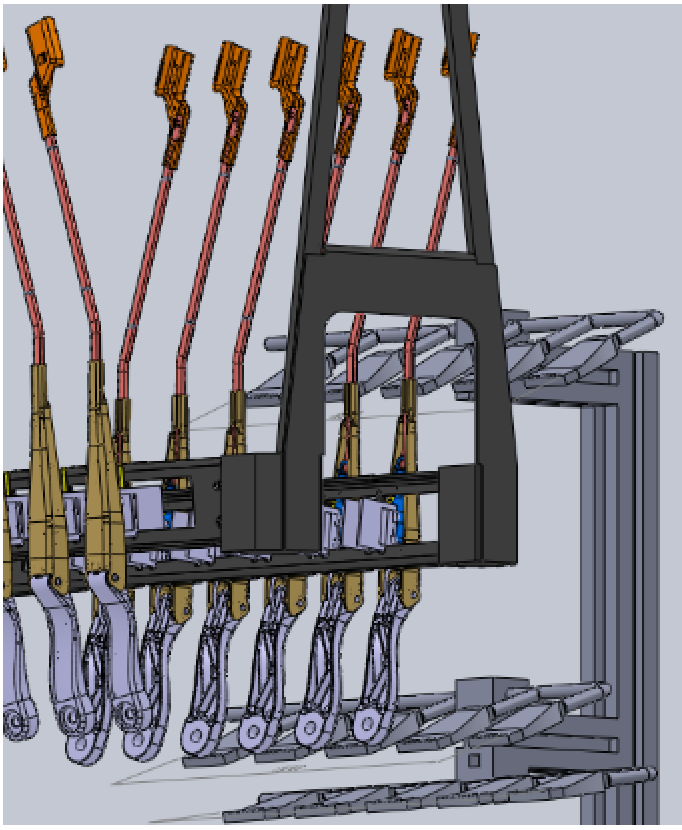


Figure 20 Another screenshot from the real process on going

6.1) GAUGE PROTOTYPE INTO THE SYSTEM

After these several attempts, we finally reached the last prototype of the gauge that it is ready to use it.

The solution has been found using the conveyor system as a reference for the system. This means that I studied in deep the shape and the characteristics of the conveyor and about the trays, the wagons and so on.

First of all, it was necessary to use a really small space into the conveyor to insert a tool as the first part of the system.

Figure 21. Conveyor system with detail of top insert part and G-shape

It is possible to insert a small part like this on the picture above and turn it of 90 degrees on the right. After this, the wheels will stay on the platforms of the conveyor and you can shift this part ahead and back through it.

In about 5 seconds you can insert this one and in other 5 seconds, you can remove it turning the metal sheet or moving it on the top and then turn.

Pictures of insert system

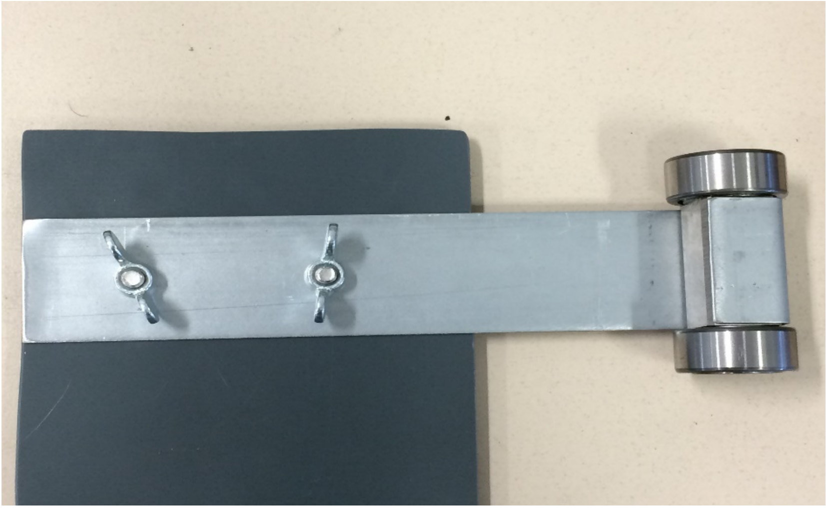


Figure 22. Tool realized using wheels, plugs and metal sheet

Figure 23. Detail of wheels running on the conveyor

This part has been made with metal because of its importance into the system and because it is in a heavy space to turn it and sometimes it is possible to have some issues meanwhile you are removing it.

This part has two screws ready on the front part to connect the G-shape part.

Figure 24. Detail of quick fix & remove

Picture of G-shape

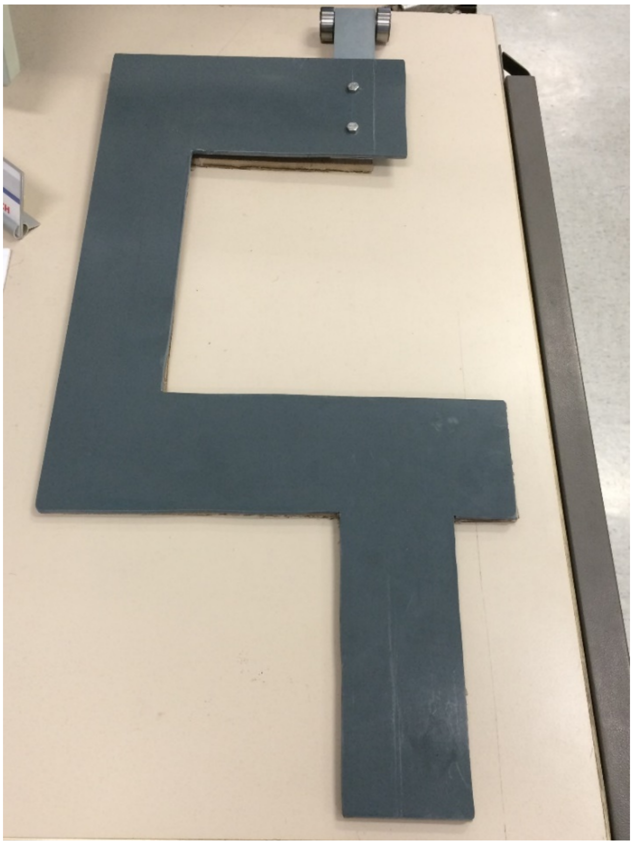


Figure 25. Prototype of G shape tool

This particular shape has been thought and realized due to the obstacles on the way to the nozzles. One is on the left side and it is the Bosch Profile from the top with a horizontal laser at the end. This is really close to the conveyor and we have to avoid it and do not damage it.

The second issue is the tray under the conveyor system. It is there because it reaches all the dust coming from the top. This G-shape is important to have a good way to avoid these issues; avoiding the obstacles and keeping a stable position on the bottom part of it. This part is ready to be connected with the long middle part of the system.

Picture of middle part

Figure 26. T shape for the middle of the system

This third part, as the first one on the top, has been made with metal because of the height and the weight of it.

It is very important to notice that these three components are universal, so you can use them for all the stations with the same way to install and remove them.

You also be able to shift this complete prototype from the first station to the last one, only adding the flat gauges on the bottom when you need it.

The top connection (between the G-shape and this one) is like the first one with two screws, really easy to insert and remove them. I reserved this mode to connect it because of the execution speed. Also for the bottom part, this time is really reduced and you only have to clamp the gauge on the folder.

Picture of the bottom part

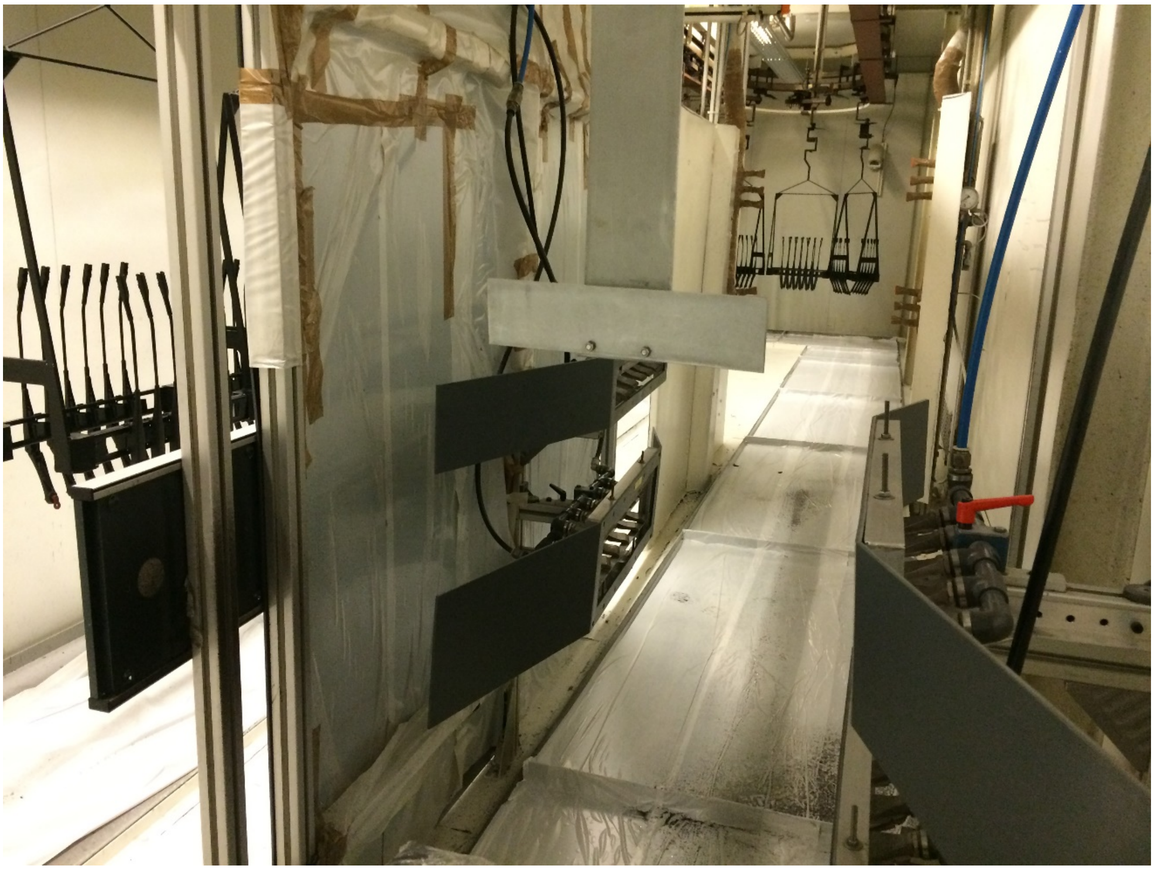


Figure 27. Overview of bottom part running without final part

6.2) GAUGES FOR THE STATIONS

Each blow off station has its layout and design, so it is fundamental to respect the heights and the orientations of the nozzles. This means that you have to change the gauge for each station.

The material for these parts is plastic (as the G-shape), because you do not need too much weight for it and also has to be easy to hold it and shift it when it is working. Each gauge follows the shape in the middle of the station and leaves the space around the nozzles. After several tests and attempts, we created the shapes for the maintenance activities.

It is noticeable that in each gauge, we pasted the arrows that they indicate the orientation of the nozzles. It is really easy to check immediately if there are some mistakes or if everything is working properly.

Also each gauge has on the top the number of the station to recognize which station is for and almost in the middle we realized a sort of handle (hole) to hold the gauge when you want to clamp it on the system, shift and remove it.

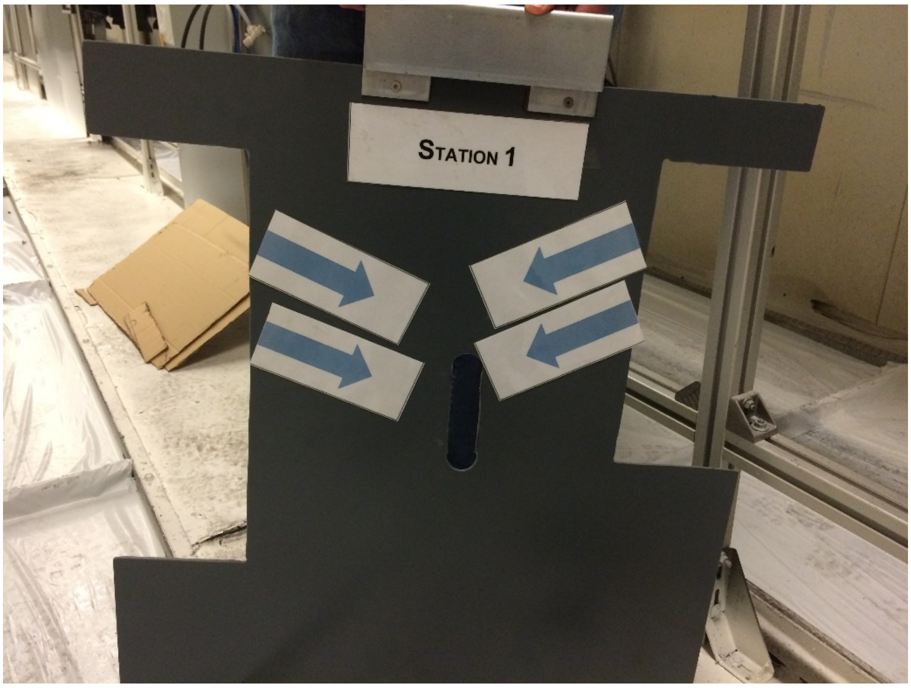


Figure 28. Prototype of gauge for Station 1

Figure 29. Prototype of gauge for Station 2

Figure 30. Storage of gauge prototype for Station 4

The picture above shows the small place where it is possible to store the gauges

Figure 31. Prototype gauge for Station 5

7) MAINTENANCE for BLOW OFF AREA

An important task is to check the actual maintenance activities, giving a feedback and realizing a short vademecum to improve the components life and get ready to any criticalities in process.

As already explained, for this blow off area, the maintenance activity was only to change the old nozzles broken with the new ones, following the standard one.

To get an important improvement, it has been relevant to educate the engineering team and the workers into the stations how to check the functionalities of each part and durability of them.

So the first point is to check the air pressure into the pipes that are going into the blow off system in entrance. If this doesn't work properly, they need to manage with supply valve and correct it.

After that, it is important to check each nozzle with the tools and if it is broken, switch it with a new one. For the blowers we can have a similar approach but the process has to be stopped if they don't work at 100%.

Sometimes It is not clear the decrease of air pressure from them. It could be necessary to add some sensors connected with an easy tester.

If two operators are working into the station, the first one can execute these tasks, meanwhile the second has to get the new gauges from the security points and start to fix the G shape with the bottom part and adding the gauge too.

This means that they can check the position of the nozzles, the orientation, the side layout and the height of them, all in one movement.

For this operation is calculated an average time (tested from workers, engineers and me) about 90 secs for each station (with an operator).

The full control of the 4 stations is around 400-450 secs, 7/8 mins that can be scheduled each 4 weeks, meanwhile the dust control on the conveyor every 3 weeks. The dust accumulated on the bottom part of the conveyor can contaminate the wipers generating failures.

Some additional controls can be done at the entrance of the blow off area, that means before to start the main process. For example, we checked each week the temperature in some checkpoints of the Paint shop and also registering the amount of particles minor of 10 micron, of 1 micron, and 10^{-5} microns to understand if the area was contaminated and it needed the cleaning from external supplier.

Another maintenance activity is about the measurement of resistance of the wipers before the E-coating process. This is another test to check if there are some connections between resistance and failures, also to see if the conveyor + rack system is working properly without any leakages.

Table of tests (before the improvements)

	Air pressure [bar]	Nozzles system	Height	Orientation	Layout	
1 station	3,2	NOK	OK	NOK	NOK	
2 station	2,3	OK	OK	NOK	NOK	
4 station	3,6	NOK	NOK	NOK	NOK	
5 station	3	OK	OK	NOK	OK	

After the MAINTENANCE:

	Air pressure [bar]	Nozzles system	Height	Orientation	Layout	
1 station	3,1	OK	OK	OK	OK	
2 station	2,3	OK	OK	OK	OK	
4 station	3,2	OK	OK	OK	OK	
5 station	2,7	OK	OK	OK	OK	

Table of additional tests:

	Dust	Temperature [°C]	Particles [micron]	Resistance on WAA [Ohm]	
1 station	OK	32	180	2,2	
2 station	OK	35	100	2,1	
4 station	OK	37	120	2,3	
5 station	OK	27	87	2,6	

In theory, keeping a good maintenance activity, that means to have a continuous control of the area with a lot of feedbacks from the tests, it can get us confident about the process. This is the standard guaranteed to have less failures than before. So, if the failures are increasing, it is mandatory to check the parts and do a complete maintenance service.

If this does not have any results, we need to go in detail and start to plan a more complex system into the blow off area investing R & D budget to achieve full automated control reducing the man control at the minimum.

The work is already done in step 1 that is about the baseline of automatization the area like some others locations.

We respected the deadlines and budget limits for this task because it was not possible to achieve a complete transformation from “black box” to the highest level (0 failures) through an intermediate level.

I also approached this issue mindset on budget targets, costs and environmental conditions.

7.1) MAINTENANCE ACTIVITIES (TPM)

Robert Bosch Produktie NV has focused on maintenance activities for all the devices, machines and processes that establish the cycle time of the production lines and all the rest (calibration of measurements tools for example).

Regarding the maintenance of the B.O. Area, at the moment the unique work is the substitution of air nozzles when they are broken. There is not a plan of maintenance or an information about the duration of them.

Several air nozzles are stored into the paintshop and an expert operator can check if the nozzles are working or not.

Here a picture of nozzle

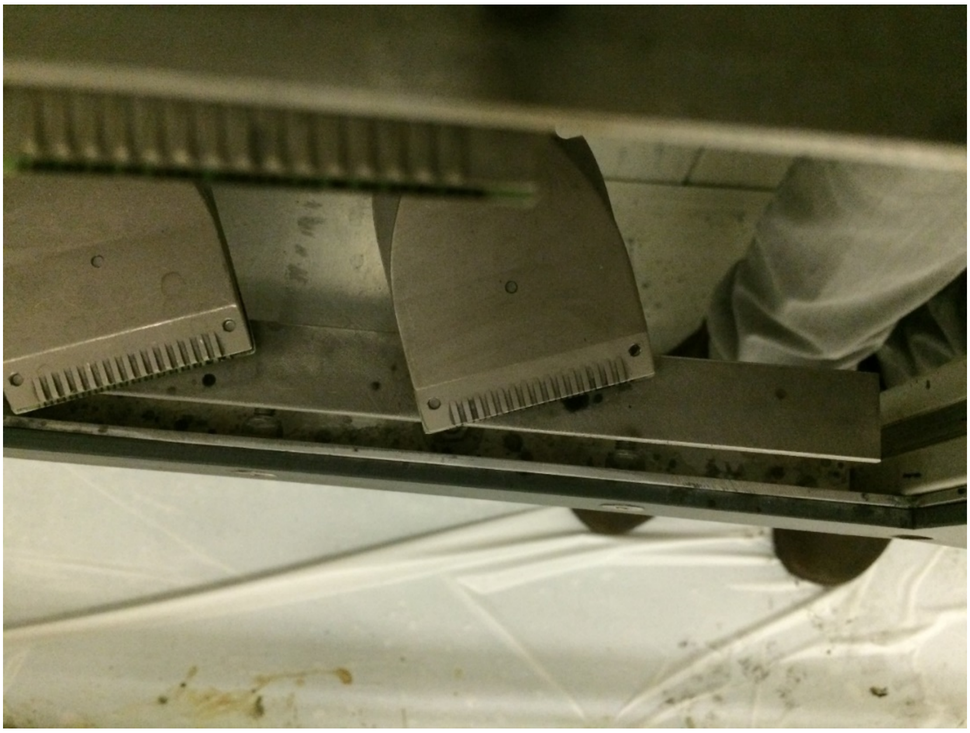


Figure 32. Top view of nozzle

It is noticeable that without any indications of time and installation, you can't forecast the duration of them and redact a plan with maximum of cycles, duration of the nozzles, description and planning of the maintenance activity stopping the production line.

Each pause for the process had to be accepted from the team and it takes a substantial loss of time and money. The production needs to reach a series of produced quantities of wipers and respect the deadlines with the customers.

For these reasons, it is an important goal to study and create some maintenance activities that you can check online without stopping production flow.

Some sections of the route are checked 24 hours per day because they are very important and easy to change some parameters. For example, the substitution of water used during the painting needs to be checked several times or the robots and lifts into the painbooth have to be cleaned properly every hour from an operator.

(Picture of paintbooth with reciprocators and robots)

Figure 33. The robots work close to the racks due to the shiftable floor

Figure 34. Robots and reciprocators in action

This procedure has a duration of 10 minutes at the end of 60 minutes of continuous work. Extending this, every day the plant spends circa 17 % of the time for this cleaning. It is a mandatory and necessary activity, of course, but still a huge percentage of waste time.

Observing the last data, it is fundamental to find a solution for the Blow Off Area and implement a specific online practice.

I observed and discussed about different solutions and ways to create a tool that encases all the main characteristics already mentioned.

8) COST ANALYSIS AND FUTURE OBJECTIVES

One of the objectives for each company is to achieve economic results that are important as the production improvements, even more.

For this discussion, I can't publish the real quantities or values for the investments and the savings. But I can use the percentages to explain the achieved advantages.

For example, the R & D budget for the full year was 30% of the total from RBBE NV. This is used for a lot of activities, mainly to pay the external suppliers for the paint shop area; then, to improve the production cycle and finally to test the components.

The proposal is to change less parts as possible, but only check and improve the quality that means reduce the number of failures. I only spent some money to create the prototype of gauge realized from me and an expert operator into the plant.

Considering this chart:

	First batches	After improvements	Before maintenance	After maintenance
% of failures	6,62%	1,88%	1,88%	1,76%
% of scrap	1,12%	0,77%	0,77%	0,75%

About these percentages, the total quantity of parts is 5786314 wipers and the period of counting was from 30th of April to 3st of August 2017.

	First batches	After improvements	Before maintenance	After maintenance
N° of failures	383053	108782	108782	101839
N° of scrap	64806	44554	44554	43397

We can easily calculate the number of saved wipers and the theory saved cost:

N° of saved parts = 383053 – 108782 = 274271 (after improvements)

N° of saved parts = 108782 – 101839 = 6943 (after maintenance activities)

N° of saved scrap = 64806 – 44554 = 20252 (saved after improvements)

N° of saved scrap = 44554 – 43397 = 1157 (saved after maintenance)

I can multiply the total n° of saved failures (274271 + 6943 = 281214) for the rework cost of each part (around 1,08 euros/each one), I obtain:

Saved cost = 303,7 k€

It is a huge amount of money saved due to the missed rework of them from the operator at the end of the cycle. They need around 5 mins to rework it from paint runners.

I also suppose the cost to cover with paint the rework parts around 0,35 euros each one. Total cost = 98,4 k€

Here I can evaluate the saved cost reducing the scrap parts. The total not scrap is 21409 parts.

Saved cost = 192,7 k€.

Total saved cost = 595 k€ in 3 months.

It is noticeable to consider the other accessories expenses that we are saving during this activity not considered until now.

For example, I suggested to synchronize the start of blow off time meanwhile the parts are into the area and not outside of it. There was a kind of delay from the blowers to the batch, around 5 seconds.

I checked the time with a chronometer and I saw the same delay at the end of blow off area. This means that the total delay is around 10 secs for each batch and we can save a huge amount of airflow. If I suppose that the cost of airflow is around 0,1 euros/min, we can save 0,01 euros for each batch.

I evaluate that every day are running around 700 batches, the saved cost is 7 euros per day. If we enlarge the evaluation for three months, the total is 0,63k€.

I can estimate a very important Cost Saving about 600 k€ in 3 months.

About the future objectives, I thought a lot about these trying to get more ideas from the workers and colleagues into the Tienen plant and I had different feedbacks from them. I listened to my RBBE referent there and we agree that the next step for this thesis could be an automatization of the Blow off Area and Line.

This means that it will be necessary to improve the structures (nozzles, blowers, etc.) adding some sensors to have an online feedback from the stations to correct immediately the failures on it-

It could be also possible to create a Database with all the different models of the wipers (Head or Bottom part) with heights and measures.

I started to collect the measures of different wipers for many suppliers and created a kind of Excel Macro to keep them together and have a rudimental kind of DB.

This can help to have a baseline where the wiper is 100% OK and if the measures change, you know where you can optimize the airflow.

Finally, I could retain this Master thesis over and I'd like to get a new experience like this as soon as possible.