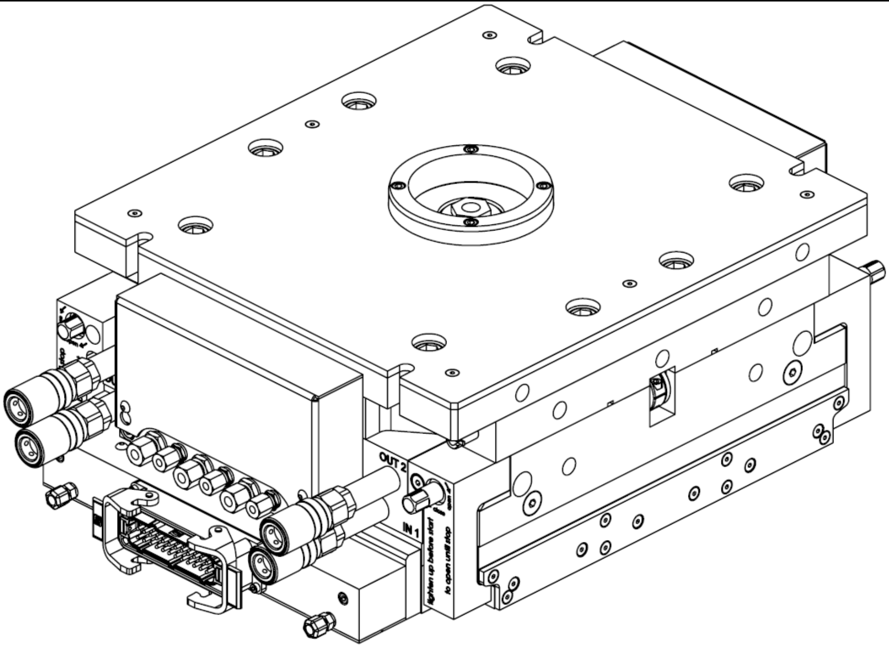

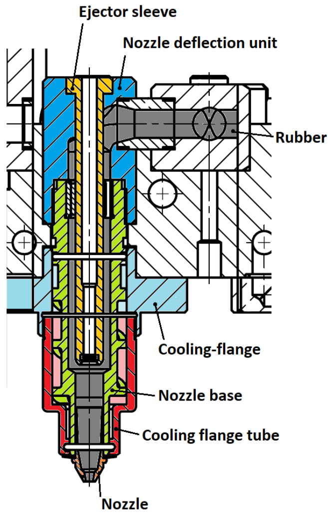

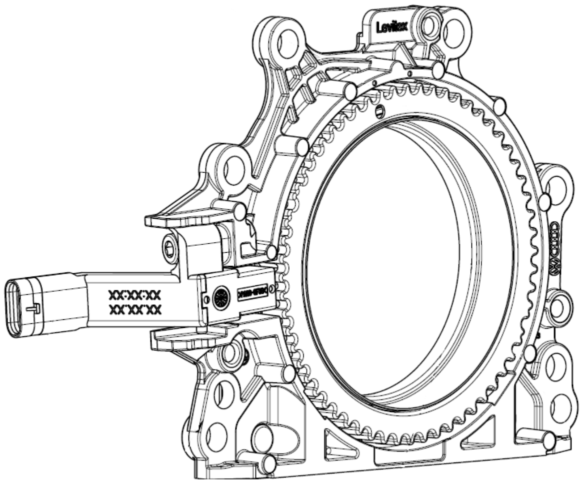

Graduation Assignment

Manufacturing and control of engine sealing rings and its improvements

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Freudenberg Sealing Technologies

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CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

MASTER'S THESIS ASSIGNMENT

I. Personal and study details

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Department / Institute: **Department of Automotive, Combustion Engine and Railway Engineering**

Study program: **Master of Automotive Engineering**

Specialisation: **Advanced Powertrains**

II. Master's thesis details

Master's thesis title in English:

Manufacturing and control of engine sealing rings and its improvements

Master's thesis title in Czech:

Výroba a kontrola motorového těsnění a možnosti zlepšení

Guidelines:

Make a literature overview of used engine sealing rings and their fabrication procedures. Accomplish a study of Valgate technology and prepare a portfolio designed to help the maintenance technicians. Describe the process of control check of produced sealings. Investigate the high wear of the shock absorber on the robotic arm. Propose new solutions. Document them appropriately, choose the best solution and prepare assembly of manufacturing drawings of the improved design. Make all necessary calculations.

Bibliography / sources:

Name and workplace of master's thesis supervisor:

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Yannick Prodhon Freudenberg Sealing Technologies

Date of master's thesis assignment: **30.04.2022** Deadline for master's thesis submission: **12.08.2022**

Assignment valid until: ______________

doc. Dr. Ing. Gabriela Achtenová Digitálně podepsal doc. Dr. Ing. Gabriela Achtenová Datum: 2022.07.20 15:16:58 +02'00'

doc. Dr. Ing. Gabriela Achtenová Supervisor's signature	doc. Ing. Oldřich Vítek, Ph.D. Head of department's signature	doc. Ing. Miroslav Španiel, CSc. Dean's signature

III. Assignment receipt

The student acknowledges that the master's thesis is an individual work. The student must produce his thesis without the assistance of others, with the exception of provided consultations. Within the master's thesis, the author must state the names of consultants and include a list of references.

01/08/2022 Date of assignment receipt	Roulin Student's signature

CVUT-CZ-ZDP-2015.1

Acknowledgment

This Master's thesis and final internship was carried out in the R&D premises at the Freudenberg Sealing Technologies production site in Langres, France.

First, I would like to thank my supervisor at Freudenberg Sealing Technologies, Yannick PRODHON, for his guidance and for the trust he gave me throughout this internship. He was able to put everything in place as soon as I arrived to put me at ease and allow me to work in the best conditions. He was always available to advise me, and his support has made me gain more autonomy and self-confidence.
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My thanks also go to Jean-Luc FAYE from the maintenance workshop for all the knowledge he was able to pass on to me on production machines and rubber injection, to Raphael BAGOLIN for the time he spent showing me the machines for which he is responsible, and to all the maintenance employees with whom I had the opportunity to work.

Finally, I want to thank all the employees of the production site I met and discussed with, from those who were able to help me when I needed it to those with whom I was able to chat during lunch breaks.

Abstract

For a few years, to reduce the quantity of wasted primary resources and meet new economic and environmental standards, Freudenberg ST has been using a new type of machine known as Valgate to inject rubber and produce engine sealing rings. Despite a drastic reduction in wasted material by not using any sprues, these machines are more complex and more susceptible to leaks. After multiple generations of Valgates, The FST factory of Langres uses now up to 20 machines to mass produce sealing rings, and while the most recent ones contain all the upgrades added along the way, the older ones need some parts to be replaced. Moreover, in order to prevent leakage, each Valgate need to perform a maintenance every six months to check the state of every part and to replace the most critical parts like the O-rings.

The main mission entrusted to me was to study every Valgate independently to monitor their continuous improvement and to prepare their maintenance. That is to say to list the parts that must be mandatorily changed due to wear, to prepare the parts included in the Valgate update process and to keep track of the upgrades, and also to create a portfolio specifically designed to help the maintenance technicians during the maintenance. in addition to helping technicians, these documents will allow the supply department to be able to order the necessary spare parts.

To accomplish this task, I had the opportunity to read complex industrial plans, to participate in the maintenance of the injection plates, to identify the parts at risk and discuss with the technicians about the points to be highlighted for the maintenances in the future. I also had interactions with the manufacturers about upgrades and technical improvements to it and managed multiple dashboards related to the tracking of spare parts.

later during the internship, when my main mission was completed, I was given another mission. In the Freudenberg factory, every part must be controlled one by one to assure that every part delivered provides enough sealing. To do so, the sealing rings go through automated production lines where they are handled by robotic arms.

On one of the robotic arms, the shock absorbers wear out faster than expected, causing daily maintenance and high spare part costs. I therefore had the mission of studying the breakdown and finding a suitable solution to the problem. After investigation and dialogue with the shock absorber manufacturer, I deduced that the problem came from the angle of deviation created by the rotating motion of the arm that put too much stress on the bearings inside the shock absorber. In this report, I reviewed multiple solutions to prevent the shock absorbers to wear abnormally fast and I further developed the solutions I found the most effective by drawing 3D models to recreate the problem and calculate the effects of the solutions on the shock absorber. I finally designed an adaptor to solve this problem based on models found online and on calculations to fit the problem and prepared a technical drawing to machine this adaptor and test it on the actual system.

Keywords: rubber injection, sealing, leakage, premature wear, shock absorption

Presentation

As a French student pursuing a double course in engineering school and a master's degree, a 6-month internship in a professional environment is the last step to conclude my scholarship.
Since my scholarship was mainly focused on automotive engineering, and my goal is to start a career in the automotive industry, I naturally sought to join a company specializing in the manufacture of automotive parts. I thus had the great opportunity to join a global company, European leader in its field of manufacture: Freudenberg Sealing Technologies.

When joining the company, my main mission was centered around the new production method they developed to produce sealing rings for ICE engines. FST main activity has always been the manufacturing of sealings for ICE vehicles, but the current electrification of vehicles is changing the tendency at an astonishing pace. Fortunately for FST, they reacted quickly and adapted their production to manufacture gaskets for electric vehicles, and thanks to this new market in full expansion they largely compensate for the decline of thermal engines and ensure a promising future.

But what about the production of sealings for ICE vehicles. Despite this change in the mentalities, parts for ICE vehicles and hybrid vehicles are still needed, and the need for spare parts will probably remain for at least a decade. Instead of being satisfied with the traditional means of production that they had been using for years to continue to produce ICE parts, they preferred to develop a new innovative production method that hugely reduces the scrap rate. this new means of production has a positive ecological and economic impact, but the technology behind it is still under constant development.

at the Langres production site and under the supervision of the process engineer manager, my master’s thesis focuses on this new technology nicknamed Valgate.
After a presentation of the company, I will explain how Valgate injection plates work, I will also highlight the more problematic parts which needed upgrades, and then I will describe how did I participate in the monitoring of the continuous improvement on the Valgates.

In a second time, I will present my work on another topic related to the wear of shock absorbers on the automated production line. After investigating the problem, I will propose solutions and develop further the most convincing solution. Although not related to Valgate plates, this problem is a classic example of a problem encountered in the industry and constitutes a relevant form of continuous improvement.

Keywords: rubber injection, sealing, leakage, premature wear, shock absorption

Table of contents

1. The Freudenberg Group

1.1. Company history

Freudenberg is a German family business founded in 1849 in Weinheim, Germany, by Carl Johann Freudenberg. Originally, this group specialized first in the production and marketing of calfskin products, then in synthetic elastomers in 1936. Today, the company is owned by approximately 320 members of the founding Freudenberg family, with more than 48,000 employees in 60 countries around the world. The Freudenberg Group is present in four major areas: sealing and anti-vibration, nonwoven fabrics, household products and medical products.
But among all the areas, sealing remains the main sector of activity and Freudenberg Sealing Technologies (FST) is the leader in the field of automotive and truck sealing in Europe.

1.2. Freudenberg Sealing Technologies

FST provides with sealings car manufacturers, truck manufacturers and spare parts distributors.

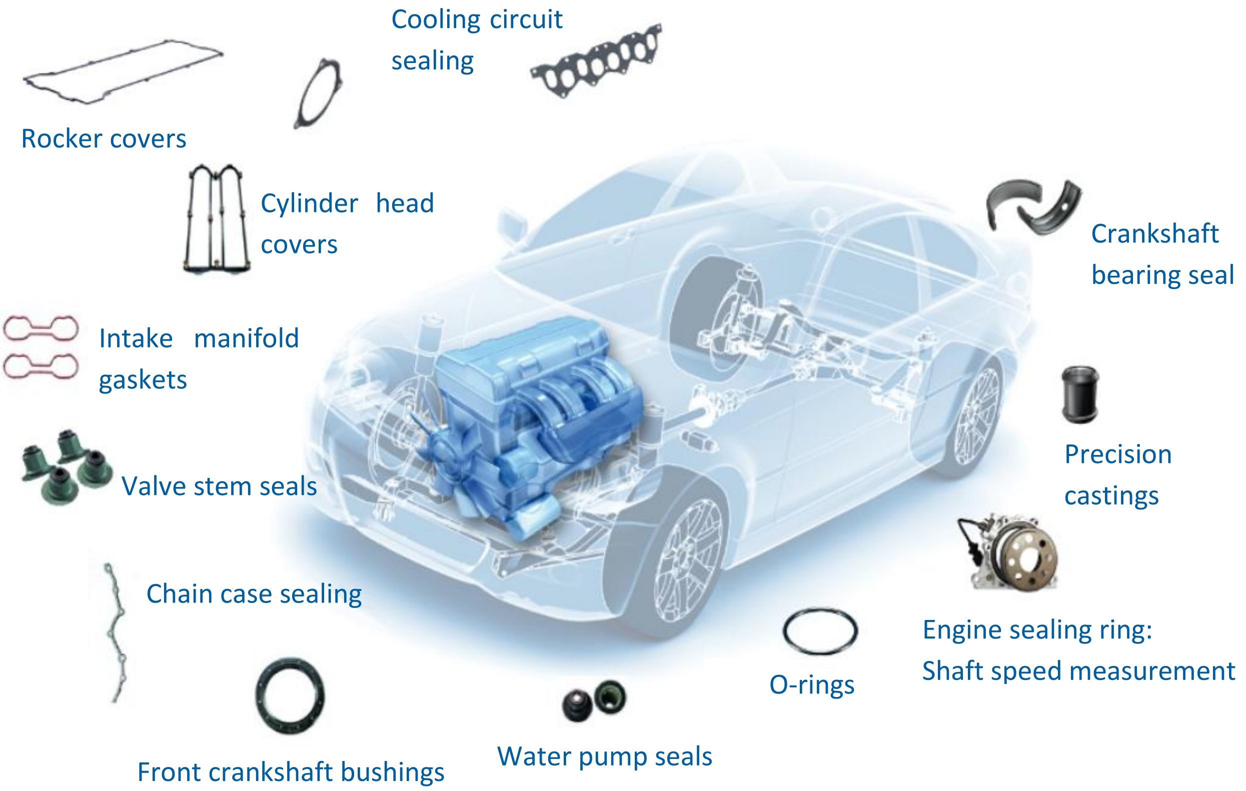


Figure 1 : auto parts produced by FST

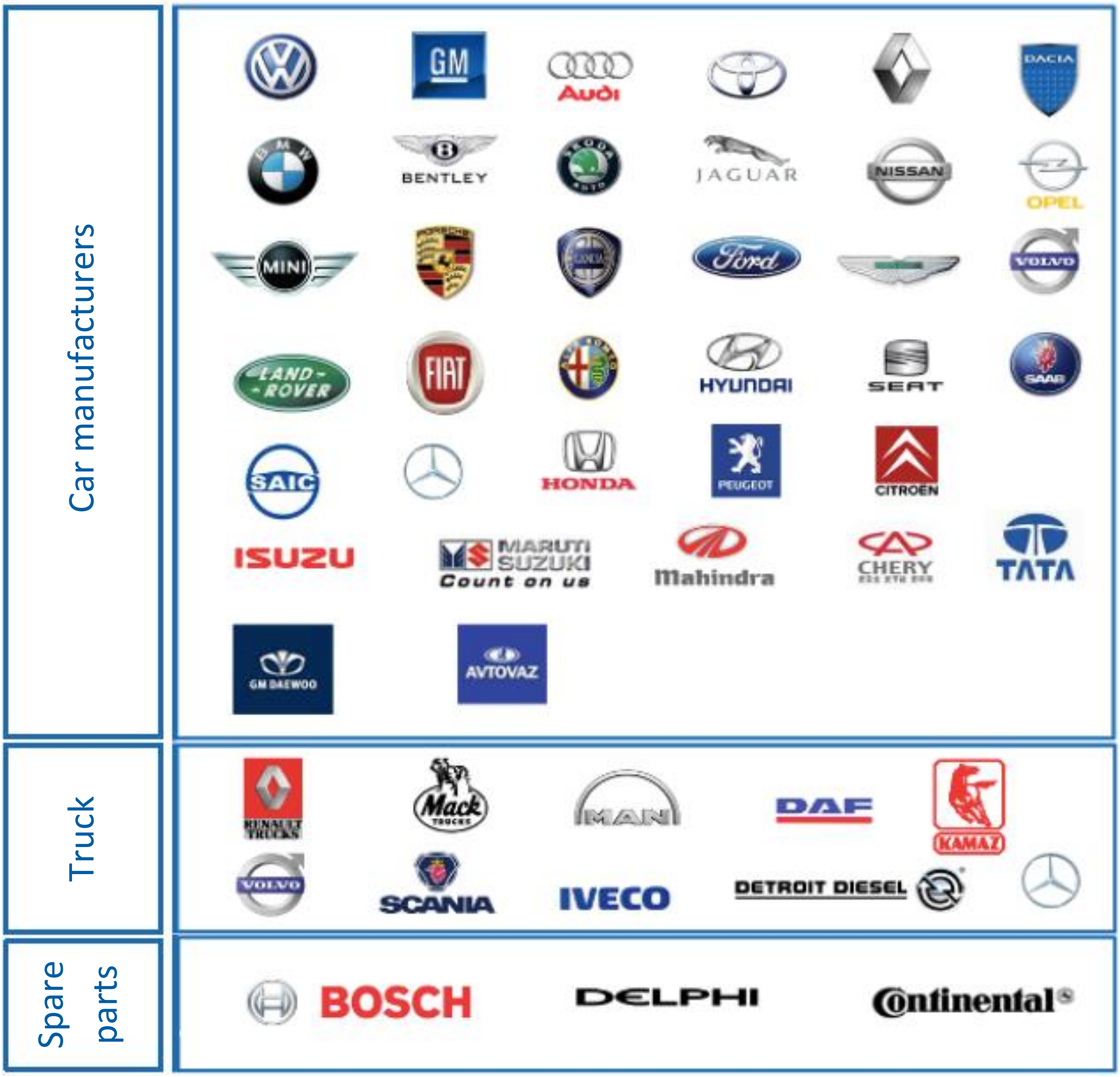


Figure 2 : FST customers for vehicle parts

My internship took place at Freudenberg SAS Langres, a factory built in 1963 in the northeast of France and later bought by Freudenberg in 1993. Freudenberg Langres is part of the FST division, and it contains multiple Business Units (BU) as well as a research and development center.

The main parts produced in Langres are sealing rings and sealing housings. Most of the activity revolves around rubber injection, but two BU are also specialized in plastic and aluminum to manufacture the housings on which the rubber is injected. Aside from the sensors, the factory is therefore able to produce almost all the components necessary to assemble the final product.

In 2019, their turnover reached 75 621 900,00 € thanks to its 250+ employees, number that went down during the pandemic but that is coming back up thanks to telework and to a relaunch of industry in France and around the world.

1.3. Sealing technologies produced in Langres

The main products manufactured in Langres are radial shaft seals for ICE engines, from simple sealing rings to sealing flanges with crankshaft sensors and covers made of plastic or aluminum.
Thanks to its wide area of expertise, going from aluminum stamping to plastic injection, the covers and the armatures for the rings are also made in Langres, the only part not manufactured in the factory are the sensors.

Sealing ring

Sealing flange with sensor

Plastic cover

Aluminum cover

guide sleeve

blueseal ring

Figure 3 : Parts produced at FST Langres

These sealings prevent the oil from leaking, but they also protect the engine from water, mud, clutch dust.
A sealing ring must ensure a static seal at the housing and a dynamic seal at the rotating shaft.

1.4. An overview of engine sealing rings and their fabrication procedures

An engine must ensure that all fluids involved, fuel, air, lubricant, coolant, remain inside despite high pressures or moving parts. I will do an overview of the main sealings used in engines.

-Piston rings

In an ICE engine, one of the most important things to take care of is to be sure that the air and mixture can be trapped inside combustion chamber and prevent the mixture from leaking and the pressure from dropping before the expansion. The problem is the pistons move along the cylinder wall so piston rings must be used to prevent blow-by as much as possible. So, piston rings are used to solve this problem. The piston rings are also responsible for the cooling of pistons by transferring the heat from the pistons to the cylinder walls. The piston rings are placed in a groove inside the piston and usually three of them are used on each piston.

The compression ring is the ring closest to the piston head and compression chamber, so it is the most exposed to heat and chemical corrosion[1]. As implied in its name, the main goal of this one is to counter blow-by. During the expansion phase, the combustion gas pressure pushes the piston ring against the cylinder wall to form a seal. Since the compression ring is the closest to the high temperature, it transfers most of the heat to the walls[1].

The oil ring is the closest to the crankcase and is used to wipe all the excess oil on the walls and send the oil back to the reservoir through openings[1]. This ring can only be found in 4-stroke engines since 2-stroke engines do not use an oil reservoir, the lubrication comes from the oil in the gasoline mixture.

The wiper ring is situated between the compression ring and the oil ring, it serves as a secondary sealing to provide an even better sealing between the piston and the cylinder wall. It also provides a constant layer of oil between the two surfaces and ensure optimal lubrication[1].

Piston rings are usually made from cast iron. Cast iron possess a very good heat conduction to cool the cylinders and deforms sparsely under high temperature and heavy load.

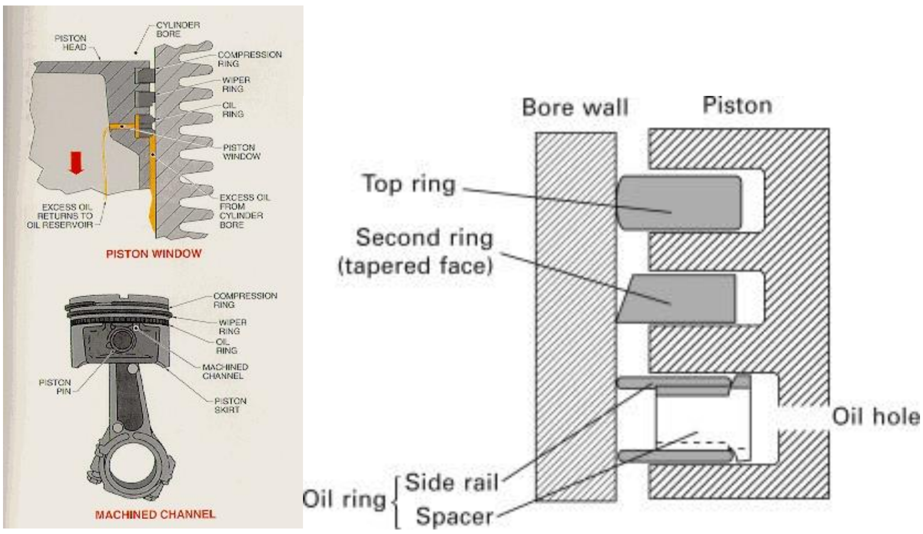


Figure 4 : Piston rings on a piston

To produce piston rings, two main methods are used.

The first one consists of using a cylindrical mold with the external diameter of the piston ring to pour a cast iron cylinder inside, then when the cylinder is done, the inside of the cylinder is cut out and finally the rings are sliced from the cylinder[2].

The second method is to directly cast the piston rings with the right shape, the rings are attached one to another to form a sheet of metal. The rings are then snapped out of the sheet and are machined[2].

-Head gasket

Another seal essential for ICE engines is the head gasket. The head gasket is the seal placed between the block and the cylinder head. This gasket is used to seal the compression chamber and avoid mixture escaping and pressure dropping after combustion, but it also seals the oilways and waterways between the block and the cylinder head[3]. even though it must withstand a lot of constraints, it does not seal any moving parts unlike piston rings or radial shaft seals.

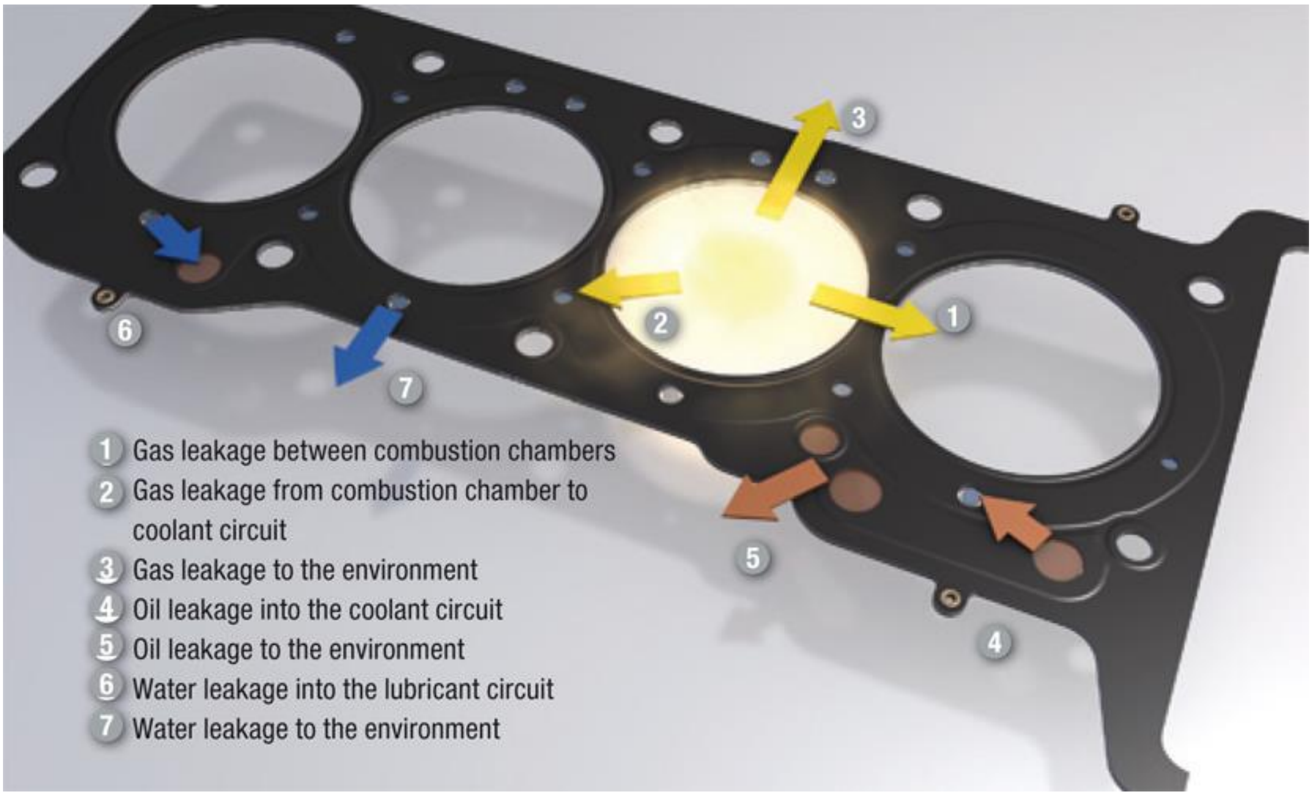


Figure 5 : Head gasket with the leakages to prevent in the engine

Head gaskets used to be made of graphite-based composite, but modern head gaskets are made of Multi-Layer Steel or MLS[4]. Three steel plates are piled, the center layer is thicker while the two other layers are thinner and are coated with Viton or other polymers to resist chemicals and high temperature and to seal the contact surfaces with the block and the cylinder head.

Head gaskets feature steel rings around the cylinder called fire ring which are crushed when the cylinder head is tightened and provide a very good resistance to high pressure and temperature[3].

-Radial shaft seals

The seals manufactured at Freudenberg Langres are radial shaft seals, they form another category and are used among other things in the crankcase, in the pump and turbine and in the gearbox.

The shaft seals made at Freudenberg are made of an armature made of steel coated in elastomer and a PTFE lip.

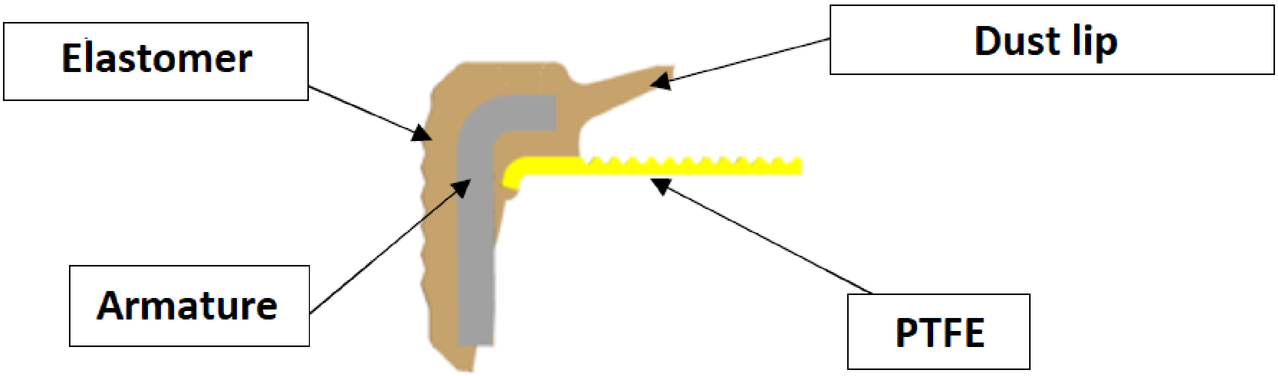


Figure 6 : Parts of a sealing ring

For shaft sealing rings, the static tightness is obtained by the tight fitting between the elastomer and the housing, and the dynamic seal is obtained thanks to the shape memory of PTFE.

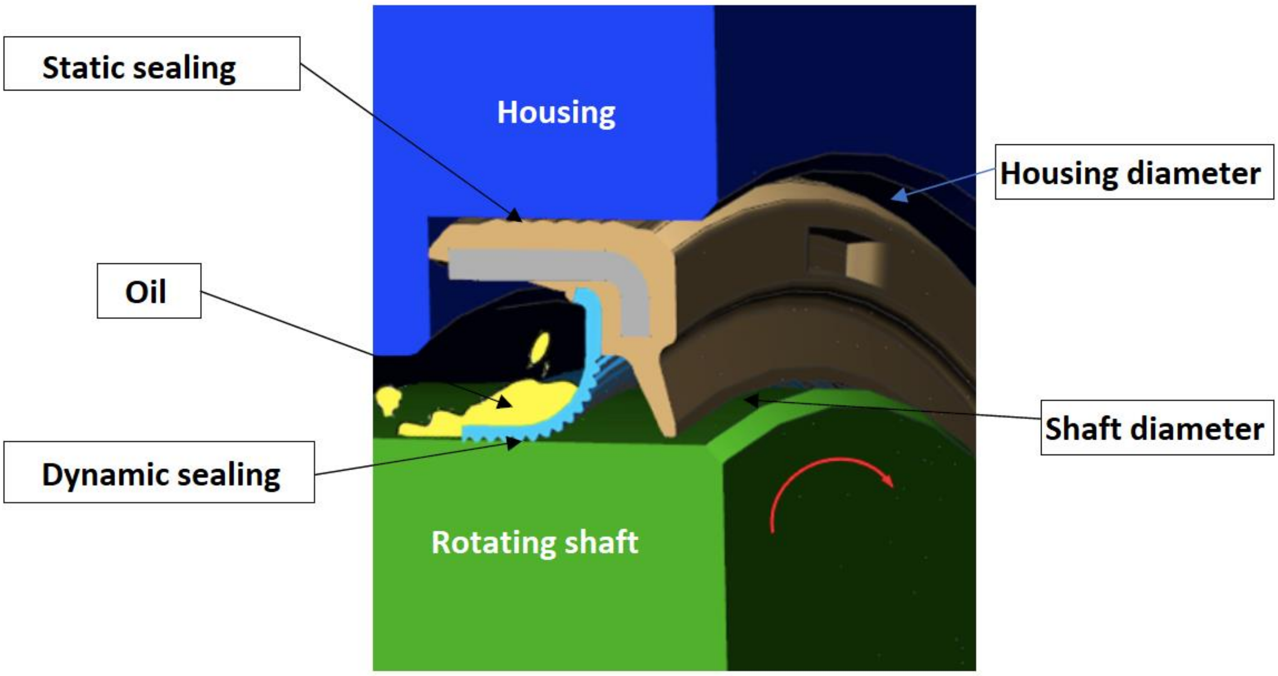


Figure 7 : Operation of a sealing ring

PTFE lips are widely used for rotary shaft seals because of its extremely low friction and resistance to wear, chemicals, and high temperatures.

PTFE, or Teflon, was discovered in 1938 by Roy Plunkett. It was developed more in depth during the 2nd world war for its resistance to toxic products and to be used in the atomic bomb[5].
To process PTFE, PTFE powder is used to perform compression moulding and obtain the required shape[6].

To produce shaft seals, the armature and the PTFE lip are put in a mold and elastomer is injected in the mold. As for plastic injection, elastomers can be molded using different techniques[7].

Injection molding: the most common method, the elastomer is melted, then injected in the mold and finally cured and cooled, forming a solid part made of elastomer.

Compression molding: the solid elastomer is pushed into a preheated mold where it softens and takes the shape of the mold thanks to the high pressure inside.

Transfer molding: a plunger pushes the molten elastomer into a cold mold.

Cast molding: the elastomer is melted and injected in a mold, then the mold is put in an oven. The mold is removed when the elastomer has hardened.

Elastomer injection is excellent to mass produce parts for the automotive industry, but we will see in the next part that elastomer injection can be improved and how Freudenberg Sealing Technologies manufactures radial shaft seals.

2. The Valgate-type rubber injection plates

2.1. Rubber injection

Plastic injection is a well-known process mastered by many factories thanks to its simplicity. Plastic pellets are melted, the molten plastic is compressed inside a mold, then the mold opens, the parts are removed and cooled down, then we remove the sprues to turn them back into pellets and we get our plastic part with very few plastic losses.
Unfortunately, rubber injection is way more difficult, the temperature curve to follow is more complex to allow the vulcanization of the part, and more importantly the sprues cannot be reused, so it is a direct loss of material.

Vulcanization: Vulcanization of rubber consists of heating the rubber with sulfur up to 200°C, the sulfur atoms bond the rubber molecules to each other, forming a 3-dimensional cross-linking and therefore changing the properties of the rubber [8]. This process, which was invented in 1839 by Charles Goodyear, hardens the rubber part, making it more elastic and less viscous, raises its tensile strength and also making it more resistant to abrasion [9].

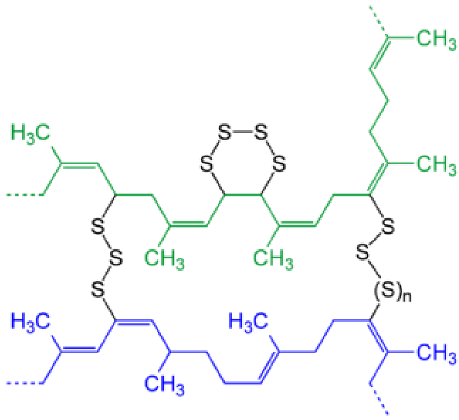


Figure 8 : Rubber after vulcanization with Sulfur cross-linking

All these properties are what car manufacturers are looking for when they use rotating shaft seals in their cars, however the vulcanization of rubber is challenging for the manufacturer and many points cannot be overlooked.
First, the vulcanization starts activating when the sulfur is added to the rubber. certainly, at room temperature the evolution is very slow, especially with all the additional activators added to the mix, but an advanced vulcanization before the injection process can lead to cracks in the final product, which is unacceptable for seals. Since the mixing of rubber with the sulfur is made in Germany, the rubber reels are transported from Germany to France by refrigerated truck. Every reel is also examined by the laboratory in Langres at the arrival to know the exact properties of the material used to avoid any problem during the injection process or cracks in the long term.
Another problem mentioned before is that once the vulcanization process is done and the cross-linking between the rubber molecules and the sulfur atoms is formed, it is not possible to melt the parts to reuse them, which means that the faulty parts and the sprues are all wastes. With a classic mold like in plastic factories, 30% to 40% of the raw material would go to waste as sprues. Freudenberg Langres has been using classic molds for decades out of option, but with the raise of environmental awareness and the rise of raw material prices, a new solution had to be found.

2.2. The principle of Valgate plates

2.2.1. How to improve classic injection

To understand how to get rid of sprues, we first need to look at how a classic injection plate looks like.

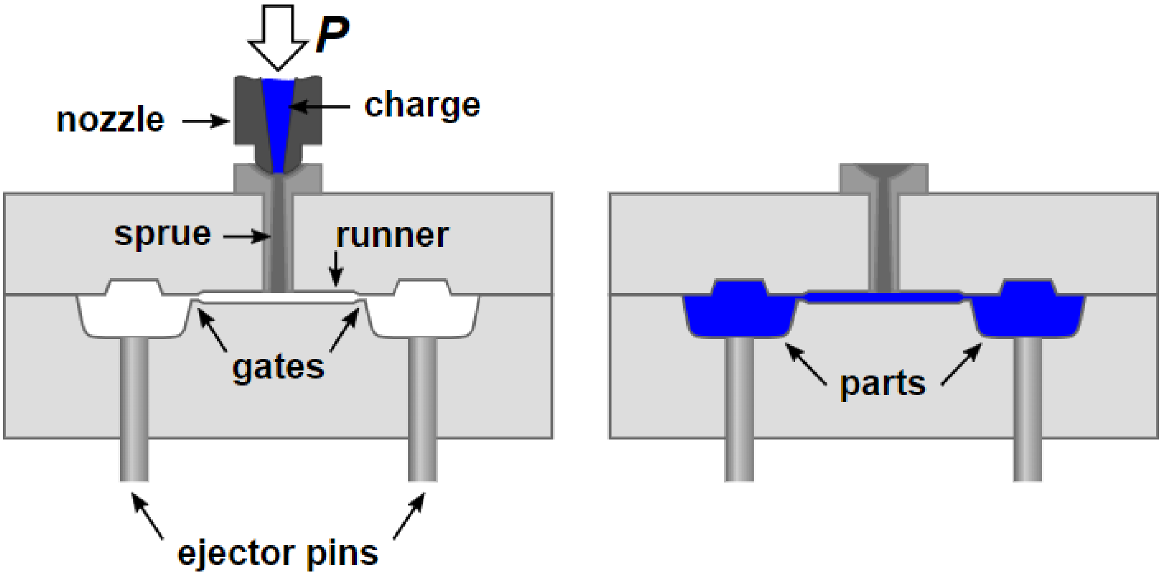


Figure 9 : Classical plastic injection

In a classic plastic injection plate, a single nozzle pushes the molten mixture into the sprue, then the runners carry the mixture into every mold, and at the end of the process we are left with hard plastic in the mold, in the runners and eventually some plastic in the sprue.

To get rid of the sprues left in the runners and the sprue, Freudenberg decided to create a plate with one nozzle per mold, with each nozzle directly in contact with the mold. So, by changing the former diagram, it would look like this:

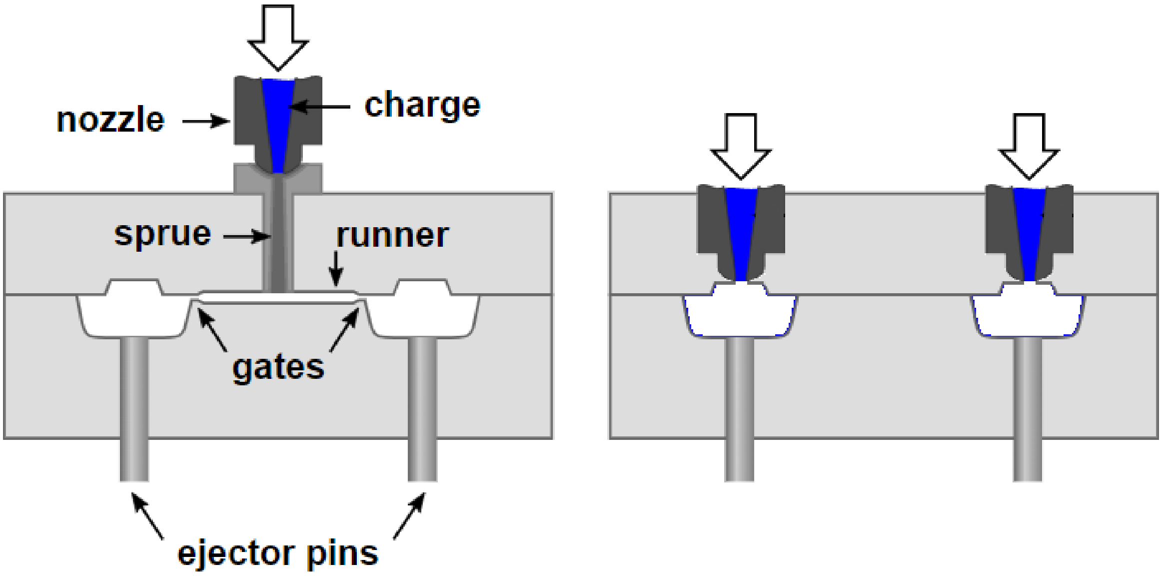


Figure 10 : Injection with multiple nozzles

Another function of the sprues is to collect the excess of matter in the mold, so if we want to inject rubber without any sprues, we must be able to inject the exact amount of matter in the mold. Too much matter would cause leaks while not enough matter would lead to incomplete parts.

2.2.2. The Valgate technology

The name “Valve Gate” comes from the solution developed by Freudenberg, they found a way to stop the matter with a gate at the end of the nozzle to dose more precisely the amount of matter injected in the mold. To do so, they developed a new kind of nozzle with a movable needle inside, and thanks to a lever system actioned by hydraulic pistons, the needles are switching between the up position and the down position at precise timings.

All the Valgates are based on the same template, but they are divided in categories according to the number of nozzles and the parts they are used for. The smallest rings need only one injection point, while the biggest ones need four, so the setup of the nozzles is not the same.

For a better understanding of the Valgate, and to sort the parts more easily, the upper tray is divided into groups, each with its own function.

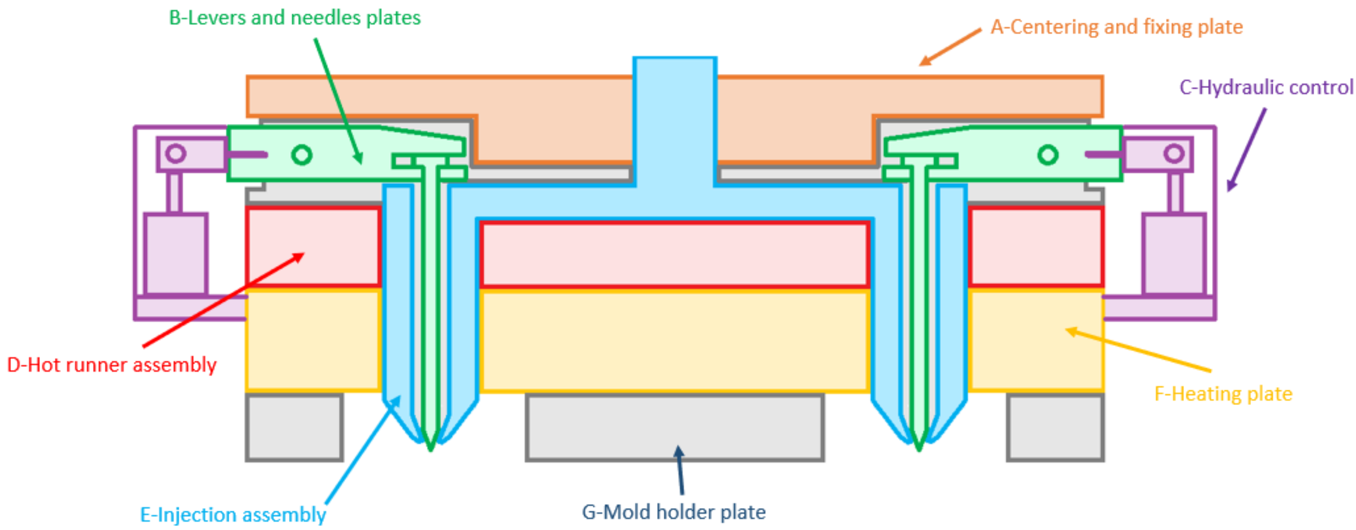


Figure 11 : Simplified diagram of a valgate rubber injection plate

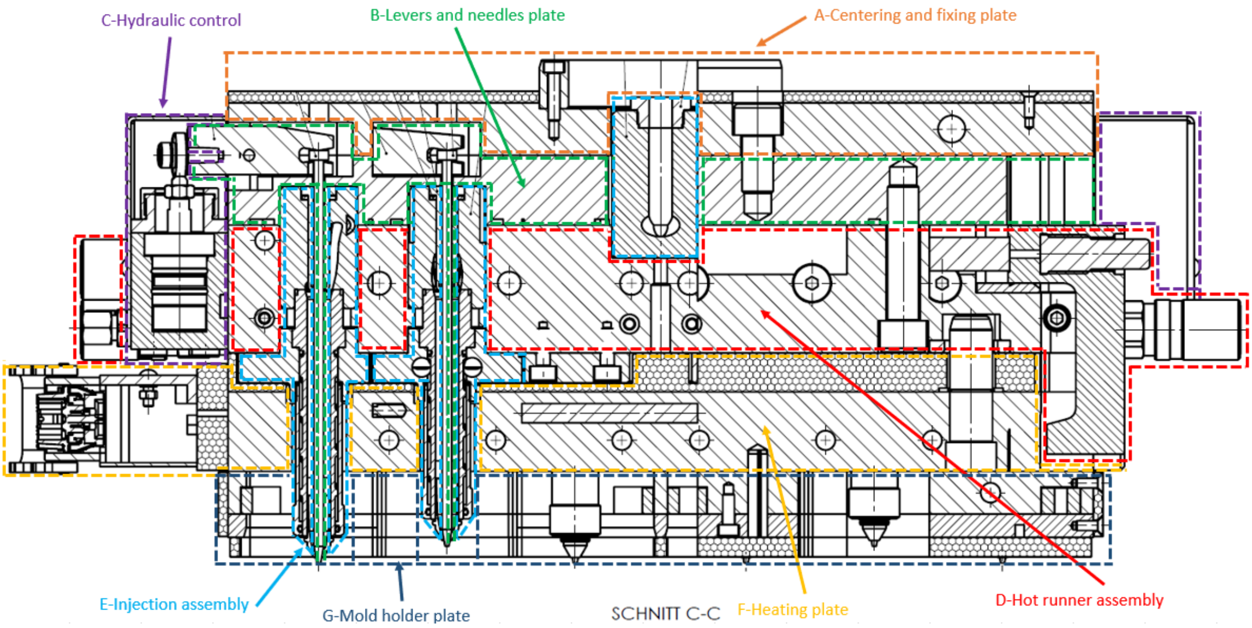


Figure 12 : Drawing of a valgate rubber injection plate

A: the top plate serves to hold everything together. It also serves to attach the whole Valgate to the lifting arm, to connect the material inlet to the injection assembly and provides some thermal isolation.

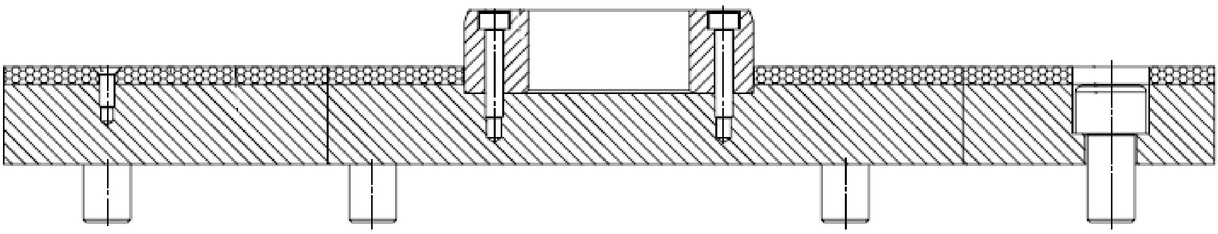


Figure 13 : Top plate

B: the lever plate is specifically made to hold the levers with bearing blocks and pins. the number and disposition of the levers depend on the part we want to make. The Valgates can inject two big parts, four medium parts or six small parts at a time. An older version also injects two medium parts at a time.

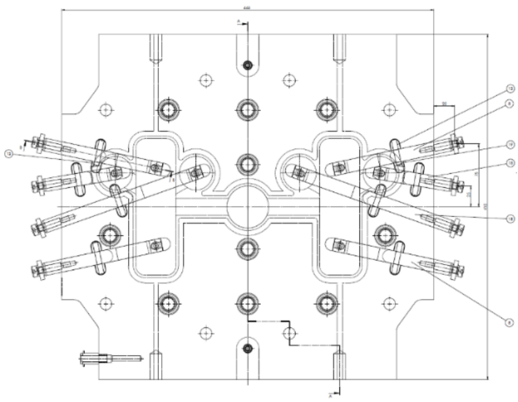


Figure 14 : Lever plate 1x2

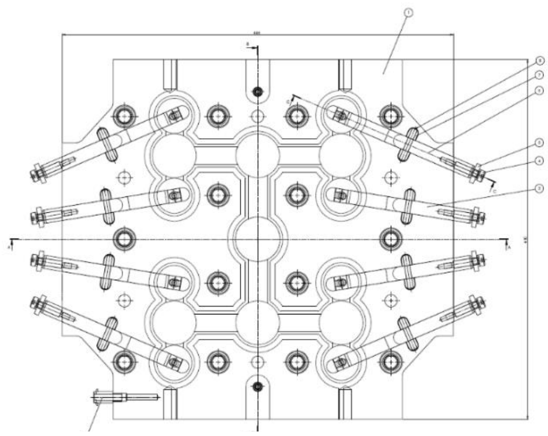


Figure 15 : lever plate 1x4

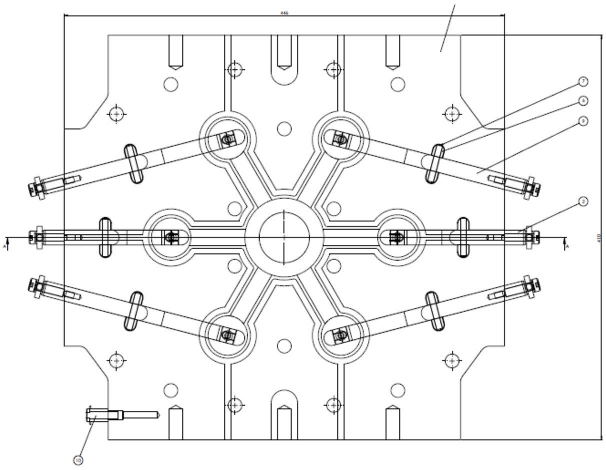


Figure 16 : Lever plate 1x6

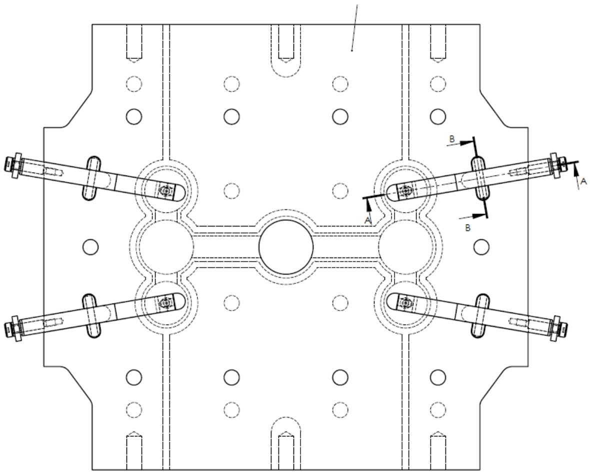


Figure 17 : Lever plate 1x2

C: the hydraulic control is made of hydraulic pistons, one per needle, which can pull and push the lever and consequently open and close the “gate” to release rubber from the nozzle. The hydraulic control must be timed perfectly to make sure that the correct amount of rubber per part is delivered.

D: the hot runner assembly is a plate with channels inside in which glycol runs at exactly 75°C. this temperature is high enough to melt the rubber to inject but low enough to not damage the parts, especially the sealings. Glycol is used instead of water because it has a greater temperature range than water, ranging from -13°C to 198°C. With a better heat transfer and a better fluidity, glycol makes it easier to maintain constant temperature[10].

Two channels are in parallel to provide better cooling, and the lower channel send glycol directly into the cooling-flange and the cooling-flange tube to cool down all the sealings in the injection assembly.

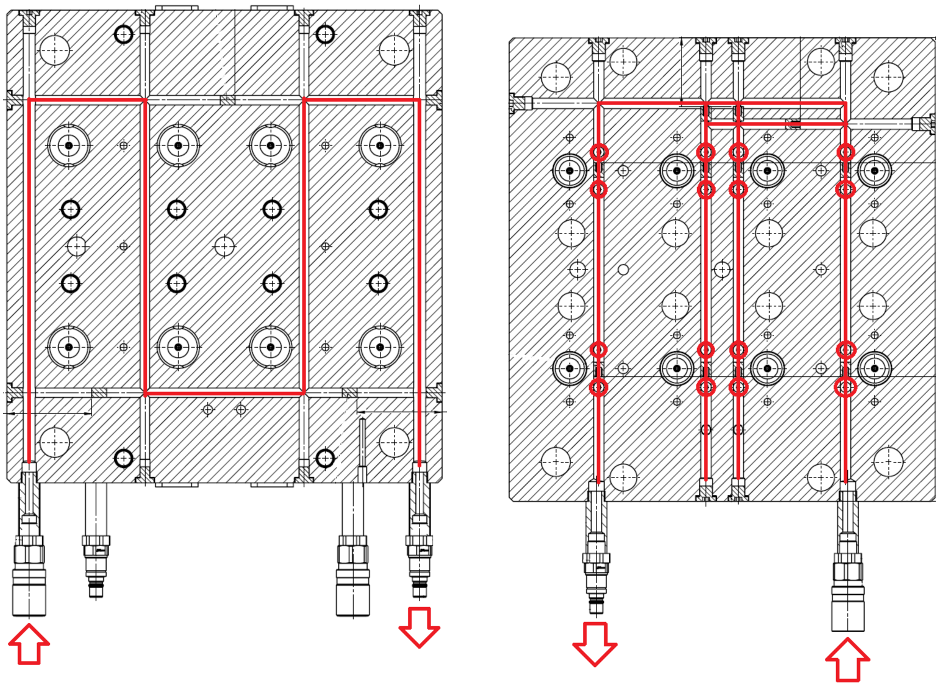


Figure 18 : Glycol channel inside the plate

E: the injection assembly is the set of parts that allow the material to be sent into the mold under high pressure. Its shape depends on the number of nozzles, and this is the part that requires the most attention during the check-up. Indeed, most of the sealing rings are situated in this area and they must be changed every time the Valgate is disassembled. The dry rubber also must be removed to make everything clean.

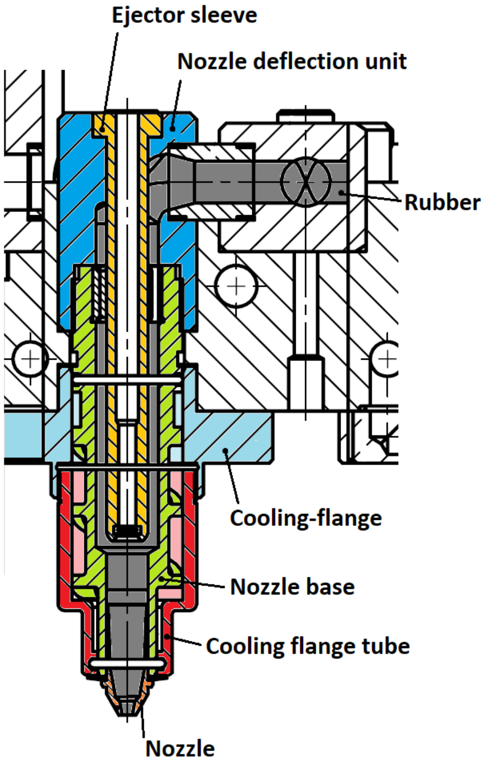


Figure 19 : Drawing of injection assembly

- The nozzle deflection units divide the flow of rubber into each nozzle.
- The ejector sleeve serves as a sheath for the needle to guide it in the right direction. A seal prevents material from escaping through the ejector sleeve.
- The cooling flange is fixed on the hot runner plate and holds the cooling flange tube. First, it keeps all the parts centered, and moreover the piping inside the cooling flange let the glycol circulate in the cooling flange tube to cool down all the sensitive parts close to the nozzle.
- The cooling flange tube is screwed on the cooling flange, and it allows to protect all the injection assembly from the heating plate at 200°C. Sealings are needed on both extremities to avoid glycol leakage.
- The nozzle base is carrying the rubber from the nozzle deflection unit to the nozzle. It is in contact with the rubber on the inside and the glycol on the outside. Its helicoidal shape improves the circulation of glycol.
- The nozzle is the exit point of the rubber. It comes directly in contact with the mold and is also designed to keep the rubber inside when the needle comes in contact.

F: the heating plate is a plate with heating resistors and isobars inside to let the rubber reach 200°C and complete the vulcanization. The heating resistors are placed horizontally while isobars, rods not powered but with very good thermal conductivity, are placed vertically to have a homogenous temperature in the plate. The plate is also surrounded with insulating plates to protect the riskiest parts, especially the rings which cannot withstand 200°C.

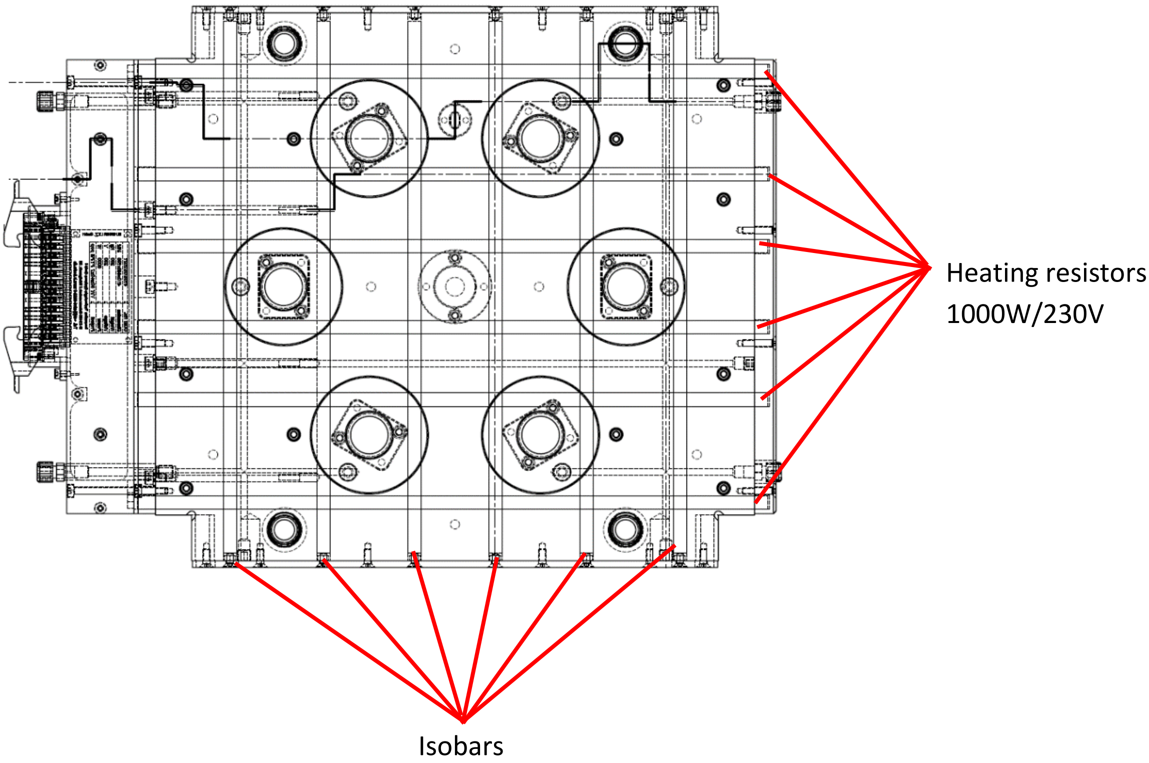


Figure 20 : Drawing of the heating plate

2.3. Possible failures and improvements

2.3.1. Glycol leakage

The first Valgates tended to leak glycol from the cooling flange tube, which is a problem if the glycol drips into the nozzle and comes in contact with the rubber.

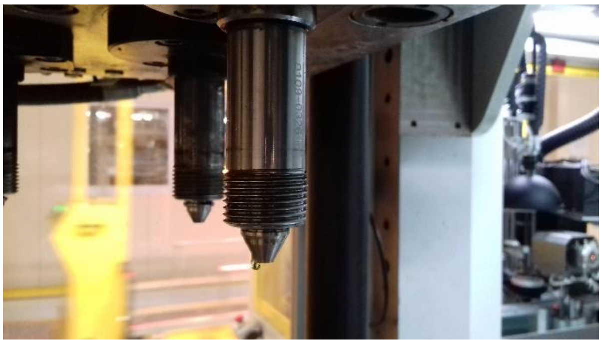


Figure 21 : Glycol leakage from the nozzle

The part supposed to prevent the glycol to leak is the O-ring between the cooling flange tube and the nozzle base.

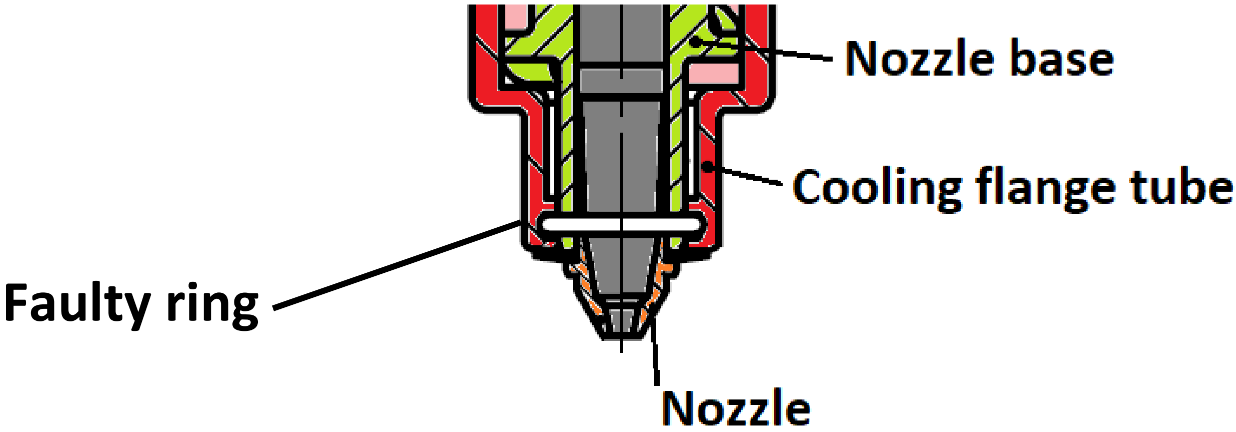


Figure 22 : injection assembly with O-ring to prevent glycol leakage

Figure 23 : Damaged O-ring found after leakage

The leakage comes from either an improper use of the O-ring, or the wear of the O-ring coming from the material used. After looking into the tube, they found out that the O-ring was heavily damaged. To avoid this kind of behavior with the newer Valgates, a new kind of O-ring made of Peroxide cured EPDM was used[11].

O-rings cured with peroxide have enhanced properties such as a better thermal and chemical resistance, particularly their resistance to alcohols such as glycol is improved. The latest Valgates equipped with the new rings have not shown any leaks, which is proof the effectiveness of this upgrade.
To standardize the parts between all the Valgates and to prevent the leakage on older Valgates, I took part of their upgrades. In addition to the rings, the nozzle base and the cooling flange tube had to be replaced with newer parts with the appropriate sizes.

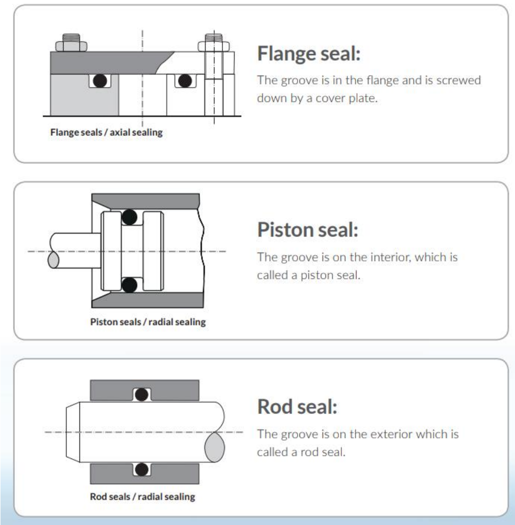


Figure 24 : O-ring installation types

To be effective, the ring must be compressed between the two parts to provide a good sealing. The shaft radius must be smaller than the inner radius of the ring [12].
The O-ring is used in a static rod seal setup, so according to the catalogue, the O-ring must be compressed between 15% and 30% of its cross-section [12].
A small gap must be left between the rod and the flange to be sure that the sealing is made by the ring and not by the contact between the two metal parts. According to the catalogue, to get this gap we must use the tolerances H8/f7.

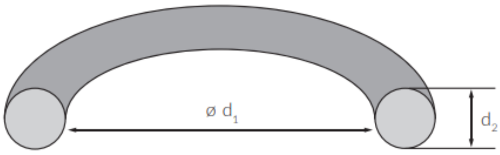


Figure 25 : O-ring main dimensions

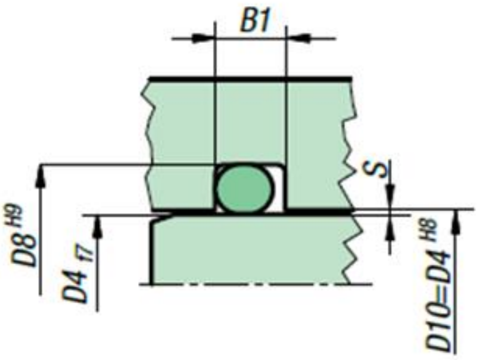


Figure 26 : Drawing of the groove for the O-ring

The new ring chosen for the sealing was the 17x2,5 EPDM Peroxide. The diameter D4=D10 which was chosen for the shaft and flange is 16,9mm, smaller than the inner diameter of the ring as advised in the catalogue to not stretch it and compress it on the shaft [12].

For a diameter of 16,9mm, H8 on the flange is equivalent to +27/-0 and f7 on the shaft is equivalent to -16/-34, so the gap S is included between +16µm and +61µm.

The groove was modified to have a diameter D8 = 20.5mm, which corresponds to a 1.8mm deep groove.
Since the cross-section is 2,5mm wide, we have a compression ratio of (2,5 - 1.8) / 2.5 = 28%.

With these new dimensions, all the older nozzle bases and cooling flange tubes were replaced by new ones during the scheduled maintenance.

2.3.2. Wrong settings and sizing issues

To provide perfect parts and keep the molds and the machines safe, installation settings on the press are very important.
The first thing to assure is that the top plate and the bottom plate are aligned. This step is to make sure that the injection nozzles go perfectly in the mold. This step rarely causes problems because the procedure is very clear, and the plates are guided to fit exactly where they should be.
The next requirement is to make sure that the machine closes correctly. The two plates must come into contact without forcing or breaking any part, and when the press is closed, the nozzles on the top plates must come perfectly in contact with the molds. If the nozzle is too far away from the mold, a small injection mark could be seen on the part which is not acceptable. Even worse, the nozzle could force against the mold, preventing the press from closing or eventually breaking the mold.

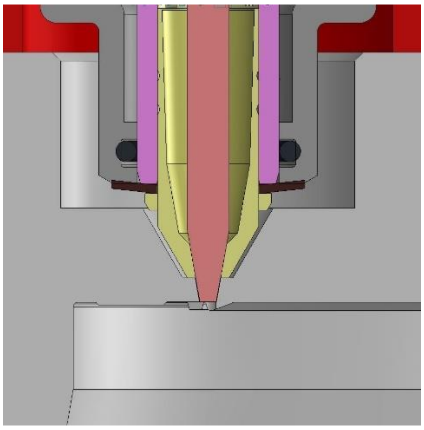


Figure 27 : nozzle contact in the mold

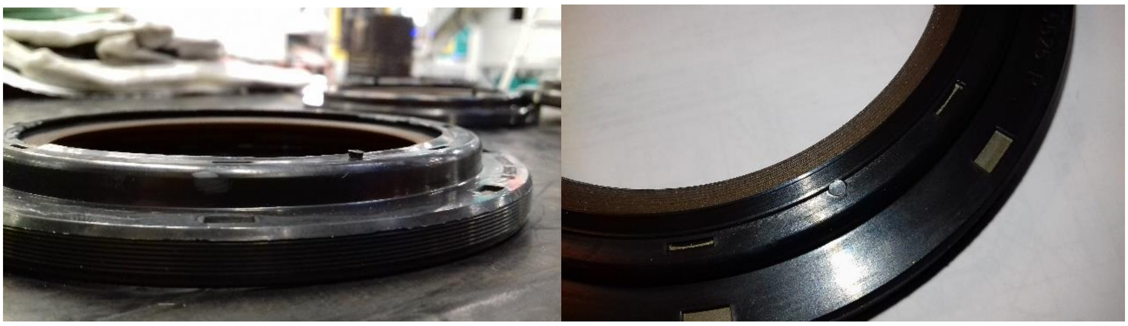


Figure 28 : Bad parts due to wrong needle position

Figure 29 : Breakdown due to forcing when closing the machine

A wrong position of the nozzle can also lead to this problem:

Figure 30 : Damage on the nozzle due to the needle forcing

The needle is forcing too far through the nozzle and damaging the inside, which can lead to small leakage. Hypothetically, each Valgate is designed with high tolerances, but in practice problems can occur. As a matter of fact, most Valgate can run full time during months with very low scrap rate once they are fully settled. Most problems occur at the launch.

To help the machine assemble well, spring discs have been added to have a margin of adaptation. Spring discs are rings with a slightly conical shape able to flatten under heavy load.

in addition, the spring discs have the additional effect of preventing rubber leakage that may occur between the nozzle and the nozzle base.

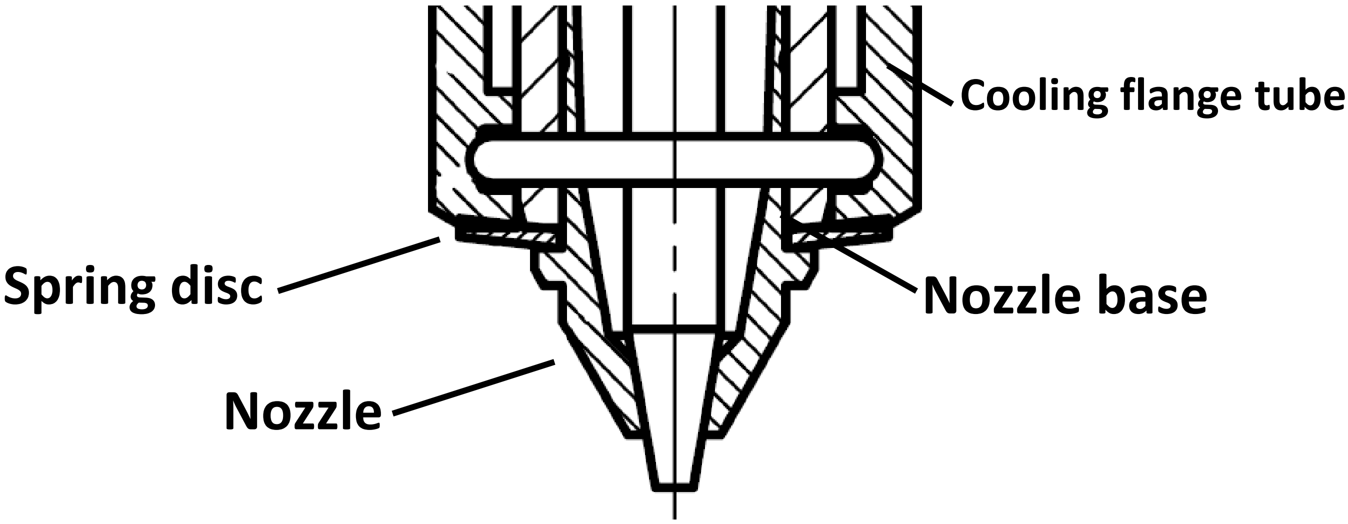


Figure 31 : Nozzle with new spring disc

As we can see on the drawing above, to add a spring disc without changing the position of the nozzle, we must shorten the nozzle base and the cooling flange tube.

Since the upgrade of the spring disc happened chronologically after the upgrade of the O-ring, we were left with two scenarios:

-If the parts were still outdated with the wrong radius, then we replaced the part with the right diameters and length to upgrade both the O-ring and the spring disc.

-If the parts already have the right radius for the O-ring, then instead of replacing the part we machine it directly in the workshop to shorten it. This way we are not wasting the parts on the Valgate and the spare parts.

2.4. Monitoring of continuous improvements

When upgrading the parts on a Valgate, several questions arise:

- What upgrades have already been made and what upgrades do we have left to do?
- Do we have the necessary parts available?
- Are the plans provided by the manufacturer up to date?
- Are the documents necessary for maintenance up to date?

The main mission that was entrusted to me was to monitor the upgrades performed during the scheduled maintenance by answering all the questions above and creating new documents to be able to answers these questions more effectively in the future.

2.4.1. What upgrades do we have left to do?

To follow the upgrades of the 20+ Valgates and to effectively organize the maintenance of the Valgates, the upgrade dashboard is a centerpiece. The upgrade dashboard is composed of a table with the Valgates on the lines and the upgrades in the columns, so for each Valgate, we can clearly tell if an upgrade is needed, not needed, or already done.

The upgrade columns are divided in sub-columns to add the reference of the new parts and to indicate their availability. Every time new parts were installed on a Valgate or were received from the manufacturer the table had to be modified accordingly.

VGCR N°	5- Cooling flange tube			6- Coolant O-Ring		7- Nozzle base		
	Drawing Nb if needed	Availability	Implementation	O-Ring reference	O-Ring implementation	Drawing Nb if needed	Availability	Implementation
2786	0000-0109-0258 A	Yes	Done	17x2.5 peroxyd	Done	0000-0106-0238 A	10	Done
3071	0000-0109-0316 C	Yes	Done	70 EPDM 16x2,5	Done	0000-0106-0281 C	6	Done
3469	0000-0109-0326 C	Yes	Done	17x2.5 peroxyd	Done	0000-0106-0288 C	6	Done
3470	0000-0109-0326 C	Yes	Done	17x2.5 peroxyd	Done	0000-0106-0288 C	6	Done
3471	0000-0109-0326 C	Yes	Done	17x2.5 peroxyd	Done	0000-0106-0288 C	6	Done
3472	0000-0109-0324 A	Yes	No	17x2.5 peroxyd	No	0000-0106-0286 B	6	No
	0000-0109-0325 A	Yes	No	17x2.5 peroxyd	No	0000-0106-0287 B	6	No
3748	0000-0109-0358 A	Yes	Done	17x2.5 peroxyd	Done	0000-0106-0313 B	4	Done
3763	0000-0109-0359 A	Yes	Done	17x2.5 peroxyd	Done	0000-0106-0314 B	6	Done
3787	0000-0109-0362 A	No		17x2.5 peroxyd	No	0000-0106-0317 A	No	
	0000-0109-0361 A	No		17x2.5 peroxyd	No	0000-0106-0316 A	No	
3878.1	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
3878.2	0000-0109-0366 A	No need		17x2.5 peroxyd	No	0000-0106-0319		
3878.3	0000-0109-0366 A	No need		17x2.5 peroxyd	No	0000-0106-0319		
3878.4	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
3878.5	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
3878.7	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
3878.6	0000-0109-0373	No need		17x2.5 peroxyd	Done	0000-0106-0324		
3882	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
3944	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
3992	0000-0109-0378	Decision to take		17x2.5 peroxyd	No	0000-0106-0334	Decision to take	
	0000-0109-0379	Decision to take		17x2.5 peroxyd	No	0000-0106-0335	Decision to take	
4103	0000-0109-0366 A	No need		17x2.5 peroxyd	Done	0000-0106-0319		
		Upgrades tot :	9	Upgrades tot :	22		Upgrades tot :	9
		Upgrades faites	7	Upgrades faite	15		Upgrades faite	7
			78%		68%			78%

Figure 32 : Upgrade dashboard for Valgates

This table is a very effective tool to keep track of the upgrades done, I also added a diagram to show the percentage of parts upgraded and waiting for upgrades to have a visual representation of the work done for

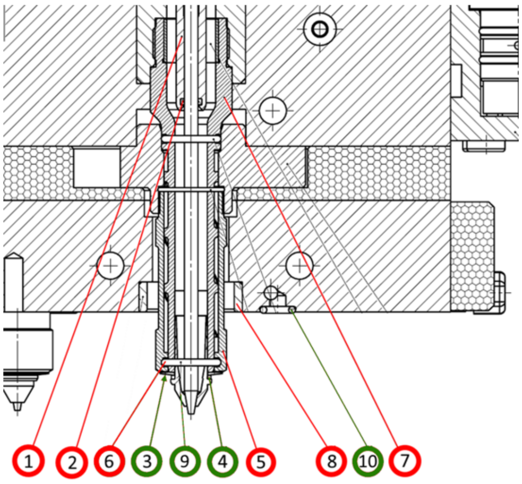
presentations to colleagues. At the beginning of my internship, about 30% of the parts were up to date, and at the end 80% of the updates were effective.
This table was also used to see if a Valgate ready for maintenance had already been upgraded in the past or not to avoid replacing good parts.
If a Valgate needs an upgrade, we must check if all the parts needed are available before programming a scheduled maintenance. Since scheduled maintenance are planned approximately every six months, we want to be sure to have every parts ready to upgrade it, or else we would have to wait six more months.
To fill this table, a discussion with the manufacturer is needed. We must agree on which upgrade must or can be done on each specific Valgate, then he would tell us about the new parts with the correct references and the new drawings.

2.4.2. The documents necessary for maintenance

To always keep track of the work done and to know what is installed in production, having files easy to understand and always up to date is a must have. And according to the situation, a specific file will be needed, so a significant part of my mission was to prepare those documents to be ready for every situation.

The document that was entrusted to me was an improvement tracking sheet. The goal of this single sheet is to always follow the Valgate, whether in the workshop or in production. On this sheet, anybody should be able to tell the upgrades needed or done on this Valgate.
Here is an example of the tracking sheet I made for the Valgate 3469.

Tracking sheet VGCR 3469 (PSA 61x75x8) et upgrades / critical parts



		Old part	Date	New part
1	Ejector sleeve	0000-0123-0096		0000-0123-0096 A
2	needle ring	Ø8,4x2,2 PTFE		Ø7,9x2,2 Pinerolo PU AU30000
3	Spring disc			Z62/23x1x12,2 Hasco
4	Spacer ring			Ø15x1,2 0000-0127-0047
5	Cooling flange tube	0000-0109-0326		0000-0109-0326 C
6	O-ring	Z98/17x2,5 Hasco		17x2.5 FPM peroxyde
7	Nozzle base	0000-0106-0288		0000-0106-0288 C
8	Centering mold			000-0113-0133 B
9	Nozzle	Ø15x32		
10	O-ring	Ø8x2,5 Vi580		

.. Upgrades and parts under maintenance responsibility

.. Parts that can be replaced in production

Figure 33 : Valgate 3469 tracking sheet

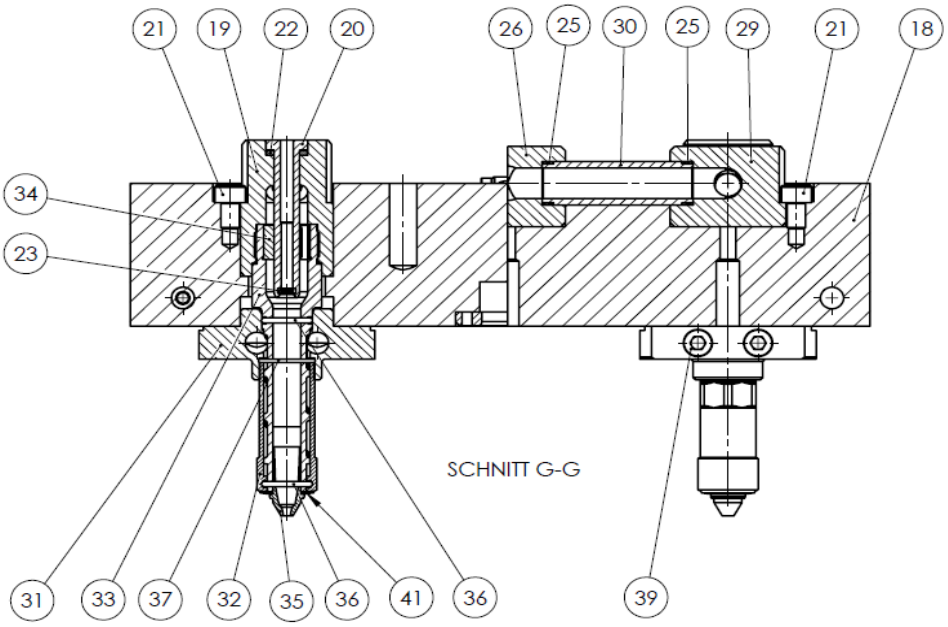
When the Valgate arrives in the workshop, the technicians know what parts to upgrade with the references to find the new parts, and when they install or replace a new part, they write the date on the corresponding line. This way, next time the plate must be checked, they will know if the upgrades are already installed.
This sheet is also very helpful to prepare the parts to upgrade before the maintenance.
And lastly, since the sheet is following the Valgate even in production, if an emergency replacement must be carried out following a breakdown, a quick look at this sheet let the technicians know if the part to replace is an old or a new version.

The next documents entrusted to me were binders for the maintenance of the Valgates. Until I joined the company, the only things the technicians could rely on to carry out the maintenance of the plates were the raw drawings provided by the manufacturers and their own knowledge. It was not enough in the long run.
To assure that the future maintenances are performed correctly, to make the work of the technicians easier and to have a better overview of the parts involved in the process before and after the maintenance, official documents had to be put in place.

Each binder must contain the drawings of the Valgates sorted by groups, so it is easier to find the drawing you need. The Valgates contain between 100 and 150 parts each, so it can take a long time for the technician to find what he is looking for, plus the drawings are in A0 format so it takes a lot of time and space to unfold them, moreover one might be tempted to not check on the drawings because of the hurdle that it is. But with a well sorted binder with dividers and a color system, a lot of time can be saved.

Once the drawings were sorted, a numbering was added so that every part has its ID indicated on the drawing. Then thanks to this ID system, a table was created to detail every part with their material, their dimensions, and their store reference number. If a part is broken or missing, with this binder one must be able to find another part quickly.

To write down the knowledge of the technicians on these machines and on their maintenance, I followed their work to note their actions. Thanks to these sessions, each part was assigned with an action, most of the time the action was checking, cleaning or replace. Additional knowledge was also added such as the solution and the tools used to clean the parts and the tightening torque when it is important.



MAINTENANCE PREVENTIVE Plateaux VGCR

E-Ensemble BCR 2 "injection"
Date O.T. N° :
Année :

MACHINE
Type : Valve Gate
N° : 4241

ID	QT	ACTIONS	MOIS				OBSERVATIONS
				OK	NOK	QT	
19	8	Nettoyage et contrôle état fuite mélange jonction buse canaux					0000-0105-0156
20	8	Contrôle fourreau aiguille					0000-0123-0115
21	15	Contrôle vis tête cylindrique					M8x12 8.8 VZ DIN 912
22	8	Remplacement joint PTFE 0000-0112-0025	★				93089698
23	8	Remplacement joint tige Ø7,9x2,2 Pinerolo PU AU30000	★				
24	8	Nettoyage et contrôle état tube 0000-0111-0487					0000-0111-0487
25	24	Remplacement joint PTFE Ø20x5 0000-0112-0010	★				93097912
26	2	Dérivation TOH					0000-0103-0070 A
27	2	Nettoyage et contrôle état tube 0000-0111-0455					0000-0111-0455
28	4	Remplacement joint PTFE 0000-0112-0023	★				0000-0112-0023
29	4	Dérivation TOH					0000-0103-0103 A
30	4	Nettoyage et contrôle état tube 0000-0111-0456					0000-0111-0456
31	8	Contrôle et nettoyage brides 0000-0109-0368					93090800
32	8	Contrôle et nettoyage brides 0000-0109-0387					0000-0109-0387
33	8	Nettoyage et contrôle corps de refroidissement 0000-0106-0343					0000-0106-0343
34	8	Contrôle et nettoyage insert de buse					0000-0108-0200
35	8	Contrôle état busette mobile 0000-0110-0178					0000-0110-0178
36	16	Remplacement joint 17x2,5 FPM Peroxyde	★				
37	8	Remplacement joint Ø21,5x1,5 Vi 580	★				93089696
38	16	Remplacement joints Z98/12x2, montage à la graisse	★				93086623
39	16	Contrôle étanchéité bouchon Z94/12x1,5					93089428
40	32	Contrôle vis tête cylindrique serrage en croix 10;20;30 Nm					M8x20 8.8 VZ DIN 912
41	8	Remplacement rondelle élastique Z62/23x1x12,2 Hasco	★				
42	1	Contrôle état pièce d'injection					0000-0101-0152
43	1	Remplacement buse d'adaptation + retouche pour remplacée	★				0000-0102-0116
		Temps prévu :	2				heures
		Temps passé :					heures

* / : sans objet X : OK O : défaut corrigé # : avis de panne ou O.T. $: autre

Figure 34 : Page for injection assembly in Valgate 4241 binder

This is an example of the type of drawing one may find in the binders. Each part has an ID, a quantity, a description of the actions to put in place and a reference. A Star is also added to the parts which are mandatorily replaced such as the O-rings.

Setting up a complete binder for each of the Valgate trays was a laborious task, but it quickly proved very useful to the technicians who were quickly able to use it in their work.

The last document put in place to monitor the continuous improvement and the maintenance of the Valgate trays was a complete spare part list. The main goal of this document is to list all the parts of the 20+ Valgates and to compare the parts between the Valgates to manage the stock of spare parts more effectively.
The first step was to do a list of the parts for each Valgate using the drawings and discussing with the manufacturers, and to identify the "spare parts" most likely to be replaced. The spare parts were also labelled with low, normal, high, or critical risk to plan the number of spare parts to prepare.

Once the list was done for every tray, the goal was to compare the parts within every list to clearly identify the parts shared between multiple trays. The most effective way to gather all the information in one table was to create a list of all the spare parts and to identify with a color system if the part is used in the Valgate.
-If the box is white, the part is not used in the Valgate.
-If the box is black, the Valgate is using the standard part common among the Valgates on the same line.
-If the box is grey, the Valgate is using a variation of the part unique to this tray.

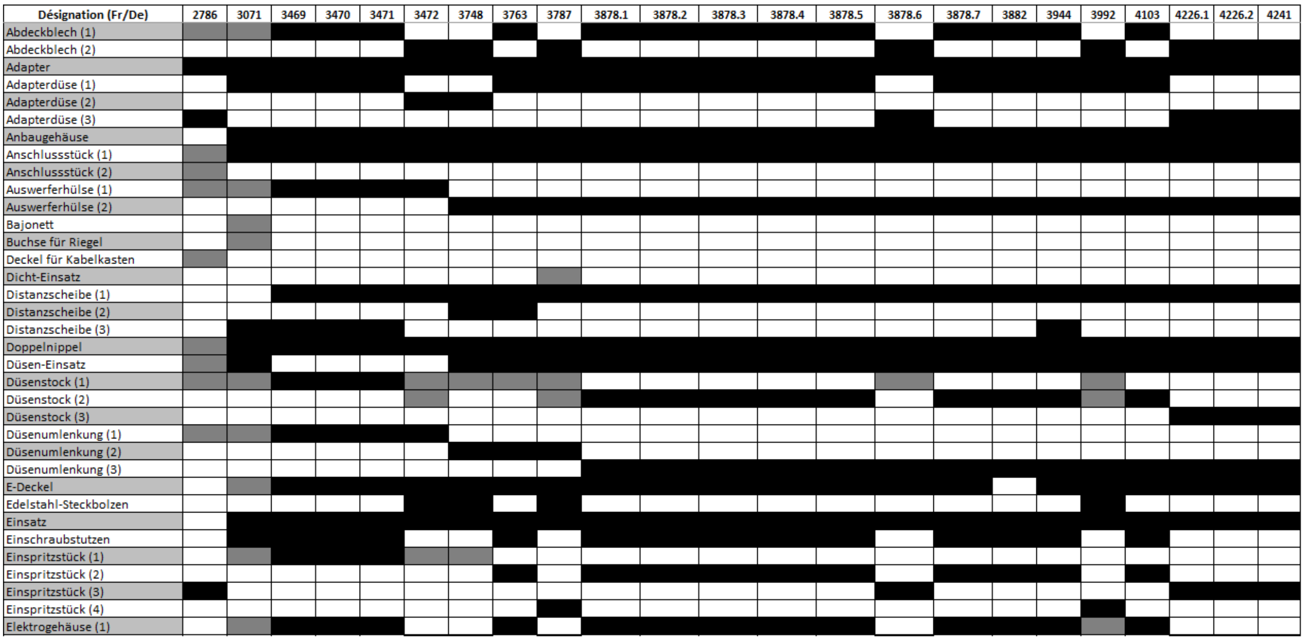


Figure 35 : Portion of the common parts determination table

This data is very important, it can be used to build a table to compare all the Valgates and see which ones are closer to each other and see the upgrades added along the way.

		VGCR 2786	VGCR 3071	VGCR 3469	VGCR 3470	VGCR 3471	VGCR 3472	VGCR 3748	VGCR 3763	VGCR 3787	VGCR 3881.1	VGCR 3881.2	VGCR 3881.3	VGCR 3881.4	VGCR 3881.5	VGCR 3881.6	VGCR 3881.7	VGCR 3882	VGCR 3944	VGCR 3992	VGCR 4103	VGCR 4226.	VGCR 4226.	VGCR 4241
		RSS 1x4	RSS 1x6	RSS 1x6	RSS 1x6	RSS 1x6	CS 1x2	CS 1x2	RSS 1x6	CS 1x2	RSS 1x6	RSS 1x6	RSS 1x6	RSS 1x6	RSS 1x6	RSS 1x4	RSS 1x6	RSS 1x6	RSS 1x6	CS 1x2	RSS 1x6	RSS 1x4	RSS 1x4	RSS 1x4
VGCR 2786	RSS 1x4		33%	26%	26%	26%	28%	28%	26%	28%	23%	24%	24%	24%	24%	31%	24%	26%	24%	26%	20%	30%	30%	30%
VGCR 3071	RSS 1x6	30%		56%	57%	57%	53%	53%	56%	52%	52%	48%	51%	51%	51%	46%	51%	52%	53%	45%	47%	44%	44%	44%
VGCR 3469	RSS 1x6	23%	54%		91%	89%	74%	66%	72%	66%	68%	65%	69%	69%	69%	59%	69%	69%	67%	60%	63%	53%	53%	53%
VGCR 3470	RSS 1x6	23%	55%	91%		90%	74%	66%	73%	66%	68%	65%	69%	69%	69%	59%	69%	69%	68%	60%	63%	53%	53%	53%
VGCR 3471	RSS 1x6	23%	55%	89%	90%		74%	66%	72%	66%	68%	65%	69%	69%	69%	59%	69%	69%	68%	60%	63%	53%	53%	53%
VGCR 3472	CS 1x2	20%	43%	62%	62%	62%		72%	55%	66%	53%	48%	52%	52%	52%	52%	52%	52%	49%	59%	48%	47%	47%	47%
VGCR 3748	CS 1x2	23%	48%	61%	61%	61%	80%		69%	82%	63%	58%	62%	62%	62%	61%	62%	62%	58%	70%	58%	55%	55%	55%
VGCR 3763	RSS 1x6	23%	55%	73%	74%	73%	66%	75%		73%	75%	69%	74%	74%	74%	62%	74%	74%	70%	65%	70%	56%	56%	56%
VGCR 3787	CS 1x2	20%	41%	53%	53%	53%	64%	72%	58%		55%	53%	55%	55%	55%	55%	56%	55%	53%	73%	50%	50%	50%	50%
VGCR 3881.1	RSS 1x6	21%	52%	71%	71%	71%	65%	70%	77%	71%		82%	89%	87%	87%	71%	85%	86%	81%	72%	82%	64%	64%	64%
VGCR 3881.2	RSS 1x6	23%	49%	69%	69%	69%	62%	66%	73%	69%	85%		87%	87%	87%	73%	87%	83%	82%	74%	77%	66%	66%	66%
VGCR 3881.3	RSS 1x6	22%	51%	71%	71%	71%	64%	69%	75%	70%	88%	83%		90%	90%	73%	88%	87%	84%	74%	80%	65%	65%	65%
VGCR 3881.4	RSS 1x6	22%	51%	71%	71%	71%	64%	69%	75%	70%	86%	83%	90%		90%	73%	88%	86%	86%	74%	78%	65%	65%	65%
VGCR 3881.5	RSS 1x6	22%	51%	71%	71%	71%	64%	69%	75%	70%	86%	83%	90%	90%		73%	88%	86%	84%	74%	78%	65%	65%	65%
VGCR 3881.6	RSS 1x4	27%	45%	60%	60%	60%	63%	66%	62%	68%	69%	69%	72%	72%	72%		72%	68%	68%	73%	62%	77%	77%	77%
VGCR 3881.7	RSS 1x6	22%	50%	71%	71%	71%	63%	68%	74%	71%	83%	83%	87%	87%	87%	72%		85%	83%	75%	77%	64%	64%	64%
VGCR 3882	RSS 1x6	23%	52%	72%	72%	72%	64%	69%	76%	70%	86%	80%	88%	87%	87%	70%	87%		83%	73%	79%	64%	64%	64%
VGCR 3944	RSS 1x6	22%	52%	68%	69%	69%	60%	64%	71%	66%	80%	78%	83%	85%	83%	69%	83%	82%		75%	79%	62%	62%	62%
VGCR 3992	CS 1x2	19%	36%	50%	50%	50%	58%	62%	53%	74%	57%	57%	59%	59%	59%	59%	61%	58%	61%		57%	55%	55%	55%
VGCR 4103	RSS 1x6	19%	46%	65%	65%	65%	59%	64%	71%	63%	81%	74%	80%	78%	78%	63%	78%	78%	80%	71%		62%	62%	60%
VGCR 4226.1	RSS 1x4	26%	42%	53%	53%	53%	56%	59%	55%	61%	61%	62%	63%	63%	63%	76%	63%	61%	61%	66%	60%		96%	89%
VGCR 4226.2	RSS 1x4	26%	42%	53%	53%	53%	56%	59%	55%	61%	61%	62%	63%	63%	63%	76%	63%	61%	61%	66%	60%	96%		89%
VGCR 4241	RSS 1x4	26%	42%	53%	55%	53%	56%	62%	55%	61%	61%	62%	63%	63%	63%	76%	63%	61%	61%	66%	60%	89%	89%	

Figure 36 : Valgate comparison table

We can see on this table that the two latest Valgates share 96% of their parts, while the latest one and the oldest one share only about 20% of their parts.
But the most effective use of this data is to plan the number of spare parts to have in stock according to the number of parts used and the risk on this part. A minimum limit under which parts must be ordered from suppliers can then be implemented to automatically order, this ensures production and avoids press stoppages due to a lack of spare parts.

my work on the Valgates gave me a lot of knowledge about mass production and the difficulty of making improvements on machines used in production. many actors are involved, and careful planning is required. My discussions with manufacturers and my study of technical documents have also given me interesting technical knowledge and a better understanding of the issues related to wear and maintenance of machines used at a sustained pace.
and finally, my work on the production documents allowed me to see other aspects of continuous improvement, it is not just a question of making changes on a machine, but it is also necessary to keep abreast of all the production line and order managers, and above all my actions have been recognized and appreciated and I have been able to witness the usefulness of the new monitoring documents put in place.

3. Solving premature shock absorber wear

3.1. Control check of produced sealings

As a sealing ring supplier, Freudenberg must assure that 100% of the product delivered obey the specifications, and to do so each part must undergo tests.
Human operators are here to do a first visual check of the parts to remove the faulty parts with visible defects. But to verify the sealing, each part must survive multiple tests.

The camera Control: To control the quality of the sealings produced in the factory, Freudenberg has been developing a new technology using cameras to spot defaults and drips.
The sealing rings in black are put on a white plate, the plate turn on 360° and three cameras film the ring from three different directions, and a software analyzes the results. If a black dot is spotted on a surface, then the part is not validated and is discarded instead of being forwarded to the next test.

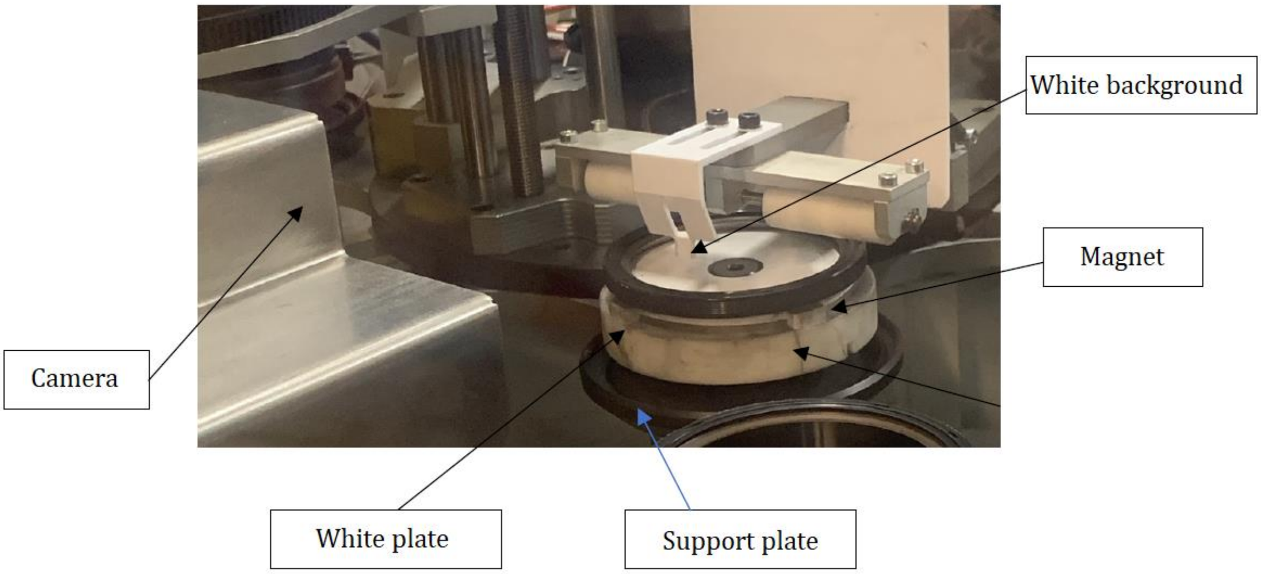


Figure 37 : the camera control assembly at Freudenberg Langres

The part is held on the plate thanks to magnets and to its metallic armature.

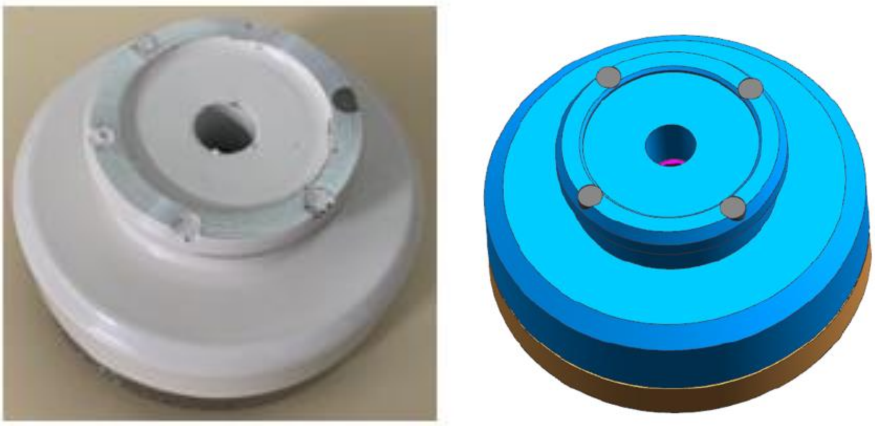


Figure 38 : the white plate used to hold the part during the inspection

Figure 39 : pictures taken by the cameras and analyzed by the software

The test-air: After validating the visual test, the sealing rings withstand a test to measure their ability to seal. During this test called test-air, the part is trapped between two plates and a machine will rise the air pressure at 300bar and measure the volume of air which made it through the seal in mL/h. If the measurement is too high the part is removed. This test is a good way to make sure that every part sent to a manufacturer is effective.

3.2. Description of the problem

To be able to test every part at a high pace, all this process has been automated, robotic arms pick up the rings to put them on and take them off the treadmills and the test-air. The robotic arms manipulate on average 1400 parts per hour, and to avoid the breakdown of the robotic arms and particularly the rotary pneumatic actuators, shock absorbers are mandatory.

But even if changing a shock absorber is simpler and cheaper than replacing an actuator, it becomes a problem if they must be changed regularly. On the automated carousel, two shock absorbers in particular wear faster than the others, forcing the technicians to change them daily.

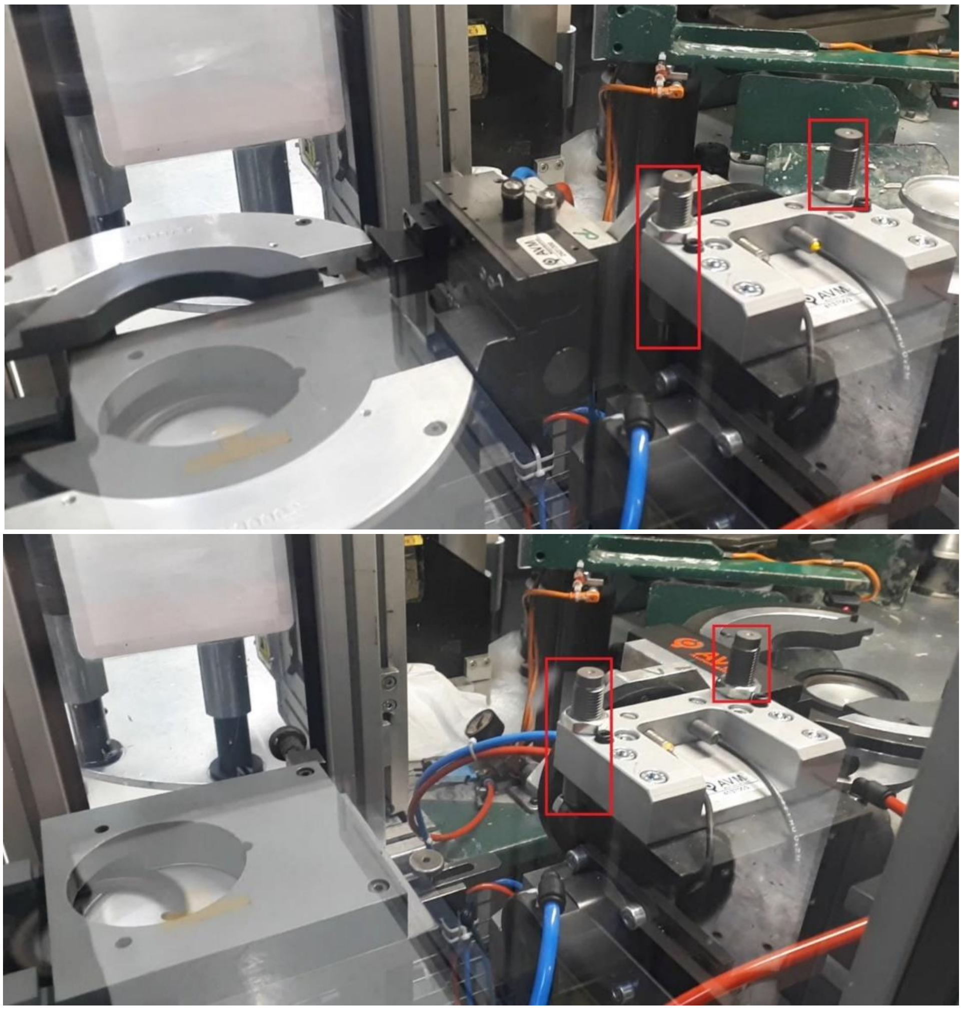


Figure 40 : The two shock absorbers that will be studied

the task that was then entrusted to me is to determine the cause of the wear and propose solutions to correct it. First, I will calculate the energy involved in the problem and investigate the datasheet to be sure that the current shock absorber is fitted for the problem, and if it is I will look further for the problem. Then I will think of solutions to solve the problem and finally I will determine the most feasible solutions.

3.3. Determining the source of the problem

3.3.1. Calculation of the quantities involved and comparison with the specifications

Industrial shock absorbers are supposed to provide a constant damping compared to hydraulic dashpot or pneumatic cylinder cushion, which means that the stopping is constant all along the stroke. It provides a smooth damping. This kind of damping is perfect for the situation we are in, indeed if the damping is too hard, it would make the cycles longer and the weight of the rotating arm alone wouldn't be able to push the damper alone to the catching position. On the contrary, with a softer damping, the rotating would still have speed at the end stroke, most energy would be absorbed by the shock between the clamp and the treadmill, leading to a bad grabbing position and a premature wear of the pneumatic motor [13].

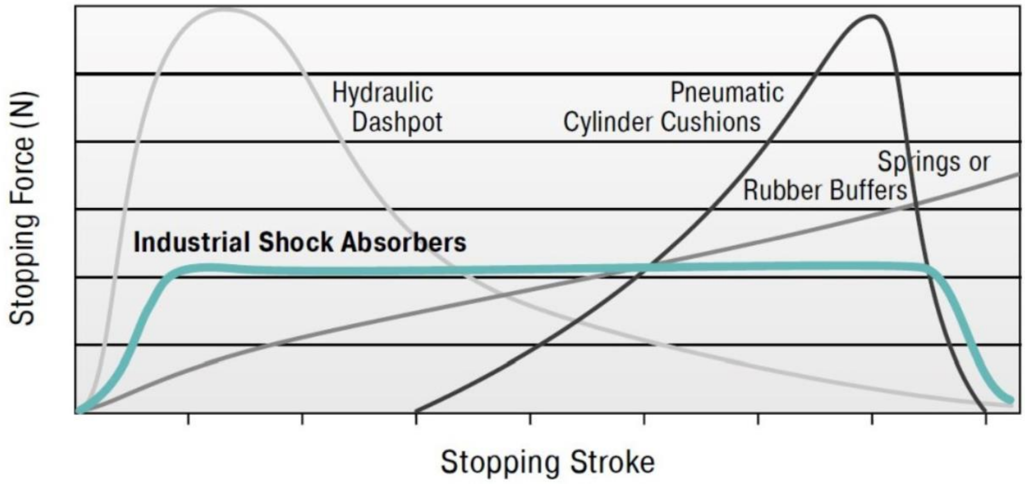


Figure 41 : Absorption curve of a shock absorber

In most of the datasheets provided by shock absorber manufacturers, all the steps necessary for the determination of a product are explained. The most important values to calculate are:
- Maximum Energy Absorption / cycle
- Collision speed
- Maximum allowable thrust
- Max operating frequency (cycle/hour)

To calculate these values, I draw a diagram of my problem with all the data I need, and then I proceeded to measurements.

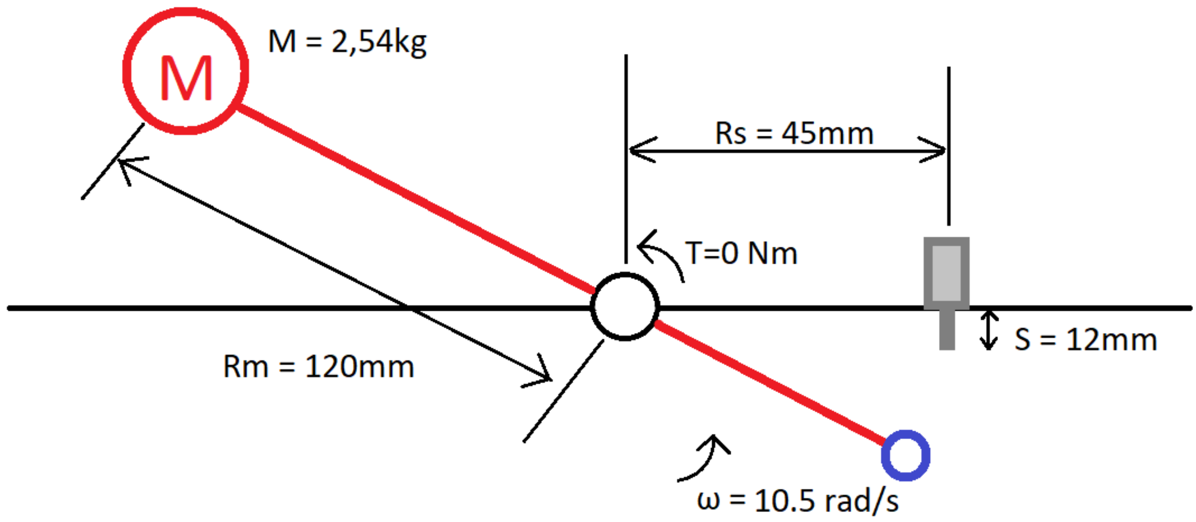


Figure 42 : Diagram of the problem with the values involved

Rs and S were the easiest to measure. After discussion with the technician responsible for this machine, he explained to me that the torque at the end of the movement was null, the arm is in free fall past the top, so I made the hypothesis T = 0 Nm.
I also made the hypothesis ω = constant, so I could get the collision speed by measuring the travel time of the rotating arm. After multiple measurements, I determined that the arm travelled the 180°= π rad in 0.3 s, so the rotation speed that I kept for my calculus was π/0.3 = 10.5 rad/s.

To determine M and Rm, I first planned to weigh every spare parts separately to try to calculate the total weight and center of gravity in a second time. But thankfully during a machine maintenance I could get my hands on the whole rotating arm, so I was able to provide a simpler and more effective protocol.
First, I weighted the whole arm on a scale to get the total mass M = 2.54 kg.

Figure 43 : Weighing of the rotating part

Then, to determine the center of gravity I had to write a protocol to find it effectively and in a short amount of time, since the rotating arm could not leave the machine for too long.
My first idea was to weight the arm on two scales, just like what we do to find the center of gravity of cars, but I only had one available.

So, I decided to use the same principle of weighting both extremities of the arm, but I did it in two stages. First, I put one extremity of the arm on the scale while putting the other extremity on a stand to get M_1 = 1kg. Then I switched both extremities and got this time M_2 = 1.60kg.
This way, after checking that $M_1 + M_2$ = 2.60kg is close enough to M = 2.54 kg, I could calculate
$R_m = L*(M_1/M)$ = 120mm. It is an approximate value, but it will be enough for now to get the magnitude of the energy involved.

Figure 44 : Determination of the center of gravity

With all the data needed in our possession, we can now calculate the significant values to compare with the specifications provided by the manufacturer.

$E1 = 0.5*M*R_m^2*\omega^2 = 2.02$ J
$E2 = (T + M*g*R_m)*S/R_s = 0.80$ J
$E3 = E1 + E2 = 2.82$ J/cycle
$F = (T + M*g*R_m)/R_s = 66,5$ N
$V = \omega * R_s = 0.47$ m/s

Specifications

Specifications \ Model		RB0805	RB0806	RB1006	RB1007	RB1411	RB1412	RB2015	RB2725
	Basic type	RB0805	RB0806	RB1006	RB1007	RB1411	RB1412	RB2015	RB2725
	With cap	RBC0805	RBC0806	RBC1006	RBC1007	RBC1411	RBC1412	RBC2015	RBC2725
Max. energy absorption (J)		0.98	2.94	3.92	5.88	14.7	19.6	58.8	147
Stroke absorption (mm)		5	6	6	7	11	12	15	25
Collision speed (m/s)		0.05 to 5.0							
Max. operating frequency * (cycle/min)		80	80	70	70	45	45	25	10
Max. allowable thrust (N)		245	245	422	422	814	814	1961	2942
Ambient temperature range (°C)		–10 to 80 (No freezing)							
Spring force (N)	Extended	1.96	1.96	4.22	4.22	6.86	6.86	8.34	8.83
	Retracted	3.83	4.22	6.18	6.86	15.30	15.98	20.50	20.01
Weight (g)	Basic type	15	15	23	23	65	65	150	350
	With cap	16	16	25	25	70	70	165	400

Figure 45 : Specifications provided by the manufacturer

When we compare our operating conditions with the specifications required [14], we can see that we are within the optimal range of work by a huge margin.
Another way provided to select a shock absorber is by calculating the Effective Weight M_e. The effective weight is in kg and takes into consideration the Kinetic energy and the thrust energy at the position of impact. It can be calculated with the formula $M_e = 2*(E1 + E2) / v^2$. With our previous results, we have $M_e = 25.5$kg.

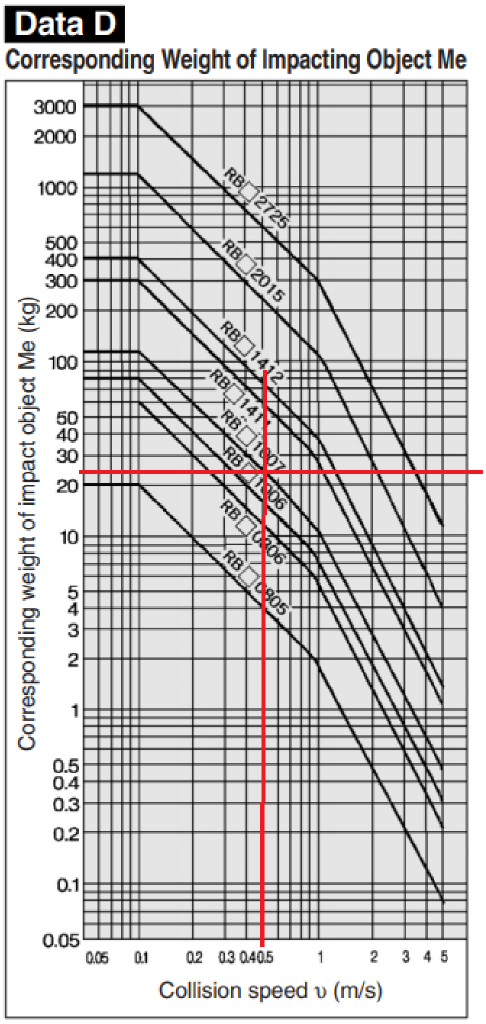


Figure 46 : Range of use according to corresponding weight and collision speed

On this diagram provided by the manufacturer, we can confront the Effective Weight to the collision speed and according to our data, the operating conditions are once again within the range of use of the shock absorber that was used until now [14].

seeing the importance of the impact velocity in these results, I thought that the constant velocity assumption was probably too restrictive, and that calculating the velocity gained by the mass following the descent in free fall would be relevant.

To calculate the new impact velocity, I assumed the friction is negligible and I used the Kinetic energy theorem on the mass Between the top position and the position where the arm touches the shock absorber. I also keep the value $\omega_0 = 10.5$/s at the beginning of the free fall.

$0.5*M*(v^2-v_0^2) = M*g*(R_m-S)$ with $v_0 = \omega_0 * R_m = 10.5 * 0.12 = 1.26$ m/s

➔ $v^2 = 2*g*(R_m-S) + v_0^2$

➔ $v = 1.93$ m/s

➔ $\omega = v / R_m = 16.1$ rad/s

The speed increases by about 50% during the fall, so the calculation of the new speed was definitely relevant. With This new rotation speed, we can recalculate our key values.

$E1 = 0.5*M*R_m^2* \omega^2 = 4.74$ J

$E2 = (T + M*g* R_m) * S/R_s = 0.80$ J

$E3 = E1 + E2 = 5.54$ J/cycle

$F = (T + M*g* R_m) /R_s = 66,5$ N

$V = \omega * R_s = 0.72$ m/s.

$M_e = 21.3$ kg

Even with these new values, the data is still well within the specifications of the absorber, so the issue must come from somewhere else.

3.3.2. Calculation of the lateral load experienced by the shock absorber

Now that we know that the current shock absorber is already correctly sized, I decided to look at the precautions given by the manufacturer. Among all the warning paragraphs, I found the crucial information that the rotating angle could be a cause of early wear.

The rotating angle is the angle between the axis of the shock absorber and the direction of the thrust. According to the datasheet, “If rotating impacts are involved, the installation must be designed so that the direction in which the load is applied is perpendicular to the shock absorber’s axial center. The allowable rotating angle until the stroke end must be θ2 < 3°”.

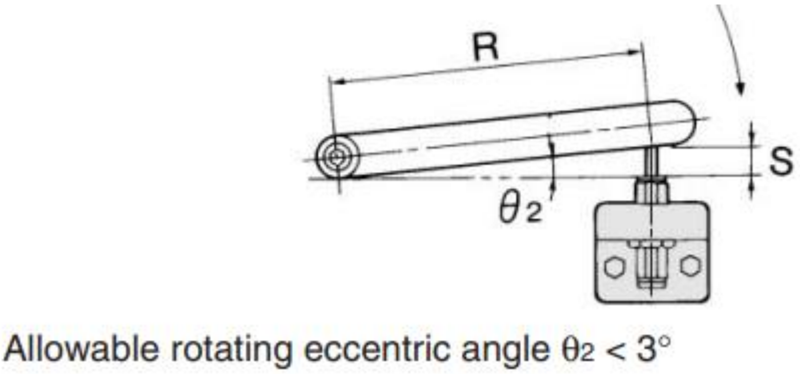


Figure 47 : Allowable rotating eccentric angle

Since θ2 is related to the distance between the axis of rotation and the shock absorber, the manufacturer also provides a minimal distance R_s to respect to make it easier for users to install.

Installation Conditions for Rotating Impact (mm)

Model	S (Stroke)	θ₂ (Allowable rotating angle)	R (Min. installation radius)
RB□□0805	5	3°	96
RB□□0806	6		115
RB□□1006	6		115
RB□□1007	7		134
RB□□1411	11		210
RB□□1412	12		229
RB□□2015	15		287
RB□□2725	25		478

Figure 48 : Installation conditions for the shock absorber RB1412

According to the table, we should have R_s > 229mm, however on the machine we have R_s = 45mm, which is way below 229m. After calculation, R_s being this small induce a rotating angle of 15°.

At this point the rotating angle is the prime suspect for shock absorber wear. To get to the bottom of it, I contacted the manufacturer about this issue and my interlocutor explained to me that side load on the rod of the shock absorber would put extra stress on the bearings inside it and cause oil leakage inside.
Fortunately, during a visit at the facility, a technical sales manager came to meet me to see the problem and discuss about this issue. He confirmed my hypothesis and showed me a tool available on their website to determine from the data provided if any shock absorber is adapted for a problem. The software came to the same conclusion we made: no matter which shock absorber is used; it will always be too close to the rotation axis.

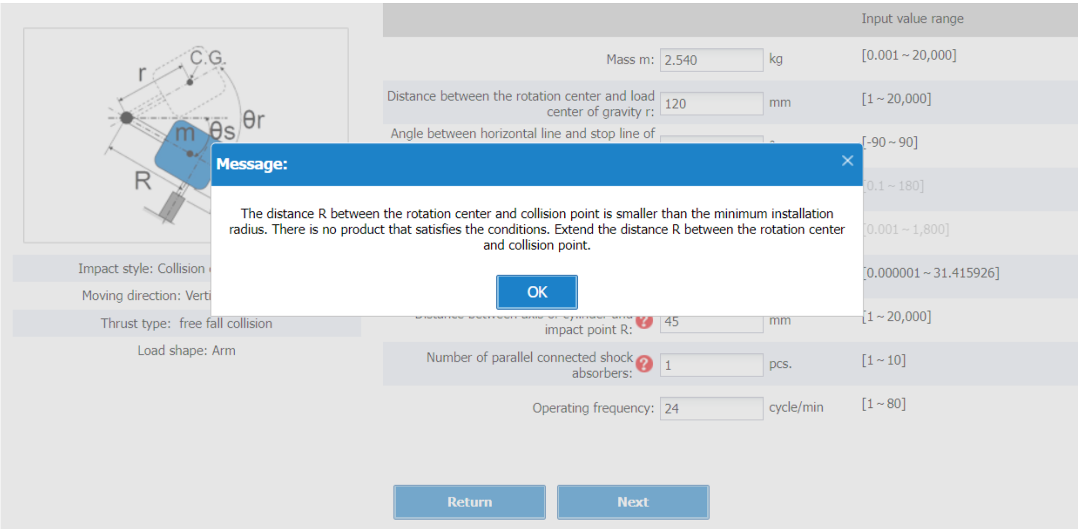


Figure 49 : Result from the simulator provided by the supplier

So now that we managed to find the main issue of the problem, I thought of multiple solutions to reduce the wear.

3.4. Solutions to the problem

3.4.1. Adding a counterweight

When discussing with the production manager about this subject for the first time, adding a counterweight was the first idea he proposed to me. At first sight, a counterweight would reduce the thrust energy at the point of impact so it could also reduce the energy of the impact. And even though we know that the energy of impact is not the main reason for the wear, it could still help to have less stress on the shock absorber, and it would also smooth the movement of the arm and prevent the arm from accelerating in the downswing.

To understand the effect of a counterweight on the system, I first added a weight M_2 at a distance R_{m2} of the rotation axis to my formulas. Then I entered my formulas on excel to draw a table considering M_2 and R_{m2} and see what setup would be best.

Absorbed energy with counterweight														
Rm2 (m)\M2 (kg)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2	1.5	2
0	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
0.01	2.81	2.81	2.81	2.81	2.81	2.80	2.80	2.80	2.80	2.80	2.79	2.79	2.78	2.77
0.02	2.81	2.81	2.81	2.80	2.80	2.80	2.80	2.79	2.79	2.79	2.78	2.78	2.77	2.75
0.03	2.81	2.81	2.81	2.80	2.80	2.80	2.80	2.79	2.79	2.79	2.78	2.78	2.77	2.76
0.04	2.81	2.81	2.81	2.81	2.81	2.81	2.80	2.80	2.80	2.80	2.80	2.79	2.79	2.78
0.05	2.81	2.81	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.83
0.06	2.81	2.82	2.82	2.83	2.83	2.83	2.84	2.84	2.85	2.85	2.86	2.86	2.88	2.90
0.07	2.81	2.82	2.83	2.84	2.85	2.86	2.87	2.87	2.88	2.89	2.90	2.92	2.94	2.99
0.08	2.81	2.83	2.84	2.86	2.87	2.89	2.90	2.91	2.93	2.94	2.96	2.99	3.03	3.10
0.09	2.81	2.83	2.86	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.07	3.13	3.24
0.1	2.81	2.84	2.87	2.90	2.93	2.96	2.99	3.02	3.05	3.07	3.10	3.16	3.25	3.39
0.12	2.81	2.86	2.91	2.96	3.01	3.05	3.10	3.15	3.20	3.25	3.29	3.39	3.53	3.77
0.15	2.81	2.90	2.98	3.07	3.15	3.24	3.32	3.41	3.49	3.58	3.66	3.83	4.09	4.51
0.2	2.81	2.98	3.15	3.32	3.49	3.65	3.82	3.99	4.16	4.33	4.50	4.83	5.34	6.18
0.3	2.81	3.23	3.65	4.07	4.48	4.90	5.32	5.74	6.15	6.57	6.99	7.83	9.08	11.17

Figure 50 : Energy absorbed as a function of the mass and the distance of the counterweight

Thrust with counterweight														
Rm2 (m)\M2 (kg)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2	1.5	2
0	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45	66.45
0.01	66.45	66.23	66.01	65.79	65.57	65.36	65.14	64.92	64.70	64.48	64.27	63.83	63.18	62.09
0.02	66.45	66.01	65.57	65.14	64.70	64.27	63.83	63.39	62.96	62.52	62.09	61.21	59.91	57.73
0.03	66.45	65.79	65.14	64.48	63.83	63.18	62.52	61.87	61.21	60.56	59.91	58.60	56.64	53.37
0.04	66.45	65.57	64.70	63.83	62.96	62.09	61.21	60.34	59.47	58.60	57.73	55.98	53.37	49.01
0.05	66.45	65.36	64.27	63.18	62.09	61.00	59.91	58.82	57.73	56.64	55.55	53.37	50.10	44.65
0.06	66.45	65.14	63.83	62.52	61.21	59.91	58.60	57.29	55.98	54.67	53.37	50.75	46.83	40.29
0.07	66.45	64.92	63.39	61.87	60.34	58.82	57.29	55.76	54.24	52.71	51.19	48.13	43.56	35.93
0.08	66.45	64.70	62.96	61.21	59.47	57.73	55.98	54.24	52.49	50.75	49.01	45.52	40.29	31.57
0.09	66.45	64.48	62.52	60.56	58.60	56.64	54.67	52.71	50.75	48.79	46.83	42.90	37.02	27.21
0.1	66.45	64.27	62.09	59.91	57.73	55.55	53.37	51.19	49.01	46.83	44.65	40.29	33.75	22.85
0.12	66.45	63.83	61.21	58.60	55.98	53.37	50.75	48.13	45.52	42.90	40.29	35.05	27.21	14.13
0.15	66.45	63.18	59.91	56.64	53.37	50.10	46.83	43.56	40.29	37.02	33.75	27.21	17.40	1.05
0.2	66.45	62.09	57.73	53.37	49.01	44.65	40.29	35.93	31.57	27.21	22.85	14.13	1.05	-20.75
0.3	66.45	59.91	53.37	46.83	40.29	33.75	27.21	20.67	14.13	7.59	1.05	-12.03	-31.65	-64.35

Figure 51 : Thrust as a function of mass and distance from counterweight

On the first table we can see that a heavy weight close to the rotation axis would be the best setup, which is consistent since the kinetic energy added by the extra weight rises proportionally with the square of R_{m2}. However, the addition of a 2kg weight close to the rotation axis only reduce the energy by 0.06J, which is negligible.

On the second table, we can clearly see the effect of the counterweight on the thrust, which could put less stress on the shock absorber at end of stroke and would make it easier for the pneumatic actuator to move the arm. However, it wouldn't solve the main problem which is to reduce the side load on the shock absorber, plus this would involve significant modifications to the rotating shaft, so I decided to search for a more effective solution.

3.4.2. Using a side load adaptor

When I found out that the problem was coming from the side load on the shock absorber, I started to look for eventual solutions available on the manufacturers catalogue. Shock absorbers with slightly better side load resistance exist, with a maximum angle of 5° instead of 3°, but it was not enough, and their dimensions were not appropriate.
On the catalogue of another manufacturer, I found an artifact called side load adaptor whose purpose is to transmit energy only parallel to the rod. According to the catalogue, this adaptor can be used with angles up to 25° instead of the previous 3° without adaptor.

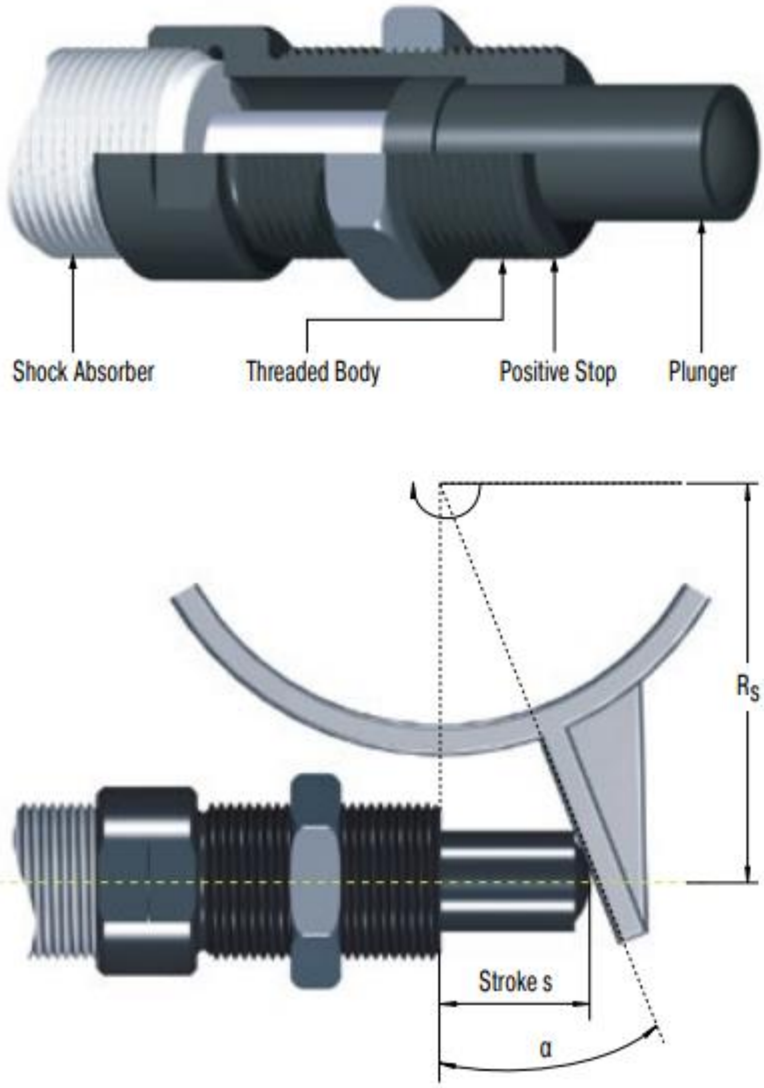
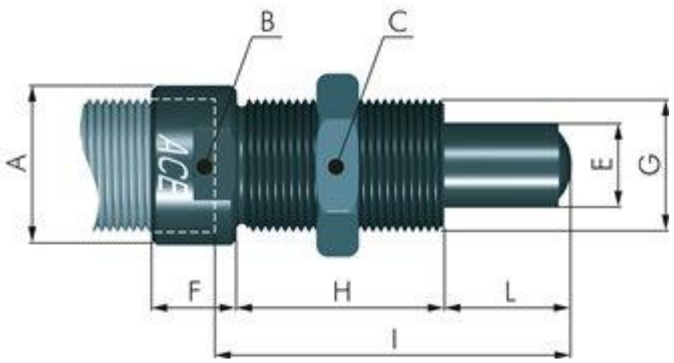


Figure 52 : Side load adaptor

This object could clearly be the solution to my problem, so I started to think of how to implement it on the machine.
First, I reviewed all the sizes available and kept the only two adaptors with the good thread to mount on the machine.



	BV14	BV14SC
Ø A	18	18
B	SW 16	SW 16
C	SW 17	SW 17
Ø E [mm]	9	9
F [mm]	12	14
G	M 14 x 1,5	M 14 x 1,5
H [mm]	20	26
I [mm]	32,5	42,0
L [mm]	12,5	16,0

Figure 53 : Dimension of the side load adaptor

Then, with all the measurements I made previously, I tried to find a way to install them on the machine. Since the thread on the adaptor is the same as the thread of the shock absorber, we have two different ways to install it: from the top of the plate or from the bottom.
For both BV14 and BV14SC, we would have the same stroke as the shock absorber, but what is important is to keep the start and end of stroke at the same height, otherwise the arm would stop at the wrong position.

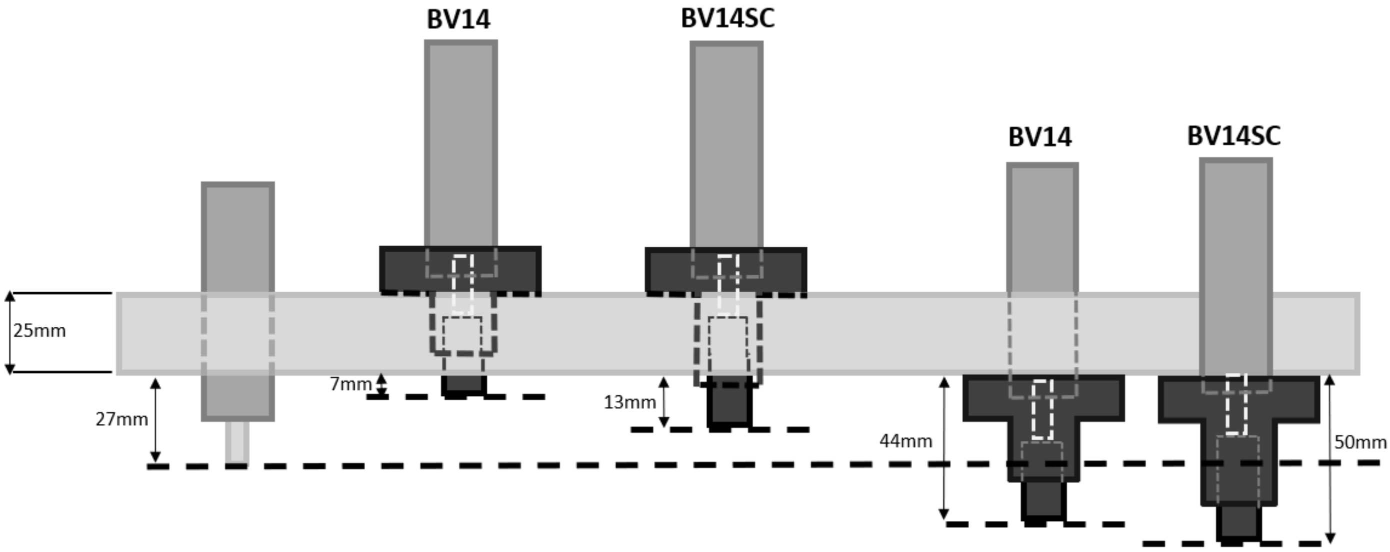


Figure 24 : The four possible installations for the adapter

On the diagram, no assembly provides the desired position directly without additional work. However, two assemblies are more likely to succeed: The BV14SC top mounted and the BV14 bottom mounted. I will now focus on these two options to see what can be done to move the stroke to where I want it to be.

-Option 1: Bottom mounted BV14

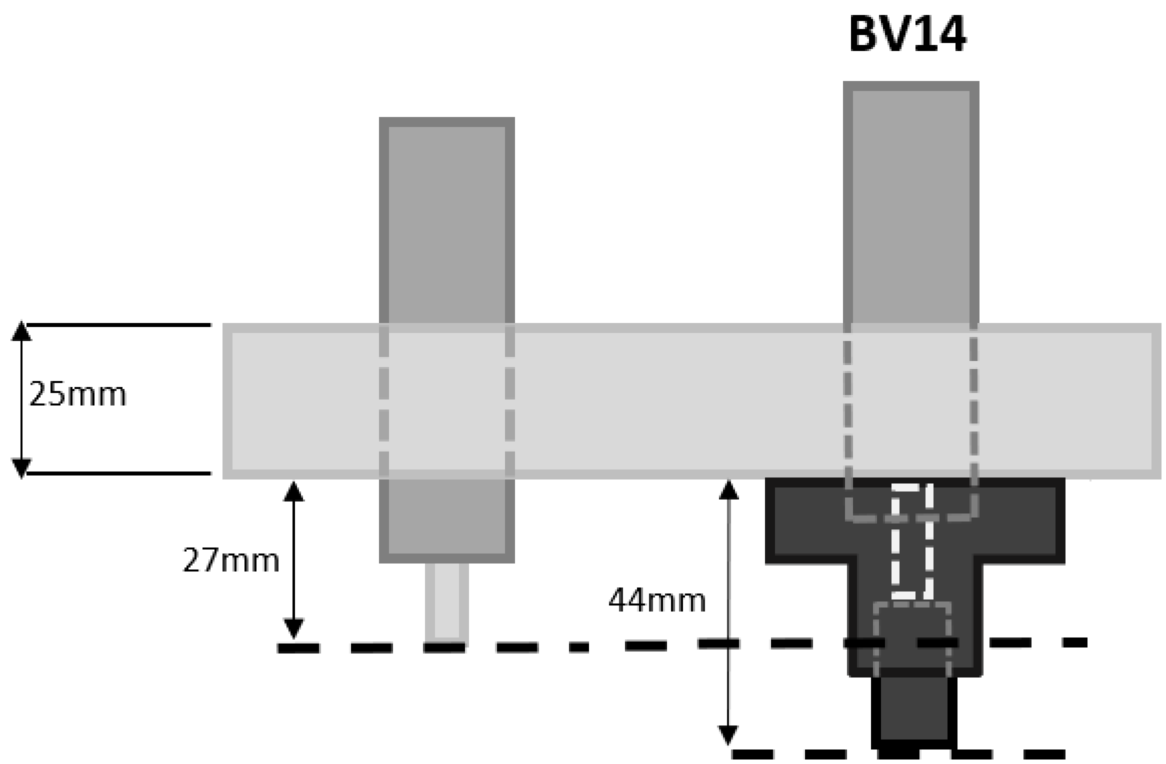
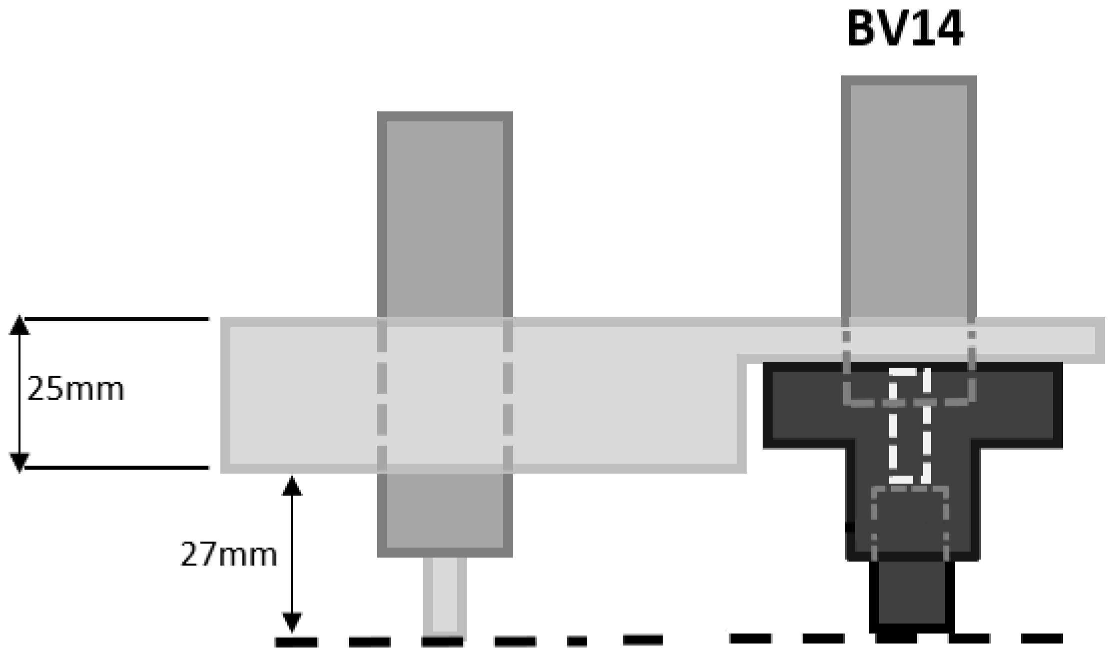


Figure 55 : Adaptor BV14 mounted from the bottom of the plate

To raise the adaptor by 15cm, the most instinctive solution would be to machine the bearing plate.



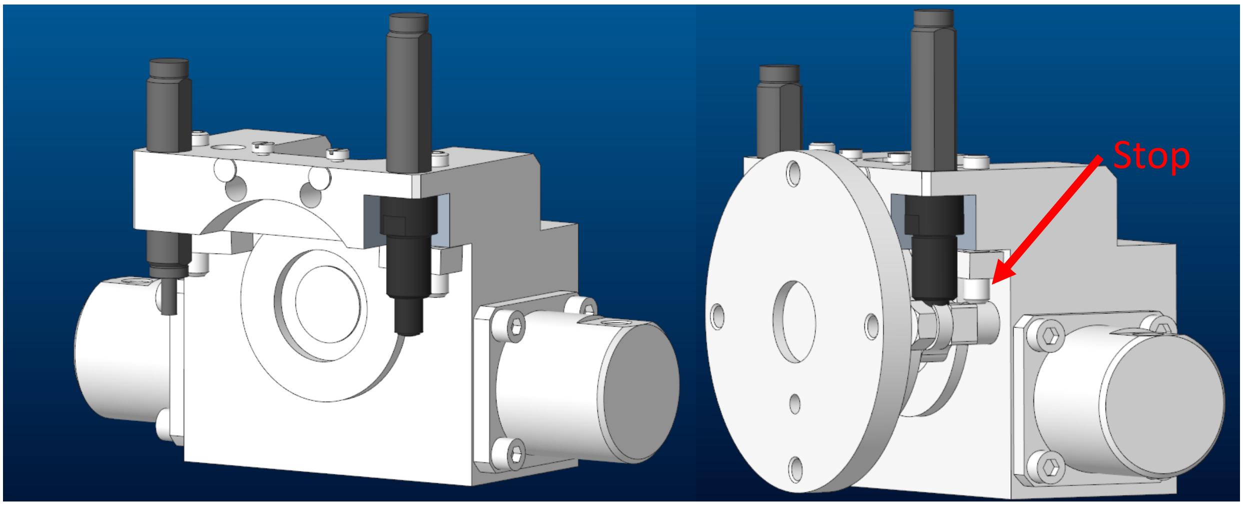


Figure 56 : Adaptor BV14 mounted from the bottom with a modified plate

As we can see on the 3D assembly, this solution would work, a 15mm extrusion would perfectly align the end of stroke with the end stop.

When discussing with the production manager about the possible issues I would face with this problem, we agreed that machining the top plate, or any part in white on the 3D model, should be considered as a last resort. Indeed, the white assembly was delivered as one block by the manufacturer, and machining the top plate means that we would have to machine the new top plate every time we receive a new block. Moreover, the technicians explained to me that mounting the adaptor and the shock absorber would be very unpractical, to replace a worn shock absorber it would be easier to take it apart and put it back from the top.

-Option 2: Top mounted BV14SC

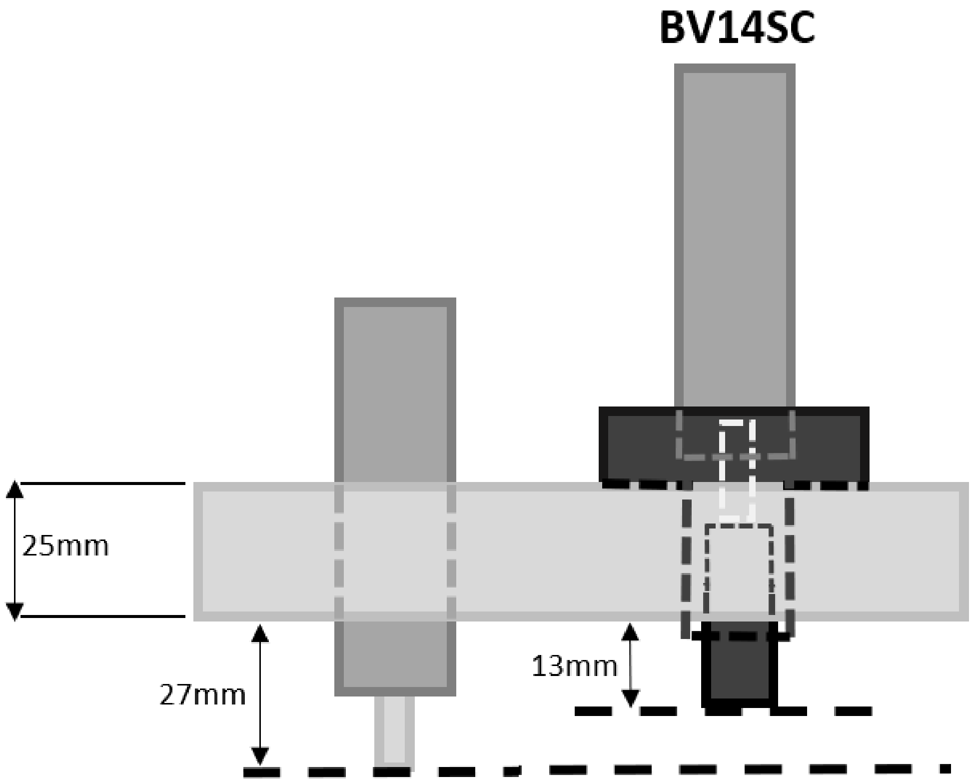


Figure 57 : Adaptor BV14SC mounted from the top of the plate

As for the adaptor BV14, machining the top plate would be a solution.

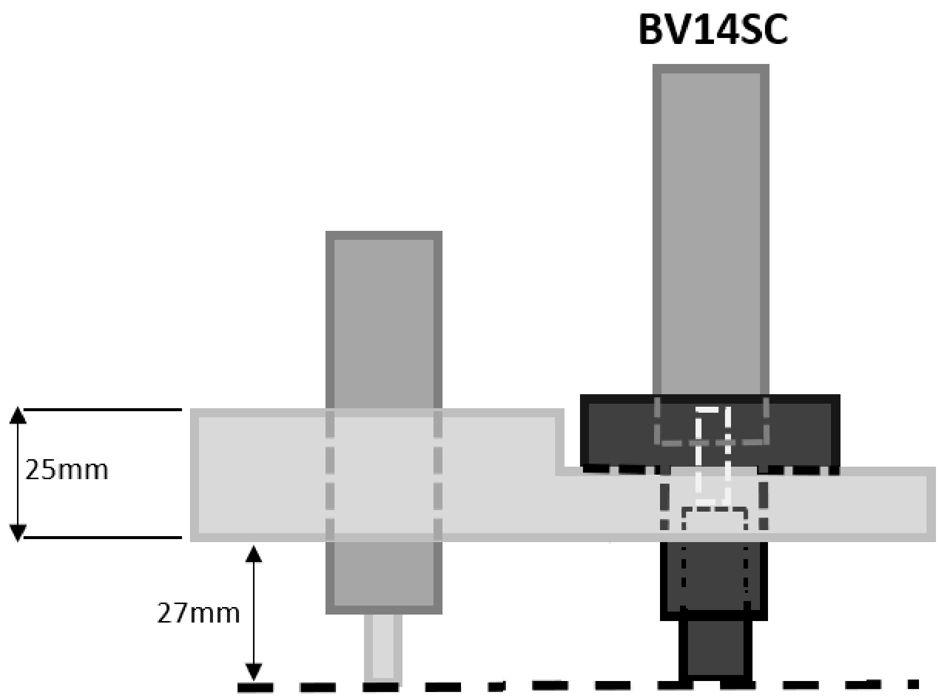


Figure 58 : Adaptor BV14SC mounted from the top with a modified plate

If we had to machine the top plate, this solution would be prioritized because it is easier to install and to replace the shock absorber this way. But I realized that we didn't necessarily have to move the whole adaptor closer to the line. For example, we could design a cylinder longer than the one included in the adaptor.

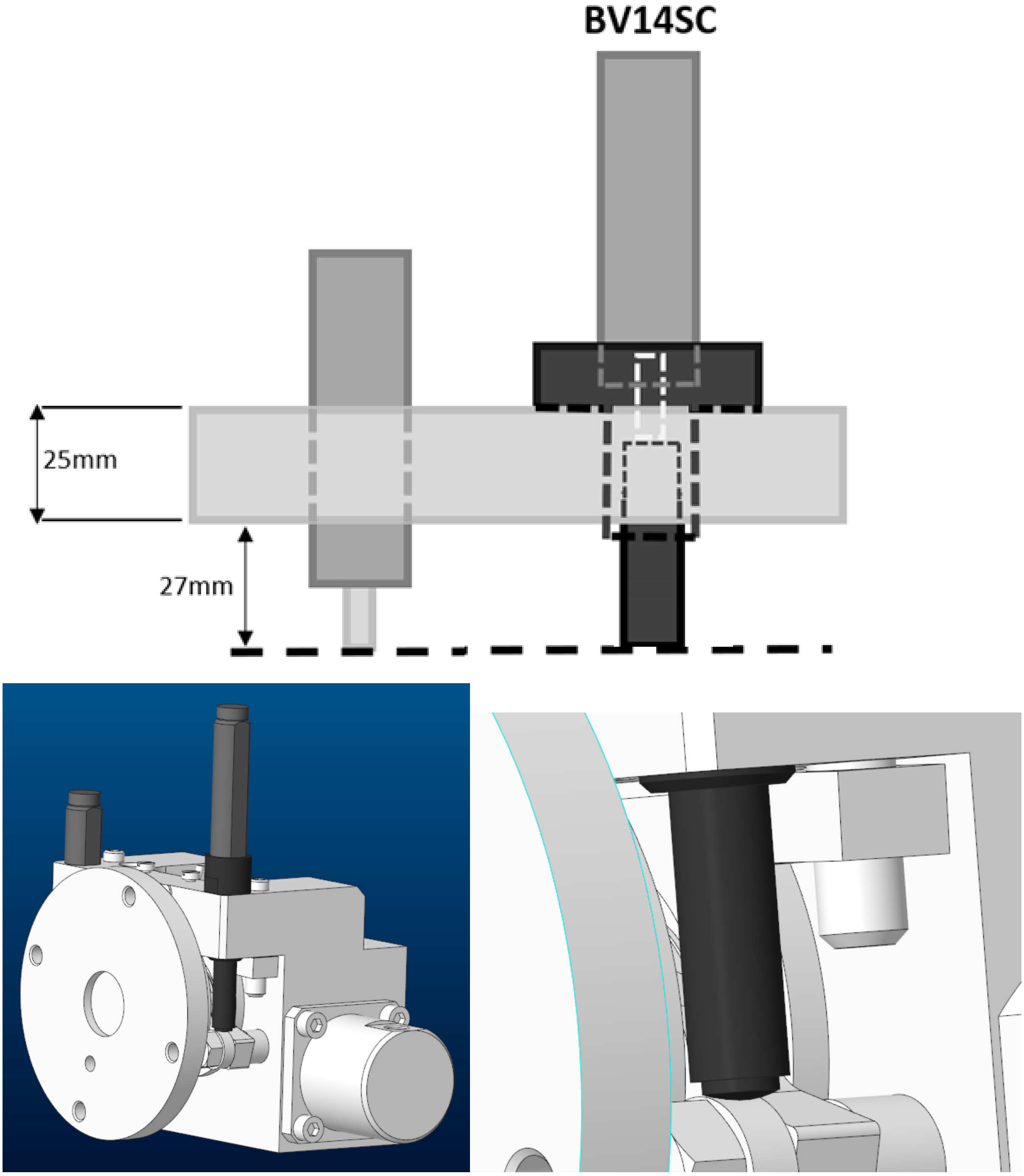
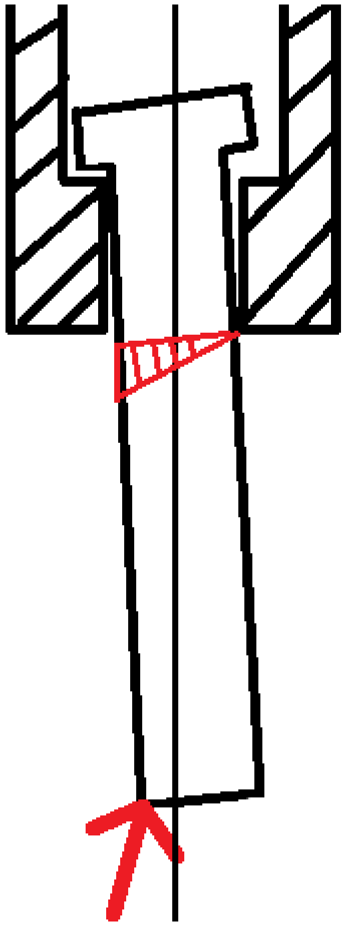


Figure 59 : Side load adpator with longer custom cylinder

This part would be simple to machine, and we wouldn't have to machine the top plate or to design a new complete adaptor.

After modification of the 3D model, I considered that there was a risk of wear and potential breakdown due to the side load with a lever arm this long.



the friction could wear the contact between the two parts, and if the translation becomes difficult because of the worn surface, breakage could occur.

Figure 60 : Risk of breakage in the cylinder

Then, instead of trying to change the adaptor and the top plate, I tried to modify the rotating part. My first guess was to use a roller with a bigger radius, this way we could stop the arm at the right position.

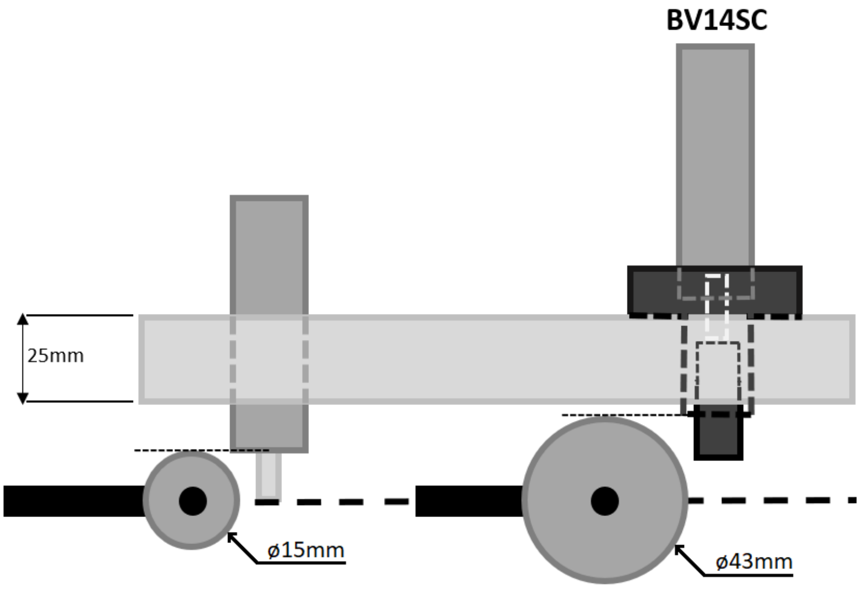


Figure 61 : Adaptor installation with a bigger roller

But unfortunately, the shape of the rotating plate holding the arm and the roller does not give enough place to put a roller this big, so I decided to design a unique part to replace the roller.
The requirements for the part are:

- Being symmetrical
- Being 43mm long
- Having flat extremities to properly press on the damper
- Do not collide with the rotating plate and the main plate

Since the part won't be a rotating part like the rocker was, we also need to lock its position and avoid any rotation, tightening the bolt won't be enough to keep the part perpendicular to the lever for a high number of cycles. So, with all these requirements a designed a part with a groove to fit the lever inside so it stays perpendicular.

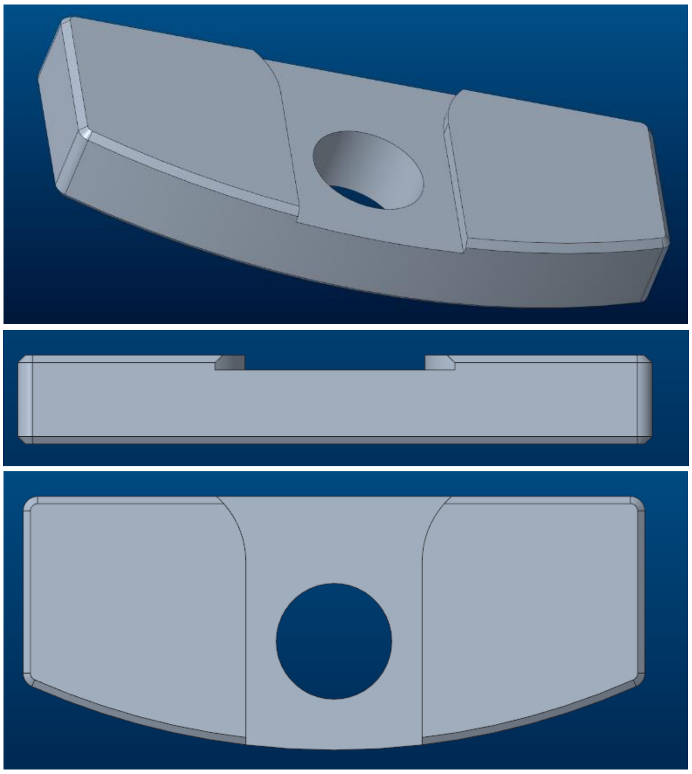


Figure 62 : Custom part to replace the roller

Just before sending my drawing to machine a prototype, I thought about another problem. If the shock absorber is too high, the clamp might collide with it.
Unfortunately, after checking on the machine, the clamp would collide with the shock absorber if it were installed this high, collision is inevitable, whether with the BV14SC or the BV14.

This idea could be a solution on other setups where we have extra room above the shock absorbers, but in our current situation if I want to add an adaptor, it will have to be either another type of adaptor or a custom-made adaptor.

3.4.3. Design a custom side load adaptor

To design a side load adaptor fitted to this situation, the main idea is to keep the main properties of the adaptor from ACE, while making the changes necessary to lower the shock absorber. To do so, the main idea was to remove the part used to hold the adaptor and the shock absorber together, and to instead use the thread in the plate to hold them together. This way, the shock absorber is partially inside the plate so it does not protrude too much to collide with the clamp, and the length of the adaptor can be specifically designed to fit the requirements.

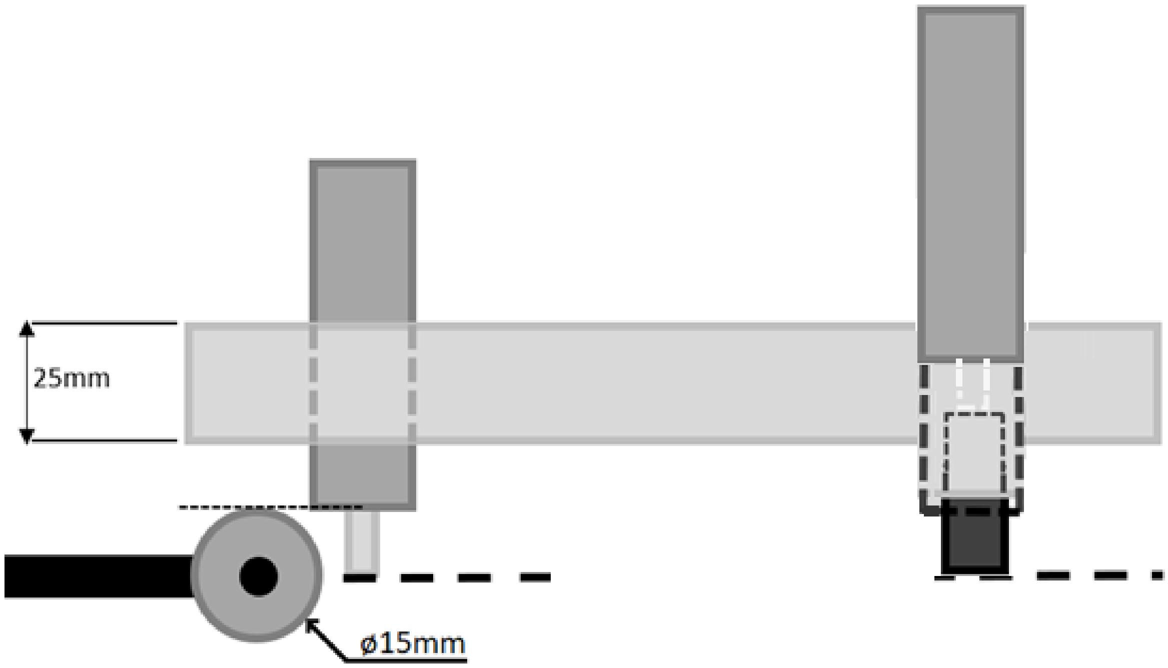


Figure 63 : Custom adaptor mounted on the plate

To design a proper load adaptor multiple calculations are needed to be sure that all the geometrical conditions are respected.

First, a problem we had on the adaptor available on internet was the milling in the moving part of the adaptor to fit the shock absorber inside. This milling is made to be sure that the two parts are aligned. But with the shock absorber rod 4mm inside the adaptor, the effective stroke is reduced to 8mm. To avoid losing 1/3 of the course, the best thing to do is to reduce the depth as much as possible.
Moreover, after discussing with the manufacturer of the shock absorbers, he explained that forcing the absorber to the max could damage the device in the long term and leaving a few tenths of a millimeter could avoid premature wear. So, the milling has been reduced from 4mm to 0.4mm to let the absorber fit without losing too much effective stroke.

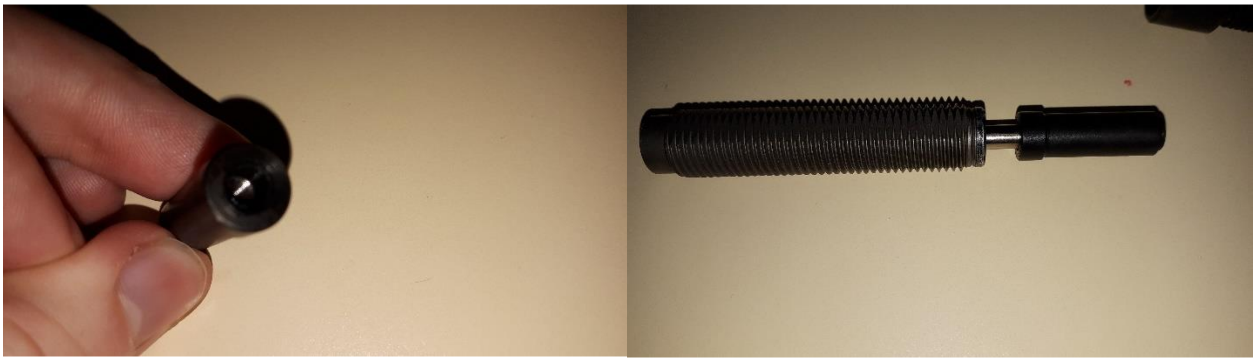


Figure 64 : shock absorber nested in the previous adaptor, with a stroke of 8mm instead of 12mm

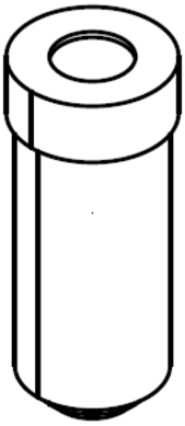


Figure 65 : custom moving part of the adaptor with a shorter milling

Another dimension to determine was the length of both parts of the adaptor. Since the adaptor didn't have to be long enough to protrude from the top of the plate, and the shock absorber must have room inside the plate to be screwed inside, the length of the fixed part must be shorter than the original adaptor.

The dimensions 4mm and 7mm on the drawing below are the two dimensions measured on the adaptor available online, and they will be kept on the custom adaptor. The dimensions L1 and L2 however are the dimensions that must be studied.

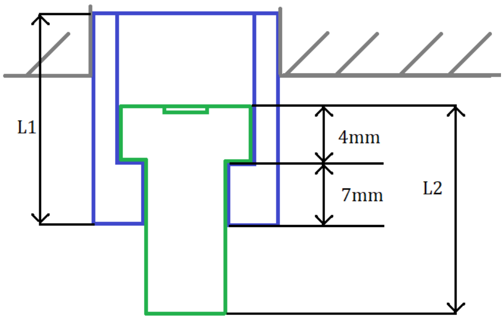


Figure 66 : Drawing of the custom adaptor with the main dimensions

To determine L1 and L2, we must make sure that the two restrictions on the drawing below are respected. At full length the tip of the adaptor must be at 27mm of the plate, and when retracted the top of the moving part (in green) must align with the top of the fixed part (in blue), remembering that the effective stroke is 11,6mm.

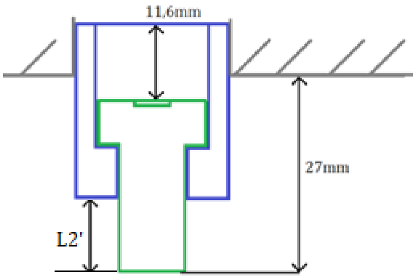


Figure 67 : Drawing of the custom adaptor with two geometrical conditions to respect

With all the data from the two drawings, we can first determine that:

L1 = 11,6+4+7 = 22,6mm

Now, to determine L2, we must make sure that the moving part is long enough, indeed if the part is too short then the full stroke will not be usable. If we call L2' = L2 – (4 + 7), we must have:
L2' > 11,6mm

So:
L2> 11,6 + (4 + 7) = 22,6mm (=L1)

Indeed, it seems logic that we must at least have L2>L1 or else the system will not be able to retract completely.

To avoid the roller hitting the fixed part of the adaptor, a little margin is necessary and so the final value decided for L2 is L2 = 24mm.

To make sure that the adaptor with the values previously determined can be mounted on the system, another dimension must be introduced: the position of the adaptor inside the plate.
If we call h the length of the adaptor screwed inside the plate, we have the equation:
h +27 = 11,6 + L2

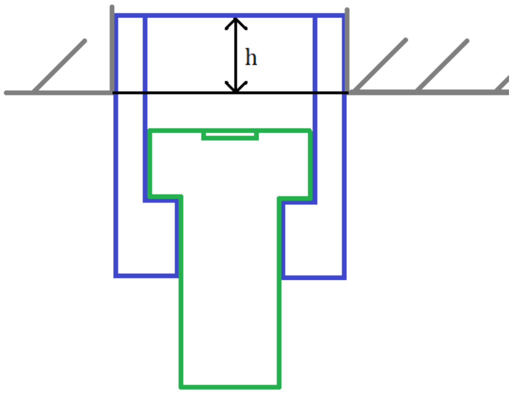


Figure 68 : Drawing of the custom adaptor with h the position inside the plate

With L2 = 24mm, we have h = 11,6 + L2 – 27 = 11,6 + 24 – 27 = 8,6mm ≈ 25/3mm ≈ a third of the plate thickness.

Having a third of the plate filled with the adaptor is enough to make sure that the adaptor is properly fixed to the plate, and two thirds of the plate can be used to fit the shock absorber inside. As it had been explained previously, the fact that the shock absorber protrudes too much above the plate could pose a collision problem with the clamp attached to the rotating arm. By setting the shock absorber this low, this problem is avoided.

After calculating the proper dimensions, the 3D model was added to the existing model of the main assembly, and the adaptor seems to fit perfectly and respect the requirements on the stroke and the position at the stroke end.

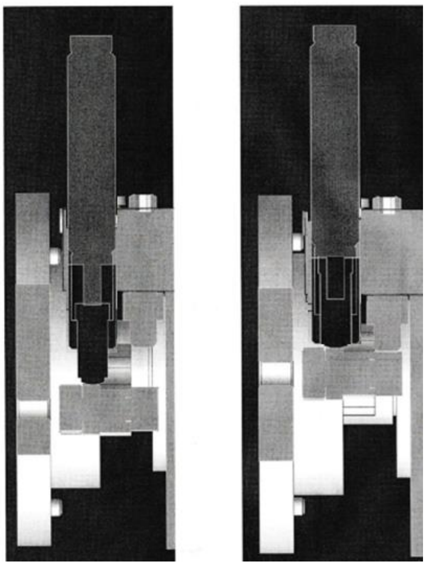


Figure 69 : Custom adaptor on the 3D model

The last step left was to send the drawings made from the dimensions we determined to a manufacturer and try the prototype on the machine, but unfortunately the current manufacturing times were too long to receive a prototype before the end of the internship. Nevertheless, my work on this subject made it possible to show where the problem came from and to provide a solid basis for solving it.

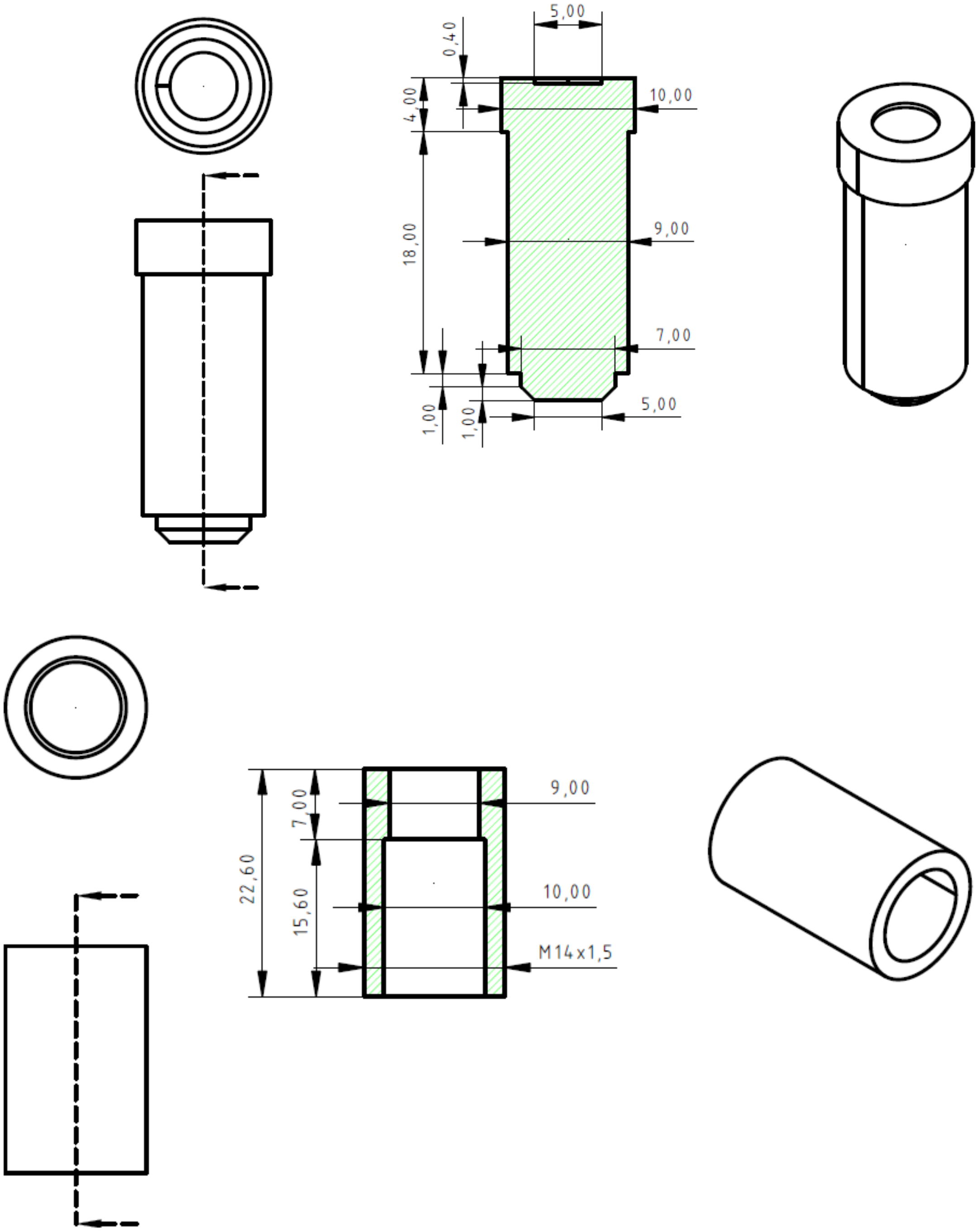


Figure 70 : Drawings of the custom side load adaptor

Conclusion

The aim of this master's thesis was to study the new rubber injection technology called Valgate and to take part in the continuous improvement of machines for the production of sealing rings for ICE engines.

after having studied in depth the operation of the Valgate plates, both on plans and during the maintenances in which I participated, I was able to invest myself in their improvement, whether on the technical level by reflecting with my tutor and with the manufacturers on the possible modifications to be made to eliminate leaks and breakdowns. But also, by participating on the organizational and informative level by producing technical documents to follow the updates and to keep the communication between the engineers and manufacturers, the production, the maintenance, and the management of the stocks.
I was able to understand the certain advantages of continuous improvement, such as reducing corrective maintenance, but also the risks. Starting an improvement maintenance on a machine amount to making a production tool unavailable for a given period, a wrong decision could lead to delay in the production. The new documents available for the monitoring of Valgates make it possible to effectively visualize all the data necessary for this decision to reduce the duration of maintenance as much as possible and aim to avoid errors such as the assembly of a wrong part, the lack of a new replacement part during reassembly, or other problems that may arise from a lack of information available.

the second part of my internship allowed me to study a problem of wear on a shock absorber. the source of the problem not being identified yet, I had to look for the cause. After investigation of the catalogs and discussions with the supplier, I was able to deduce that the problem came from the angle of the force creating side load on the shock absorber. the solution that seems to me the best is a side load adapter, and after having explained that the adapters available on the market could not be installed on our machine due to available space, I designed a custom adapter specially to this case. This internship came to an end before having time to test a prototype on the machine, but the drawings for the prototype are ready and the subject can be resumed from the work I have done. this subject allowed me to work on the wear of parts, a recurring problem in the world of the automotive industry, by providing me with knowledge on the sizing of shock absorbers, from the technical documents that I read at this subject and the professionals in the shock absorber industry that I had the chance to meet.

This 6-month internship finally allowed me to discover the production of automotive parts from the inside. the automotive industry is undoubtedly the one with the most sustained pace, with in addition growing constraints such as the microcontroller crisis which is hitting the industry hard and the gradual replacement of ICE engines. It is therefore necessarily with a lot of responsibility that I imagine my future career as an engineer in the automotive industry, but I now know what to expect and all my colleagues have been able to show me that despite a steady pace and commitment, the work is rewarding, and technological progress knows how to keep the motivation up.

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