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The purpose of obtaining master degree in
Mechanical Manufacturing and Production

THESIS:

Study and conception of bottle compacting machine Using crank-rod system

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ABSTRACT

Today, the damage caused by humanity to nature has reached the highest level in recent years. There are many reasons that trigger this, but one of the most important is the plastic bottles, cans, etc… that we use in our daily lives. This work suggests a compacting machine using a mechanical system called crank rod, we use SOLIDWORKS for the purpose of machine conception and simulation, and MATLAB code optimization for the necessary calculation.

RESUME

Aujourd’hui, les dommages causés par l’humanité eu la nature eu atteint le plus haut au cours des dernières annes.il y a de nombreuse raison de déclencher cela. Mais l’un des plus importante est les bouteilles, canettes…etc que nous utilisons dans notre vie quotidienne, ce travail suggère une machine de compactage utilisant un système mécanique appelé bielle-manivelle, nous utilisons SOLIDWORKS pour la conception et la simulation de cette machine, et code MATLAB optimisation pour les calculs nécessaires.

ملخص

اليوم، بلغ الضرر الذي ألحقته البشرية بالطبيعة أعلى مستوى له في السنوات األخيرة. هناك العديد من األسباب التي تؤدي إلى ذلك، ولكن أحد أهمها الزجاجات البالستيكية والعلب وما إلى ذلك... التي نستخدمها في حياتنا اليومية. يقترح هذا العمل آلة ضغط تستخدم نظا "مًا ميكانيكي"ا يسمى الكرنك، ونستخدم SOLIDWORKS لغرض تصور الجهاز ومحاكاته، وتحسين رمز MATLAB للحساب الالزم.

AKNWOLEDGMENT

I would like to express my deepest gratitude for Dear Dr. HADJI, Dr. LOUNICI, and the Department of Mechanical Engineering,

Your valuable guidance and support throughout the process of writing my thesis. Your expertise, encouragement, and constructive feedback have been instrumental in shaping my research and helping me navigate the complexities of my topic.

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I am honored to have had the opportunity to work alongside such esteemed professionals and am immensely grateful for the knowledge and skills that I have gained under your guidance.

With heartfelt appreciation,

DIDICATION

With the expression of my gratitude, I dedicate this modest work to those who are most dear to me:

My dear parents, whose love and support have been my compass throughout this academic journey, To my dear grandmother who she was my first supporter in my study and life, and to my companions of Alkindi physics Club, whose camaraderie and passion have enriched this experience, I dedicate this work with gratitude. Your influence and encouragement have shaped every page of this journey, and I am deeply grateful for your presence at my side.

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SUMMARY

GENERAL INTRODUCTION

Plastic is one of the most widely used materials in the world. Its versatility and durability make it ideal for various applications, from consumer goods to agricultural and building materials. However, as the use of plastic has increased, so has the amount of plastic waste produced?

The impact of plastic waste on the environment has been widely documented, and communities worldwide are beginning to recognize the importance of reducing waste and promoting sustainability. In response, plastic recycling has become an essential aspect of waste management. It has evolved from a small-scale operation to a global business with complete international reach.

Plastic recycling in Algeria is a growing industry, but it faces several challenges. The Country produces approximately 16 million tons of waste per year, and only 5-7% of this waste is recycled. The recycling rate of plastic packaging waste is between 2-3% and the loss of profit for the Algerian.

Plastic collect has a big impact on plastic recycling in Algeria, many people use it as part of their income in order to make money, but it can cause health problems for the young and not too much collect for the vehicles.

Plastic bottles has a big impact when it comes to our environment, that gives bad image to it, and plastic shifting that has an effect.

Which leads us to this solution;

In our project, we propose a machine that can help reduce the volume of plastic bottles, plastic shifting and a clean environment.

Compacting machine with autonomous, automatic and mechanical system that helps reduce the plastic bottles volume with enough space. Our work plan consists of:

- We talk about generalities concerning plastic recycling and the most recycled plastic, which is PET.
- We study the crank rod mechanism, and calculate the rotation and its translation in order to choose the motor.
- We concentrate on the study and the conception of our machine using SolidWorks.
- We present the machine and its components.

Last part will concern the general introduction, which talk about the principal results of our study.

CHAPTER 01:

GENERALITIES OF RECYCLING AND PET PLASTIC

Introduction:[2]

A plastic material is a basic material that can be molded, shaped, usually hot and pressurized to make a part or object. The word "plastic" comes from Greek "***plastikos***" -

In 1865 in the U.S.A, a competition was organized to find a material capable of replacing ivory, which became too expensive for billiard balls, Two Americans then discovered the first plastic material called "celluloid" by mixing camphor with cellulose in 1869. In 1909, an American chemist of Belgium origin patented Bakelite: ***Leo Baekeland.***

In the 1930s, plastics were first made from petroleum derivatives: PVC, PMMA (Plexiglas), PELD, PA (Nylon), PS, cellulose acetate (Rhodoid), PU, PTFE (Teflon).

Today plastic is so much part of our daily life that we forget to be surprised to be able to carry 10- kg of shopping in a bag that weighs 6 g or to be able to call while walking.

I.1 Types of recyclable plastics:

During our research, we have found that not all plastic is recyclable. There are 7 types of recyclable plastics, they are dispersed by RIC (Resin Identification Code in ENG, Resin Identification Codes in FR):

I.1.1 High density polyethylene (HDPE):

HDPE is a petroleum derivative that is obtained by adding different ethylene (hydrocarbon) units. It is known for its powerful and durable density. It hardens when the temperature decreases and, on the contrary, softens when the temperature rises. Often used in the medical and chemical sector.

Figure I.1: HDPE

I.1.2 Polyvinyl chloride (PVC or V):

PVC is the third most used type of plastic in the world. It is composed of 57% sea salt and 43% oil. This plastic is known for its strength and durability; it is very resistant to many aggressive agents. It is very often used in buildings: electrical equipment, pipes, etc.

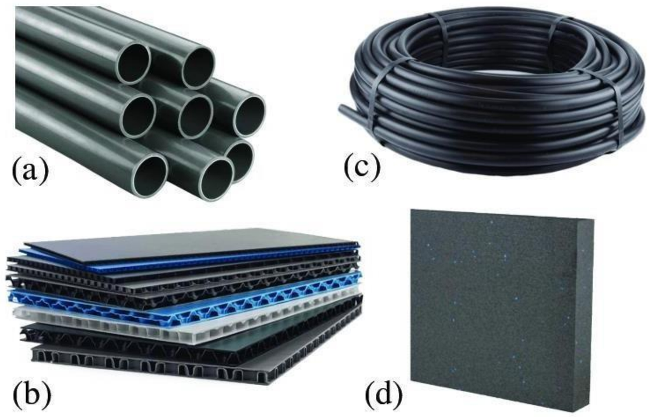


Figure I.2 : PVC

I.1.3 Bass density polyethylene (LDPE ou PE-LD):

LDPE is one of the most requested plastics in the world and also the most recycled. It is quite different from HDPE (RIC 2). It is a material that represents a significant thermal and chemical resistance; it is very flexible and manageable.

Figure I.3: LDPE

It is also pleasant to handle and is therefore appreciated at the marketing level. The LDPE is used for packaging (packaging: food/miscellaneous), cabling, etc. It is also found in plastic bags, cosmetic bottles, milk caps, etc…

I.1.4 Polypropylene (PP):

PP is the second most used plastic material in Europe. Because of these many advantages, consumer consumption is the sector that uses this plastic the most:

- Easy to color.
- Resistant.
- Affordable.
- Non-toxic.

It is also used in other sectors such as automotive, fashion…

Figure I.4: Polypropylene

I.1.5 Polystyrene (PS):

There are different types of polystyrene:

- Crystal plastic: often used to protect objects because of its hardness
- Polystyrene shock: an assembly of plasticizer and rubber
- Expanded polystyrene
- Extruded polystyrene

It is used in various sectors such as agro-food, automotive, household appliances, and more. This is due to its beneficial characteristics such as waterproof, impact resistance, ease of cleaning, and oppressiveness.

Figure I.5: Polystyrene

I.1.6 Polyethylene Terephthalate (PETE or PET):

This particular plastic is made exclusively of molecules composed of hydrogen, carbon and oxygen. PETE is known because it has been used for bottling since the 1990s (bottle, water bottle, shampoo, etc.). It offers many advantages: light, solid, recyclable and is recognized by ANSES for contact with food, it preserves any external contamination (it does not influence the taste).

Figure I.6: PET

I.1.7 Other types of plastics (O):

The best-known plastics in this category are polycarbonate and polylactide. They are used in the manufacture of baby milk bottles, riot shields, sunglasses, etc. These plastics are difficult to recycle.

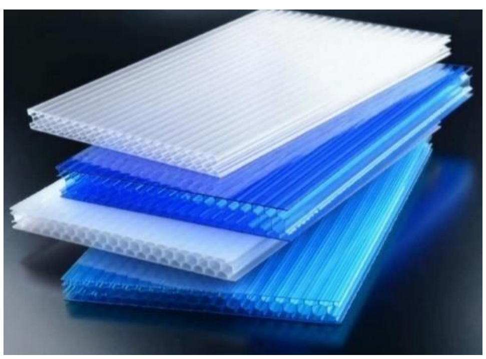


Figure I.7: Polycarbonate

I.2 Generalities of recycling:

Plastic recycling comes with an unquestionable list of benefits, such as reducing pollution and conserving resources, and benefits to communities, such as job creation, education and awareness. Still, there are some key challenges and limitations of the industry. Plastic recycling has come a long way, but there is still space for innovation.

Figure I.8: Recycling

I.2.1 History of plastic recycling:

The history of plastic recycling can be traced back to the early 1970s when the first recycling symbol was introduced. The symbol, three arrows chasing each other in a triangle, was designed to help consumers identify which plastic products were recyclable. However, it was in the 1980s that plastic recycling became more prevalent.

Figure I.9: Plastic symbols

During this time, there was a growing concern about the amount of plastic waste generated. Plastic waste was collected and recycled through recycling programs, which resulted in a decrease in plastic in landfills and the environment.

I.2.2 Plastic recycling: how does it work:[2]

At the time, our society was used to "**manufacture, take, and throw away**". Currently, behavior changes as a result of various environmental alerts. We know that some consumer models are no longer viable, and many brands are trying to remedy this by offering more environmental friendly services/ products. There are 3 families of waste: plastic, glass and cardboard/paper.

Figure I.10 Recycling process

In addition, in recent years, several methods have been implemented to recycle plastic:

- **Mechanical recycling:** To reduce plastic or metal waste into small reusable components, mechanical recycling mainly involves crushing it with machines. This mechanical process allows recycling plants to recover a certain amount of waste: recyclable packaging and plastic bottles essentially. But, depending on the waste, mechanical recycling is not enough. For example, it fails to transform certain types of plastic into material that can be used in industrial processes. That is why selective waste collection must be done scrupulously. In addition, the life cycle of mechanically recycled materials is quite short, they can only be recycled through this means two or even three times at most.

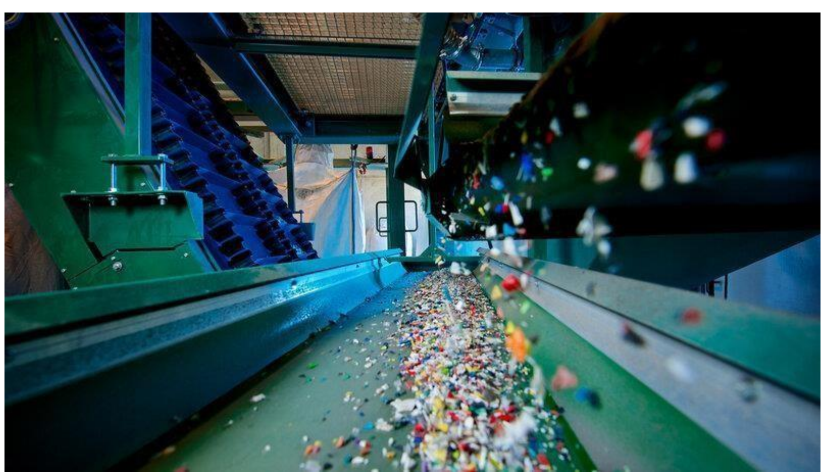


Figure I.11: Mechanical recycling

- **Chemical recycling:** Mechanical recycling's effectiveness is limited to waste that only contains one material, which is a major problem.

Chemical recycling allows for the separation of these elements to create monomers, Chemicals such as Polyethylene, Terephthalate, and Polyvinyl Chloride will separate the monomers from the dyes, additives, etc…

The chemical reaction enables the recovery of a significant amount of industrial or everyday waste, including hazardous waste. The wastewater treatment on site is done to reuse the water used in the process, not from the water table. Mechanical and chemical recycling are entwined. The debate over chemical recycling is still ongoing. Handling chemicals has the potential to cause serious accidents. Above all, on the other hand, chemical recycling does not have a neutral carbon footprint. This is the last straw for an ecological approach.

Figure I.12: chemical recycling process

Figure I.13 Organic recycling

- **Organic recycling:** Organic recycling refers to the process of converting organic waste materials into useful products like compost or biogas. It involves the collection, processing, and recycling of organic materials such as food scraps, yard trimmings, paper products, and other biodegradable waste. In the coming years, recycling processes will evolve through the development of new technologies. It is hoped that 50% of waste will be recycled in 2025, 55% in 2030.

- **Environmental Impact:** Recycling 1 ton of plastic saves 5,774 KWh of energy compared to producing new plastic from raw materials. Recycling plastic packaging reduces greenhouse gas emissions by 30% compared to using virgin plastic. The recycling rate for plastic packaging in Europe was 41.5% in 2020, up from 34.4% in 2015.

- **Circular Economy:** The global market for recycled plastics is expected to grow from $42 billion in 2022 to $57 billion by 2027, a 35% increase.

I.2.3 Packaging:

a- Recyclability and Design: 86% of plastic packaging is designed to be recyclable, up from 72% in 2018.The use of PVC and PS plastics in packaging has decreased by 32% and 45% respectively since 2018, as these are more difficult to recycle.

b- Innovation: Investment in advanced recycling technologies reached $1.1 billion globally in 2021, up from $300 million in 2019. 40% of packaging companies are exploring the use of biodegradable or compostable plastics.

These statistics demonstrate the significant impact of plastic recycling on driving more sustainable packaging design, reducing environmental footprint, and enabling a circular economy model in the industry.

I.3 Automotive:

- **Market Size and Growth:** The global automotive recycled plastics market was valued at $2.4 billion in 2020 and is expected to reach $4.3 billion by 2027, growing at a CAGR of 7.8%. The market for recycled plastics in the automotive sector is projected to grow from 1.4 million tons in 2020 to 2.5 million tons by 2025, at a CAGR of 9.5%.

- **Types of Recycled Plastics Used:** Polypropylene (PP) accounts for approximately 40% of the recycled plastics used in the automotive industry. Acrylonitrile Butadiene Styrene (ABS) accounts for around 25% of the recycled plastics used in the automotive industry.

NB: Polystyrene (PS) accounts for around 15% of the recycled plastics used in the automotive industry.

- **Benefits of Using Recycled Plastics:** Using recycled plastics in vehicles can reduce vehicle weight by up to 10%, leading to a 5-7% reduction in fuel consumption and emissions. The use of recycled plastics can reduce the automotive industry's carbon footprint by up to 70%. Recycling 1 ton of plastic saves 3.8 barrels of oil, 1.3 tons of CO_2 emissions, and 7.4 cubic yards of landfill space.

- **Challenges and Developments:** The global automotive industry aims to increase the use of recycled plastics to 20% of total plastic content by 2025. The European Union has set a target of 85% recycling rate for end-of-life vehicles by 2025. The use of recycled plastics in the automotive industry is expected to increase by 15% annually from 2020 to 2025.

These statistics demonstrate the growing importance of recycled plastics in the automotive industry, driven by the need for sustainability, reduced emissions, and a circular economy approach.

I.4 recycled plastic can get back into the supply chain:

Recycled plastic is used in many consumer products. One example is the recycled plastic Bottle which considered 2-3% in Algeria, which is commonly used for beverages and cleaning products. Another example is the recycled plastic bag thus Algeria is considering one of the top 5 countries in the world in terms of plastic bags consumption, widely used in grocery stores and retail outlets. Recycled plastic is also used to manufacture such as:

- **Furniture:** Knowing the coming facts that the global market for recycled plastic furniture is projected to reach USD 3.14 billion by 2028, growing at a CAGR of 5.8% from 2021 to 2028. The Asia Pacific region is expected to dominate the recycled plastic furniture market, accounting for over 40% of the global market share by 2028.

Figure I.14 Plastic fourniture

- **Clothing:** The clothing industry is heavily reliant on plastic, with approximately two-thirds of our clothing comprising synthetic fibers like polyester, elastane, nylon, and acrylic. Polyester alone accounts for 52% of all fiber production. The raw material for these fibers is fossil fuels, and textile production consumes 1.35% of global oil production. Major brands like Nike and H&M have set ambitious targets to increase their use of recycled polyester. Nike uses "some recycled material" in

60% of its products, while H&M, Madewell, J Crew, and Gap Inc. have committed to increasing their share of recycled polyester to 45% by 2025.

Figure 1.15: Polyester elastin fabric

- **Electronics:** The global post-consumer recycled plastics in consumer electronics market size is expected to reach USD 34.80 million by 2032, growing at a CAGR of 10.8% from 2024 to 2032. The global plastics in electrical and electronics market is valued at USD 37.72 billion in 2023 and is anticipated to grow to USD 39.94 billion in 2024

Asia Pacific is expected to dominate the recycled plastics in consumer electronics market, accounting for over 40% of the global market share by 2028.

Japan has a high percentage of elderly population, driving the demand for medical monitoring devices that require polymers like polycarbonate (PC), polypropylene (PP), and polyvinyl chloride (PVC).

Figure I.16 electronics

I.5 The benefits of plastic recycling:

The advantages of plastic recycling are numerous. One of the most significant advantages is that it reduces the amount of plastic waste in landfills and the environment. Recycling also conserves energy and resources by reducing the need for virgin plastic production.

Additionally, recycled plastic can produce a wide range of products, which helps create a circular economy in the UK, it is estimated that for every 10,000 tons of waste recycled, around 30 jobs can be created.

Recycling plastic saves energy during production. For example, the energy required for recycling PET bottles is only 30% of the energy used during re-manufacturing.

Recycling product materials, rather than harvesting and processing raw materials, can lower or reduce the energy cost of production by up to 95%.

- **Revenue Generation:** The annual market value of landfilled plastic ranges from $4.5 billion to $9.9 billion, or $7.2 billion on average, in the U.S. Recycling enables the reuse and resale of remanufactured plastic materials, contributing to economic growth and increasing business profitability.

- **Environmental Cost Savings**: Marine plastic pollution alone causes a loss of ecosystem benefits that would cost up to $2.5 trillion every year. Communities across the U.S. spent about $2.3 billion on plastic waste disposal in 2019. Recycling plastic reduces pollution and saves animal species by decreasing plastic waste. It conserves natural resources like oil, natural gas, and coal that are used to produce new plastic. Recycling plastic saves energy compared to manufacturing new plastic from raw materials. It takes 75% less energy to make a plastic bottle using recycled plastic. Recycling 1 ton of plastic saves 3.8 barrels of oil, 1.3 tons of CO_2 emissions, and 7.4 cubic yards of landfill space

I.6 Plastic recycling cycle:

Here is how a recycling cycle works:

- **Purchase:** the consumer purchases consumer products (food, beverages, cosmetics, hygiene, etc…).

- **Consumption:** after being purchased, the product is consumed, so it is up to the consumer to do what is necessary to recycle his products. Indeed, not all waste has the same destination (here are the different specific recycling bins: yellow, green, blue, classic...). Today in France, 67% of waste is sorted and recycled, but in large cities, this figure only reaches 30%.

- The sorting centers

- Conditioners and recyclers

- Waste reuse

Figure I.16 plastic recycling cycle

I.7 Recycling of plastic waste in sorting centers:

The concept of a sorting center in the context of recycling and logistics involves a facility where items or packages are processed, sorted, and prepared for further handling or distribution. Here are some key points about sorting centers based on the provided sources:

Within a sorting center, various activities such as receiving, storage, picking, packing, and labeling are carried out to ensure efficient order processing and delivery.

- **Automating Sorting Centers:** Automation technologies in sorting centers optimize speed, efficiency, and accuracy in parcel sorting processes, reducing delays and errors in package handling. Automated sorting systems improve delivery accuracy, reduce labor requirements, maximize space utilization, and enhance scalability during peak demand periods.

- **Duration of Stay and Dispatching:** Packages can stay at a sorting center for varying durations, depending on factors like shipping method, center workload, and available resources. After leaving a sorting center, packages are tagged for tracking and dispatched to their next destination, which could be another sorting facility or the final delivery location.

- **Handling Delays and Tracking:** Delays in sorting centers can occur due to various reasons, such as misplacement or high workload, but many issues are typically resolved over time. Tracking packages through a package tracker can provide real-time updates on the location and status of shipments, enhancing visibility and communication between senders and recipients.

1- After placing the waste in the recycling bins, it is collected and sent to the sorting centers.

2- Waste is sorted into the various categories (1 to 3):

- **Soft Plastic:** Food packaging; Carrier bags and bubble wrap; Wrapping from toilet paper.

Figure I.17: Plastic bags

- **Hard Plastic:** Meat trays; Packaging from items like hand soap, roll-on deodorant, drinking yoghurt, and ketchup bottles; Plastic toys (without batteries); Plastic items not for recycling

Figure I.19 hard plastic

- **PVC plastic:** Unhygienic plastic like toilet brushes and toothbrushes; Packaging from chemicals and paint makeup

3- Then, bales of waste are created and sent to recyclers or conditioners.

Figure I.20 Toilet brush

I.8 The creation of recycled plastic objects:

When plastic waste has been processed, it is possible for conditioners and recyclers to recover it to give it a new life.

❖ **Packers and Recyclers:** Packers buy waste from the sorting centers; prepare waste before it is recycled. The materials are washed and cut to be more easily recycled. The recyclers buy the waste from the sorting centers; the materials are processed to be used to manufacture new products.

❖ **Waste reuse:** companies or organizations, to be introduced into their production process, then purchase recyclable materials and products. Recycled materials are often construction materials, textile products, etc. Finally, the products and materials are then put back on the market as everyday consumer goods and the cycle starts again.

I.9 Certain methods to sort the different types of plastic:

❖ **Recycling of plastic bottles:** To properly recycle your plastic bottles, you need to throw them in the yellow bin. Before discarding, be sure to drain the air from the bottle by flattening it. It is best not to rinse it so as not to waste water. All plastic bottles containing toxic products (solvents, phytosanitary products, photographic products) are not to be disposed of in recyclable waste; they must go to the landfill. To avoid the use of plastic bottles, it is recommended that you invest in a gourd or solid bottle.

Figure I.21 recycling of plastic bottles

❖ **Recycling of food packaging:** A yogurt jar is made of different materials, which could hinder its recycling. In the majority of cases (3/4 of yoghurt in France): the jars are made of polystyrene (PS). They are then dressed with a banner which in most cases is made of paper, and an operculum (aluminized or not). They are to be thrown in the trash to recycle (yellow).

Figure I.22 Food packaging

❖ **Recycling of plastic bags:** Reuse and recycling are the most effective ways to prevent plastic from being spilled into our environment. Not all types of plastic bags are recyclable. Small test to know if the one you are about to throw is recyclable: grab the bag or packaging and try to stretch it by pushing it with your finger. If the plastic stretches easily, it means it is recyclable. If not, it goes to the trash. To avoid plastic bags, you can get a cloth bag or a shopping cart to do your shopping.

Figure I.23 Plastic bag recycling

❖ **Nesting and washing plastic waste:** It is useless to nest your waste, it will complicate recycling. Indeed, the waste must be separated in order to be sorted, if compacted; they will be difficult to break down. There is also no need to wash your waste before disposal. However, its contents should be emptired of facilitate cleaning.

Figure I.24 washing plastic waste

I.10 Plastic collection in Algeria:

- **Problems:** With the increasing volume of waste produced by our lifestyle; waste management has become a major issue in our society. This phenomenon is also reinforced by the emergence of concerns about sustainable development, and the increasing rejection of waste in the collective unconscious, as well as by the high cost of waste treatment, that plays a major role in the will of state government. We can see that the plastic collection has a huge impact for recycling. We use certain vans in order to have plastic bottles only. The issue is we are wasting much space so we can ship the plastic, and recycle it without having pure first material for remanufacturing.

- **Proposed Solution:** Which leads us to finding a solution for a better collection, volume saving, and pure plastic recycling. We propose our machine that can help our society into having a better environment and recycling pure plastic without extra treatment. Our compacting machine has an automatic system with a crank rod mechanism that helps reduce the volume of plastic bottles and increase plastic shifting.

Conclusion:

It is important to recycle plastic because it is a material that can be renewable, but it is also very long to disappear. Indeed, plastic takes hundreds or even thousands of years to disappear. This material also has irreversible and disastrous impacts on our environment in the long term. If we do nothing, the flora and fauna will die.

CHAPTER 02:

FUNCTIONAL ANALYSIS FOR BOTTLE COMPACTING MACHINE

Introduction:

Functional analysis of a machine is a method used in process engineering to analyze and develop the functions of a process or a product. It involves breaking down the process into individual functions and tasks, identifying the relationships between these functions, and prioritizing them according to importance. This analysis helps in systematically identifying, checking, and validating requirements and clarifying concrete use cases.

II.1 Machine Definition:

The plastic bottle compaction machine is an equipment designed to reduce the volume of plastic waste by compacting rather than crushing it and collecting it. This machine is designed to meet the growing needs of plastic waste recycling, allowing efficient and economical compaction and collection of PET and HDPE bottles. The machine consists of the following main components.

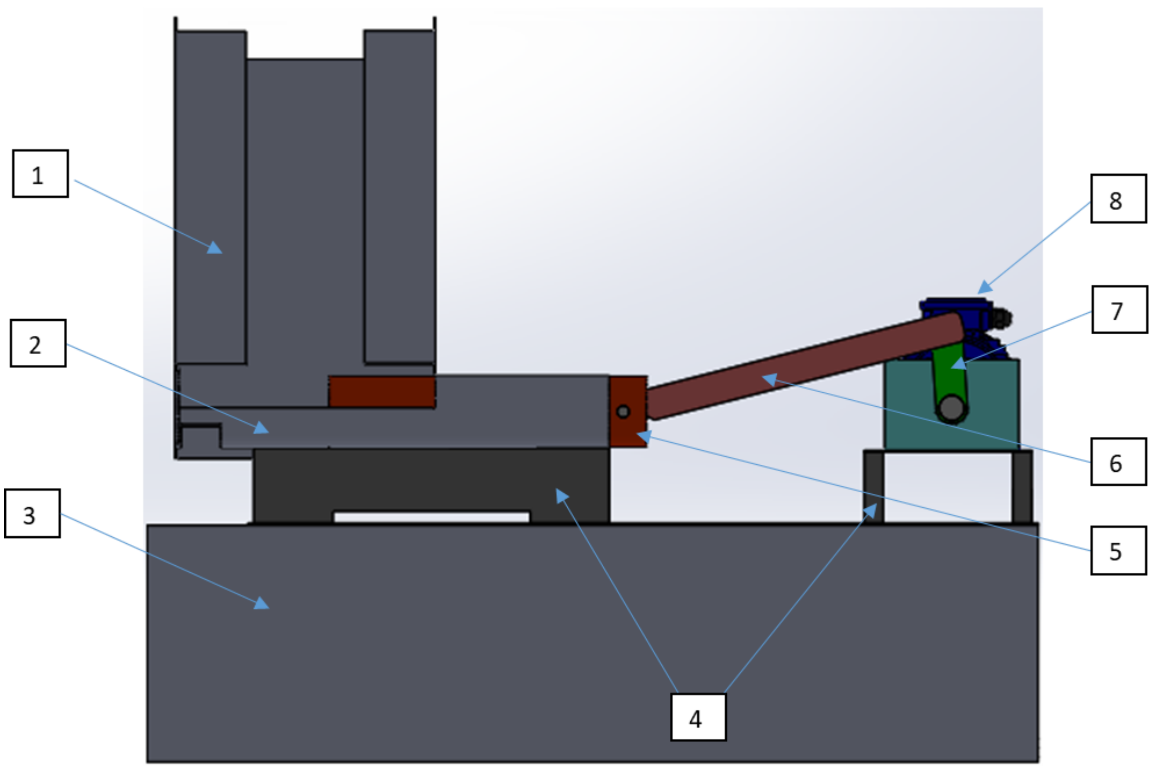


Figure II.1 : machine parts

1: Feed hopper	2: Piston chamber (compacting chamber)
3: Reservoir	4: Table (holder)
5: Piston	6: Crank
7: Rod	8: Electric Motor

II.2 Needs Analysis:

The need analysis operation consists of entering, stating and validating the need. In general, it is the "marketing" department that carries out a market study to identify the need which will then be stated using a Horned Beast diagram, for example. The validity check validates the expressed need. For our study, we have identified the potential needs, which are summarized in the diagram in Figure II.2. It is these needs that make this project meaningful and can exist.

Machine parts	Their role
Feed hopper	The feed hopper is designed to receive bulk bottles. It is made of 3 mm thick sheet steel and has a 60° tilt to facilitate the flow of bottles to the compaction chamber
Compacting chamber	The compaction chamber is the heart of the machine. It is equipped with a crank-rod system that reduces the volume of bottles by compacting them.
Crank-rod	The crank-rod system replacing the hydraulic system, using this mechanical system to assure a thin continues compacted bottles
Piston	A piston, designed to equally match the diameter of the bottles, made by metal and dimension of 400mm × 45 r
Electrical engine	Using an electrical engine to develop a rotational force transmitted to the piston in order to reach a compacting result of 500 N (50kg)
Collecting bin	A metal box of dimension 1000 × 300 × 300 mm, to contain and save the compacted bottles for the collectors
chassis	The chassis is made of steel profiles and ensures the rigidity and stability of the whole. It supports all parts of the machine and allows easy access for maintenance.
Security system	A presence sensor is installed at the entrance of the hopper to detect the possible presence of foreign objects (cans, caps, etc.) and automatically stop the machine if necessary.

Table II.1 : machine components

Figure II.2: costumer needs

Questions	Answers
The product serves whom?	Bottle collectors
What does the product work on?	Compacting and collecting bottles
For what purpose?	Reducing bottles volume and clean plastic

Table II.2: board of questions according to the customer needs

The «beast-to-horns» diagram makes it possible to graphically formalize the previous answers as illustrated in Figure II.3 this tool is located in the first step of the method of functional analysis and value analysis (APT). It aims to graphically represent the expression of the customer's (or user's) need through the 3 simple questions in Table II.2

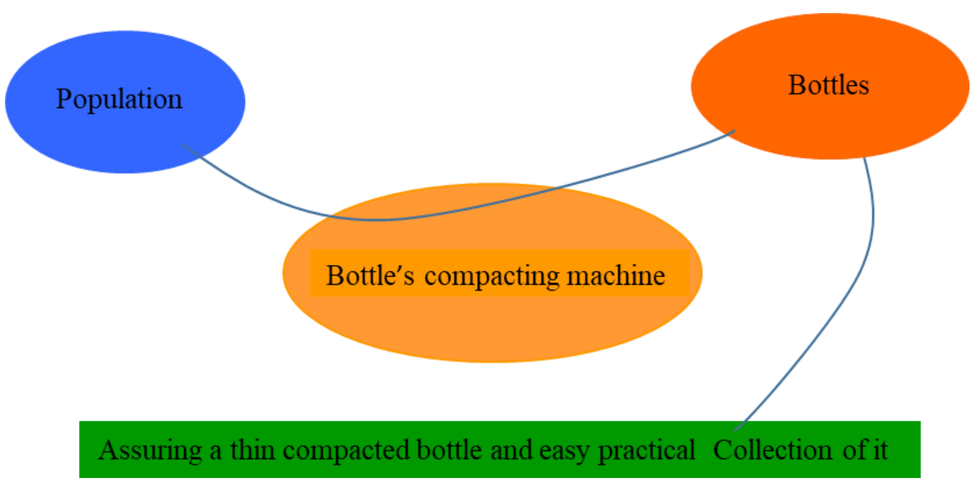


Figure II.3: Horned beast diagram

II.3 Function of machine:

1. Bottle Input: Bottles are placed into the input hopper, one either at a time or in a batch. The hopper guides the bottles into the compaction chamber.
2. Crank Rod Mechanism: The crank is turned, either manually or by a motor, to move the connecting

rod and plunger downwards. As the plunger moves, it applies pressure to the bottle, crushing it. The crank rod mechanism provides mechanical advantage, allowing even manual operation to generate significant force to compact the bottle efficiently.

3. Compaction: As the plunger moves down, the bottle is compressed into a smaller volume. The compaction force flattens the bottle, making it easier to store or recycle.
4. Collection: After compaction, the crushed bottle drops into the collection bin located below the compaction chamber.

Once the collection bin is full, it can be removed and emptied for recycling. The collection bin can be designed to handle multiple compacted bottles, depending on its size.

5. Repeat Process: The machine is ready for the next bottle. In automated versions, the machine might cycle continuously as bottles are fed through the hopper.

II.4 SADT diagram:

The SADT diagram is a graphical tool used in the SADT top-down functional analysis method.

It provides a structured and hierarchical representation of the functions of a complex system.

Key features of the SADT diagram:

- ❖ It consists of "boxes" or "modules" that represent the different functions of the system.
- ❖ Each SADT box contains the name of the function it represents.
- ❖ The boxes are connected by arrows that symbolize the flows of inputs, outputs, controls and mechanisms.
- ❖ Arrows do not represent sequencing or control, but rather constraints and interactions between functions.
- ❖ The SADT diagram proceeds by successive decomposition, starting from a global function (level A-0) to move towards more and more detailed sub-functions (levels A0, A1, A2, etc.).
- ❖ This decomposition allows analyzing in detail the functioning of the system and its various components.

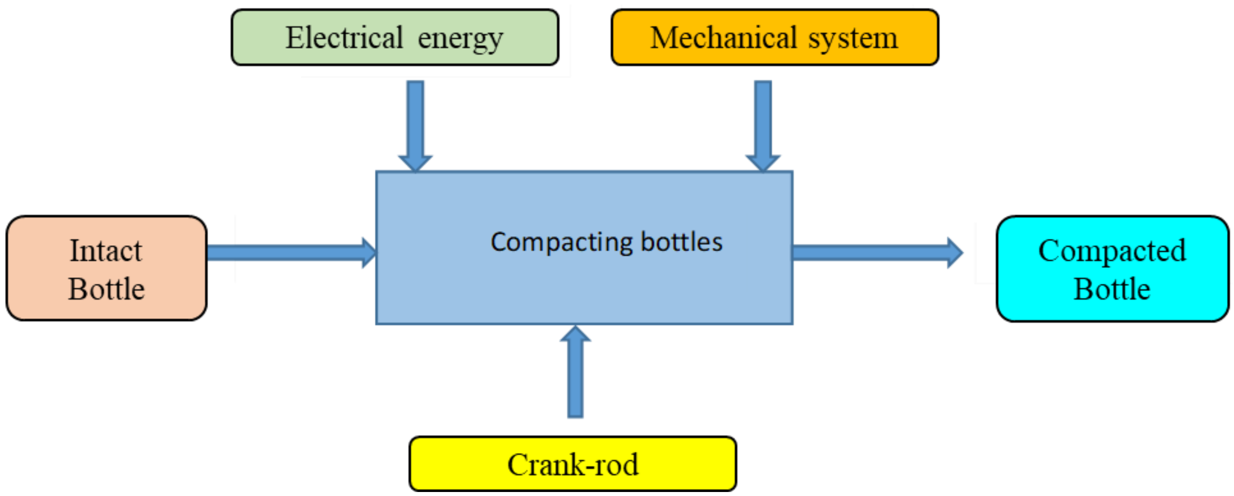


Figure II.4: SADT diagram A0

II.5 FAST diagram:[7]

A FAST (Function Analysis System Technique) diagram is a visual tool that represents the logical relationships between the different functions of a project, product, process or service. It is built from left to right and answers the questions "how" and "why" to determine the scope of the project and the relationships between functions

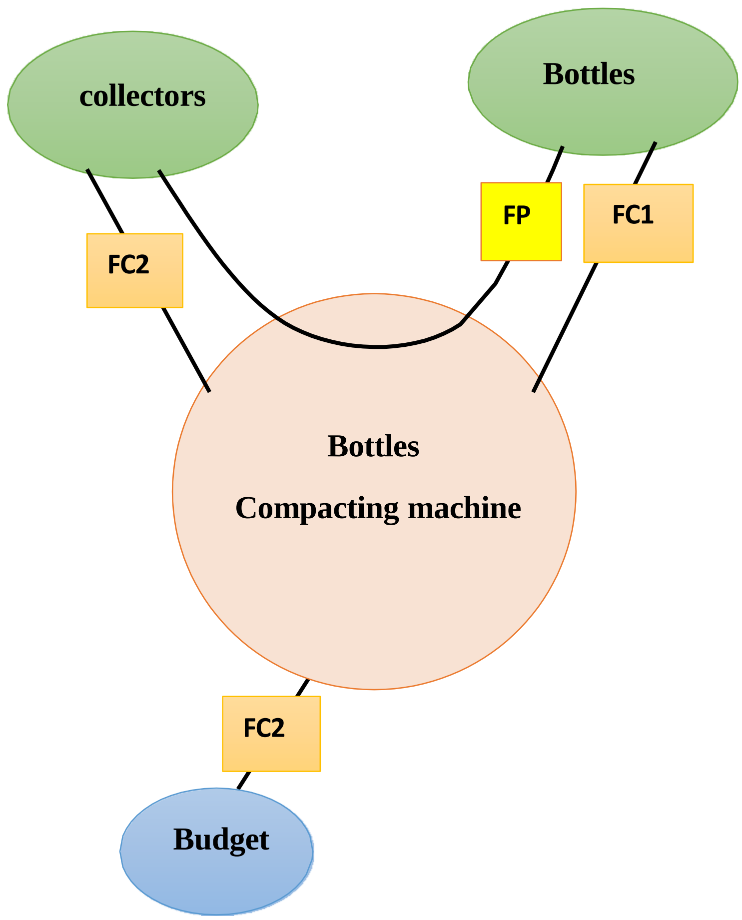


Figure II.5:FAST diagram

FP	Reducing the volume of bottles by compacting them
FC1	Compacting using crank rod system
FC2	Easy to use , placed almost anywhere
FC3	Can have an affordable price

Table II.3: Function service's discretion

II.5.1 Internal functional analysis:

The internal functional analysis defines the design vision that must implement the product to meet the expressed needs. The system is no longer considered a black box, but instead the analysis will focus on the inside of the box to understand its internal features.

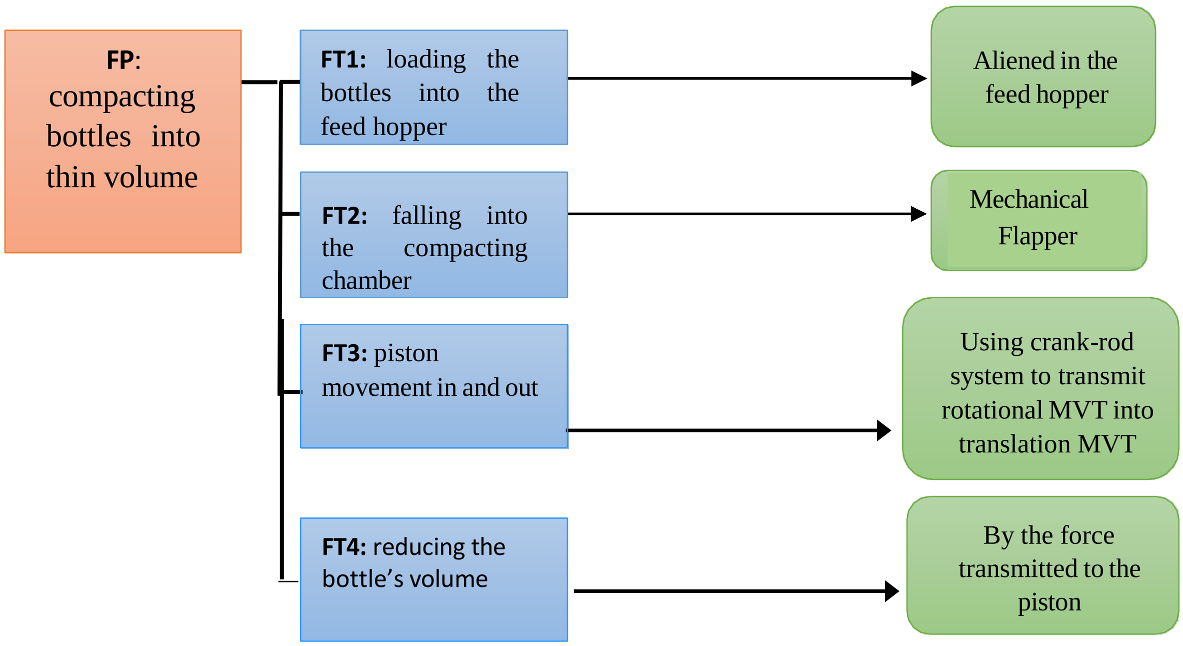


Figure II.6 : FAST diagram of internal functioning

II.5.2 External functional analysis:

The external functional analysis defines how the machine works from the outside perspective, the population's perspective.

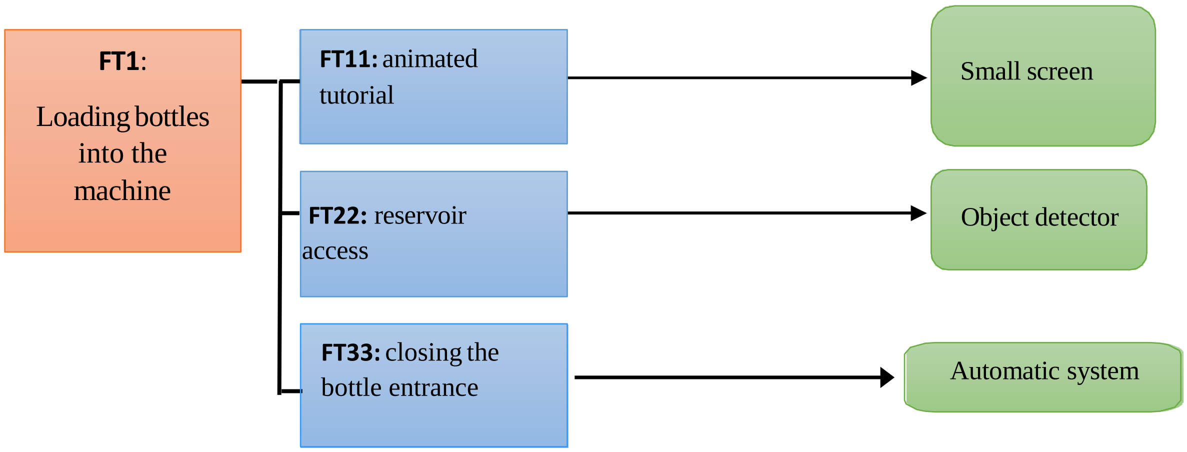


Figure II.7 : FAST diagram of external functioning

II.5.2.1 Bottle compacting solutions:

There are several other mechanical and non-mechanical options for compacting bottles. Each has its advantages and disadvantages depending on the use case, scale, and complexity. Here's a comparison of various bottle compacting methods, and why the crank rod system may be considered the best solution for certain situations:

- Hydraulic Compactor:
  How it Works: A hydraulic system uses pressurized fluid to move a piston or ram to compact bottles.
  - Advantages:
   High Force: Hydraulic systems can generate very high levels of compaction force, ideal for industrial applications.
  Consistency: They provide consistent pressure, which ensures uniform compaction.
  - Disadvantages:
  Complexity: Requires hydraulic fluids, pumps, and seals, which increase maintenance costs and complexity.
  Expensive: The cost of components and the energy required to operate the hydraulic system can be higher than other methods.
  Space Requirement: Hydraulic systems are often bulkier.

Figure II.8: hydraulic compactor

- Pneumatic Compactor :
  How it Works: Similar to hydraulic systems, but uses compressed air instead of fluid to move a piston.
  - Advantages:
   Less Maintenance: Pneumatic systems generally have fewer fluid-related issues like leaks.
  Faster Operation: Air pressure systems can cycle faster than hydraulic systems.
  - Disadvantages:

Lower Force: Pneumatic systems cannot achieve the same high compaction pressures as hydraulic systems.
High Energy Use: Compressors needed to generate air pressure can be energy-intensive.
Noise: Pneumatic systems tend to be noisy, especially in large-scale operations.

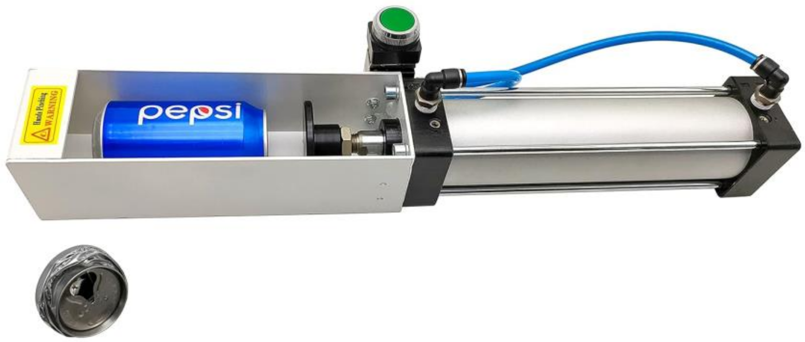


Figure II.9 : pneumatic machine

- A hand-crushing bottle machine:
  How it works: his type of machine relies solely on human effort to apply force and crush the bottles.
  -advantages:
  Simple to Operate: The design is straightforward, requiring no special training to use. Simply place the bottle, press the lever, and the bottle is crushed.
  No Power Required: Since the machine relies on manual effort, it doesn't need electricity, making it ideal for off-grid locations or areas with limited power access.
  - Disadvantages:
  Limited Capacity: This type of machine is best suited for low-volume applications,. It may not be practical for crushing large numbers of bottles in a short amount of time.
  Manual Effort: The user must apply physical force to crush the bottles, which can be tiring if used frequently or for large quantities of bottles. It's not as efficient as powered systems for high-volume operations. difficult to crush particularly tough or large bottles.

Figure II.10 : hand crushing bottle machine

Why the Crank Rod System May Be the Best Solution:

- Efficient Waste Management: - By reducing the volume of the bottles, the machine can handle larger quantities of waste, reducing the number of trips needed to empty the collection bin.
- Simple and Durable Design: - The crank rod system is mechanically simple, requiring fewer components than hydraulic or pneumatic compactors, reducing maintenance costs and improving durability.
- Manual or Motorized Operation: - Flexibility in power options. It can be operated manually for small-scale use (e.g., homes or small businesses) or motorized for larger-scale applications (e.g., schools, offices, or recycling centers).
- Cost-Effective: - Since the crank rod system is a mechanically simple design, it is more affordable to build and maintain compared to other compacting machines that rely on hydraulics or pneumatics.
- Compact Design: - This system does not require bulky equipment like hydraulic pumps, making it more compact and suitable for locations with limited space.
- Environmentally Friendly: - By compacting bottles, the machine reduces the volume of waste, minimizing the space required in landfills or recycling facilities. This also reduces the carbon footprint associated with transporting large volumes of uncrushed waste.

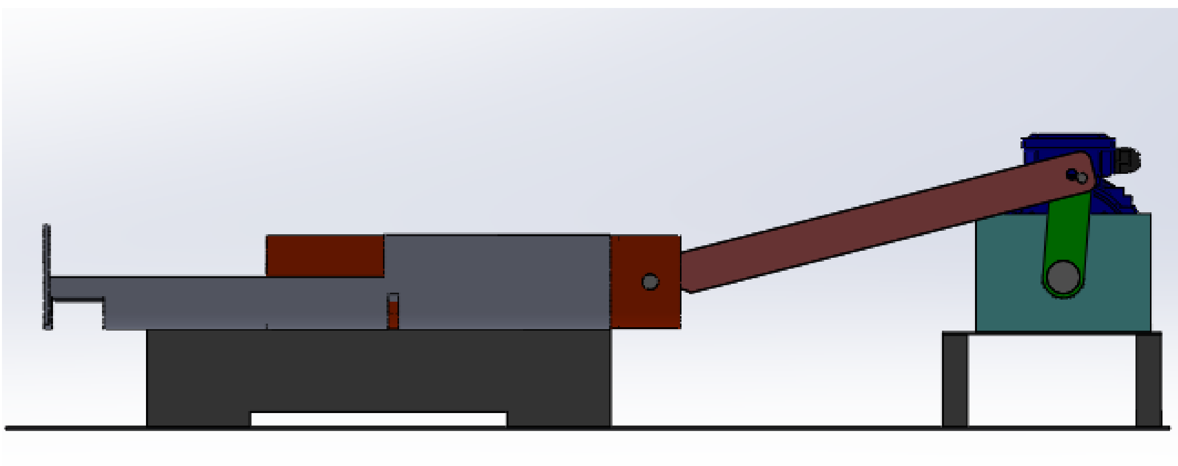


Figure II.11: crank-rod machine

II.5.2.2Automatic system components:

Arduino 5v to 12v Uno:

- To quickly turn the circuit on and off, an unlimited number of switches;
- The driving and cutting process produces no noise, no spark, no electromagnetic interference;
- Compared to electromagnetic relay products, longer service life;

- A method to control motor, lights, LEDs, DC motors, micro pumps, solenoid valves, etc., very convenient.

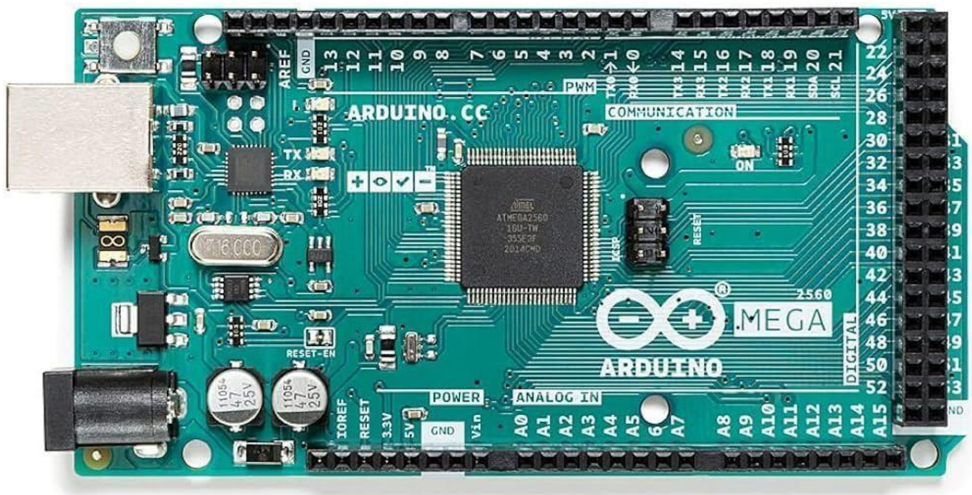


Figure II.11: Arduino card

Weight Sensor (1,5,10,20,50) KG + HX711 Arduino: We used two one for the bottle volume and the other for the reservoir volume:

- It is designed for high-precision balances with two analog inputs. The internal gain of 128 is programmable. This module can be configured as a pressure or weighing bridge.

Figure II.12: Weight sensor

We can demonstrate how sensors work using the following organogram:

C1:to detect that a bottle was inserted

C2:detects if there is still for the bottle

To be stocked.

c.weight:detects the weight of the bottle

if superior to a defined weight X the bottle

will be ejected.

M1:the step motor responsible for the

Ejection.

M2:the step motor responsible for

sending the bottle to get compressed.

Motor:is the main motor.

M3:the step motor responsible for

allowing 1 bottle at a time to be

compressed

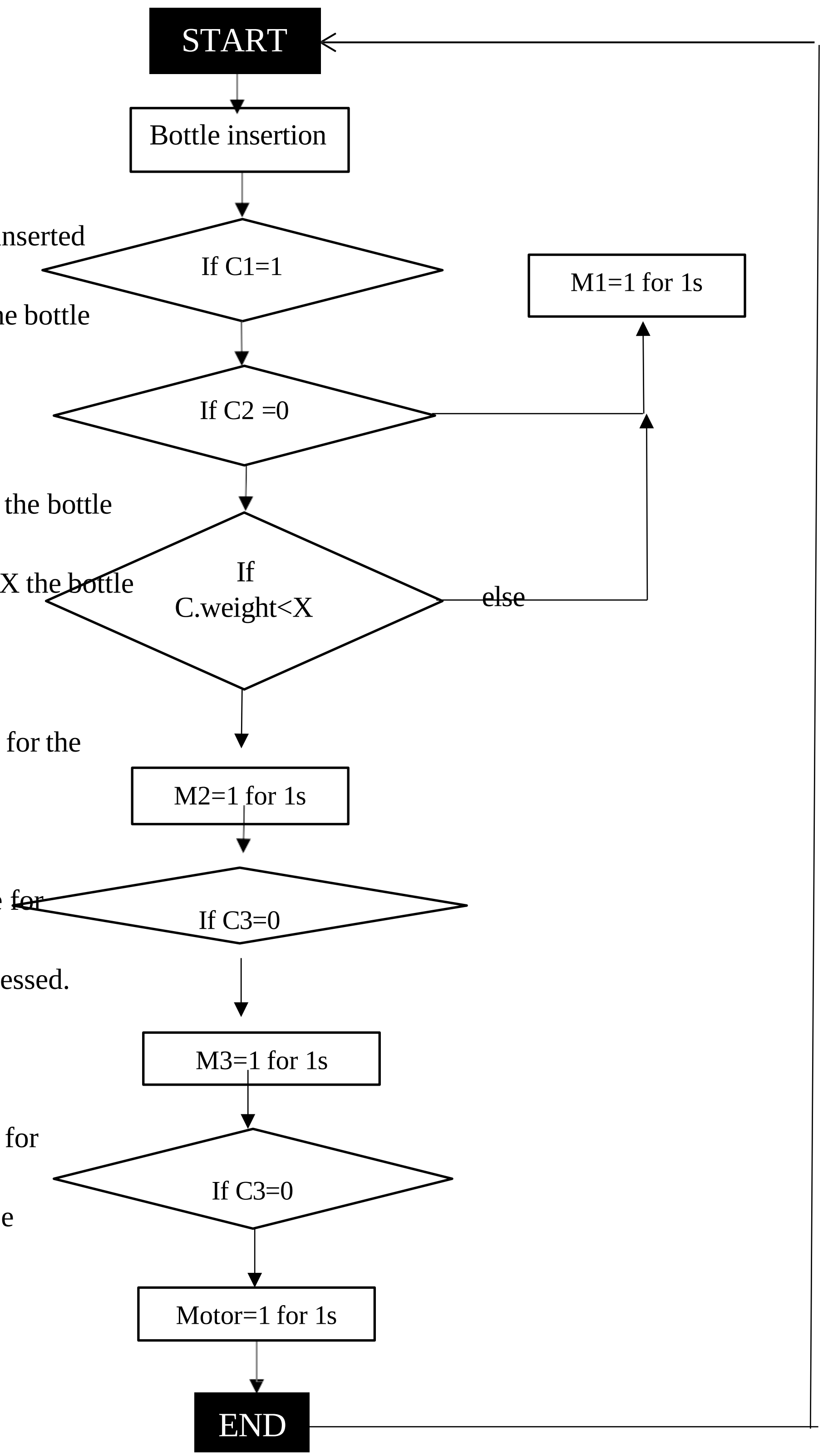
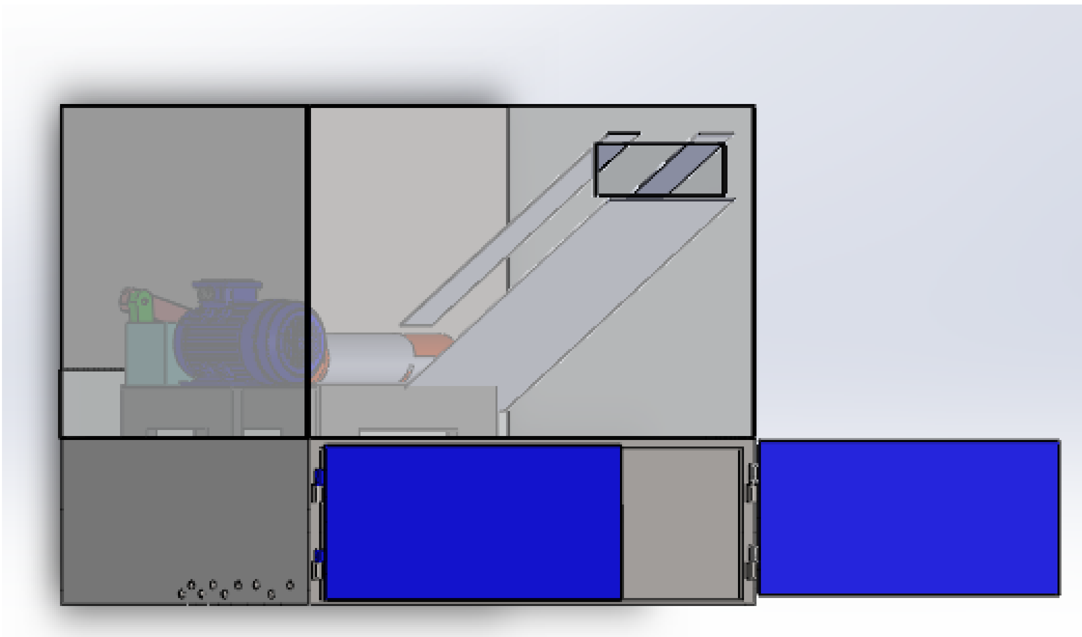


Figure II.10: Sensor's organogram

Conclusion:

Functional analysis applied to a bottles compacting machine involves using mathematical tools to understand and explain the machine's performance. It helps in understanding the behavior of functions (such as forces transition and the mechanical system synchronized with the automatic system) and operators (like mechanical components) within the machine, ensuring efficient design and operation to compact bottles effectively.



Bottle compacting machine final product

CHAPTER 03:

STUDY ANALYSIS OF THE MACHINE

Introduction:

Our Bottle compacting machine is a new idea that can solve the collecting problem and environment using crank rod system as the main mechanism for compacting. Therefore, in this chapter we used optimization to calculate the design parameters as the length of connecting rod, crankshaft and its angle to achieve a better performance and efficiency. Moreover, in order to choose the motor and the redactor, we use MATLAB code for précised results.

III.1 The Mechanism:

The crank rod mechanism is a system of interconnected parts that transforms the reciprocating motion of a piston into rotational motion of a crankshaft. It is commonly used in internal combustion engines, pumps, and compressors.

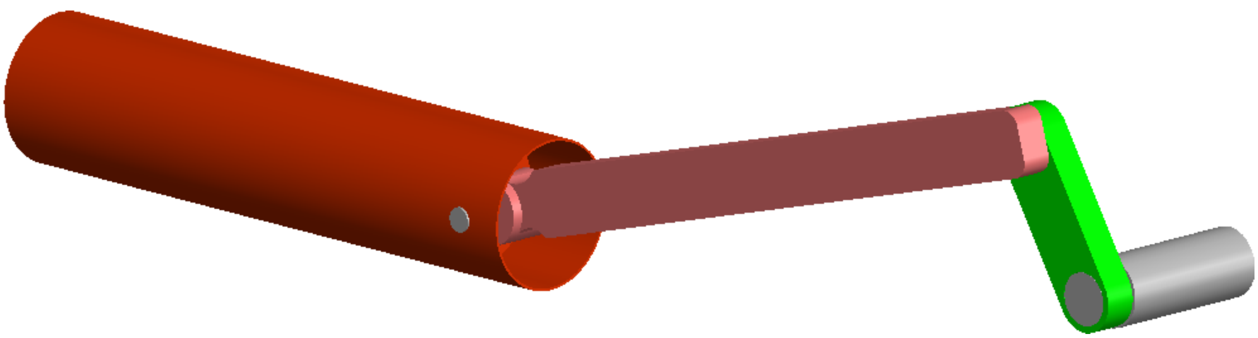


Figure III.1: crank rod system

The mechanism consists of a rod (connecting rod) and a crank (crankshaft) that work together to convert the linear motion of the piston into rotational motion. Here is a detailed explanation of the mechanism:

1. **Crank**: The crank is a connecting rod that connects the piston to the rod. It is typically a long, thin rod with two ends, one connected to the piston and the other to the rod.

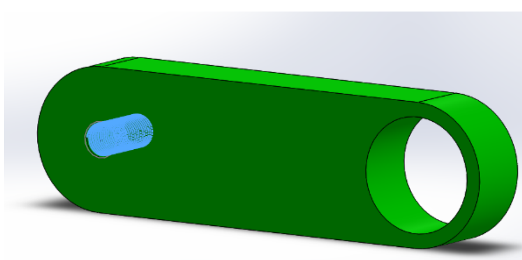


Figure III.2: connecting rod

2. **Rod**: The rod is the crankshaft that converts the linear motion of the rod into rotational motion. It is typically a long, thin rod with a crankpin at one end and a journal at the other.

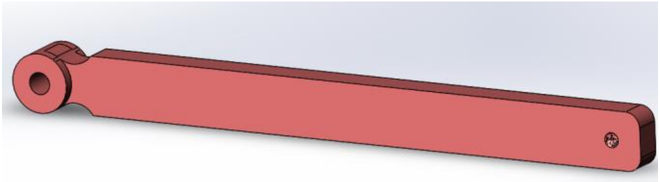


Figure III.3: crank

3. **Motion Transformation**: When the piston moves up and down, it causes the bielle to move in a linear motion. This linear motion is then converted into rotational motion by the manivelle, which rotates around its axis.

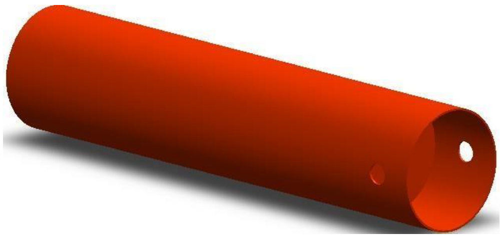


Figure III.4: Piston

4. **Crank Angle**: The crank angle is the angle between the bielle and the manivelle. This angle determines the speed and direction of the rotational motion.

5. **Force Transmission**: The rod transmits the force from the piston to the crank, which then converts it into rotational motion. This force transmission is critical for the proper functioning of the mechanism.

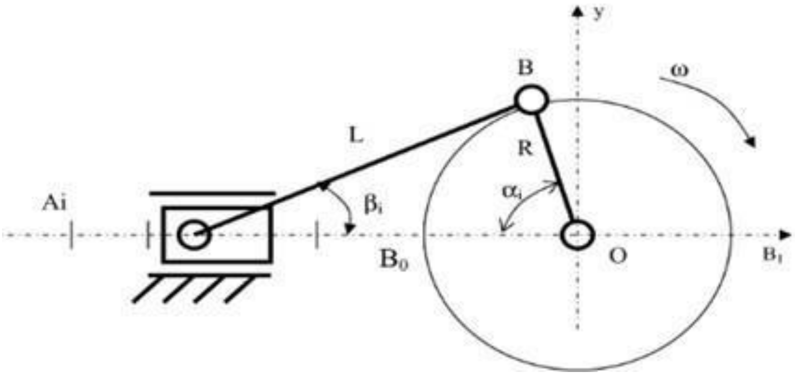


Figure III.5: Crank rod system mechanism

III.2 Compacting System

To calculate the engine torque used for compacting, a cinematic study is necessary to know the description of the positions, velocities and accelerations of system of compacting, which is in our case a connecting-crank system connected by a piston, which allows the compacting function to be performed according to the following figure:

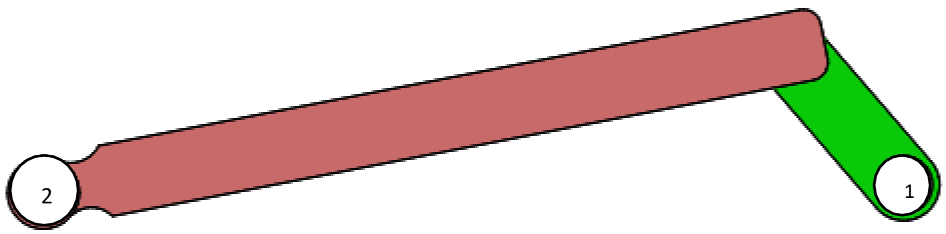


Figure III.6 Crank rod model

The design and dimensions of the compacting system are chosen in order of the axe Motor to run half a turn, thus obtain maximum opening of this system.

Therefore, we can easily know the starting position and arriving from part (1). For the purpose of good and precise results to predict the position, velocity and acceleration of the engine axes during operation. We use polynomial interpolation 3rd degree and optimization with MATLAB.

III.2.1 Optimization Method:

Definition: Optimization is a branch of mathematics, the goal of which is to find, analytically or numerically, the best (optimal) solution to a given problem. The origin of the word optimal comes from the Latin optimum, which means the best. Nowadays, optimization plays a very important role in different areas of life. We list some areas of application of optimization:

- Transport and deliveries.
- Manufacturing and production.
- Agriculture and civil engineering.

We calculated the length of the connecting rod and crankshaft using this method to have better results; we present this organogram to understand out optimization code with generic algorithem method:

[8]

- Generic algorithm: A genetic algorithm (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution.
- **How does it work?** At each step, the genetic algorithm selects individuals from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. You can apply the genetic algorithm to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, non-differentiable, stochastic, or highly nonlinear.
- The key steps to genetic algorithm:
    1. **Initialization:** Generate an initial population of candidate solutions.
    2. **Selection:** select individuals from the current population to be parents for the next generation. The selection is generally stochastic and can depend on the individuals' fitness scores.
    3. **Crossover:** Combine two parent solutions to form children for the next generation.
    4. **Mutation:** Apply random changes to individual parents to form children.
    5. **Replacement:** Replace the current population with the children to form the next generation.
    6. **Termination:** Repeat steps 2-5 until a termination criterion is met, such as a maximum number of generations or no improvement in the best solution.

We used generic algorithm in order to fine the maximum length for both crank and connecting rod for a better torque.at the start we chose an interval for r and L and linked it with the torque function.afetr the process we obtained these results:

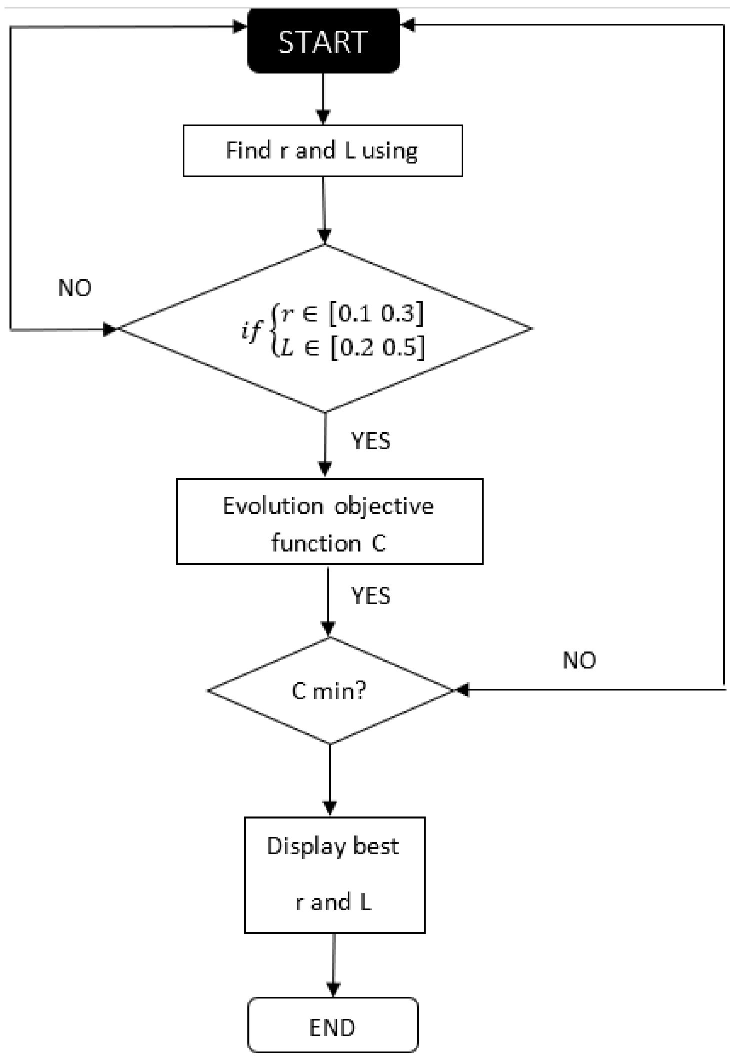


Figure III.7 Optimization organogram

After optimization, we got these results: r=0.1m; L=0.444 m

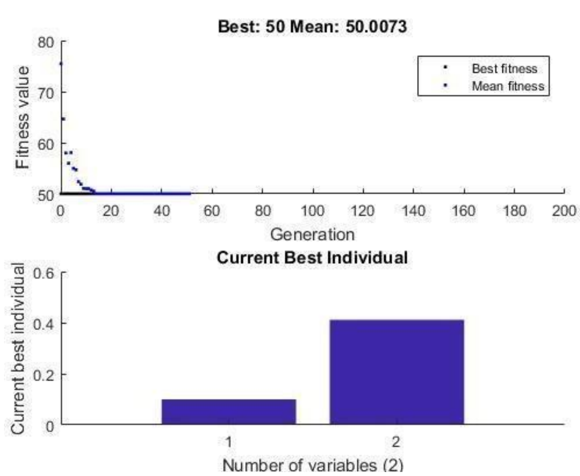


Figure III.8 Optimization Results

III.2.2 Motor Point:

The calculation of motorization point is determined by the following equations using polynomial interpolation 3rd degree:

$$position(t) = pos(i) + \left[3\left[\frac{t}{tf}\right]^2 - 2\left[\frac{t}{tf}\right]^3\right] * (pos(f) - pos(i))$$

We note that: tf=1 second, posi= 180 deg, posf= 0 deg.

The rotational velocity of this part is calculated by diverting the previous equation:

$$velocity(t) = \left[\frac{6}{tf^2}t - \frac{6}{tf^3}t^2\right] * (pos_f - pos_i) \quad (3.2)$$

Using the same method, we figure the acceleration:

$$acceleration(t) = \left[\frac{6}{tf^2} - \frac{12}{tf^3}\right] * (pos(f) - pos(i)) \qquad (3.3)$$

Finally, the simulation of part one is just like the following:

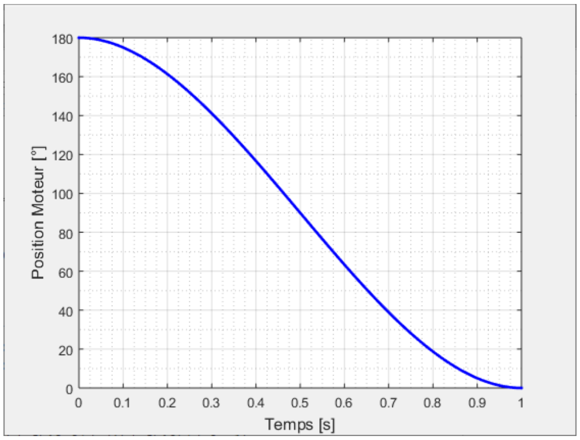


Figure III.9 Motor position results

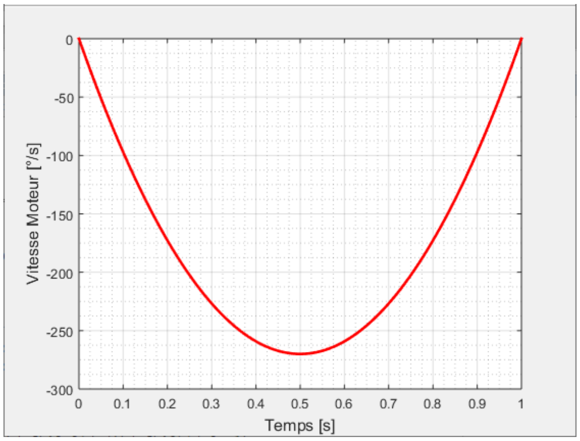


Figure III.10 Motor velocity results

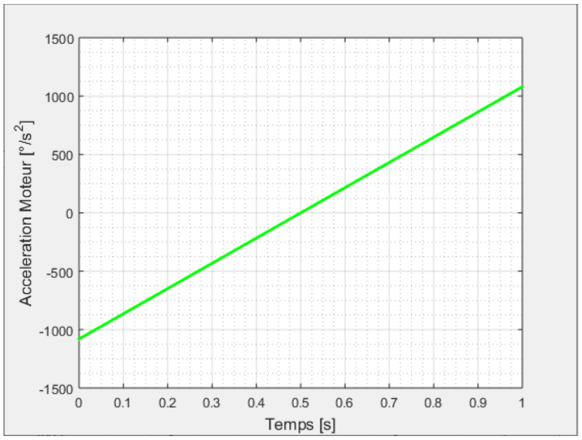


Figure III.11 Motor acceleration results

III.2.3 Piston Point:

By using the same equations that we used above (3.1), (3.2), (3.3), we can calculate position, velocity and acceleration of the piston using these informations:

Position = $x_f -$;   with: xf = L-e and xi = L+e

We note that, tf=1 second, posi= xi (m), posf=xf (m).

After calculations, we obtain these results:

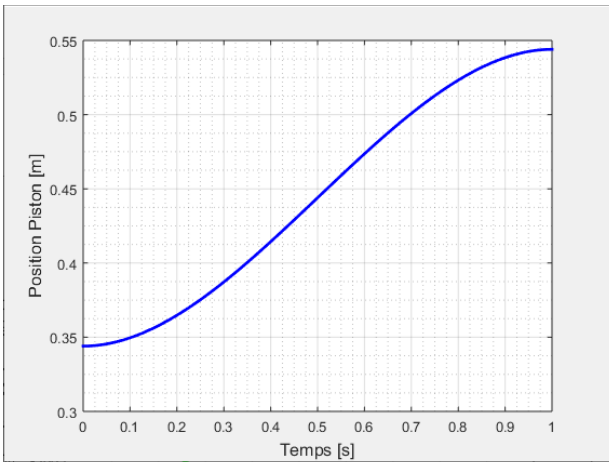


Figure III.12 Piston position results

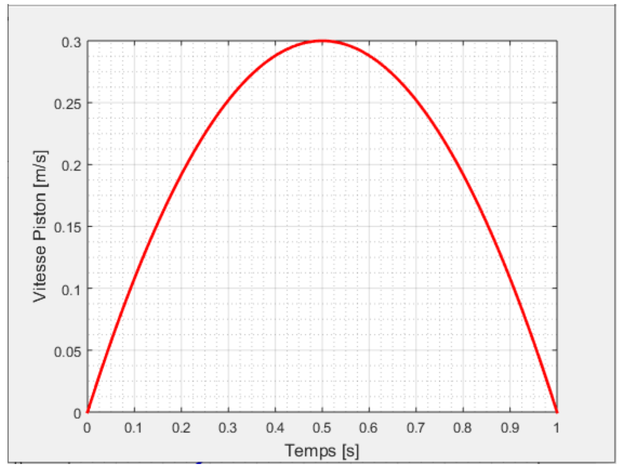


Figure III.13 Piston velocity results

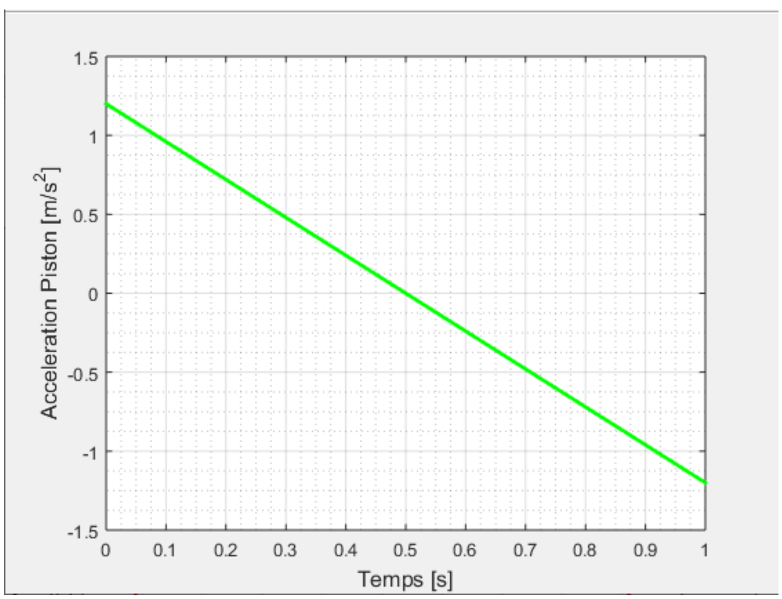


Figure III.14 Piston acceleration results

The diagram shown in Figure (III.15) illustrates the transition of the force FH (Fp) from part (2) to part (1):

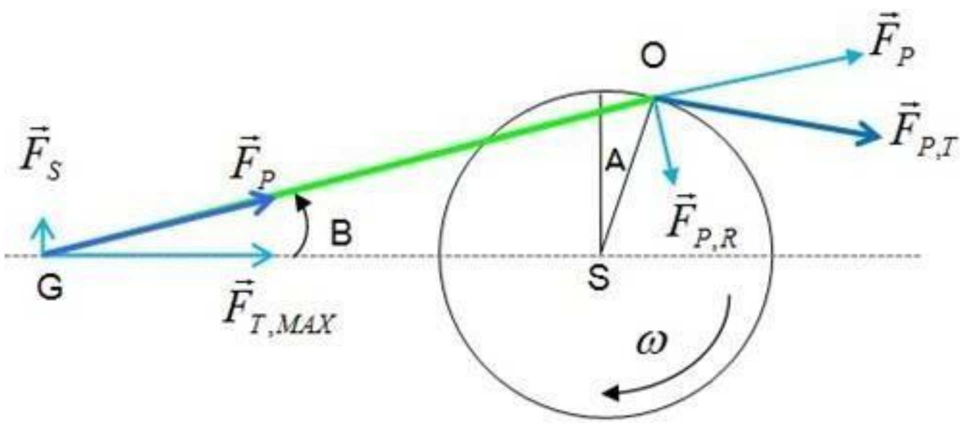


Figure III.15 Force transition

III.3 Motor choice:

In order to calculate the motor torque, we use a certain formula for calculating the torque on point "O":

$$Ft = \frac{C2}{r} \quad (3.4)$$

$$F_p = F_H = F_S \times \cos\beta \quad (3.5)$$

$$Fs = \frac{Fp}{cos\beta} \quad (3.6)$$

$$\frac{Fp}{\cos\beta} = \sqrt{Ft^2 + Fd^2} \quad (3.7)$$

$$\left(\frac{}{cos\beta}\right)^2 = Ft^2 + Fd^2 \quad (3.8)$$

$$\left(\frac{Fp}{\cos\beta}\right)^2 = Ft^2 + Ft^2\, tg^2\,(90° - (\alpha +)) \quad (3.9)$$

$$\left(\frac{Fp}{\cos\beta}\right)^2 = Ft^2\,(1 + tg^2\,(90° - (\alpha +))) \quad (3.10)$$

$$Ft^2 = \frac{\left(\frac{}{cos\beta}\right)^2}{1 + tg^2(90° - (\alpha + \beta))} \quad (3.11)$$

$$Ft = \frac{\frac{Fp}{cos\beta}}{\sqrt{1 + tg^2\,(90° - (\alpha(t) + \beta(t)))}} \times r$$

The torque equations eventually is as following

$$C_2\,(t) = \frac{\left(\frac{Fp}{c(t)}\right)}{\sqrt{1+ tg^2(90° - (\alpha(t)+\beta(t))}} \times r$$

For our system, we have:

r=0.1m

L=0.444m

According to the equation (3.1) we have α= position (t):

We have two methods to calculate beta:

- $\beta(t) = \theta(t) - \alpha(t)$
- $\theta(t) = \frac{pos(t)^2 + position_y(t)^2 - r^2 - L^2}{2 * L_1 * L_2}$

Alternatively:

- $\sin\beta = \frac{\sin(\alpha) * r}{L}$

NB1: we used the second method due to our system.

NB2: the force that we chose is according to the experiment that we did using 10 kg to compact a bottle so in order to have better results we escalated it to 50 kg which equals to 500N.

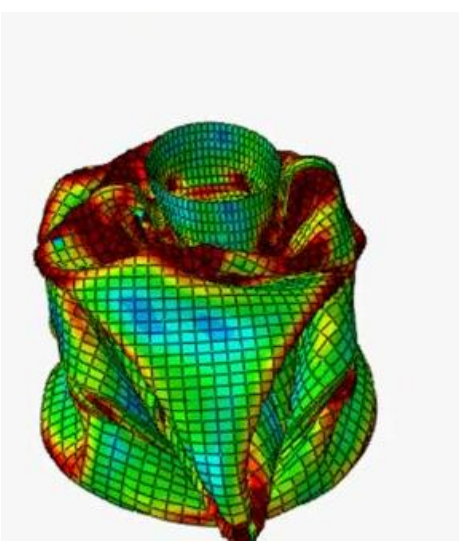


Figure III.16: Force experiment

NB: calculation of friction

Fr = U x Fn

U: coefficient of friction

In our system we have steel on steel without lubrication

U= 0.15

Fn = normal force

In our case it's slide on surface

Fn= m x g , F= M x a , a = g (after newton second law)

After all the information :

M = 4kg , g = 9.81

Fn = 4 x 9.81

Fn = 39.4 N

Fr = 0.15 x 39.24

Fr = 5.886 N

After calculating using MATLAB code, we obtained these results:

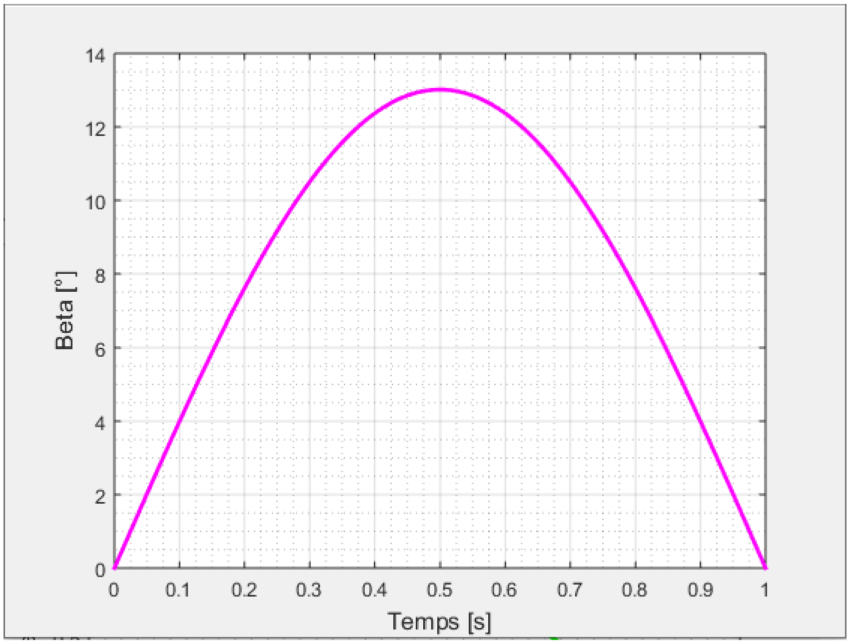


Figure III.17 Beta variation results

According to all these results, the variation in torque during lifting is shown in Figure (III.17):

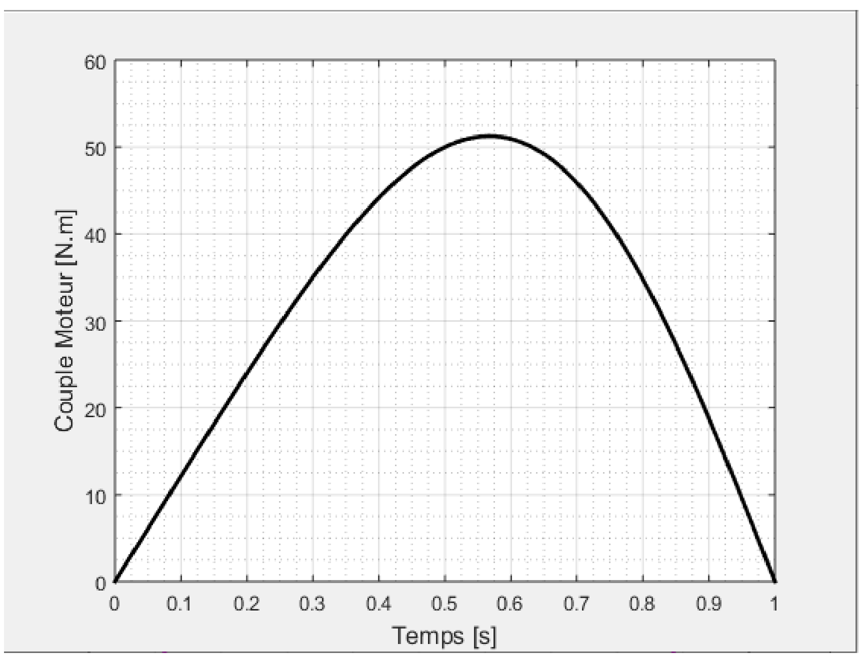


Figure III.18 Torque variation results

This figure shows that the maximum torque needed for compacting is approximately: **C=51.20**

Regarding the rotation speed N it is deduced from the working data: the lifting time is set at 1 second, 1/2 turn of the crank is enough for a maximum compacting bottle. So we take an average rotation speed N=30 rpm.

In order to choose the right motor, we need to know the necessary power:

1. *Output power:*

$$p_s = \frac{C * N}{9550}$$

$$p_s = \frac{52*30}{9550} = 0.1610 \text{ KW}$$

Ps=161 W

$$Pe = \frac{p}{\mu}$$

$$Pe = \frac{161}{0.68} = 236.75 \text{ W}$$

2. *Nominal power:*

Fs: is the service factor (1.0 < Fs< 2.0)

Pn= Pe *Fs

Pn=236.75*1.1

Pn=0.2059 KW

Based on the results of the above calculations, we have chosen a motor (JM 2 POLES SERIES 63 c) with a rated speed: N = 2700 rpm, and a nominal power P = 0.25KW.

JMM 2 POLES SERIES — **Tab. 8.2.1**

2 Poli	JMM Motor	Poles	P_N kW	n_N min^{-1}	T_N Nm	I_N A	COSφ 100%	η 100%	I_S/I_N	T_s/T_N	T_{max}/T_N	C (450V) μF	C^E μF	J Kg m^2	Weight Kg
230 V - 50 Hz	63 b	2	0,18	2700	0,64	1,40	0,95	56,0	4,0	0,7	1,7	10	10	0,00032	4,0
	63 c	2	0,25	2700	0,88	1,90	0,95	57,0	4,0	0,7	1,7	12	10	0,00041	4,3
	71 b	2	0,37	2710	1,30	2,52	0,98	65,1	3,4	0,8	1,9	20	20	0,00065	6,1
	71 c	2	0,55	2745	1,91	3,72	0,94	68,3	3,8	0,8	2,0	25	20	0,00075	7,2
	80 b	2	0,75	2776	2,58	4,93	0,94	70,7	4,1	0,8	2,1	30	40	0,00110	10,5
	80 c	2	1,1	2733	3,84	6,75	0,96	73,5	4,1	0,9	1,9	40	40	0,00140	11,0
	80 d	2	1,5	2749	5,21	8,87	0,98	74,7	4,2	0,9	2,0	60	60	0,00145	11,1
	90 Sb	2	1,5	2749	5,21	8,87	0,98	74,7	3,6	0,9	1,8	50	60	0,00170	12,6
	90 Lb	2	1,85	2760	6,40	10,9	0,98	74,7	3,9	0,7	1,8	60	60	0,00210	13,1
	90 Lc	2	2,2	2743	7,66	12,9	0,98	75,3	3,9	0,6	1,9	70	85	0,00240	14,4
	100 La	2	2,2	2840	7,40	12,6	0,99	77,0	5,0	0,7	2,0	90	85	0,00250	20,8
	100 Lb	2	3	2850	10,1	16,3	0,99	80,4	5,3	0,8	2,1	90	85	0,00270	22,7

Figure III.19 Motors Catalogue

The necessary motor torque for compacting is 52 N.m, and since the speed of the motor is equal to 0.65 N.m, the choice of gearbox is quite simple, just calculate the nominal reduction ratio:

$$i = \frac{C_m}{C_1} = \frac{N_1}{N_m}$$

NA: $i = \frac{0.88}{52} = 0.02 < 1$

III.4 Reductor choice:[6]

a. Types of mechanical reductors:

The **Mechanical gearbox** allows you to reduce the rotational speed of an electric motor, increasing the output torque. Mechanical gearboxes are typically used in many industrial applications. They can take different forms depending on the series. The most commonly used are:

- Wheel and screw gearboxes.
- Coaxial gearboxes.
- Orthogonal gearboxes.
- Planetary gearbox.
- Pendulum gearboxes.
- Parallel shaft gearboxes.

b. Mechanical gearboxes: Advantages and disadvantages.

- **The wheel and screw gearbox:** This type of gearbox is the most widely used in various applications. It has many advantages such as high torque. This is because this type of gearbox can produce:

- High torque, so they are suitable for applications that require a powerful output force.
- A weak game. Wheels and screws generally have low mechanical backlash, i.e. this translates into better positioning accuracy, which is important in a large number of applications.
- Long service life. Wheel and screw gearboxes are generally considered robust and durable in all types of environments.

Figure III.20 Wheels and screws gearbox

- **The coaxial gearbox:** As with the wheel and screw gearbox, the **coaxial gearbox** has many advantages such as:

- Great compactness. All components are housed in a small, compact package. The coaxial gearbox can therefore be installed in a place where space is limited.
- A wide range of discounts. Coaxial gearboxes have a high degree of flexibility in speed reduction. This is because they can be easily adapted thanks to their wide range of reduction ratios.
- High torque. A coaxial gearbox increases the output torque by reducing the speed. So it can handle heavier loads and provide
- High precision. Coaxial gearboxes provide high levels of accuracy on output speed. An essential point in many industries.

Figure III.21 Coaxial gearbox

Coaxial gearboxes are therefore essential for many industrial applications, especially where speed reduction and torque increase are required. Their efficiency and reliability are real assets in many industrial sectors. They can provide a power of up to 200kW and have a high efficiency.

- **The orthogonal gearbox:** The **Orthogonal Gearboxes** are also called bevel torque gearboxes. This type of gearbox is typically used in many applications such as machine tools, conveyor systems, construction equipment, and other applications that require high horsepower at lower speeds. It also has a high efficiency.

Orthogonal gearboxes can also be used to reverse the direction of rotation of the output shaft depending on the gear configuration. The orthogonal gearbox has many advantages. However, the bulky shape of it may make it less suitable on some applications where space is limited. **The**

Figure III.22 Orthogonal gearbox

- **Planetary gearbox:** The **Planetary gearboxes** also known as epicyclical gearboxes are used in many industrial sectors. This type of gearbox is generally used when high torque moments, high efficiency and service life as well as maximum load capacity are required.

The pendulum gearbox is generalized by its compact design and low weight, which allow installation in the tightest of spaces.

Figure III.23 Planetary gearbox

- **Parallel shaft gearboxes:** The **Parallel shaft gearbox** is widely used in conveyor and other industrial applications. It offers many possibilities of power (from 0.12kW to 200kW) and torque (up to 90,000Nm). A large number of manufacturers are satisfied with the parallel shaft gearbox due to:

- Its reliability and efficiency, parallel shaft gearboxes have a high efficiency, they minimize energy losses.
- Adhesion to high loads, making them suitable for many applications that require high power.
- Quiet operation and long service life.

Figure III.24 parallel shaft gearbox

- **The pendulum gearbox:** The **pendulum gearbox** is typically installed on applications using conveyor belts. This type of gearbox has various advantages that make it an essential for the industrial sector:

- The gearbox adapts to variable loads by adjusting the position of the pendulum gears according to the requirements of that load.

- The gearbox is compact, making it suitable for very tight spaces.
- Pendulum gearboxes can regulate overloads, which will extend its life and reduce the risk of damage in the event of unforeseen loads.

To sum up, the pendulum gearbox is suitable for many industrial applications thanks to its efficiency, flexibility and compactness. However, the choice of a gearbox varies depending on the needs of the application.

Reductor choice: Regarding the choice of our gearbox, we chose a referenced coaxial gearbox (CMG023U090291425B5160) from the TRANSTECNO brand thanks to its compatibility with our needs as well as its great flexibility in speed reduction.

Mark	TRANSTECNO
Reducer	CMG023
Reduction Range	90-600
Reduction	90,29
Ø input shaft	14
Bridle	B5
Ø flange	160
Matter	Aluminium
Output shaft Ø	25
Axle height (mm)	Legless
Weight	6 kg

Figure III.25: Reductor technical information

The CMG cylindrical gear speed reducers are composed of helical gears and have a very progressive mesh. In addition, thanks to this energy-efficient technology, the noise and vibrations generated are significantly reduced.

The aluminum series gearboxes are lightweight and can withstand medium loads. These gearboxes are perfect for an application with medium torque constraints and comply with the standardization of the IEC standard fastener. This allows them to be adapted to any type of asynchronous motor.

Conclusion

In this chapter, we learned that optimization and polynomial interpolation is important in order to have better results, we have also discussed some calculations needed to achieve better compacting results with a better system mechanism.

CHAPTER 04:

MOTION ANALYSIS OF THE MACHINE

Introduction:[7]

Motion studies are graphical simulations of motion for assembly models. You can incorporate visual properties such as lighting and camera perspective into a motion study.

A virtual prototyping tool supports the animation, analysis, and design of mechanisms. Instead of physically building and testing prototype mechanisms, SOLIDWORKS Motion (SW-Motion) can be used to evaluate and refine the mechanism before finalizing the design and performing functional prototyping. This tool was used intensively in our project to validate the different mechanical solutions.in this chapter we are going to use SW motion in order to verufy the results that we had in the previous chapter.

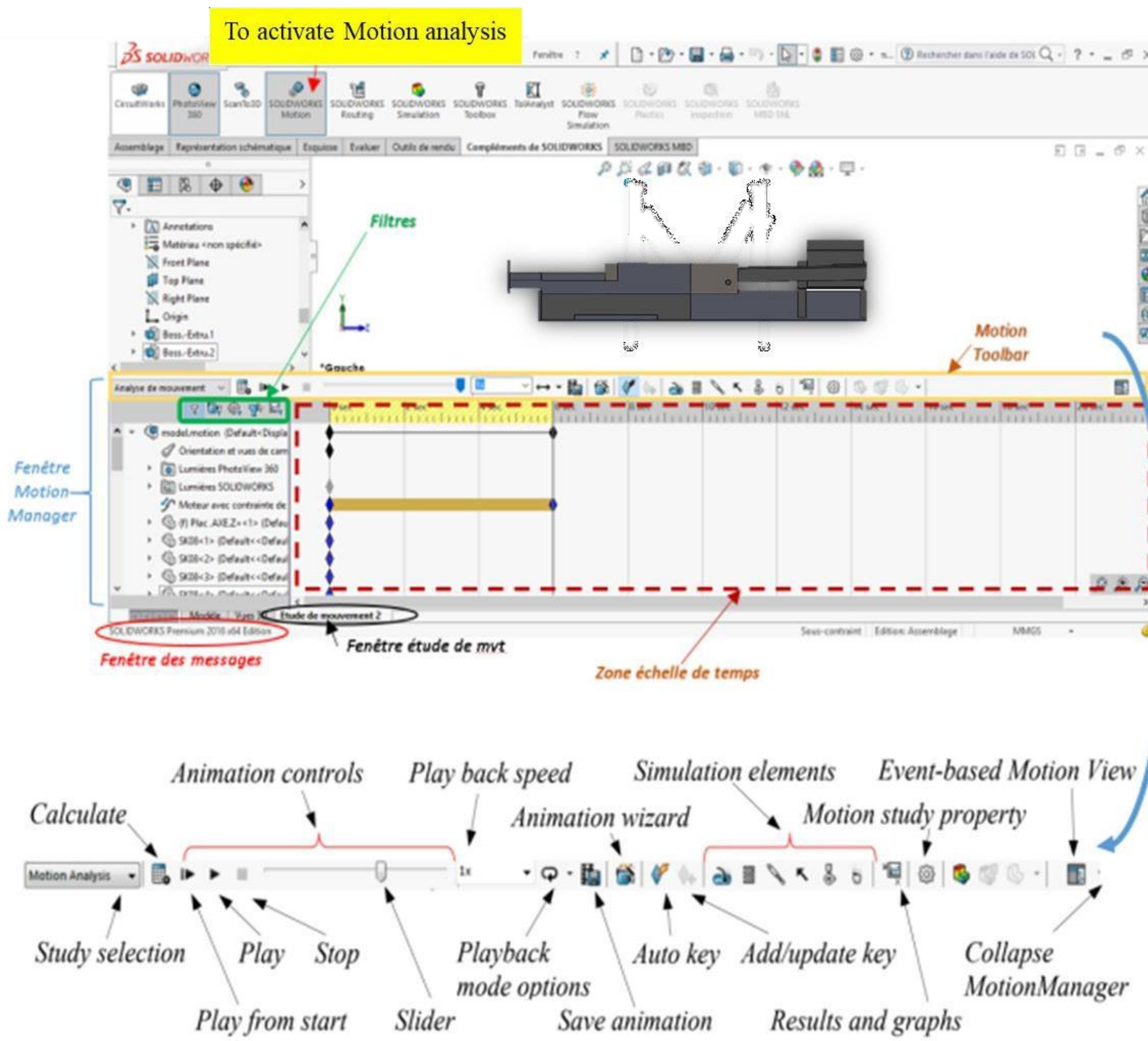


Figure IV.1: User Interface Basics for SolidWorks Motion

The overall process of using SW-Motion to analyze a mechanism consists of three main steps: model generation, analysis (or simulation), and visualization of the results. The key entities that make up a simulation model include servomotors that drive the mechanism for kinematic analysis, external loads (force and torque), force-imposing components such as the spring and damper, and the initial conditions of the mechanism. Not to mention the assembly constraints that must be correctly defined so that the simulated mechanism reproduces the physical behavior of the real mechanism as closely as possible.

IV.1 Overview of the motion study window:

From a motion study, you can use Motion Manager, a timeline-based interface that includes the following motion study tools:

- **Animation:** You can use Animation to animate the motion of assemblies.

- Add motors to drive the motion of one or more parts of an assembly.
- Prescribe the positions of assembly components at various times using set key points. Animation uses interpolation to define the motion of assembly components between key points.

- **Basic Motion:** You can use Basic Motion for approximating the effects of motors, springs, contact, and gravity on assemblies. Basic Motion takes mass into account in calculating motion. Basic Motion computation is relatively fast, so you can use this for creating presentation-worthy animations using physics-based simulations.

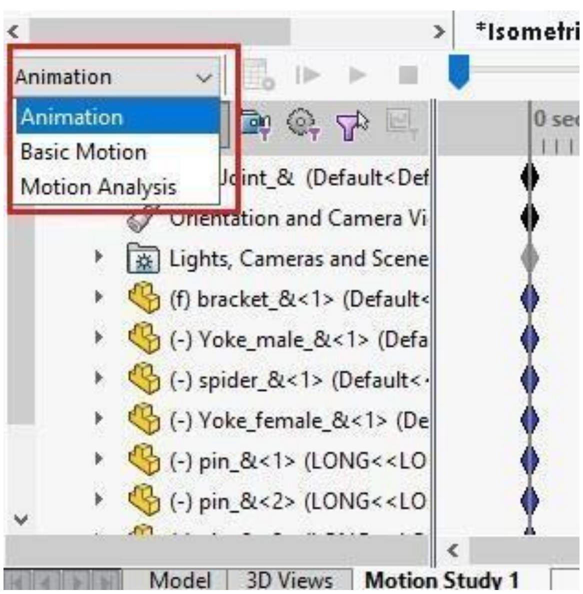


Figure VI.2 Motion window

- **Motion Analysis:** You can use Motion Analysis for accurately simulating and analyzing the effects of motion elements (including forces, springs, dampers, and friction) on an assembly. Motion Analysis uses computationally strong kinematic solvers, and accounts for material properties as well as mass and inertia in the computations. You can also use Motion Analysis to plot simulation results for further analysis.

In addition, you can use the Motion Manager Toolbar to:

- Change viewpoints.
- Display properties.
- Create distributable, presentation-worthy animations depicting the motion of an assembly.

VI.2 Mechanical elements for the implementation of a movement study:

The user of SolidWorks Motion has a set of tools to carry out an accurate modeling of the mechanical actions applied to a mechanism. The following types of force elements are available in Motion Studies:

Tool		Animation	Basic Motion	Motion Analysis
	Calculate. Calculates the current simulation. If you alter the simulation, you must recalculate it before replaying.	X	X	X
⏵	**Play from Start**. Resets components and plays the simulation. Use after calculating the simulation.	X	X	X
▶	**Play**. Plays the simulation beginning at the current time bar location.	X	X	X
■	**Stop**.	X	X	X
	Time Bar. Specifies the start of the animation by moving the slider.	X	X	X
	Playback Speed.	X	X	X
	Playback Mode. → **Normal**: Plays from beginning to end one time. **Loop**: Continuous play, beginning to end, and then loop to beginning and continue playing. ↔ **Reciprocate**: Continuous play, beginning to end, then reverse-play end to beginning.	X	X	X
	Save Animation	X	X	X
	Animation Wizard	X	X	X
	Autokey. Automatically places a new key when you move or change components.	X		
	Add/Update Key. Adds a key or updates properties of an existing key.	X	X	X

TableVI.1: Motion tools

The user of SolidWorks Motion has a set of tools to carry out an accurate modeling of the mechanical actions applied to a mechanism. The following types of force elements are available in Motion Studies:

- Gravity.
- Springs, dampers, friction, and bushings. Forces apply to translational springs, torsion springs, translational dampers, torsion dampers, static friction, dynamic friction, joint friction, and bushings.
- Forces. Applied forces in SOLIDWORKS Motion define loads and compliances on parts so that they move in certain directions. You must select the type of Force Function and its parameter values. You can also use mathematical expressions for forces. You can apply combinations of linear force or Torque.
- Contact. Forces are generated between contacting components, or components are constrained to touch continually. Define contact to prevent the components from passing through each other during the motion analysis.

As a rule, force elements do not prevent or prescribe movement imposed by a motor. As a result, they do not add degrees of freedom to the model studied, nor do they remove them. Forces can resist movement or they can induce it.

	Motors
	Gravity (Motion Analysis and Basic Motion only)
	Springs (Motion Analysis and Basic Motion only)
	Dampers (Motion Analysis only)
	Forces (Motion Analysis only)
	Contact (Motion Analysis and Basic Motion only)

TableVI.2: Key Force Elements in SolidWorks Motion

IV.2.1 Motors:

Using motors in motion studies, you can apply motion to a component without consideration of mass or inertia. Motion due to a motor supersedes motion due to any other Motion Study element. Any element that tends to resist motor motion increases the power consumption of the motor, but does not slow down the motor motion. You can view this effect, for example, in Motion Analysis results. However, if something causes the reference of the motor direction to change, the motor motion is applied in the new direction. You can select motor motion from a set of defined motor types:

Motor Type

↻	**Rotary Motor**	Specifies a rotary motor.
→	**Linear Motor (Actuator)**	Specifies a linear motor.
	Path Mate Motor (Motion Analysis only)	For a selected path mate in the assembly, specifies displacement, velocity, or acceleration as a body moves along a path.

TableVI.3: Motor types

You must also choose the right constraints and directions according to the following indications:

Mate/Direction

	Path Mate	Selects the path mate that defines the path of motion.
	Reverse Direction	Reverses the direction of motion.
	Component	Selects the component relative to which the motion is applied.

Component/Direction

	Motor Location	Selects a feature at which to locate the motor.
	Reverse Direction	Reverses the direction of motion.
	Motor Direction	Selects the feature, such as a face or an edge, that defines the directional axis of the motor.
	Component	Selects the component relative to which the motion is applied.

Table VI.4 Constraints

Motors move components in a given direction, but they do not constitute a force. The strength of the motors does not vary according to the size or mass of the components. For example, a small cube moves at the same speed as a large cube if the motor speed is set to the same value in both cases. If the Reference Point of the engine direction changes for any reason, the motor continues to move the component in the new direction. This can happen, for example, in the event of a collision between the component moved by the engine and another component.

The properties of the motion of a motor are described according to the following nomenclature:

Segments	Selects the component relative to which the motion is applied.	Defines profile from piecewise continuous functions of time or cycle angle.
Data Points		Defines profile from an interpolated data set as a function of time, cycle angle, or motion study results.
Expression		Defines profile as mathematical expression of time, cycle angle, or motion study results.
Load Function from File		Permits importing of a function created with the Function Builder from a `.sldfcn` file.
Delete Functions		Permits deletion of functions created with the Function Builder.
Edit		Permits editing of selected profile type.

TableVI.5: Motor motion tools

VI.2.2 Chronogram:

Located to the right of the Motion Manager Design tree, it displays the timeline and type of animation events in the motion study. When you position the timeline, move components around the graphics area, add simulation elements, or change visual properties, the timeline displays the changes using keys and change bars.

Vertical grid lines corresponding to numerical markers showing the time divide the timeline. The numerical markers start at 00:00:00. The time scale depends on the size of the window and on the zoom level.

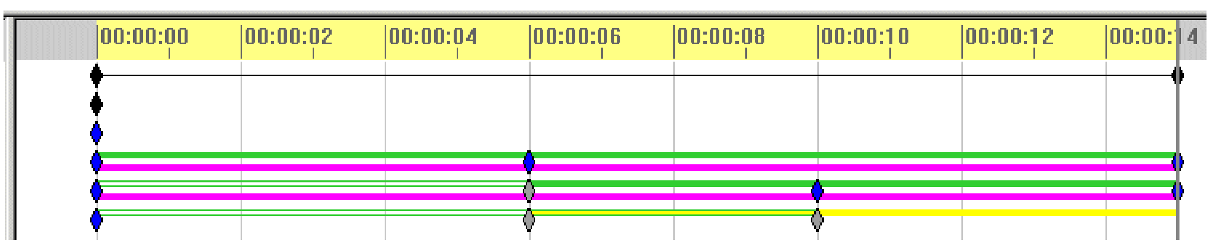


Figure VI.3: Chronogram Lines

To view the components at a specific point in time, click the corresponding time in the timeline. The time bar is then set to that moment and a preview of the position of the components is displayed. The dark gray solid vertical line on the timeline is the timeline. It represents current time.

To move the timeline, do one of the following:

- Drag it anywhere along the timeline.
- Click anywhere in the timeline except on a key.

When you move the timeline, you change the current time in the animation and update the template.

FigureVI.4 Timeline

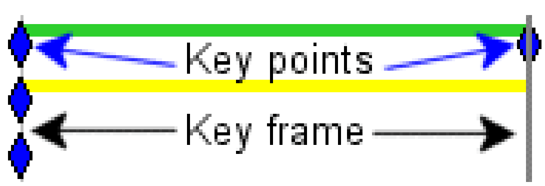
- Change bars are the horizontal bars connecting key points. They indicate a change between key points.

Changes include:

- Animation duration
- Component motion
- View orientation such as rotation
- Visual properties such as color or view

You can use key points to represent a beginning or end of a change in animation position or other attributes at a given time. Whenever you position a new key point, it corresponds to motion or to changes to visual attributes.

- Key frames define the portion of the timeline that separates key points. A Key point is the entity that corresponds to defined assembly component positions, visual properties, or simulation element states.



FigureVI.5: Key frame

- The Key frame is the area between key points, which can be any length of time. It defines the time frame in which assembly component motion or visual property changes take place.

VI.3 Motion analysis application in our machine:

The kinematics of the compacting machine that we want to make depends on the proper functioning of the redactor. The study of this mechanism is therefore important to verify whether our machine is working with a rescannable displacement, velocity and acceleration according to our previous results.

VI.3.1 Path mates in motions analysis:

To constrain assembly component motion to a path:

1. Select Insert > Mate.
2. Define a path mate for components.
3. Select the Motion Study tab, and select Motion Analysis for Type of Study.
4. Include motion study elements as necessary.
5. Run the study

You must include a Motor, a Force, or Gravity to force the motion.

FigureVI.6: Different steps followed to perform the simulation

To profile the engine from a function or from data, click Expression, Data Points, or Segments

VI.3.2 Comparison of MATLAB results with SolidWorks motion simulation results:

We will take the results of the MATLAB program that we obtain for several trajectories (displacement, velocity and acceleration) and compare them with the results of the SolidWorks software. The program that we made in MATLAB is given in Figure 5.7. The resulting plots are shown in Figure 5.8. These PLOTS are then exported to Excel where we have recorded the evolution of the Y1 and Y2 variables to use them as an input to SolidWorks. Indeed, under SolidWorks the study is carried out in the opposite way. The following steps were taken:

1. Select Motor

2. Click on rotary Motor to select Type.

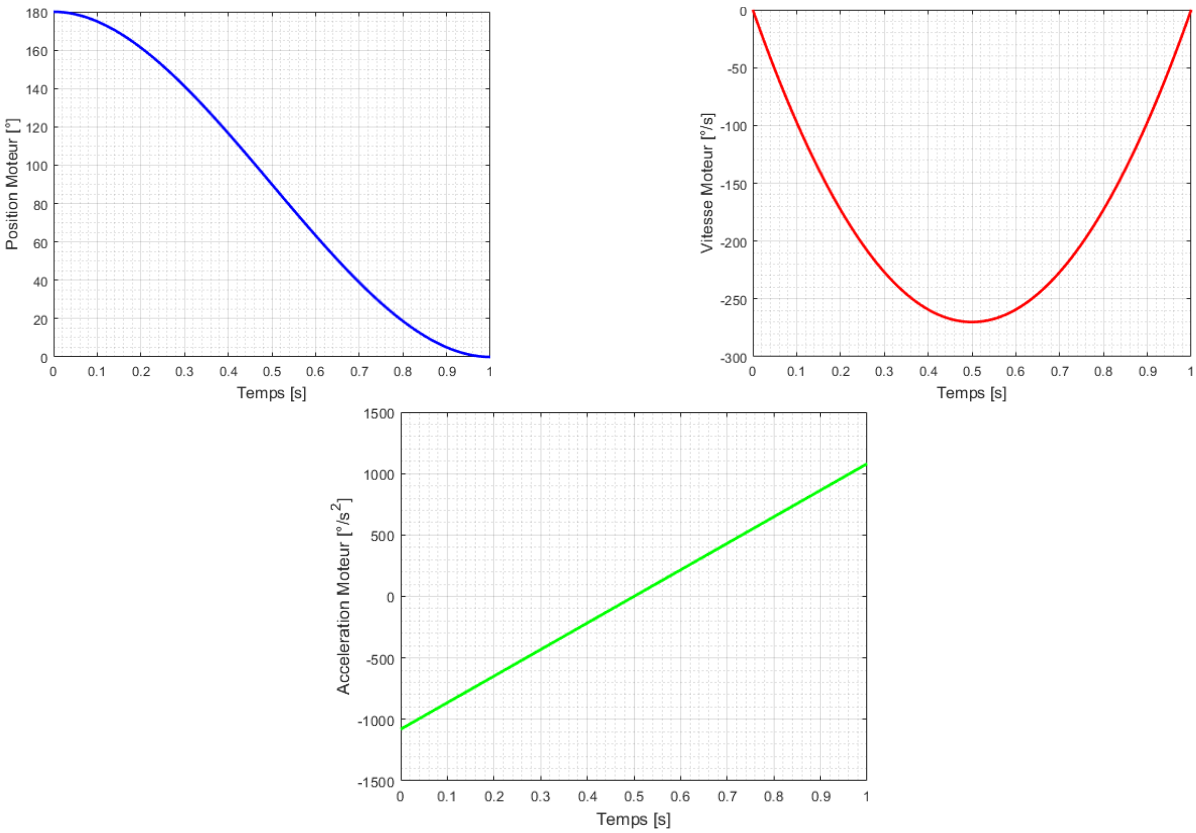
3. Set the movement:

3.1. Click on given point.

3.2. Imported the Excel sheet (SVG) to be inserted Contains the Y1 displacement (same for Y2)

```
clear all
clc
F=500;                      %Effort de compactage (N)
r=0.1 ; L=0.444;            %Langueurs Bielle-Manivelle (apres optimisation) (metre)
theta1=180; theta2=0;       %Angles de Rotation Moteur (deg)
x1=L-r; x2=L+r;             %Positions Piston (metre)
tf=1;                       %Temps final d'execution (second)
t=linspace(0,tf,100);       %Temps d'execution (second)
alpha=linspace(180,0,100);  %Angles de compagtage (deg)
%Position, Vitesse, Acceleration Moteur
for i=1:100
    Pm(i)=theta1+(3*(t(i)/tf)^2-2*(t(i)/tf)^3)*(theta2-theta1);
    Vm(i)=(6*(1/tf^2)*t(i)-6*(1/tf^3)*t(i)^2)*(theta2-theta1);
    Am(i)=(6*(1/tf^2)-12*(1/tf^3)*t(i))*(theta2-theta1);
end
%Position, Vitesse, Acceleration Piston
for i=1:100
    Pp(i)=x1+(3*(t(i)/tf)^2-2*(t(i)/tf)^3)*(x2-x1);
    Vp(i)=(6*(1/tf^2)*t(i)-6*(1/tf^3)*t(i)^2)*(x2-x1);
    Ap(i)=(6*(1/tf^2)-12*(1/tf^3)*t(i))*(x2-x1);
end
for i=1:100
    beta(i)=asind(sind(alpha(i))*r/L);
    Couple(i)=(F*r/cosd(beta(i)))/sqrt(1+(tand(90-alpha(i)-beta(i)))^2);
end
```

Figure VI.7: MATLAB code for plots



FigureVI.8 MATLAB results of motor point

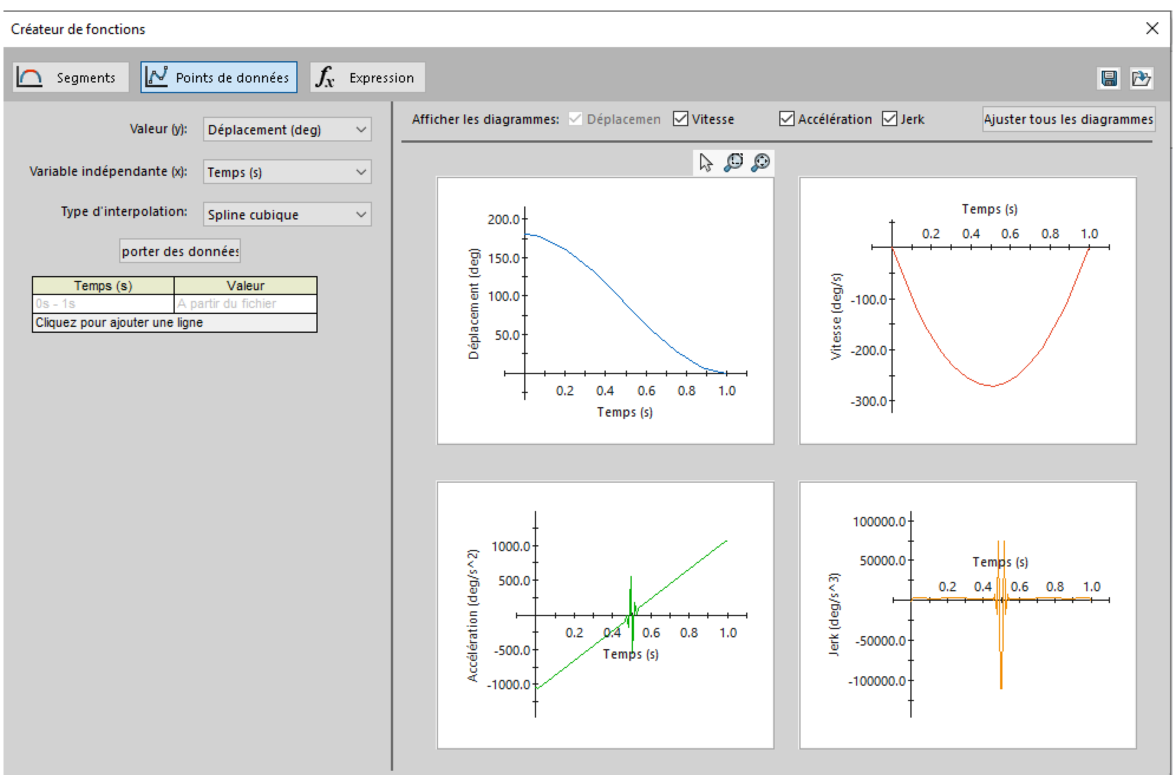


Figure VI.9: Motion analysis results1

For Path Constraint, under Constraints in the Feature Manager Design Tree, select a path constraint.

1. Select the engine profile.
2. To profile the engine from a function or from data, click Expression, Data Points, or Segments.
3. Select options and click. To reverse the direction of the engine, for Constraints/Direction, click reverse Direction.

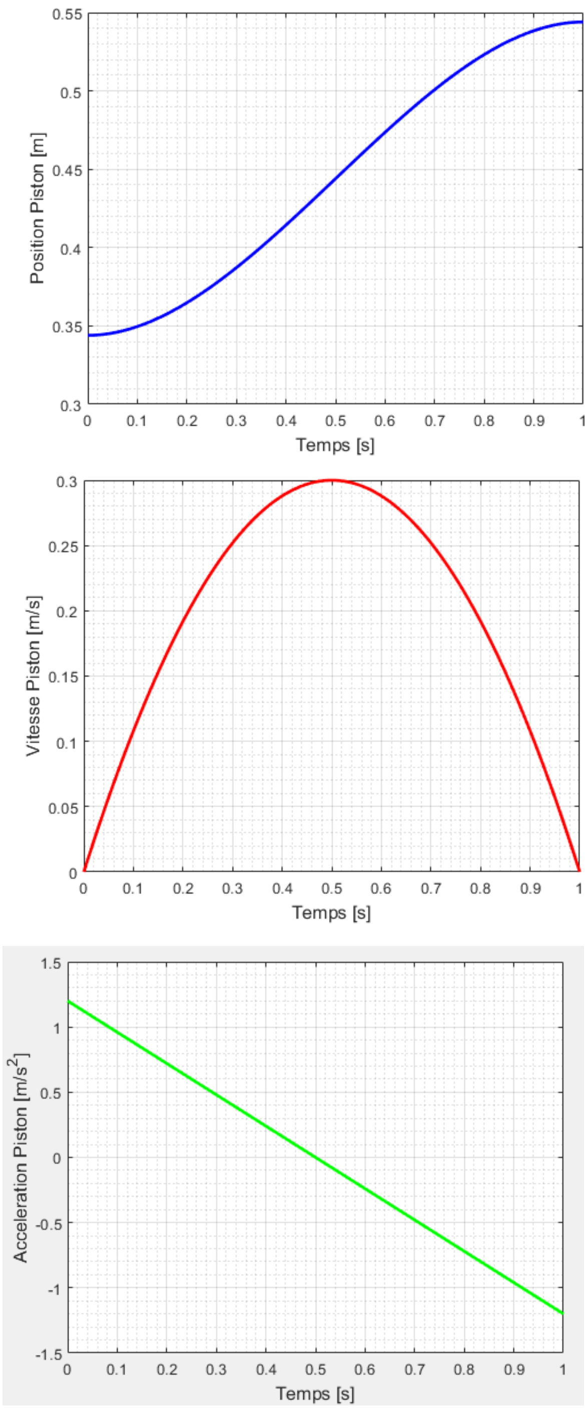


Figure VI.10 Piston MATLAB plot results

After importing the results above to SW we obtain these results:

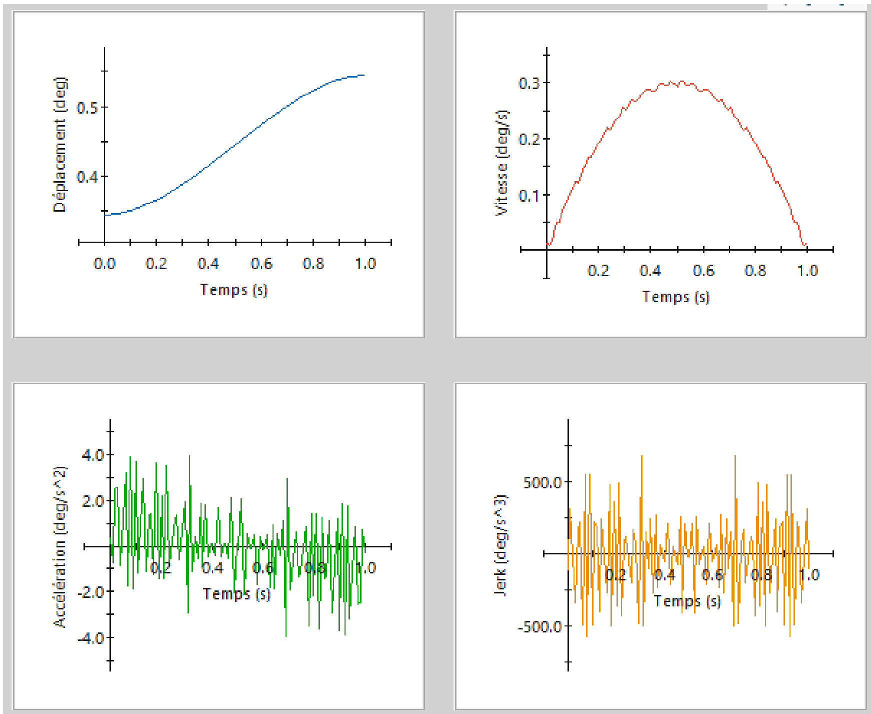


Figure VI.11: Motion piston results

Through the results obtained in SolidWorks, we can say that they are a 100% match with MATLAB results.

Conclusion:

The purpose of this chapter was to present the motion analysis of the basic structure of our machine using the SolidWorks Motion Analysis companion tool. We first reviewed the basic elements of this tool and then presented its application to our case. In addition, we were able to compare the results obtained by MATLAB, with those delivered by motion from SolidWorks, the results were conclusive.

CHAPTER 05:

SIMULATION OF COMPACTING MACHINE

Introduction:

After designing our machine and crank rod system using SOLIDWORKS, we will use simulation function to check the resistance of crank rod system using static study and solid meshing. SW Simulation is integrated into some of the SW products, for example, SW Premium, SW Simulation Premium or SW Simulation Professional, allowing the development of a finite element analysis (FET). One of its main advantages is the close interaction between the CAD model (geometric) and FE model.

SolidWorks CAD software is a 3D mechanical design application parametric that allows designers to quickly sketch ideas, experiment features and dimensions to produce accurate models and drawings.

V.1 Simulation Study:[10]

V.1.1 Type of studies:

There are different types of studies that helps our model to have presided results such as:

- **Static (or Stress) studies:** Static studies calculate displacements, reaction forces, strains, stresses, and factor of safety distribution. Material fails at locations where stresses exceed a certain level. Factor of safety calculations are based on a failure criterion. The software offers 4 failure criteria.
- **Frequency studies:** A body disturbed from its rest position tends to vibrate at certain frequencies called natural or resonant frequencies. The lowest natural frequency is called the fundamental frequency. For each natural frequency, the body takes a certain shape called mode shape. Frequency analysis calculates the natural frequencies and the associated mode shapes.
- **Buckling studies:** Buckling refers to sudden large displacements due to axial loads. Slender structures subject to axial loads can fail due to buckling at load levels lower than those required to cause material failure buckle. Buckling can occur in different modes under the effect of different load levels. In many cases, only the lowest buckling load is of interest.
- **Thermal study:** Thermal studies calculate temperatures, temperature gradients, and heat flow based on heat generation, conduction, convection, and radiation conditions. Thermal studies can help you avoid undesirable thermal conditions like overheating and melting.
- **Nonlinear studies:** In some cases, the linear solution can produce erroneous results because the assumptions upon which it is based are violated. Nonlinear analysis can be used to solve

problems with nonlinearity caused by material behavior, large displacements, and contact conditions. You can define static as well as dynamic studies.

V.1.2 Concept of FEA:

Finite Element Analysis (FEA) provides a reliable numerical technique for analyzing engineering designs. The process starts with the creation of a geometric model. Then, the program subdivides the model into small pieces of simple shapes called elements connected at common points called nodes. The process of subdividing the model into small pieces is called meshing. Finite element analysis programs look at the model as a network of interconnected elements.

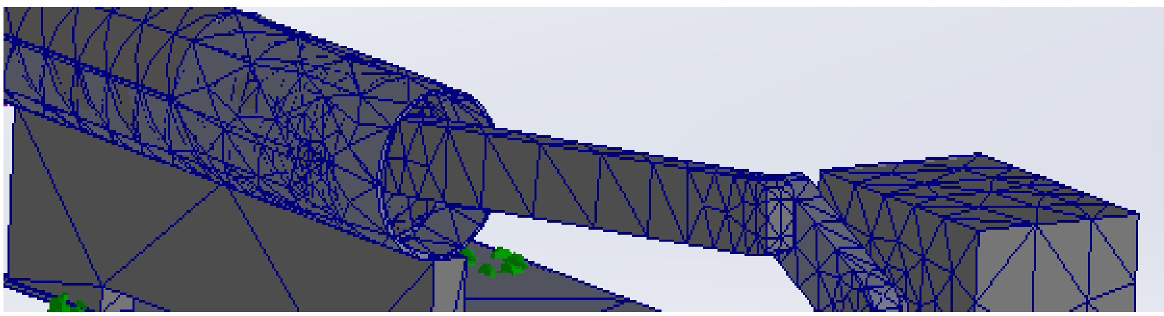


Figure V.1 system mashing

V.1.3 Types of meshing:

SolidWorks CAD software is a 3D mechanical design application parametric that allows designers to quickly sketch ideas, experiment features and dimensions to produce accurate models and drawings.

- **Solid Mesh:** The program automatically creates a shell mesh for metal sheets of uniform thickness (except for drop test studies) and surface geometries. For metal sheets, the mesh is automatically created on the middle surface. The program extracts the shell thickness from the thickness of the metal sheet.

- **Shell Mesh:** Surface geometries and sheet metals with uniform thickness mesh with triangular shell elements. Sheet metals defined in a drop test study mesh with solid elements.

- **Beam Mesh:** Structural members and weldments mesh with beam elements. You can treat an extrusion (meshes with solid elements by default) as a beam by right clicking on the solid icon and selecting Treat as Beam.

- **Mixed Mesh:** When different geometries are present in the same model, a mixed mesh is generated.

SolidWorks simulation provides 3 different types of meshers:

- **Standard mesher [Standard]** has a fairly uniform element size across the model including the fillet

- **Curvature-Based mesher [Curvature]** is able to locate the small features and highly curved locations automatically as we can see refined elements in the fillet. However, due to the more freeform algorithms, we see that the elements on the flat faces are not as consistent. The results will still be accurate, provided the mesh size has been sufficiently refined.

- **Blended Curvature-Based mesher [Blended]** is still able to automatically refine the mesh in the fillet, yet provides a higher quality consistent mesh in other locations.

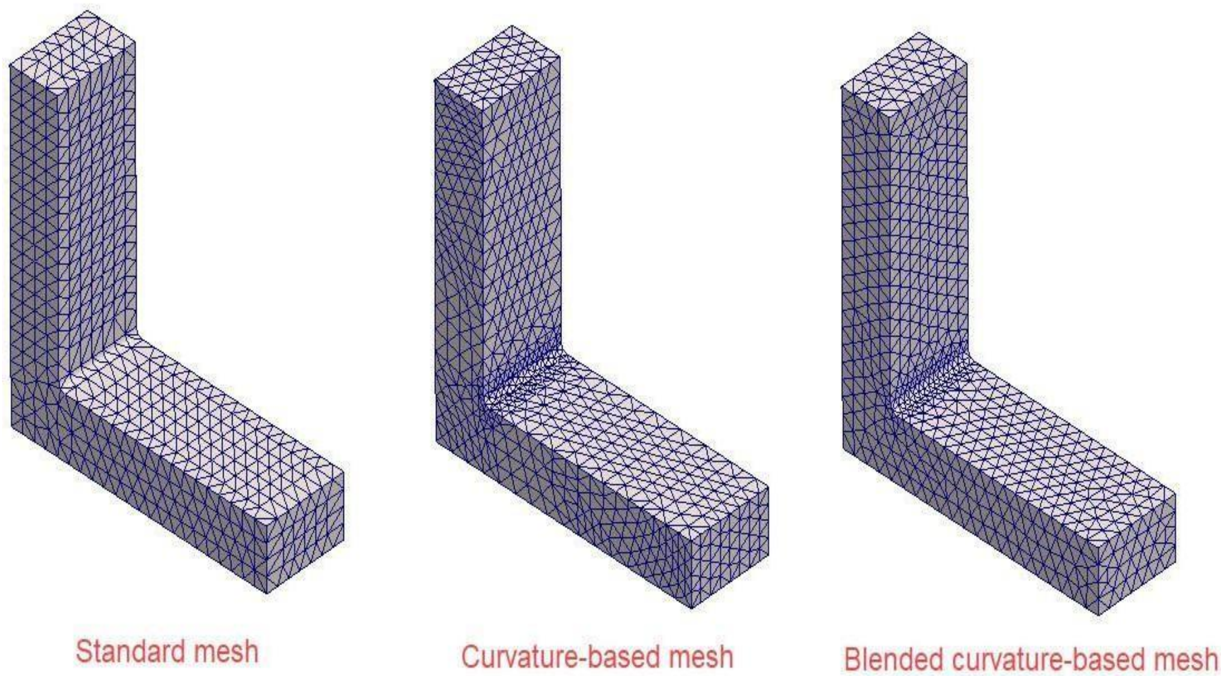


Figure V.2 Mesher types

The mesh appears to be **triangular elements** (likely tetrahedral if it is a 3D model). These triangular elements are common in finite element analysis (FEA) for complex or curved geometries, as they can better approximate irregular surfaces compared to quadrilateral elements. (Figure 1)

This meshing appears to be well suited for a simulation that involves complex geometries and forces applied to different regions. It helps in ensuring that stress, strain, and displacement are calculated accurately throughout the structure.

V.2 Crank rod simulation:

In our study, we used blende curvature based mesher for its higher quality mesh and takes 21 Seconds to generate. We simulated our model in 3 positions using the following factors:

• The dimensions of the model,

• The properties of the material,

• Boundary condition loadings,

• Presentation of the results

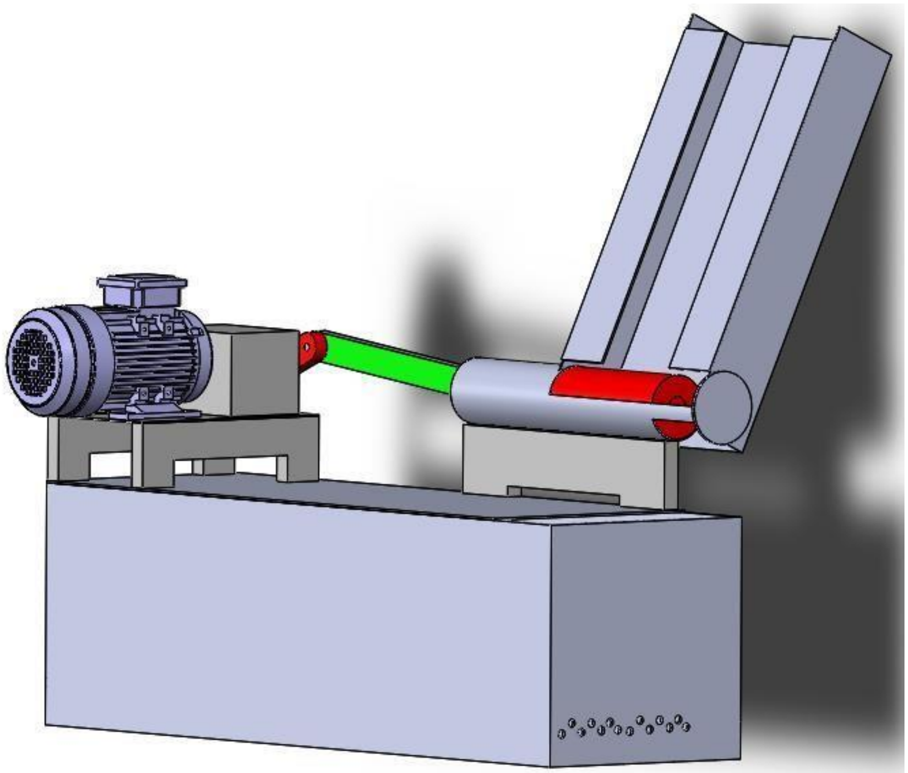


Figure V.3 System model in SW

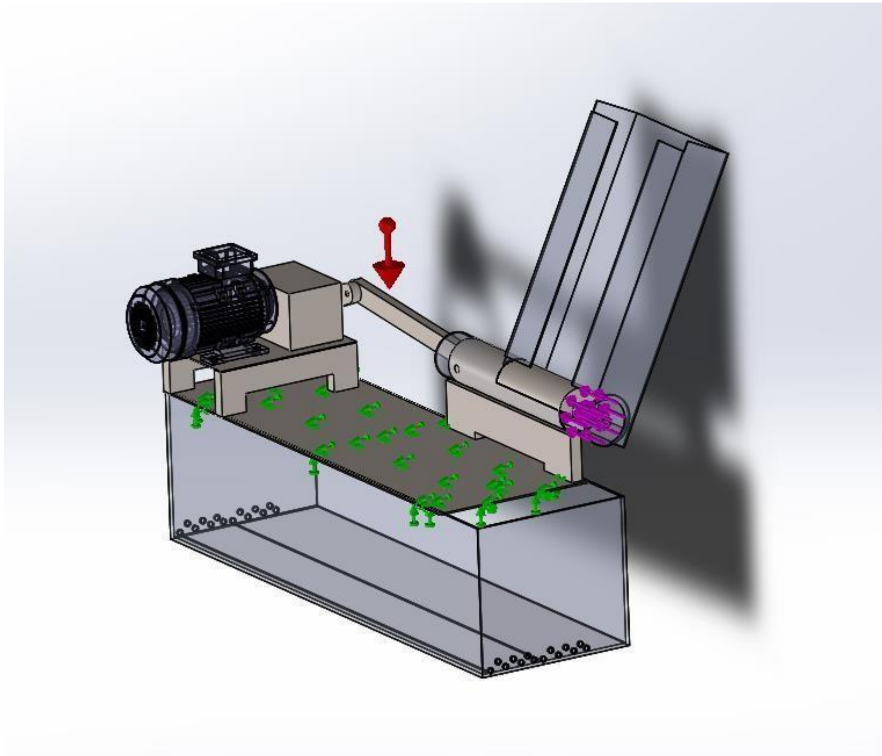
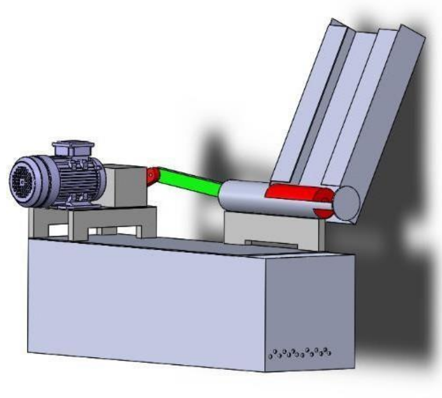
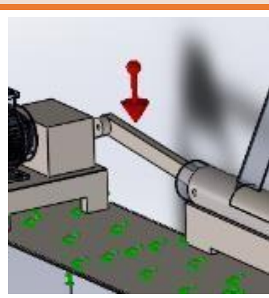
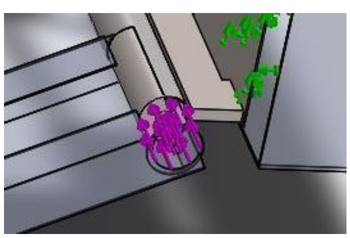


Figure V.4 Analyzed model

V.2.1 Material properties:

Model Reference	Properties
	Name: **Alloy Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **6,20422e+08 N/m^2** Tensile strength: **7,23826e+08 N/m^2** Elastic modulus: **2,1e+11 N/m^2** Poisson's ratio: **0,28** Mass density: **7 700 kg/m^3** Shear modulus: **7,9e+10 N/m^2** Thermal expansion coefficient: **1,3e-05 /Kelvin**

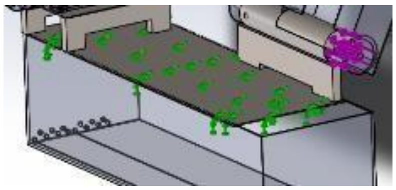
V.2.2 Loads and Fixtures:

Load name	Load Image	Load Details
Gravity		**Reference:** **Plan de face** **Values:** **0 0 -9,81** **Units:** **m/s^2**
Force		**Entities:** **1 face(s)** **Type:** **Apply normal force** **Value:** **500 N**

V.2.3 Meshing:

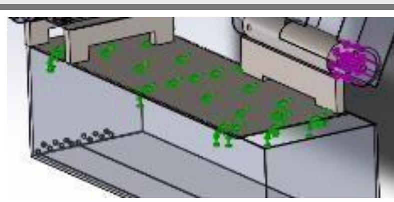
V.2.3.1 Meshing informations:

For first position (α=180°):

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **1 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**-500**	**-9,01187e-05**	**622,679**	**798,58**
Reaction Moment(N.m)	**0**	**0**	**0**	**0**

Fixture name	**Fixture Image**	**Fixture Details**
Fixed		**Entities:** **1 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**-500**	**-9,01187e-05**	**622,679**	**798,58**
Reaction Moment(N.m)	**0**	**0**	**0**	**0**

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	28,3089 mm
Minimum element size	1,41544 mm
Mesh Quality	High
Remesh failed parts independently	Off

For second position (α=90°):

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	50,5822 mm
Minimum element size	3,82683 mm
Mesh Quality	High
Remesh failed parts independently	Off

NB: For third position (α=0°) it has the same results as $\alpha = 90$

V.2.3.2 Meshing informations – details:

1. For first position (α=180°):

Total Nodes	16618
Total Elements	8710
Maximum Aspect Ratio	452,17
% of elements with Aspect Ratio < 3	64,2
Percentage of elements with Aspect Ratio > 10	23,1
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:04
Computer name:	

2. For second position (α=90°):

Total Nodes	16618
Total Elements	8710
Maximum Aspect Ratio	452,17
% of elements with Aspect Ratio < 3	64,2
Percentage of elements with Aspect Ratio > 10	23,1
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:04
Computer name:	

3. **For first position (α=0°):**

Total Nodes	16586
Total Elements	8711
Maximum Aspect Ratio	452,17
% of elements with Aspect Ratio < 3	63,7
Percentage of elements with Aspect Ratio > 10	23,1
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	

V.3 resultant forces:

V.3.1 for when (α=180°):

Reaction forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-500	-9,01187e-05	622,679	798,58

Reaction Moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0,00073719	0,00018692	449,773	449,773

Free body moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

V.3.2 For when (α=90°):

Reaction forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0,999987	-4,75049e-05	633,27	633,271

Reaction Moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0,999987	-4,75049e-05	633,27	633,271

Free body forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0,000793442	-5,7213e-05	438,012	438,012

Free body moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

V.3.3 For when (α=0°):

Reaction forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1	-1,22018e-08	-5,66943e-08	1

Reaction Moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	4,84397e-08	6,98401e-09	-3,93629e-08	6,28062e-08

Free body moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

V.4 Study Results:

V.4.1 Stress:

a. Von mises stress: is a value used to determine if a given material, will yield or fracture.it is mostly used for ductile materials, such as metals. The von mises yield criterion states that if the von mises stress of a material under load is equal to a greater than the yield limit of the same material under simple tension then the material will be yield.

Stress also plays a significant role in determining the yield strength of a material. The yield strength is the maximum stress a material can withstand before it undergoes permanent deformation. By comparing the principal stresses to the yield strength, we can assess whether a material is likely to fail or not. he figures below (adapted from [4]) illustrate the curve obtained when studying the strain response of the uniaxial tension of a mild steel beam. These will help us understand why von Mises is important. [7]

The description of each emphasized point is as follows:

- **Elastic Limit**: The elastic limit defines the region where energy is not lost during the process of stressing and straining. That is, the processes that do not exceed the elastic limit are reversible. This limit is also called yield stress. Above that limit, the deformations stop being elastic and start being plastic, and the deformation includes an irreversible part. The stress value of the elastic limit is used here as Sy.
- **Upper yield and lower yield**: When mild steel is in the plastic range and reaches a critical point — called the upper yield limit —it will drop quickly to the lower yield limit, from which deformation happens at constant stress until it starts resisting deformation again.
- **Rupture stress**: Rupture, or fracture, is the separation of an object caused by stress. Therefore, at this point, a fracture of the body is expected. Materials such as mild steel — which have the property of fracturing only after large plastic deformations — are called ductile. The fracture illustrated here is called a ductile fracture. You can recognize a ductile fracture when the diagram has a curve like the one shown below. This means that as the material gets thinner, more pressure is applied until it suddenly breaks at the rupture stress point.

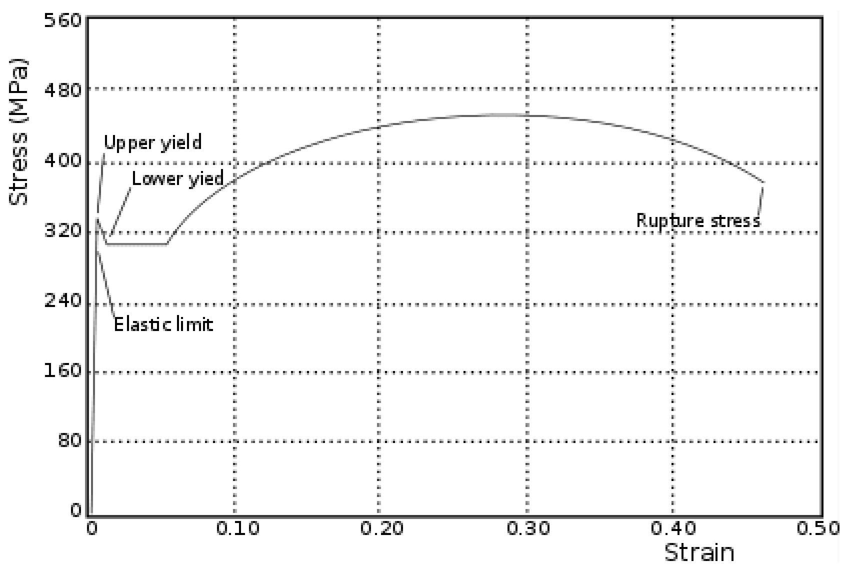


Figure V.5 Stress strain diagram

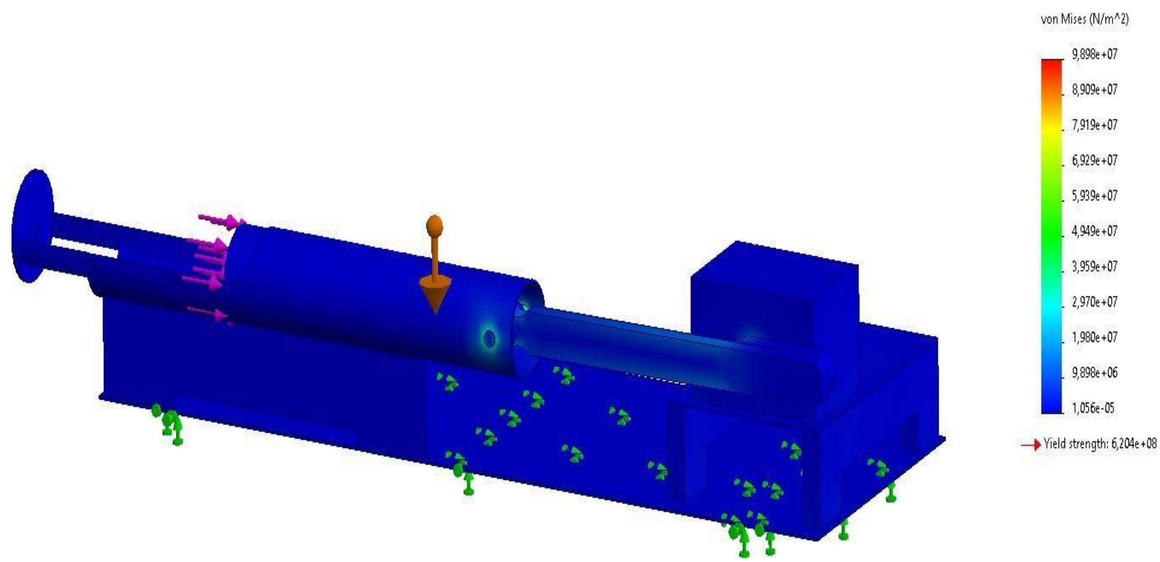
To calculate the von Mises stress, we use the following formula:

$$\sigma v = \sqrt{(\sigma 1^2 + \sigma 2^2 + \sigma 3^2 - \sigma 1\sigma 2 - \sigma 2\sigma 3 - \sigma 3\sigma 1)} \quad (5.1)$$

Where σ1, σ2, and σ3 are the principal stresses. The von Mises stress allows us to compare the stress state of different materials and determine their likelihood of failure.

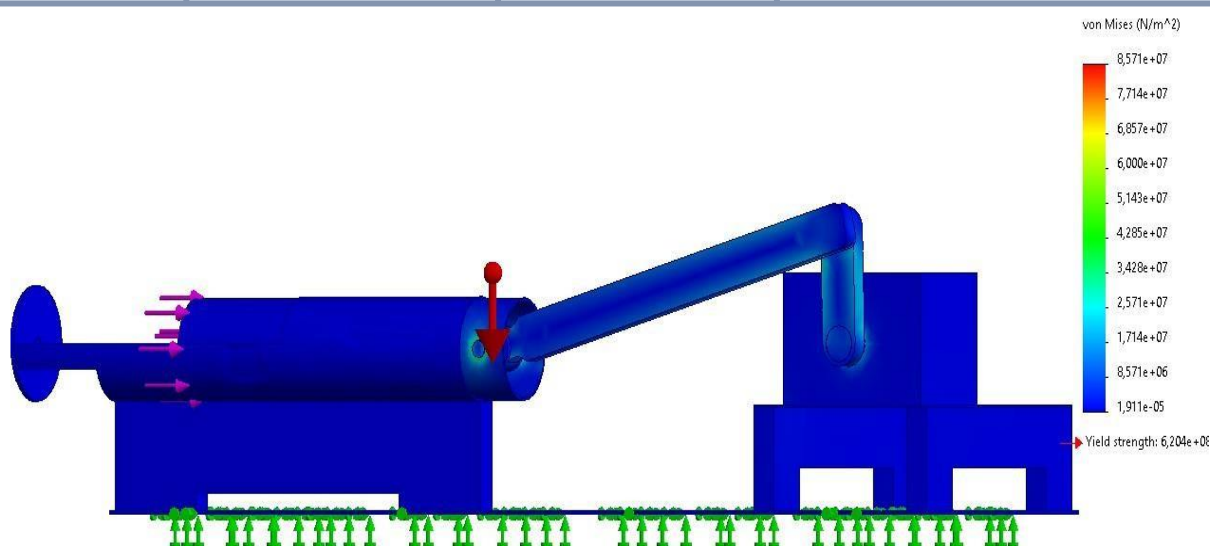
After simulating our system, we have these results for the 3 positions:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2,891e-05N/m^2 Node: 3008	9,031e+07N/m^2 Node: 5448



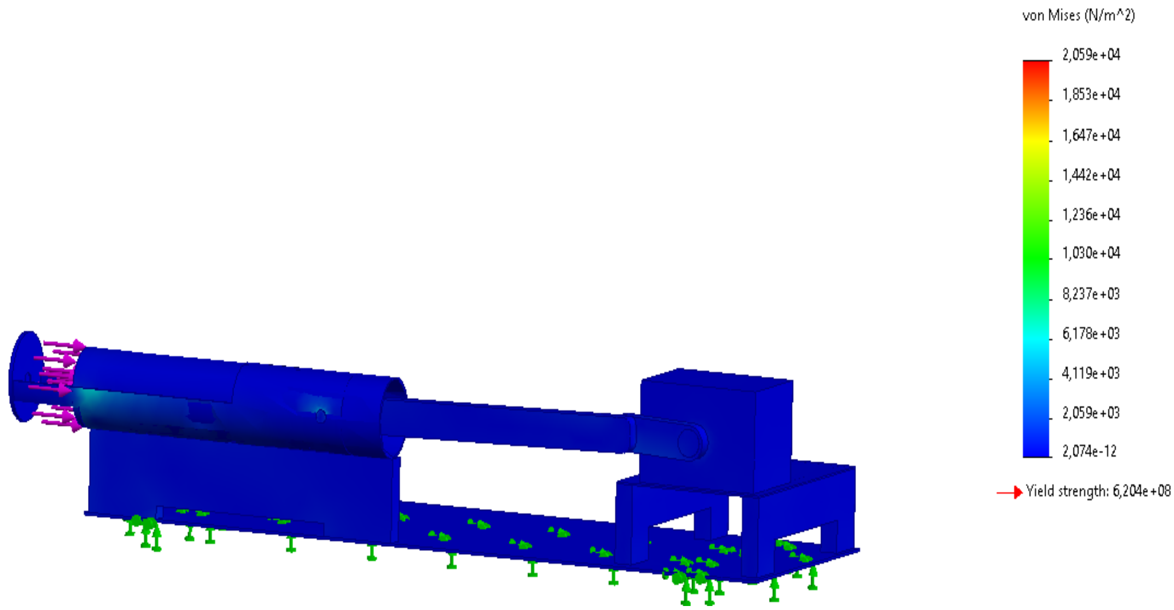
Stress for position $\boldsymbol{\alpha} = \mathbf{180°}$

Name	Type	Min	Max
Stress2	VON: von Mises Stress	1,911e-05N/m^2 Node: 859	8,536e+07N/m^2 Node: 2151



Stress position $\boldsymbol{\alpha} = \mathbf{90°}$

Name	Type	Min	Max
Stress3	VON: von Mises Stress	2,074e-12N/m^2 Node: 1678	2,059e+04N/m^2 Node: 6161



Stress position $\boldsymbol{\alpha} = \mathbf{0}°$

We notice that the system does not yield or fail under complex loading in the 3 positions

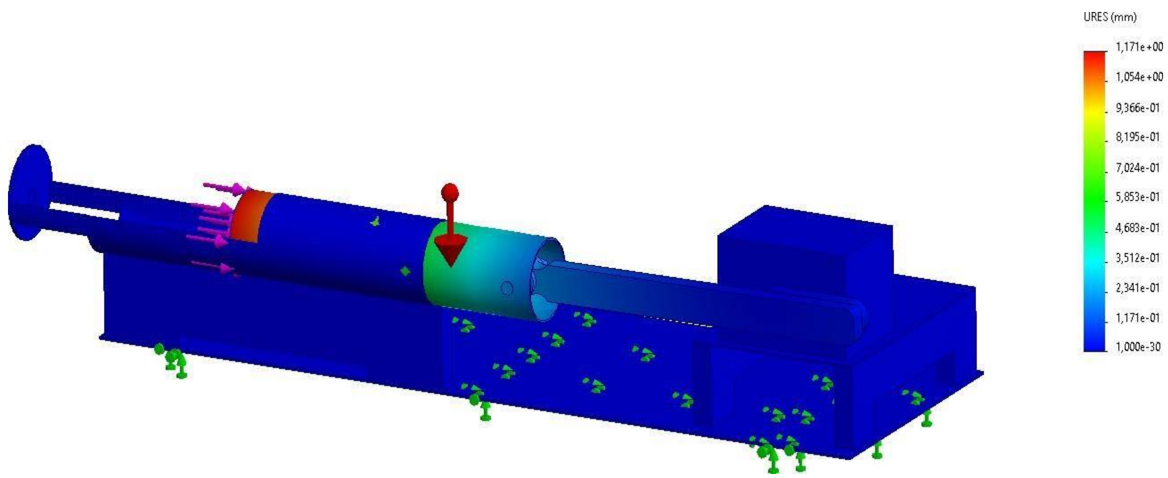
For the second position we notice a light blue in the crank rood which endicates that the structure might be under bending ,torque,or concentrated load.

V.4.2 Displacement:

The displacement shows how much the part is expected to move or deform under loads.
In the results below we notice that:

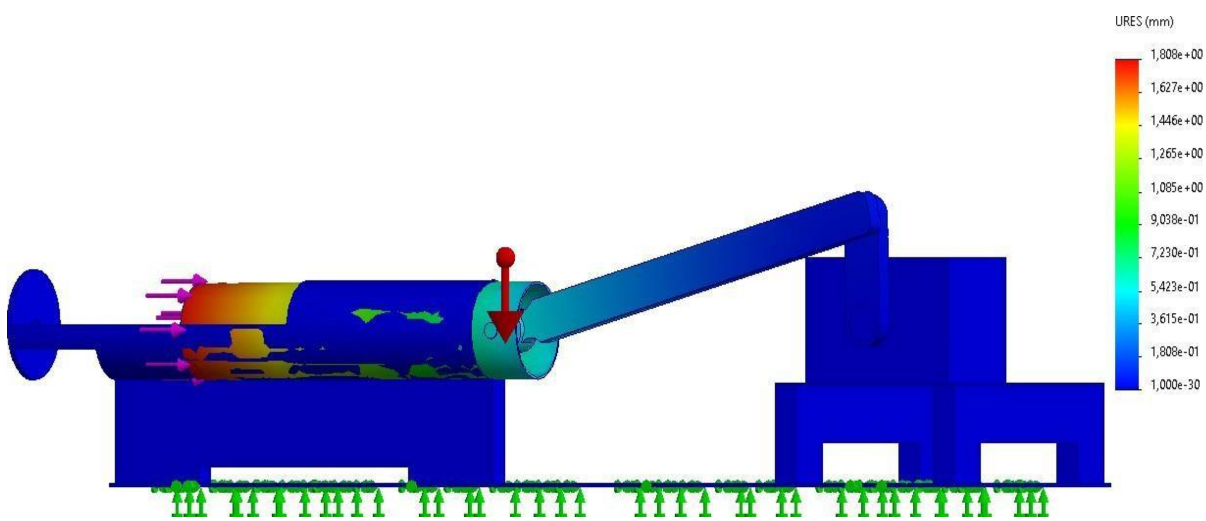
- the structure is mostly rigid around the base and larger body, while the middle section (where force is applied) shows the highest displacement. This could be a part of a cylinder or press-like system subjected to vertical load.
- The displacement values suggest that the system is under controlled deformation, as the displacements are relatively small (below 1.2 mm at maximum).

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0,000e+00mm Node: 3	1,182e+00mm Node: 5516



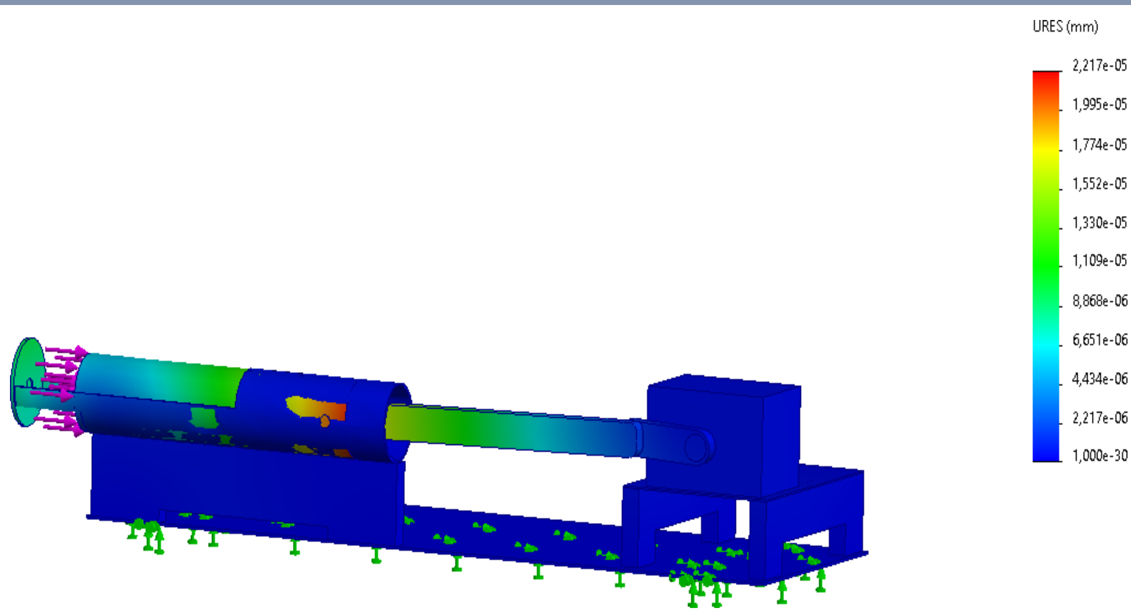
Displacement position $\alpha = \mathbf{180}°$

Name	Type	Min	Max
Displacement2	URES: Resultant Displacement	0,000e+00mm Node: 3	1,943e+00mm Node: 2217



Displacement position $\boldsymbol{\alpha} = \mathbf{90}°$

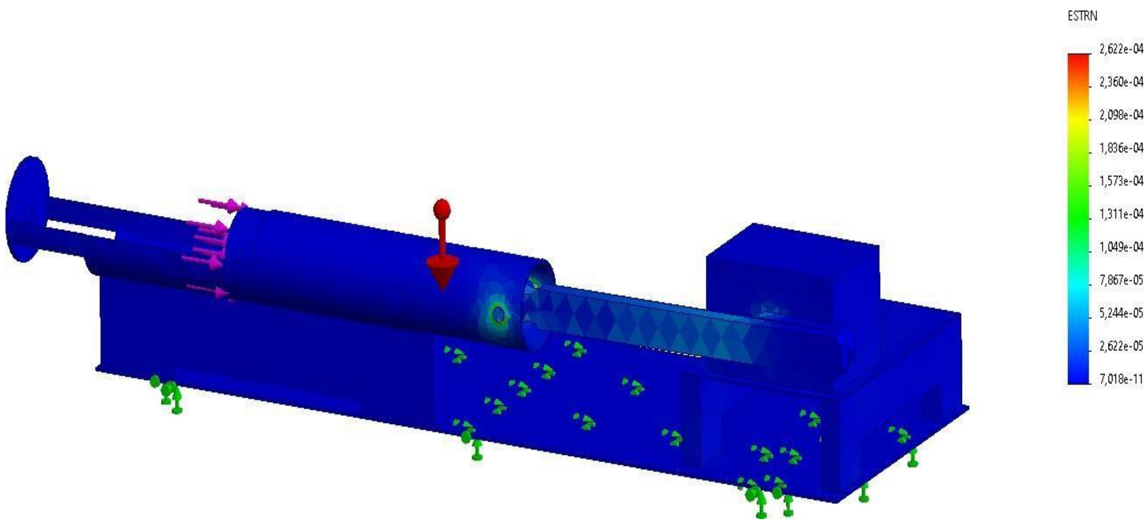
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0,000e+00mm Node: 2	2,217e-05mm Node: 2170



Displacement position $\boldsymbol{\alpha} = \mathbf{0}°$

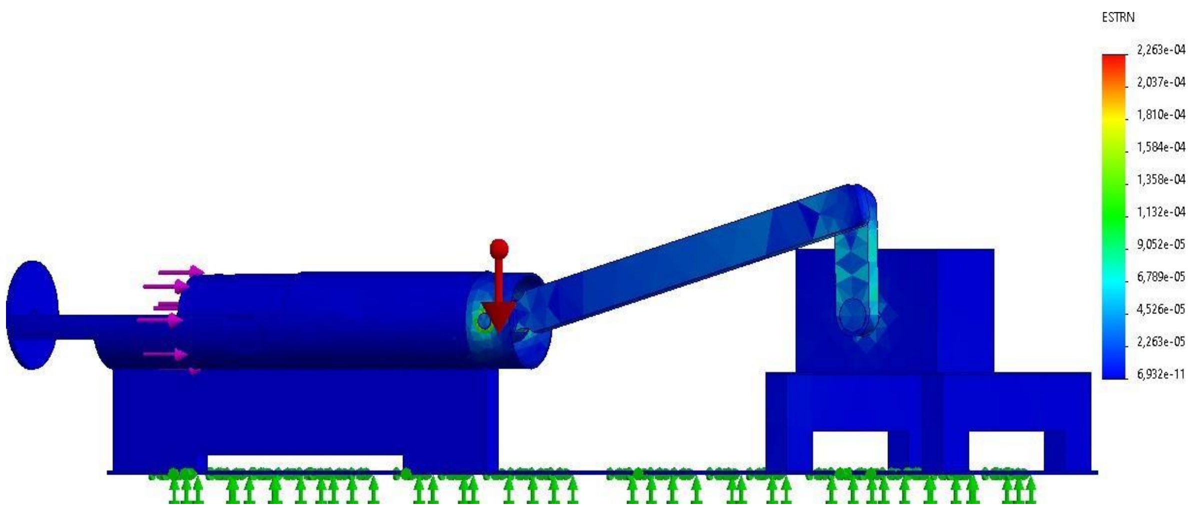
V.4.3 Strain :

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5,362e-11 Element: 853	2,520e-04 Element: 3701



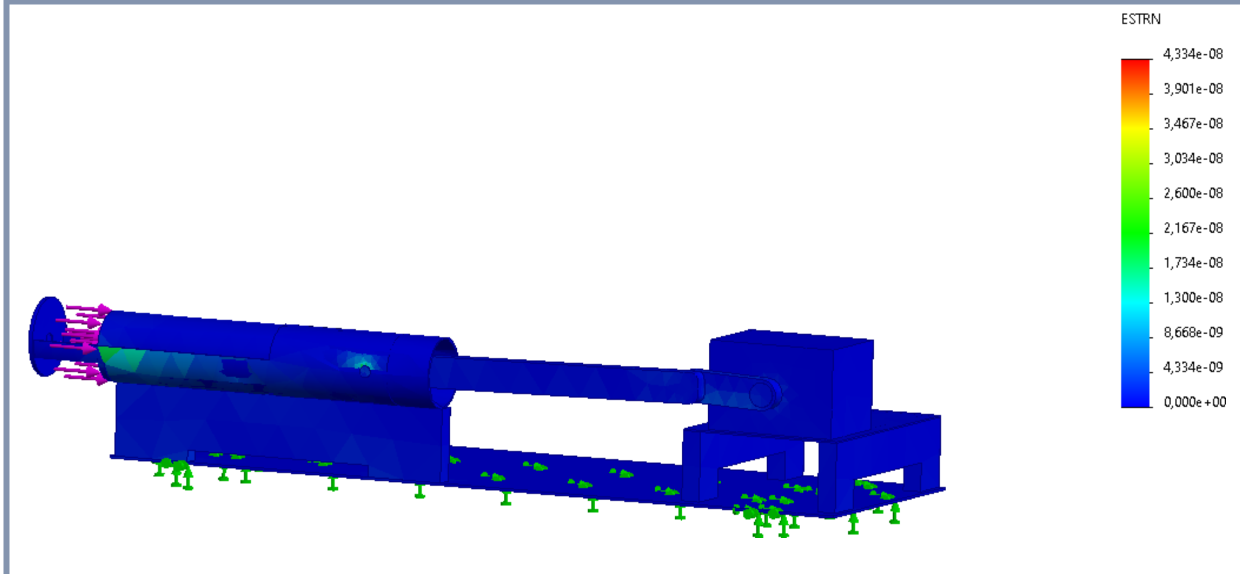
Strain position $\boldsymbol{\alpha} = \mathbf{180}°$

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6,932e-11 Element: 680	2,256e-04 Element: 1921



Strain position $\boldsymbol{\alpha} = \mathbf{90}°$

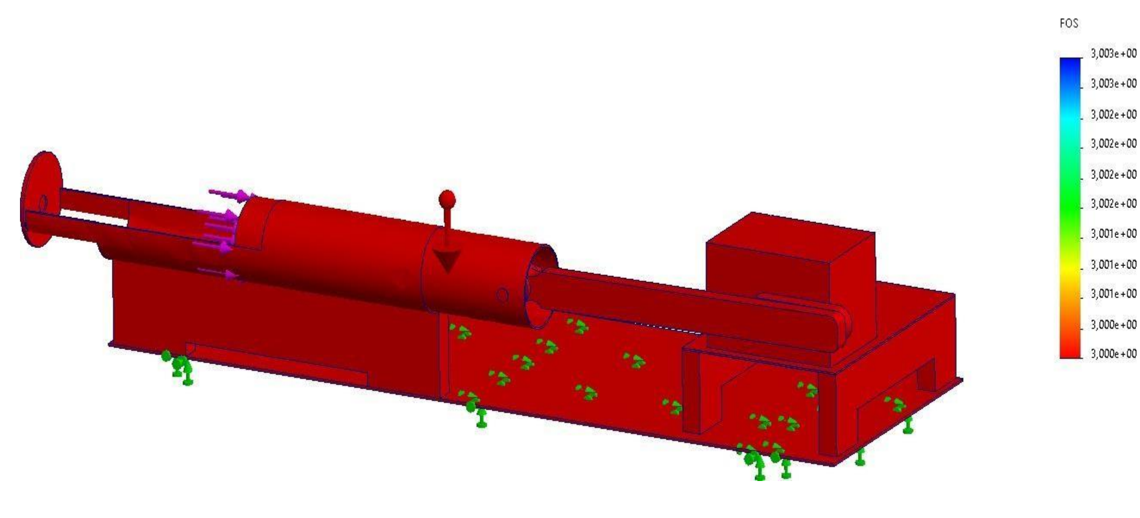
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0,000e+00 Element: 171	4,334e-08 Element: 2637



Strain position $\boldsymbol{\alpha} = \mathbf{0}°$

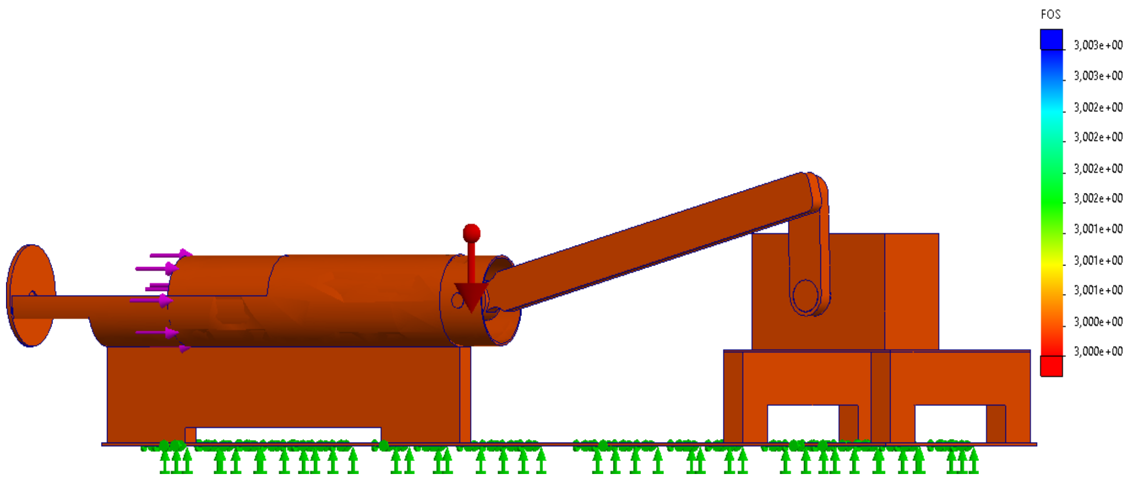
V.4.4 Security Factor:

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	3,000e+00 Node: 1	3,000e+00 Node: 1



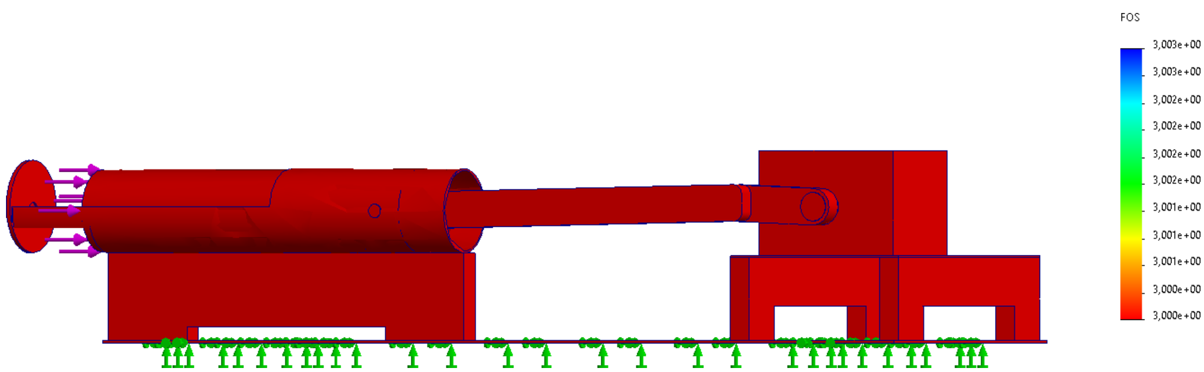
Factor of Safety1 (NB: color indicates its safe)

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	3,000e+00 Node: 1	3,000e+00 Node: 1

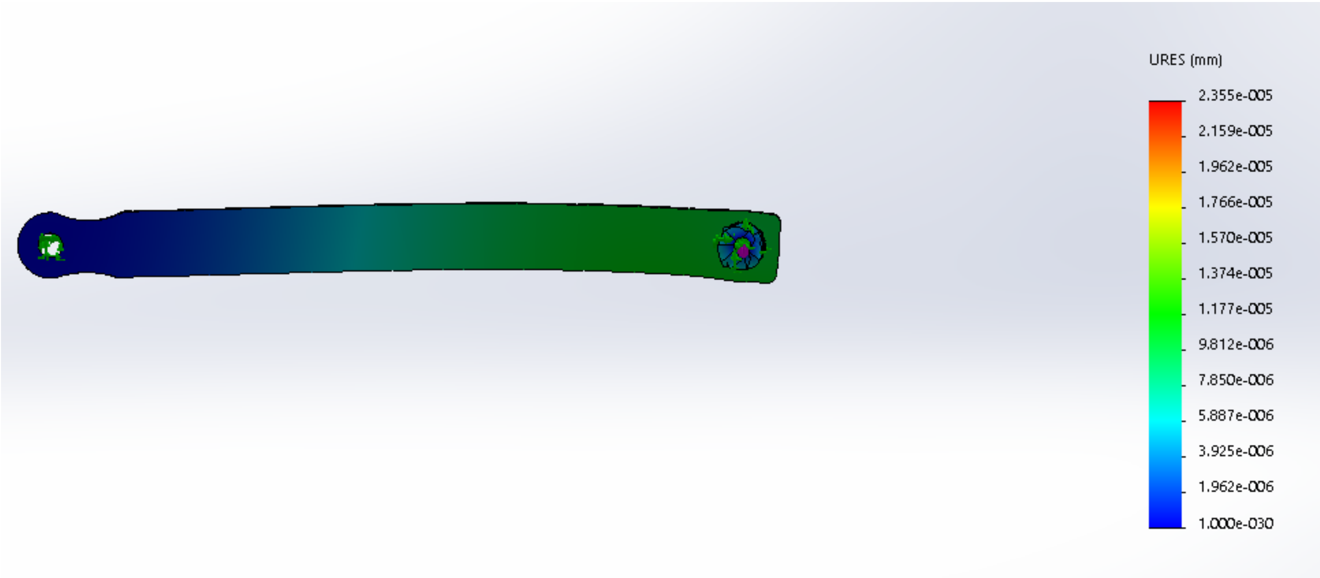


Factor of Safety2 (NB: color indicates its safe)

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	3,000e+00 Node: 1	3,000e+00 Node: 1



Factor of Safety3 (NB: color indicates its safe)



After simulating the crank with the focus on the rotation positions we can see that:

- The structure has minimal deformation under the applied conditions. Most of the deformation occurs on the right end, which may indicate this is the free end of a cantilevered beam or lever that is experiencing bending or twisting forces.
- The simulation likely aims to verify that the part will not experience significant displacement under working loads, ensuring structural integrity.

Conclusion:

From this chapter, it is concluded that the results obtained show that the dimensions and the material selected can ensure the proper operation of the machine. The results cited below also show that the resistance of the main organs was respected. In addition, these calculations were based on the model dimensions, material properties and limit condition loads.

GENERAL CONCLUSION

After all our research and according to chapter one, we realized that recycling plastic bottles is more profitable than we ever knew, thus we discovered the problem of collecting what we are supposed to recycle. And also, how disturbing the pollution of it.

So, our solution begins in where we suggested a machine that can be placed anywhere, at least anywhere near those bottles. But of course, we can’t just create something out of nowhere, so we used an experiment to figure how much force we need to crash the bottle, we calculated the necessary length of the crank-rod, the angles, position, acceleration.

By using MATLAB code and motion analysis in SW we managed to reach reached a satisfying result. And we ended our study with SolidWorks simulation that had an impact on our crank rod system which has very accurate.

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[1]:

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[2] :

Claire. Quels sont les différents types de recyclage ? - Cy-Clope. Cy-Clope. Published March 18, 2023. Accessed March 22, 2024. https://www.cy-clope.com/les-differents-types-de-recyclage/

[3] :

F1920-generalites-sur-les-matieres-plastiques.pdf - Google Search. Google.com. Published 2023. Accessed March 2024

[4]:

intechfunctional_analysis_in_systems_engineering_methodology_and_applications.pdf

[5]

Critères de Von Mises et Tresca: Analyse, Stratégies | StudySmarter

[6]

Quels sont les différents types de réducteurs mécaniques ? - DYMATEC INDUSTRIES

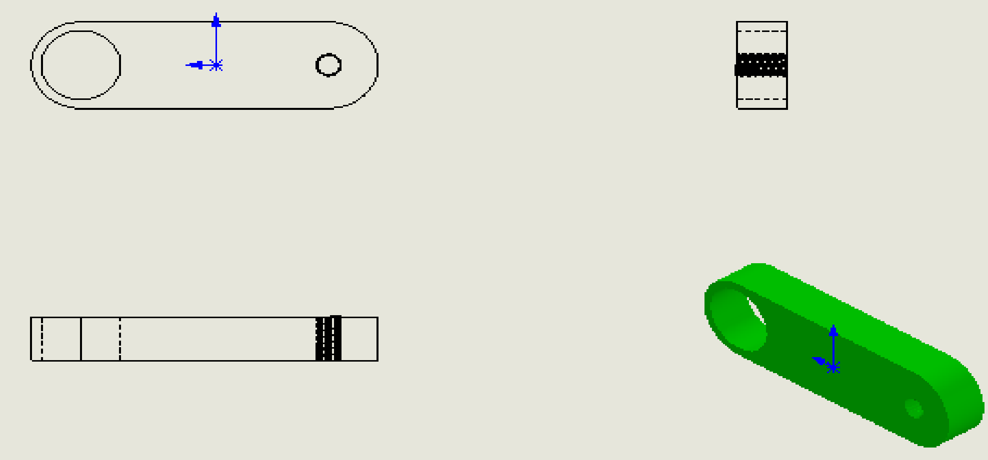
[7]

https://centralinnovation.com/technical-resources/learn/how-to-use-solidworks-static-simulation-in-an-assembly/

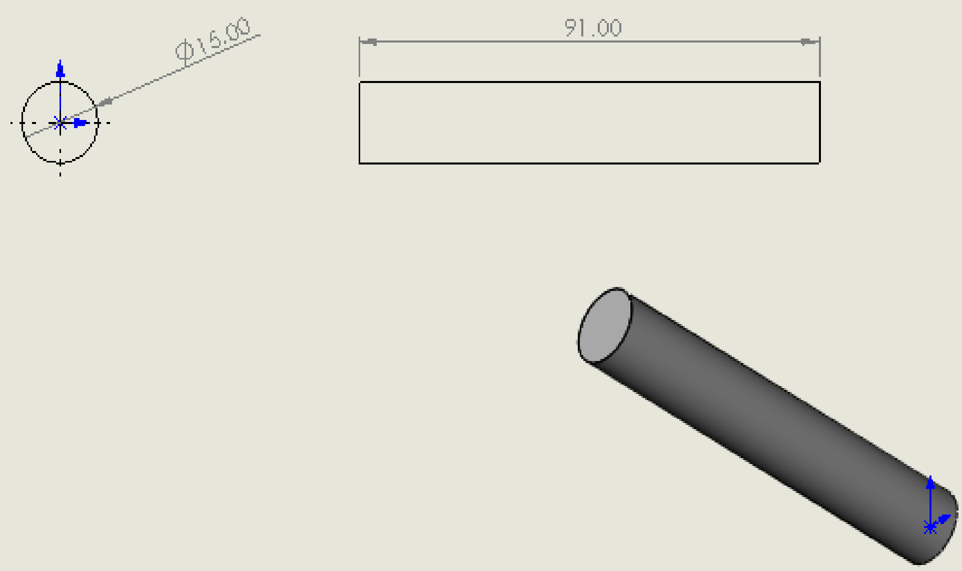
[8]

https://www.mathworks.com/discovery/genetic-algorithm.html

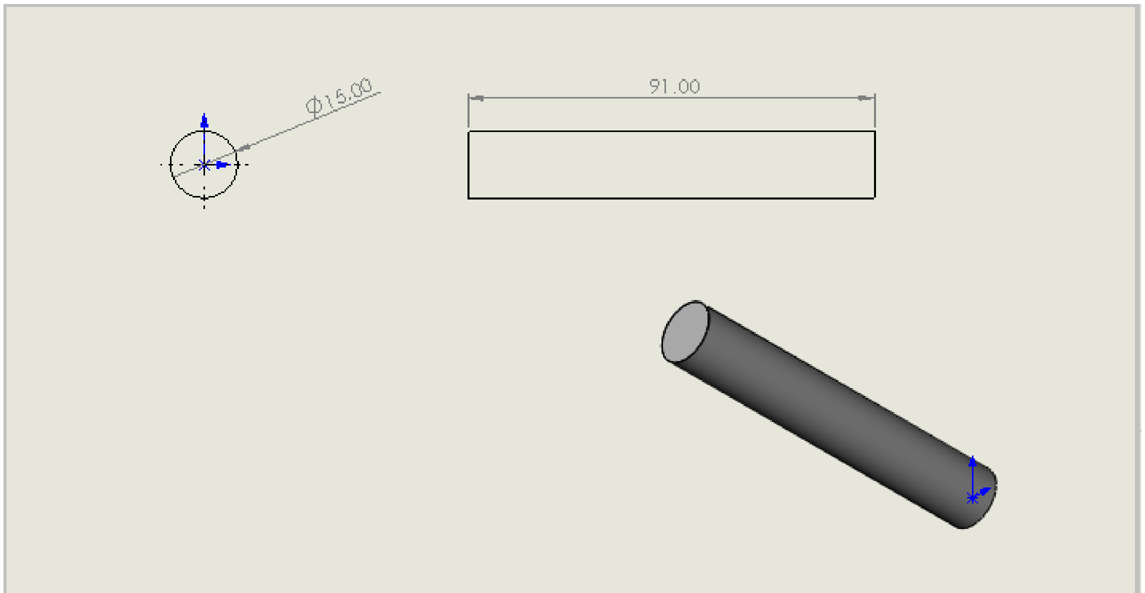
APENDIX



	number	designation	material	
rep	1	rod	alloy steel	observation
echelle 1:2		bottle compacting machine		realised by: tabti narimane hammadi mohamed chawki REV
		saad dahleb blida		master 2 fmp

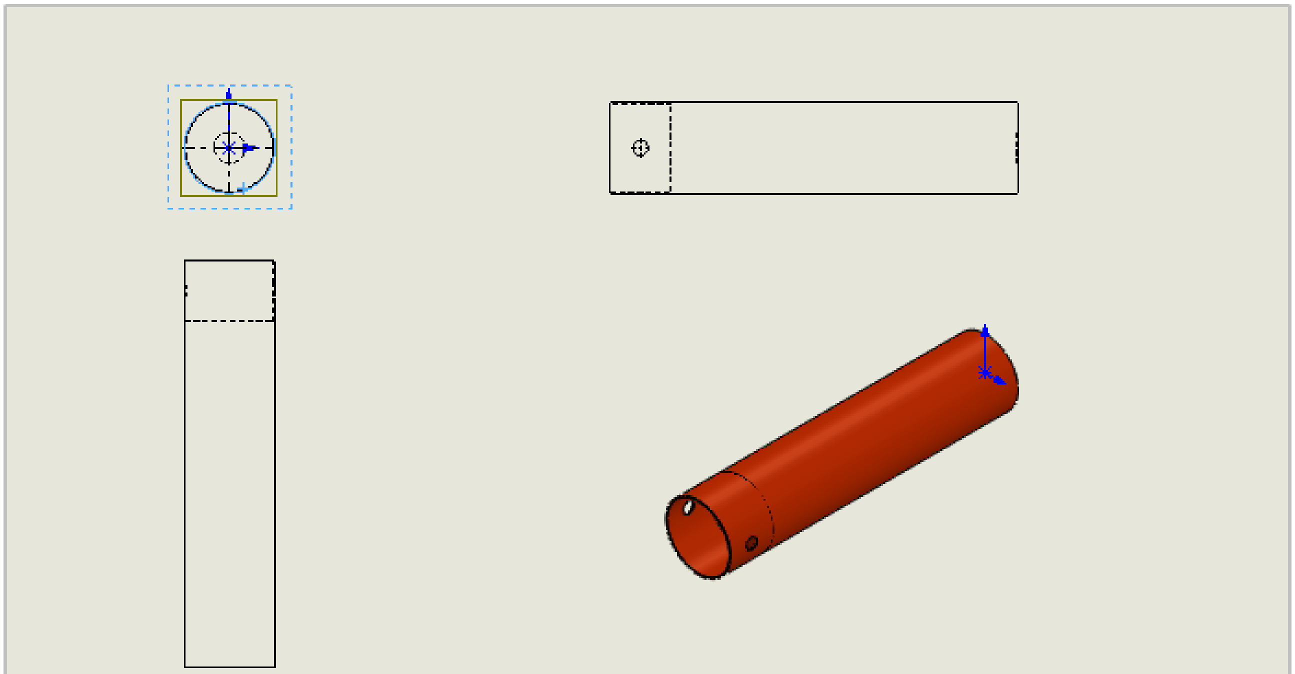


	2	CRANK-PISTON AXE	alloy steel	
rep	number	designation	material	observation
echelle:1.2		bottle compacting machine		realised by: hammadi mohamed chawki tabti narimane
A4		Saad Dahleb Blida university		fmp master 2



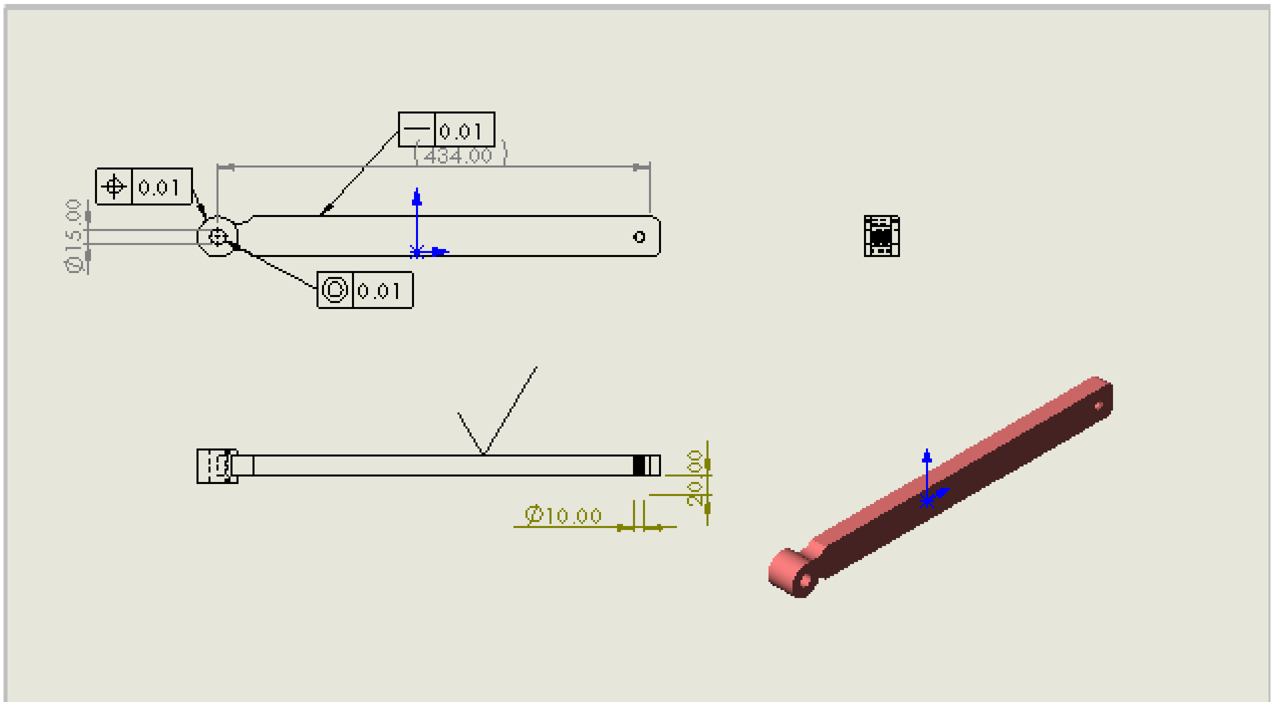
	2	CRANK-PISTON AXE	alloy steel	
rep	number	designation	material	observation

echelle:1.2	bottle compacting machine	realised by: hammadi mohamed chawki tabti narimane
A4	Saad Dahleb Blida university	fmp master 2



	2	CHESIS	alloy steel	
rep	number	designation	material	observation

echelle:1.2	bottle compacting machine	realised by: hammadi mohamed chawki tabti narimane
A4	Saad Dahleb Blida university	fmp master2



	number	crank	material	
rep	2	designation	alloy steel	observation
echelle 1:2		bottle compacting machine		realised by: tabti narimane hammadi mohamad chawki
		saad dahleb university		master 2 fmp

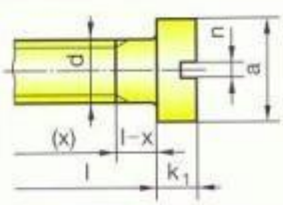
Fente

- Ces vis sont utilisées pour des assemblages à faibles sollicitations mécaniques.
- Ce type d'entraînement ne convient pas au vissage automatisé.
- Fabrication courante : extrémité RL.

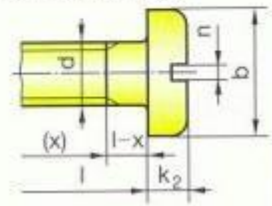
d	a	b	c	k_1	k_2	n
M1,6	3	3,2	3,6	1	1	0,4
M2	3,8	4	4,4	1,3	1,3	0,5
M2,5	4,5	5	5,5	1,6	1,5	0,6
M3	5,5	5,6	6,3	2	1,8	0,8
M4	7	8	9,4	2,6	2,4	1
M5	8,5	9,5	10,4	3,3	3	1,2
M6	10	12	12,6	3,9	3,6	1,6
M8	13	16	17,3	5	4,8	2
M10	16	20	20	6	6	2,5

EXEMPLE DE DÉSIGNATION : Vis à tête fraisée bombée ISO 2010 – Md × l – classe de qualité***.

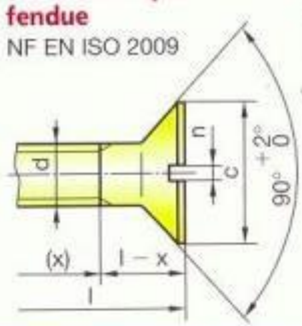
Tête cylindrique fendue
NF EN ISO 1207



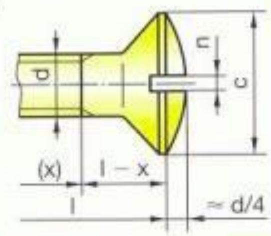
Tête cylindrique large fendue
NF EN ISO 1580



Tête fraisée plate fendue
NF EN ISO 2009



Tête fraisée bombée fendue
NF EN ISO 2010



Vis à tête cylindrique fendue

Vis à tête cylindrique bombée large à empreinte cruciforme

Longueurs l* et longueurs filetées x**

We used M10 for the crank rod assembly