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Development of thermal hydraulic press to produce two layers rubber tile

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Abstract

Egypt creates 20 million waste tires annually, which damage the soil due to oil leakage and causing fires that cannot be easily extinguished due to its high calorific values. In order to reduce waste tires and encourage green manufacturing, this book has focused on manufacturing and developing of rubber tiles machine. Much information was collected from different researches and company communication such as tile components and manufacturing parameters. Manufacturing metal mold for practical testing and develop it using 3D printing technology. Using solidworks software for designing, modeling and analyzing the machine. Designing the hydraulic circuit and automatic control.

Keywords: Waste tire, Green manufacturing, Rubber tile, Mold development, Hydraulic Press, Automatic control

Chapter 1

Introduction

The rapid growth in the amount and types of solid waste and hazardous waste produced is posing a growing problem for national and local governments in terms of waste management sustainability. Waste management has a major impact on the atmosphere and human life quality. Waste management also necessitates both financial and technological capital. Collection alone, for example, consumes 80 to 90 percent of the urban solid waste management budget in low-income countries. Owing to extreme negative environmental effects, a lack of resources to efficiently handle it, and the loss of resources that could be saved and/or recovered by proper waste management focused on the waste hierarchy, circular economy, and 3R (reduce, reuse, and recycle) strategy, waste management is high on the national and international agenda [1].

End-of-Life (EoL) tires, also known as waste tires, are one of the waste sources that are slowly increasing and predicted to continue in the future. In 2014, it was announced that the world produced 15.85 million tons of tires per year, around the same number of items reach the end of their useful lives. Every year, they hit the end of their useful lives. These EoL tires are either illegally landfilled or disposed of in the waste stream for recycling. In all cases, if not treated scientifically, they pose an environmental and health risk. In the absence of a regulatory regime, it is difficult to develop and enforce an effective EoL tire waste management scheme. Furthermore, one of the most important factors in supporting waste management systems is technology selection for recovery routes [1].

The growing number of vehicles has resulted in a massive increase in the amount of used tires. While used tires represent a small percentage of the overall waste stream, they are extremely important in terms of volume and chemical composition. In Egypt, there is no special program for the processing of discarded tires. A portion of this waste is disposed of in the municipal solid waste collection system. Tire dealers store the bulk of tire waste and sell it to recycling mediators. The majority of rubber recovered in Cairo comes from car tubes, which are prized for their softness and elasticity. In Cairo, about 1% of waste tires are re-treaded, remoulded, or used directly in the secondary manufacture of new goods [2].

The nylon cords from nylon cord beaded tires are removed and used for baling various materials, including waste paper. Gaskets, small swivel wheels for office chairs and tables, and briefcase handles are among the semi-final and final items made from the recovered rubber. Furthermore, tires or tire covers are directly used to line the wheels of waste collectors' animal-drawn carts. Tires are often broken into layers, either longitudinally or radially, for direct use in the manual manufacture of rubber items such as sandals, gaskets, conveyer belt parts, stool seats, carrier straps, bed springs, and door mats. Tires are often burned for a variety of purposes, including obtaining steel wires, which are then used to tie paper bales, and for the rubber's calorific value for asphalt melting vehicles [2].

Our aim to manage tire wastes and use the benefit of it, by manufacturing and development of a rubber tiles machine. This machine is used to press rubber powder mixed with special glue under certain temperature and pressure in order to produce tiles that can be used in many applications as gym, hospitals, playgrounds and as alternatives for concrete pavement for more comfort and healthier life. In the following chapters we will illustrate everything related with our machine.

Chapter 2

Recycling (tires)

2.1. Main characteristics of tires

2.1.1. Composition and properties of tires

The tire is a rubber product with a complex structure. Chemical material, physical structure, and properties of a tire ultimately define overall tire characteristics over the course of its entire life cycle.

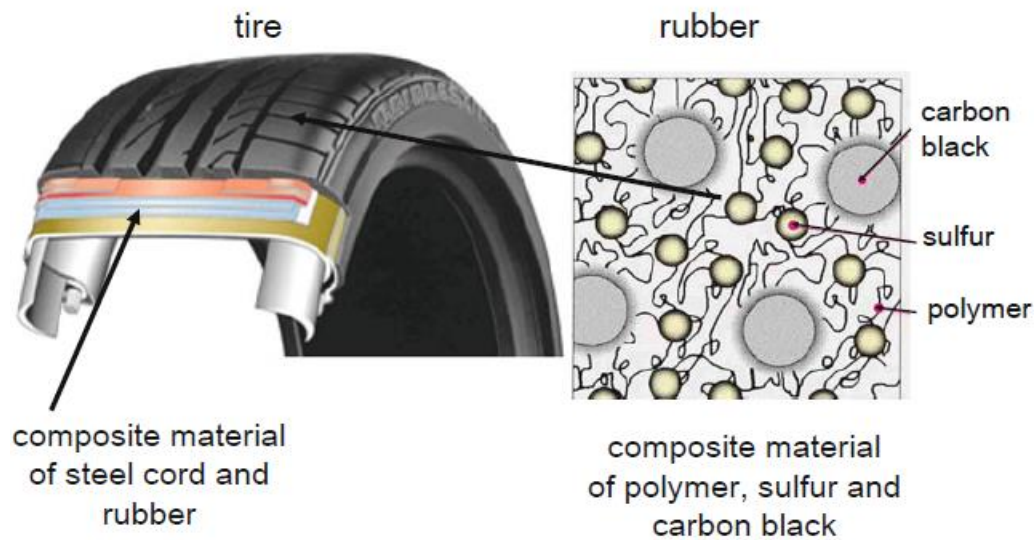


Figure 1: Composite structure and composite materials of a tire

2.1.1.1. Chemical composition

A tire is made up of various materials and structural components that improve the tire's performance and properties. The composition of a tire varies depending on its size and form. Rubber resin, which is a mixture of natural and synthetic rubber hydrocarbons, makes up about 70% of the total weight of car tires and 65 percent of truck tires. Truck tires, on average, have a higher natural rubber content than car tires. Tire reinforcement materials include steel, fiber, and carbon black. The volume of steel wire used in truck tires is higher than in passenger car tires. As shown in fig.2, the average content composition of new and used passenger car and truck tires [3].

Tyre materials	Car		Truck	
	new	used	new	used
Rubber hydrocarbon	48	47	45	43
Carbon black	22	21.5	22	21
Steel	15	16.5	25	27
Textile	5	5.5	-	-
Zinc oxide	1.2	1	2-2.2	2
Sulphur	1	1	1	1
Others	8	7.5	6	6

Figure 2: Average composition in % of new and used passenger car and truck tires

2.1.1.2. Physical composition

Tires differ significantly depending on their application, not just in terms of material composition, but also in terms of structural elements, construction, and total weight. The weight of a tire ranges from 7 kg for a passenger car tire to about 60 kg for a truck tire on average. Tires can meet a variety of requirements and demands based on their structure, including reliability, economy, driving safety, and others.

Tread strip, belt, casing, inner lining, sidewall, bead reinforcement, and bead core are the basic structural components of tires. While all components affect a tire's existence, the casing's longevity has a direct impact on the potential reuse of post-consumed tires, especially in the case of retreading. The building methods are the most critical division of tires into diagonal and radial tires. The reinforcing material is configured differently in each construction. The introduction of the radial tire concept significantly changed design and had an impact on meeting today's tire specifications and requirements. As a result, the radial tire now dominates the passenger and truck market in the majority of countries.

2.1.1.3. Thermal properties

A tire's calorific value ranges from 30 to 35 MJ kg⁻¹ (8.3-8.5 kWh. kg⁻¹). Given their high hydrocarbon content, it's no surprise that tires are an outstanding fuel, offering calorific values comparable to those found in traditional fossil fuels. As a result, used tires are suitable alternative fossil fuels [3].

2.2. Environmental impacts

The post-consumption stage of a tire is the source of the most serious environmental concern. A tire does not have a major environmental effect when it

is treated properly. When disposed of, on the other hand, it can pose significant environmental and public health risks. Tires are resistant to natural decomposition, resulting in a build-up of solid waste that harms the climate, natural beauty, and scenic value of the landscape. When disposed of by landfills, tires remain intact for decades posing potential risk for leakage of zinc, Sulphur and other pollutants. Landfilled tires pose a hazard to soil, groundwater, and surface water in this regard. Furthermore, when whole tires are landfilled, they have a tendency to migrate, breaking the sanitary landfill limit, increasing landfill instability [3].

Tires in landfills are both a fire hazard and a health hazard. Major fires can continue for days or weeks, impacting air quality due to uncontrolled releases of contaminants. Landfilled tires can gather rainwater and windblown pollen due to their shape, creating an atmosphere that is conducive to rats, rodents, and mosquitoes, both of which pose health risks, like mosquito-borne diseases. Furthermore, recycling used tires in landfills is a waste of useful resources and energy. In this regard, future used tire management should pay special attention to alternatives to this disposal method [3].

When tires are burned, air contaminants are released; however, flue gas treatment facilities can effectively regulate this release. Despite the removal of zinc oxides and up to 90% of SO_2 by scrubbers and other end-of-pipe environmental technology, incineration only produces 24 grams of CO_2 per million joules. This is the same amount of pollution generated by a coal-fired power plant [3].

2.3. Material Recycling: Treatments and Technologies

Tire recycling treatments vary from simple mechanical cutting or compression devices to advanced, multiphase chemical, mechanical, and/or thermal processes that overcome many of the major obstacles to thermoset rubber recycling. The treatments and technologies that have developed, in particular, do not attempt to dissolve or melt the rubber into the virgin compound. Rather, they want to take advantage of and improve those aspects of the compound [4].

Treatment is divided into four categories. Each can be broken down into its basic functions, which become more complex as the levels progress. Capabilities may be increased by repeating a procedure or by combining two or more technologies to achieve the desired outcome [4].

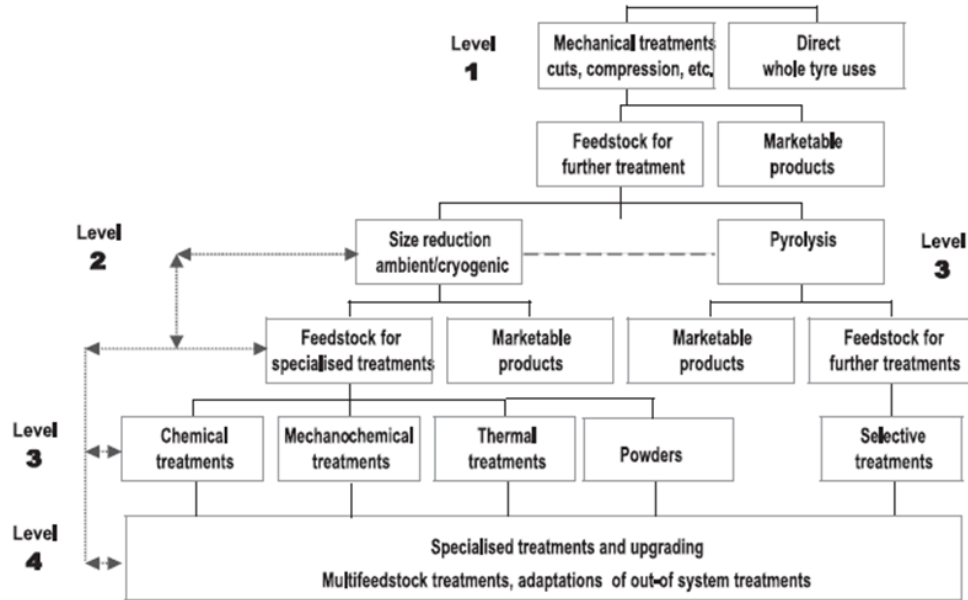


Figure 3: Schematic of the four levels of treatment

As shown (fig.3) presents a schematic diagram of the four levels of treatment and illustrates the progressive, often inclusive nature from the “first cut,” by mechanical means, through the “higher level” specialized treatments and technologies which add distinctive characteristics or properties to the material outputs.

2.3.1. level 1 treatments: destruction of the structure of the tire

Car and truck tires are used as feedstock in these treatments. They are simple mechanical devices that kill one or more of the tire's physical characteristics, such as form, load bearing power, and rigidity. They're made to make materials that can be used for basic civil or environmental engineering items right away, or as feedstock for more recycling. Bead, sidewall, and tread removal, compression, baling, and cutting are the most popular techniques [4].

2.3.2. level 2 treatments: liberation and separation of the elements of the tire

These treatments isolate the material's main components, namely the rubber, metals, and textiles. The most popular technologies for treating tires are ambient and cryogenic size reduction, as well as some newer technologies such as microbes and water jetting [4].

2.3.3. level 3 treatments: multi treatment technologies

By using mechanical, thermal, chemical, mechano-chemical, or multi-treatment methods, this category of treatments and technologies further processes the first and second level material outputs to change one or more characteristics. Level 2 outputs are sometimes used as feedstock [4].

2.3.4. level 4 treatments: material upgrading

Level 4 treatments refine, enhance, alter, or create new characteristics or properties in materials created by Level 3 treatments, which are typically used as feedstock. Among the most representative outputs are updated reclaim, reactivated, surface adjusted, or devulcanized materials, upgraded char (carbon products), and new compounds [4].

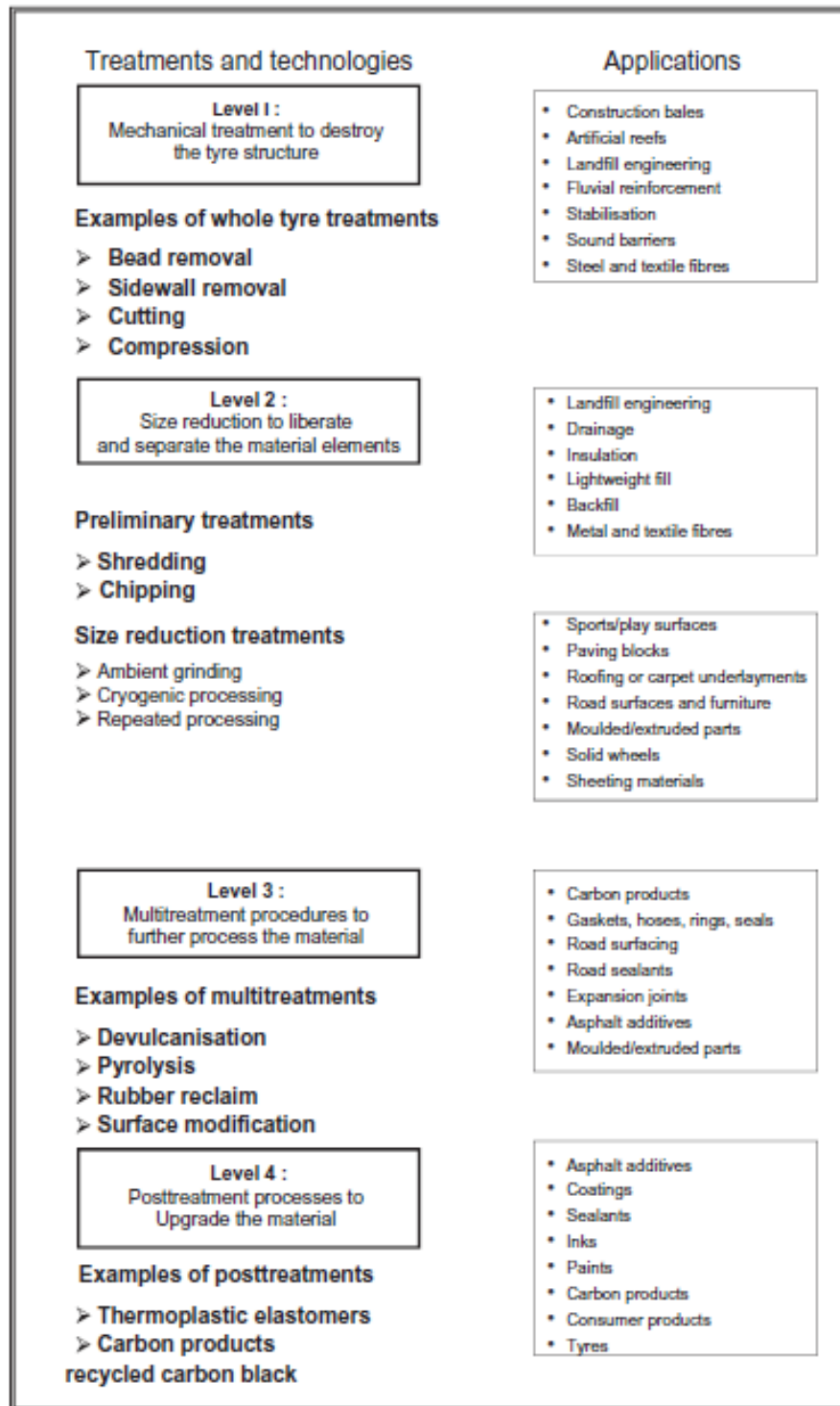


Figure 4: A summary of the treatment levels.

2.4. Project treatment technique:

In our project we are concerned with level 2 of tire treatment due to the reduced size of rubber produced by grinding, grinding is mainly divided into two categories [5]:

a) Ambient grinding:

Since all size-reduction steps take place at or near ambient temperatures, no cooling is used to embrittle the rubber particles.

b) Cryogenic grinding:

Since whole tires, or tire chips, are cooled to a temperature below -80°C using liquid nitrogen.

- **Ambient grinding:**

A preliminary shredder is used to process the tires in a standard plant configuration. The tire chips are then fed through a granulator, which reduces them to less than 10 mm (0.38 in.) in diameter. This separates the rubber granules from the majority of the steel and fiber. The steel is magnetically removed after leaving the granulator, and the fibre fraction is removed using a mixture of shaking screens and wind sifters [5].

Although 10 mm rubber granules are in demand, most applications need finer mesh content, usually in the 0.6-4.0 mm range (5-30 mesh). As a result, most ambient grinding plants use several grinding phases in succession. Secondary granulators, high-speed rotary mills, and extruders, screw presses, or cracker mills are the most popular machines used for fine grinding in ambient plants [5].

Ambient grinding is the preferred technology to produce relatively coarse crumb rubber material 0.6-4 mm diameter which is ideal raw material for rubber tiles and rubber flooring manufacturing [5].

Chapter 3

Rubber tiles and flooring benefits

The perfect robust flooring is non-toxic over its life cycle, functional (hygienic and easy to clean), long-lasting, dry, silent underfoot, visually appealing, and cost-effective. Although this ideal material does not yet exist, some of the existing options come close to achieving these desirable characteristics while posing less chemical risks. Even so, flooring material manufacturers can continue to conduct research and development in order to create even more long-term sustainable materials.

3.1. Considerations for flooring choice:

Although the immediate cost of new flooring is inevitably a top priority, sustainability and "green" practices have become increasingly popular in recent years. These are becoming important decision-making factors in deciding the type of flooring to be installed, and are being integrated into flooring requirements. Although much of the attention on sustainability is on the carbon footprint of products, this emphasis also overlooks another important aspect of sustainability as harmful and hazardous chemical compounds found in flooring, associated materials, and during installation [6][7].

The potential for hazardous chemical emissions and their effect on indoor air quality are major concerns that should be considered when choosing flooring. Cost, surface characteristics (cleaning and disinfection ease), durability, and overall appearance of the floor are all important considerations. While some of the sustainability standards focus on dangerous chemicals in the products, construction methods and associated compounds (glues, etc.) may also affect the final overall quality [6][7].

3.2. Rubber flooring:

Rubber flooring's environmental effect is directly proportional to the type of rubber used. The only way to know how green a material is to understand where it comes from, how it was made, and how it arrived at your place.

3.2.1. Types of Rubber Flooring:

3.2.1.1. Synthetic Rubber Floors:

When it comes to rubber products, this is the least environmentally friendly choice. Petroleum is used to make synthetic rubber, which is a non-renewable resource. Despite this, the manufacturing process for this material is both energy efficient and low-impact. Synthetic rubber floors have the advantage of being more durable and long-lasting than natural rubber alternatives. Although finite resources are used in their processing, the long life of the finished product helps to balance this out. This effect can be amplified in some cases by recycling the rubber floor at the end of its life cycle.

3.2.1.2. Natural rubber

Natural latex derived from the sap of rubber trees is used in the production of certain rubber flooring materials. The resulting tiles and sheets are long-lasting, water-resistant, and simple to clean and maintain. The disadvantage is that natural virgin rubber flooring has a strong odor that can irritate some people. With adequate ventilation, this should fade with time.

3.2.1.3. Recycled rubber

These are the most eco-friendly rubber floors available. This material, which is made from recycled rubber such as that used in old car tires, helps to reduce waste build-up, making it a low-impact floor covering option. The manufacturing process is low-cost and energy-efficient compared to most other resilient flooring options. It is also, in many cases, the most inexpensive rubber flooring alternative. While recycled rubber flooring is generally stronger and more durable than natural rubber flooring, there are a few drawbacks.

Due to benefits of recycled rubber ecologically, economically and energy efficiency, our project is concerned with this type of rubber.

3.2.2. Characteristics of rubber flooring:

3.2.2.1. Comfort

Spend a lot of time standing up. Standing exhaustion can occur with hard-surface flooring, which can lead to leg pain and back issues over time. Rubber flooring, on the other hand, solves this issue by conforming to the shape of your foot and providing a soft, comfortable surface for you to stand and walk on [8].

3.2.2.2. Nonconductive

Rubber is often used as an insulator because it does not conduct electricity naturally. While you certainly don't have to think about electricity flowing through your floors at home, this property does have some practical applications. Nonconductive rubber flooring, in particular, aids in the prevention of static electricity accumulation. As a result, many static-prone companies (such as those that manufacture or store electronics) [8].

3.2.2.3. Bacteria-resistant

Rubber flooring often resists the growth of mold and bacteria, making it a common choice for places like hospitals that need to prevent germs spread. Rubber flooring may be used to build a comfortable play area for small children or a healthy room for elderly people at home [8].

3.2.2.4. Slip-resistant

Rubber flooring's properties make it a good option for the elderly and the very young once again – its slip resistance ensures that these vulnerable individuals are kept safe. Rubber flooring also tends to make kitchens a little less slick [8].

3.2.2.5. Resilient in high-impact areas

Rubber floors do not wear out as quickly as other flooring materials. As a result, it's common in gyms and other high-traffic areas that the floor maintains its appearance despite the high volume of traffic. Furthermore, it can withstand the impact of automobiles and is available for use in your garage [8].

3.2.2.6. Absorbent

While rubber flooring does not absorb liquids, it does absorb impact and sound. Jumping up and down on tile is uncomfortable, but the same motion on rubber flooring is less taxing on your joints. Rubber flooring is probably used in your local gym for ergonomic purposes, but it can also be used in home gyms. Rubber flooring can also help to create a more relaxing gym or play room environment because it absorbs sound [8].

Impact absorption is the main advantage of rubber tiles due to real dangerous of fall accidents. Accidents including falls to the floor below the machinery are a severe concern, with falls being the most common cause of accident. Significant head injuries, such as fractures, concussions, and internal organ damage, may have serious long-term consequences or even result in death. Protective surfacing around playground equipment is commonly stressed in developed countries to provide sufficient shock attenuation and prevent falls [8].

3.2.3.Environmental and medical impact of rubber

Environmental toxicity of leaching and the potential release of carcinogens are among the public's concerns. If rubber crumb is used in playgrounds, the risk is greatest, since Playgrounds are an important part of a child's growth. Metal ions associated with a tire's composition are relatively mobile once released into the atmosphere, and may migrate to ground and surface waters through soil leaching and runoff, but the concentrations of metals that leach from tires and tire chips are typically very low. As a result, the environmental effects of metals from tire leaching is minimal [9].

The existence of an intact route of exposure and direct interaction with contaminants that may be found in tire crumb determines whether or not there is a health risk for children associated with its use in playgrounds. This exposure can happen through ingestion or skin touch. Since no volatile compounds are likely to remain in the shredded crumb, inhalation of volatile constituents is not a feasible route of exposure. As well, ingestion of tire crumb on the ground is not likely. Tire crumb does not contain chemicals with high vapor pressures. Therefore, exposure via inhalation was deemed inconsequential and the resulting hazard negligible.

Dermal exposure was deemed to be unlikely and thus presented a low overall hazard [9].

A new tire needs 103 MJ/kg of energy to make, which equates to 6.9 kg CO₂ emissions per kilogram of tire manufactured. By using recycled rubber instead of virgin synthetic rubber, these emissions can be reduced [9].

3.2.4. Life cycle of rubber flooring

Rubber flooring is a durable, long-lasting flooring option that, with proper care, can last for up to twenty years. This will reduce the cost of waste and replacement for less durable flooring materials significantly. Sheet rubber flooring has a shorter lifespan than tiles. Since individual tiles can be replaced with less waste than removing and reinstalling an entire sheet floor.

3.2.5. Cost

Rubber flooring tiles cost between \$3 and \$8 per square foot, plus \$2 per square foot for professional installation. As a result, rubber tiles are more costly than most other durable flooring options. The cost of thicker, plusher, and better-made products would be higher, but they will last longer.

Chapter 4

Rubber tile composition and parameters

This declaration for conventional Rubber Floor Tile encompasses a wide variety of classes, designs, and colors manufactured by five major manufacturers. Rubber tile may be homogeneous (solid color or mottled) or heterogeneous (layered) (solid color wear layer and mottled wear layer). Both classifications are described. Rubber tile is vulcanized and composed of a homogeneous blend of synthetic and/or natural rubber, high-quality additives, and colorants. This tile is most commonly used in commercial structures. The rubber tile is available in thicknesses of 2.0mm, 3.0mm, 5.0mm, and 6.0mm [10].



Figure 5: Rubber tile

4.1. Rubber tile composition:

Rubber tiles is composed mainly of rubber granules and adhesive “the most commonly used is polyurethane (PU) glue. The quality of rubber tile produced depend mainly on various parameters mainly, the pressure acting on the mixture, temperature and percentage of PU glue to rubber

4.1.1. Rubber granular

4.1.2. Polyurethane (PU) glue

Polyurethane adhesives, also known as PU adhesives, are high-strength adhesives that can be used as both inelastic and permanently elastic adhesives.

They are polymer-based but frequently include other components such as various additives [11][12].

The majority of polyurethanes are thermosetting polymers. Thermosetting polymers, also known as thermoset plastics, are polymers that harden and set when heated. Room temperature is often sufficient to provide the heat needed to set thermosetting adhesives. The adhesive is applied as a liquid or, in some cases, as a paste if it has been filled or changed. Warmth, As the glue hardens, it absorbs heat energy, which drives the chemical reaction, cross-linking to form a strong network of chemical bonds. When heated, polyurethane adhesives do not melt [11][12].

4.1.2.1. The main advantages make PU glue ideal for rubber tile manufacturing [11][12]:

- High resistance to weathering, UV, environmental influences and its ability to set in high moisture conditions
- Will set in a wide range of temperatures
- High resistance to aging and high structural strength
- High impact and shear strength
- Outstanding bridging ability with the possibility to join even large gaps
- Good properties for large area bonding
- Clean, simple and good processing possibilities
- Suitable for many different surfaces indoors and outdoors
- 100% solids so it does not tend to crack and shrink as it sets.
- Once set it will not creep.

4.2. Manufacturing of tile:

The first step in recycling tires is grinding to remove rubber powders/granules from steel and organic fibers. Ground tire rubber (GTR) is a recycled material that has the ability to be reprocessed further. Most rubber products are made by applying 5-8 wt percent binder (polyurethane, PU, based) to GTR and molding by compression at low pressure and temperatures ranging from room temperature to 120°C. Agglomeration improves with increased pressure and temperature. The amount of time required for binder curing is determined by the size of the product [13].

The quality of rubber tile produced depend mainly on various parameters mainly, the pressure acting on the mixture, temperature and percentage of PU glue to rubber.

4.3. Manufacturing parameters:

The recycling of exhausted tires by compression molding of ground rubber is simple and inexpensive: the most widely accepted theory about this method describes the impact of pressure and temperature as follows. Because of the comminution process, broken links are present on the particle surfaces. The pressure is required to bring the particle interfaces into immediate contact, whereas the heating provides the energy to break the cross-link bonds and increase molecular mobility; thus, the broken links on the surface of the rubber particles initiate new links, thereby “sintering” the particles into a single piece.

Furthermore, if a residual reactivity is present in the ground material, polymerization occurs in the bulk powder as well as on the particle contact surface. Another important effect of temperature is material softening, which causes more contact between the particles under pressure. All of the temperature effects mentioned above are beneficial to the agglomeration of rubber particles, but the temperature increase has a limit due to the possibility of material burning or degradation.

4.3.1. Pressure:

Pressure between the mould and the rubber particles, as well as pressure within the same rubber particles, reduces porosity, both on the component surface and in the bulk. As a result, raising the moulding pressure was required to increase plate density, as shown in Fig. 6. The lower density value () was related to the lower pressure value (MPa): raising the moulding pressure up to (MPa) resulted in a rapid decrease in density to 1.05 g=cm3 [14].

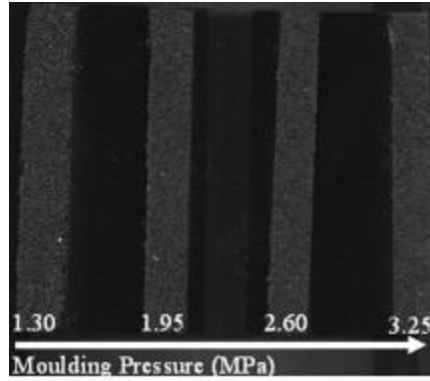


Figure 6: Effect of molding pressure on porosity and density of rubber

In addition to the density, the percentage thickness and length reduction were recorded in Fig. 7. The reduction in thickness is highly dependent on the molding pressure, and its pattern is very close to that of the density. In reality, raising the molding pressure resulted in a peak in density and thickness reduction: length reduction increased as well, due to higher normal stresses and the resulting transverse deformation, but no peak was observed [14].

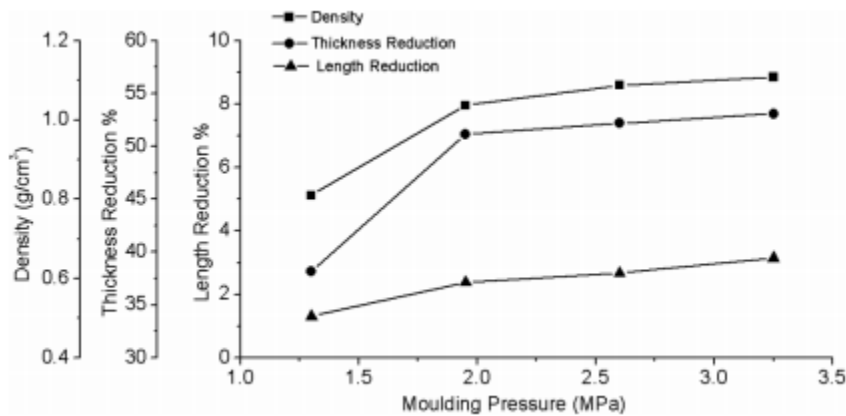


Figure 7: Effect of pressure on density, thickness and length reduction

Density is a significant parameter for evaluating the effectiveness of the molding process, but it is not sufficient on its own: analyzing the tensile strength and strain at break of the molded parts may provide useful information about the adhesion among the rubber particles. Figures 8 and 9 demonstrate how these properties change with molding strain. By increasing the molding pressure, the tensile strength improves [14].

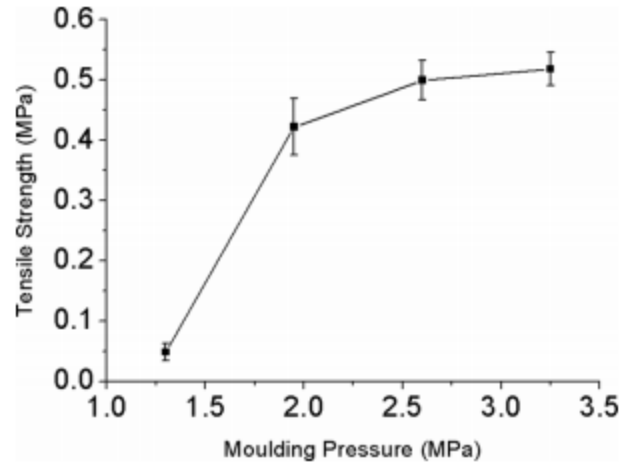


Figure 8: Effect of pressure on tensile strength

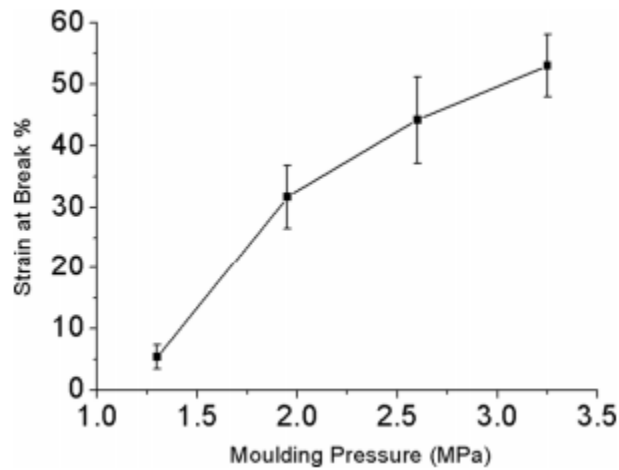


Figure 9: Effect of pressure on strain at break %

Rubber hardness is strongly influenced by the material's elastic properties. The Shore A hardness test results are shown in Fig. 10, the reported trend confirms that a significant improvement in elastic properties was achieved with a pressure greater than 2 MPa. Mechanical properties change slightly as this value is increased [14].

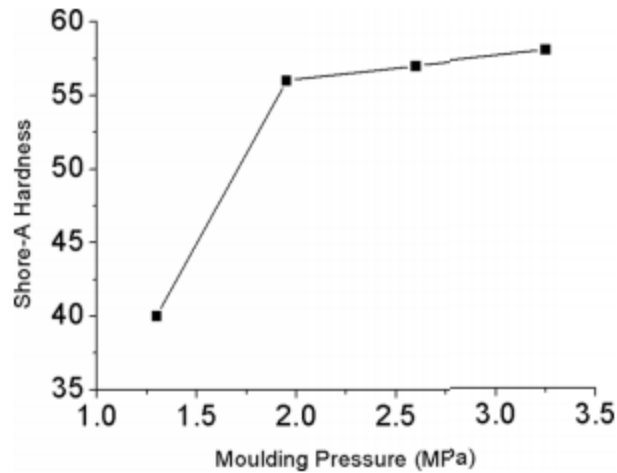


Figure 10: Effect of pressure on hardness

4.3.2. Temperature:

The effects of curing temperatures were also investigated in order to determine the most advantageous thermal system. After curing at 60°C, the best tensile properties were obtained. When cured at 25°C, the properties were slightly stronger than when cured at 75 or 85°C. The decrease in tensile performance might be a result of fast congealing of the PUR adhesive, before it spread out through the mixture and wet the rubber particles. Curing at temperatures below 60°C does not damage tensile properties as much as curing at higher temperatures [14].

The effects of curing temperatures on compressive properties were less obvious (Fig. 11&12). In reality, the compression at break or yield was nearly independent of the current temperature. Only after curing at 85°C were large decreases in compressive strength observed. Otherwise, all compressive properties tested for curing temperatures ranging from 25 to 75°C were similar [14].

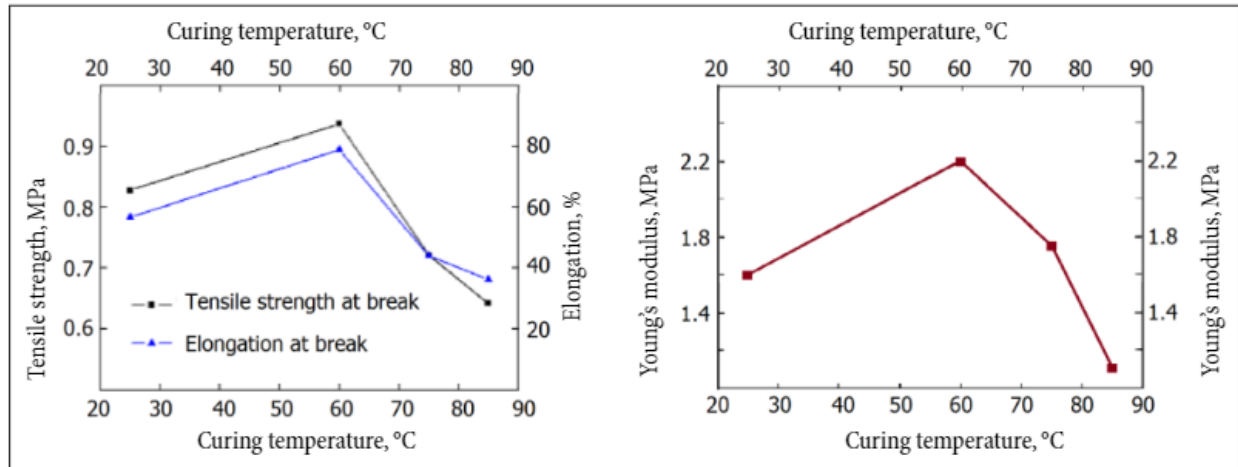


Figure 11: Effect of curing temperature on tensile strength, elongation and young's modulus

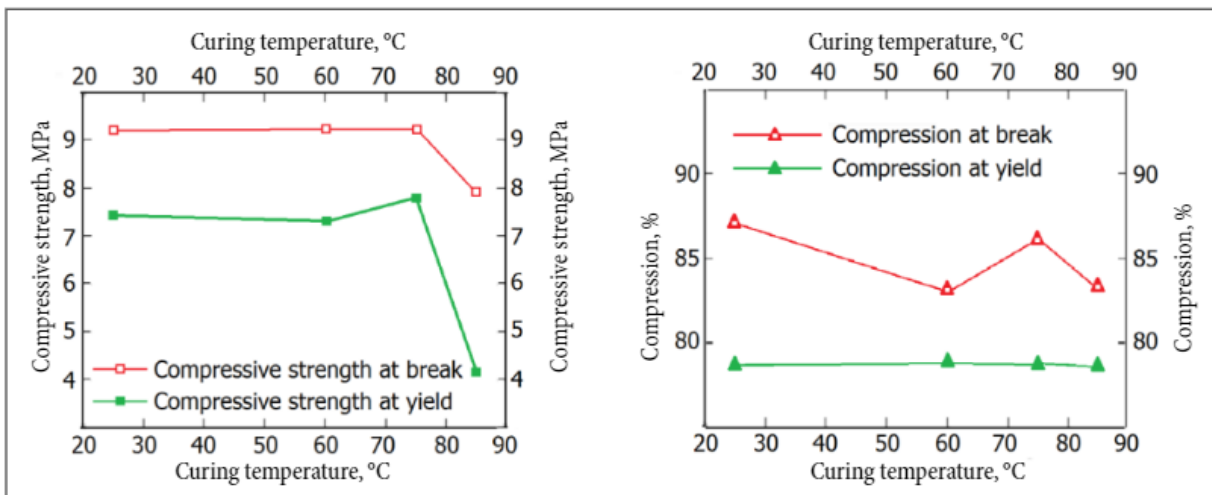


Figure 12: Effect of curing temperature on compression

4.3.3. PU adhesive concentration:

PU adhesive concentrations of 30 and 40 wt. percent produce the best tensile and compressive properties. Because several additional factors may still be necessary, further optimization of curing conditions, hardener selection, and incorporation of supplemental additives may significantly change this

concentration. For example, it would be anticipated that rubber particles will swell in the presence of the PUR adhesive, making bonding more powerful [15].

Surface morphology variations can also play a role in rubber particle swelling, but they may have a greater impact on wet-ting and void filling. If the surfaces of the rubber particles were highly uneven, several more voids would remain unfilled if they were not filled with adhesives. Rough particle surfaces, on the other hand, should increase the total area of bonding. This factor will boost the composites' strength and other physical mechanical properties [16][17].

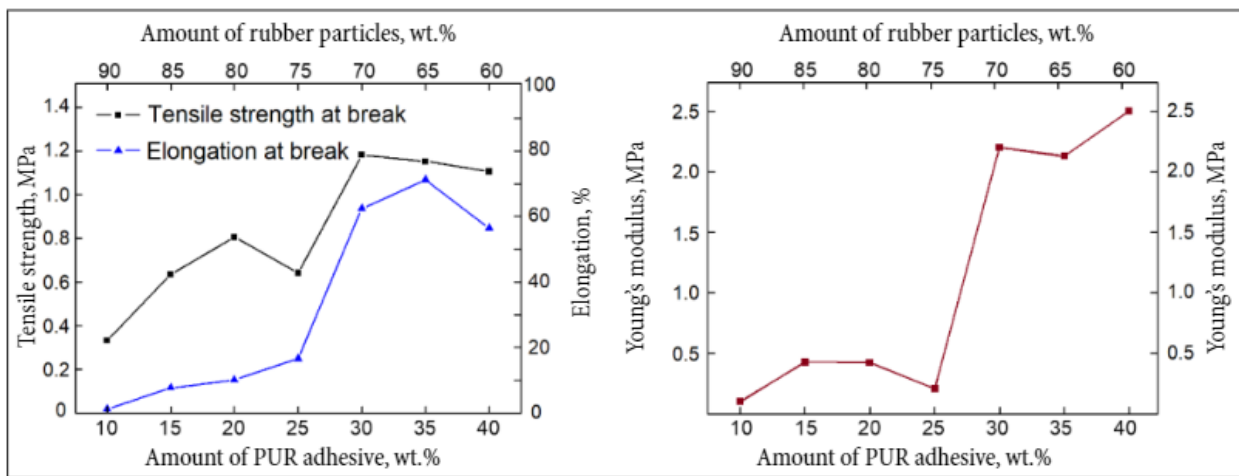


Figure 13: Relation between percentage of rubber to PU glue and Tensile strength, elongation and young's modulus

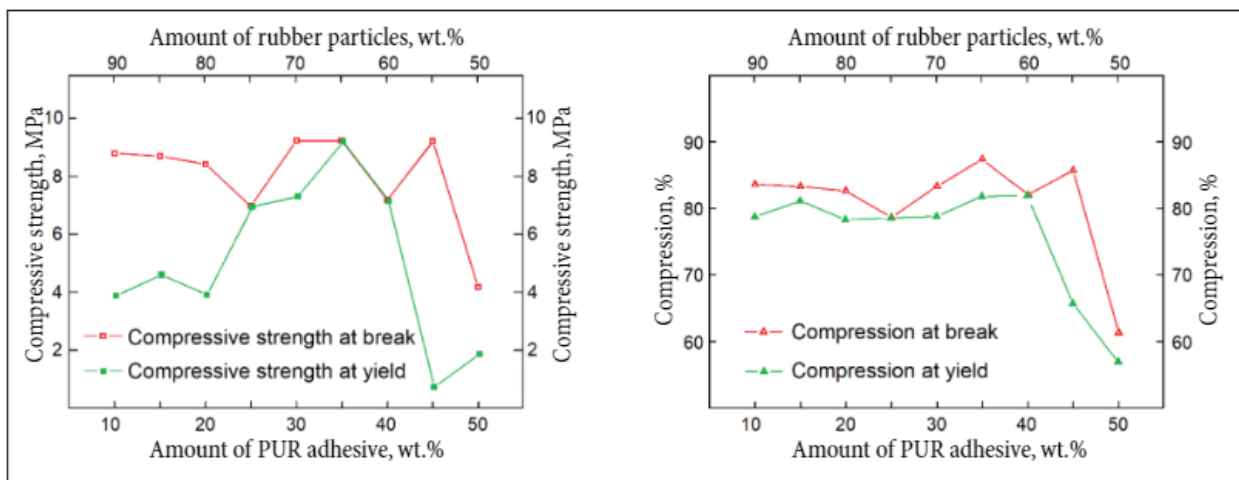


Figure 14: Relation between percentage of rubber to PU adhesive and compressive strength

4.4. Materials and method:

According to Lucignano, C., Gugliemotti, A. and Quadrini the pressure required to produce a rubber tile of high hardness, tensile strength and density is 3.5 MPa. Key information in this process is force required to act on rubber mixture which is important for press construction, so in order to produce a rubber tile in form of dog bone with a dimension of 200mm*165mm of overall affected area 27115.8 mm^2

$$F = PA = 3.5 * 27115.8 = 94905.3N = 9.678 \text{ ton}$$

On other way, by contact with a Chinese company of rubber tiles manufacturing “JINGYUAN Group CO.,Limited” it is known that the pressure per unit area required to produce a rubber tile is 20.41 Kg/cm^2 which is equivalent to 204.1 ton/m^2

$$F = \frac{204.1}{10^6} * 27115.8 = 5.53 \text{ ton}$$

The datasheet of the XLB-25T is as below table, from the datasheet you can see that this press is very small, normally for experiment use only. Not suitable to produce rubber tiles in bulk.

Clamping Pressure:	0.25MN(25Ton)
Unit Area Pressure:	20.41Kg/cm2
Daylight Opening:	220mm
Hydraulic Cylinder:	1pcs
Maximum Stroke of Plunger:	220mm
Working Layer Quantity:	1 Layer
Motor:	1pcs 2.2Kw Motor
Heating Type Available:	Electricity
Control Method:	Automatic Control Mold Open and Close,Manually Push and Pull Mold in and out
Temperature:	Max 200 ^o C for Electricity type
Weight:	About 800kgs
Production Lead Time:	10-15Days

According to Strakšys, A., Valsiūnas the optimum curing temperature is 75 celsius and the percentage of rubber to PU glue providing best mechanical properties is 60:40 [18].

To know more about manufacturing parameters and to make sure that will match previous data we get from researches. The company told us that the ratio of PU glue to rubber powder is 1:6 which means 17% glue to 83% rubber.

4.5. Experimental Work:

Due to data conflict between research and company, we had to do experimental tests on company and research data to know which of them is accurate.

4.5.1. First Test

By mixing rubber and PU glue with percentage of 60:40 with thickness of 50 mm, acting on the mixture by force of 8 ton at a duration of time of 8 minutes. The tile produced from this test was weak and crumbled due to excess of glue in a mixture which lead to break during its extraction from the mold as shown in fig.18



Figure 15: Mixing of rubber particles with PU glue



Figure 16: Pressing of rubber mixture with force of 8 ton

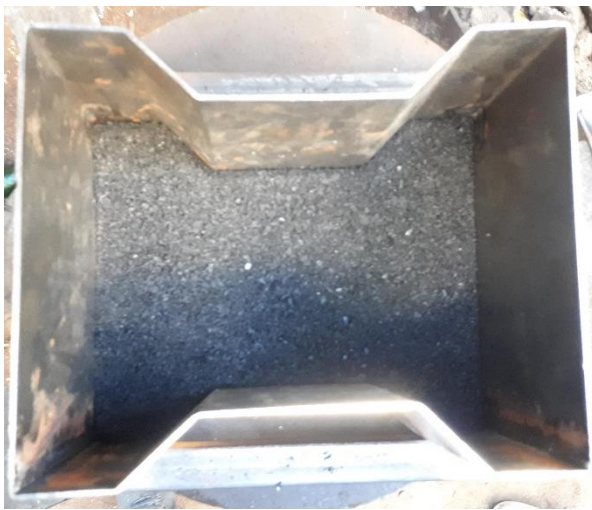


Figure 17: Final product



Figure 18: First test tile

4.5.2. Second test:

By mixing rubber and PU glue with percentage of 60:40 with thickness of 50 mm, acting on the mixture by force of 8 ton at a duration of time of 8 minutes. The tile produced from this test is more coherent and has more strength than that produced in the first test



Figure 19: Second test tile

Chapter 5

Mold design

5.1. Initial Mold

Initially, we have designed the mold using 3 mm sheet metal in order to perform experimental work, we have illustrated in previous chapter, to minimize the cost and to ensure that the process parameters is accurate and productive.



Fig 20: Initial sheet metal mold

During the first test the mold male have failed and deformed during acting on it by required pressure. This deformation is due to acting by pressure on small area from the mold male.



Fig 21: Initial mold male failure

5.2. Mold development:

All rubber tiles machines depend mainly on metallic mold made of steel in order to withstand the high pressure and force acting on it. Due to high cost and difficulty of creation wide range of shapes and complex forms of mold we decided to replace metallic mold with plastic fabricated by 3D printing. Usage of this type of molds inspired by the plastic 3D printed molds used in injection molding process.

5.2.1. 3D Printing

3-D printing, also known as additive manufacturing (AM) or rapid prototyping, has been around for a long time. The 3-D printer functions similarly to a regular ink jet, except instead of printing layers of ink on paper, it uses materials to construct a three-dimensional object. The term additive manufacturing (AM) covers a wide range of technologies, including 3-D printing, rapid prototyping (RP), direct digital manufacturing (DDM), layered manufacturing, and additive fabrication. In many industries, additive manufacturing the industrial form of 3-D printing is already being employed to create some niche items. The concepts additive manufacturing and 3-D printing are now interchangeable. The technology or additive process of depositing consecutive thin layers of material on top of one other to produce a final three-dimensional object is known as additive manufacturing. The thickness of each layer ranges from 0.001 to 0.1 inch. A wide variety of materials can be utilized, namely: plastics, resins, rubbers, ceramics, glass, concretes, and metals. The use of technology is referred to as rapid prototyping. This was AM's initial application, and it helped to improve time-to-market and creativity. It is the process of rapidly producing a model or prototype of a part or finished product. Before mass production, this part or final good will be thoroughly inspected and inspected. The majority of commercial 3-D printers offer similar features. The printer converts the design into a three-dimensional item using computer-aided design (CAD). The design is then divided into many two-dimensional plans that direct the 3-D printer where to place the material layers.

5.2.1.1. Advantages of 3-D printing over traditional manufacturing

3-D printing is genuinely inventive; it opens up new doors and opens up a slew of options for businesses trying to increase their manufacturing efficiency.

Traditional procedures are considerably streamlined by 3-D printing, which has the potential to become the norm in the coming decade. According to various academic studies, 3-D printing is an effective technique for reducing supply chain complexity in a variety of ways. 3-D printing has five major advantages over traditional manufacturing methods: Cost, speed, quality, innovation/transformation, and effect are all factors that need to be considered. Traditional manufacturing methods will not be replaced by AM. It is, nevertheless, projected to transform a number of specialized fields. Exponential growth is projected in the near future.

5.2.1.2. Uses of 3-D printing in manufacturing

- a) Mass customization
- b) Decentralized manufacturing
- c) Mass customization
- d) On-demand manufacturing
- e) Component manufacturing
- f) Printing complete systems
- g) Quality improvement
- h) Modifications and redesigns without penalties
- i) Increased supply chain proficiency
- j) Sustainable manufacturing initiatives
- k) Manufacturing of parts on demand

5.2.1.3. Application of 3-D printing

- a) Aerospace
- b) Automotive
- c) Medical
- d) Architectural
- e) Retail

5.2.2. Mold material

The materials used for 3D printing are as diverse as the products that result from the process. Over the last five to ten years, 3D printing material advancements have grown. Today's 3D printing technologies are capable of producing prototypes and end-use production parts in a wide range of plastic and metal materials. We focused on plastic material due to its availability and its affordable cost. The most common plastics are PLA, ABS and Nylon.

1. PLA (Polylactic Acid):

PLA is an excellent material for early design models because it is simple to use, office-friendly, and compatible with breakaway supports, which print and remove more quickly than dissolvable supports. PLA is a biodegradable corn-based plastic that can be used in industrial processes. PLA's brittleness is one of its potential drawbacks; if it fails, it fractures catastrophically, while other polymers can bend. The other PLA, on the other hand, has a low glass transition temperature (typically between 44 and 63 ° C). As a result, it's not ideal for high-temperature applications. And something as simple as a hot car in the summer will soften and distort pieces.

2. Nylon

Nylon is a low friction material that boasts very high strength and durability. The material is flexible especially for thinner models. Its layer bonding is the strongest of all commonly used FDM filaments. Some types of nylon are used in medical devices, toys, and FDA approved products. The main drawback of nylon is it can also be negatively impacted by UV exposure, primarily from direct sunlight.

3. ABS (Acrylonitrile Butadiene Styrene)

Due to its clean surface finish, toughness, and heat resistance, ABS is one of the most common materials for injection molded consumer goods. As a result, it's often used to prototype consumer goods that will later be injection molded. The prototype is more durable since it is made of ABS.

ABS has a higher melting point than other filaments, it is also slightly stronger than PLA, so if you want a print with more strength, ABS is the way to go. Because of its strength and durability, your print will last longer.

5.2.2.1. Mechanical and physical properties of PLA, Nylon and ABS

Table 1: Mechanical and physical properties of PLA, Nylon and ABS

Material	Tensile strength (Mpa)	Bending stress (Mpa)	Melting Temperature (°C)	Heat Deflection Temperature (°C)
PLA	61-66	48-110	157-170	49-52 at 0.46 Mpa
Nylon	76	110	220	160 at 0.46 MPa
ABS	46	74	190-270	98 at 0.46 Mpa

Initially, we have chosen ABS material to be material of mold since that its yield stress is higher than stress acting on the mold which is equal to $10 \text{ ton}/m^2$ and due to the heat deflection temperature of ABS which is higher than the operating temperature ($80\text{-}90^\circ \text{C}$), but still all the mechanical properties mentioned before is inaccurate as the properties of these material depend on the infill percentage of the mold will be manufactured [19][20][21].

5.2.3. Mold infill percentage

Infill is beneficial for a variety of purposes. The infill acts as the part's internal support structure; without it, the walls and shells will be held together by nothing! Infill gives the component some stiffness and prevents the walls from deforming collapsing. Since a less dense infill pattern leads to lower print quality and part success, most 3D printing infill patterns are between 30 and 50 percent.

The type of infill you use has little effect on flexural strength; however, if you want to make stronger sections, you can strengthen the shells with a continuous fiber backbone. Continuous fibers can give you better results if you need your element to be stronger or stiffer. Printing a partially solid component is faster, more accurate, and so on. However, different infill geometries may be used for various purposes.

1. Triangular infill

Since triangles are the strongest shape, triangular infill is the most powerful infill design. They have the least chance of deforming and have the strongest support system behind the part's walls. Since the printhead often moves in straight lines across the section, this form of infill prints easily. Triangular infill is one of the best options for infill in 3D printing because of its strength and speed [22].

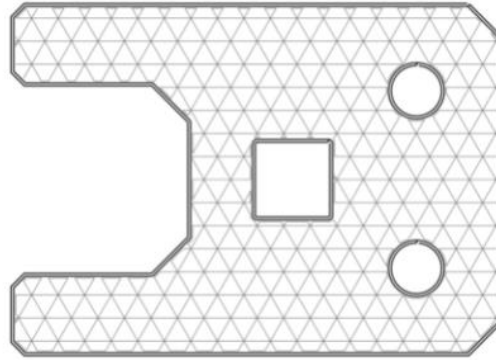


Figure 22: Triangular infill

2. Rectangular Infill:

Since it is made up of a grid of parallel and perpendicular extrusions, rectangular infill is the only form of infill that can achieve a 100 percent dense part. Since the printhead flies in straight lines, rectangular infill prints quickly as well [22].

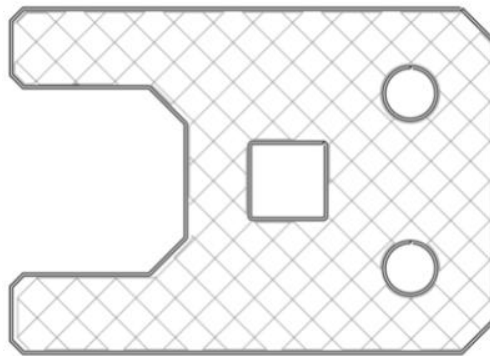


Figure 23: Rectangular infill

3. Hexagonal infill:

Since it is made up of tessellating hexagons, hexagonal infill has the highest strength-to-weight ratio of any of the infill patterns. However, since the printhead must constantly change directions, it takes the longest to print of any infill kind [22].

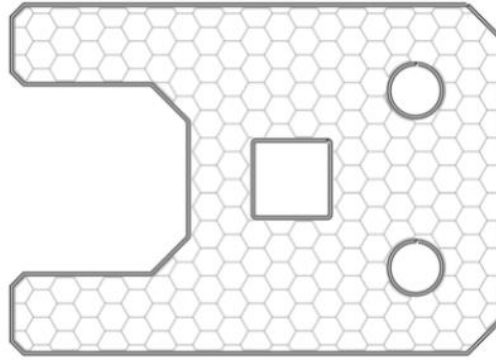


Figure 24: Hexagonal infill

5.2.4. Practical Testing

Since it is difficult and inaccurate to test the infill by finite element, we have tested a prototype of mold printed with 3d printer and of ABS material of 30% triangular infill shape to determine the maximum stress the mold can withstand.

The machine's mold area is $200 * 165 \text{ mm}^2$ affected by 10 ton/mm^2 , the prototype mold is cylindrical of diameter 65mm to be fitted with testing hydraulic press.

$$\frac{200 * 165}{\frac{\pi}{4} * 65^2} = \frac{10}{f}$$

$$f = \frac{\frac{\pi}{4} * 65^2 * 10}{200 * 165} = 1 \text{ ton}$$

So, the prototype mold has to withstand 1 ton to to be considered successful in testing.

By practical testing, the prototype mold can't withstand 1 ton and failed as shown in figure 51, therefore we have tested another prototype with 50% infill to know if it can withstand stress acting on it or not, and the results shows that it can stand for 1 ton without failure as shown in figure52. For higher factor of safety and to assure the safety of the pressing operation, we manufacture 3D printed mold with 60% infill as shown in figure 53.



Figure 25: 30% infill mold test



Figure 26: 50% infill mold test

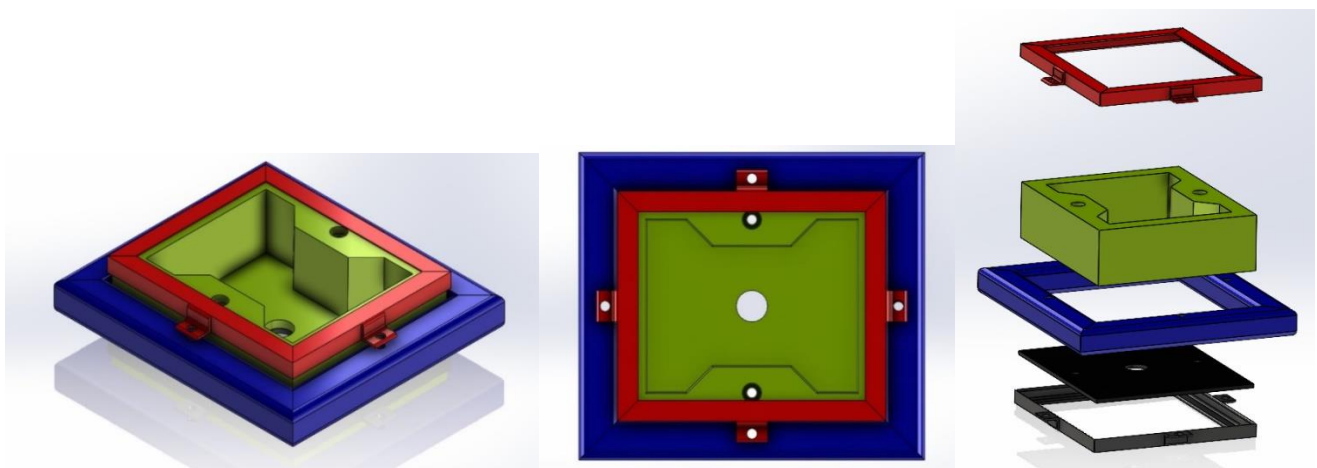


Figure 27: Mold Design

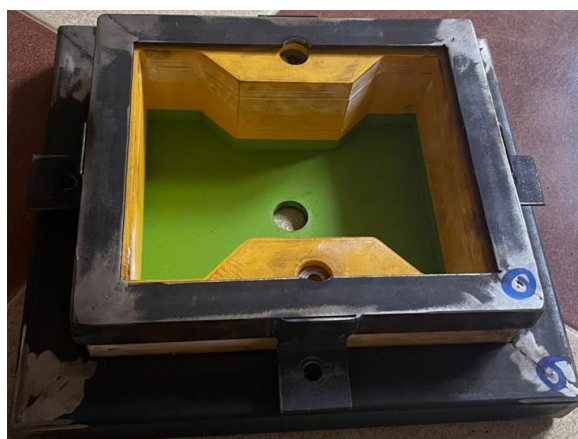
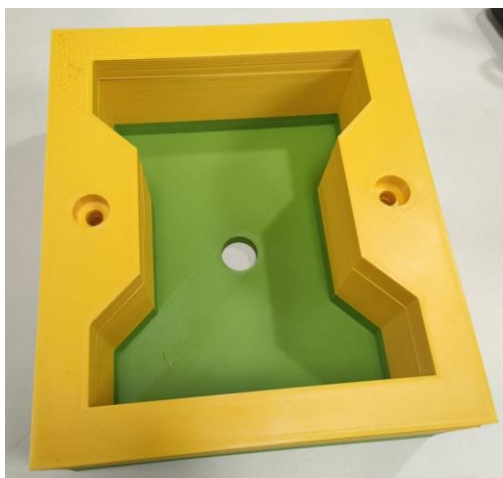
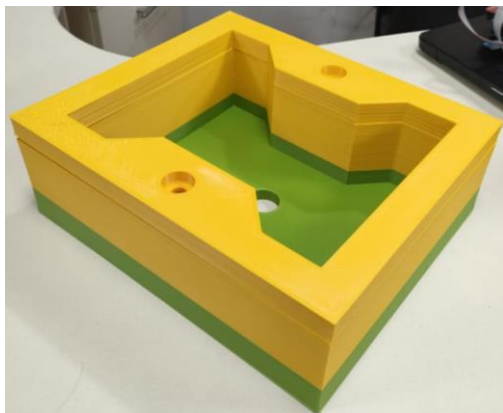


Figure 26: Final Mold

5.2.5. Male of the mold:

The male of mold is 20 mm thick, made from steel 37 and machined on laser cutting machine then drilled to form 3 holes of 10.2 mm in diameter, in order to fit 10 mm cartridge heater whose power is 400 watt. These heaters placed inside the mold male to reach required temperature necessary for tile manufacturing.

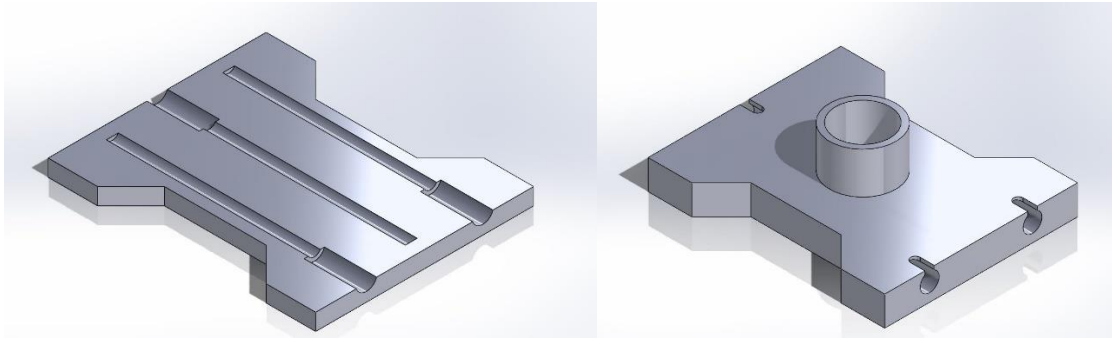


Fig 29: Mold Male Design



Fig 30: Final mold male



Fig 31: 400 watt cartridge heater

Chapter 6

Machine Body Design

A hydraulic press (also known as a machine press) is a system that generates compressive force using a hydraulic cylinder. It works on the same principle as a mechanical lever, but with hydraulics. A hydraulic press is a machine that generates compressive force using a hydraulic cylinder. The hydraulic press's main components are the frame, hydraulic cylinder, and press table. As a result, a hydraulic press is a mechanism that uses fluid pressure to crush, straighten, or mould materials [23].

The hydraulic press principle is based on Pascal's theory, which states that when pressure is applied to fluids in an enclosed system, the pressure stays constant throughout the system. The force generation, propagation, and amplification in a hydraulic press are accomplished by using fluid under pressure. The liquid system has solid-like properties and serves as a very positive and rigid medium of power transmission and amplification [23].

6.1. Main components of hydraulic press

1. Main Cylinder

A hydraulic press's main cylinder is the most important component. Using pressurized hydraulic fluid, a cylinder generates the necessary pushing or pulling force to complete the required operation.

2. Top Platen

The top platen is a steel manufactured or steel cast structure that is situated on the upper side of a vertical press and is designed to handle compressive and bending loads created by the hydraulic cylinder

3. Bottom Platen

The bottom platen of a vertical hydraulic press is a steel manufactured or steel cast structure that carries the compressive and bending loads generated by the hydraulic cylinder. In down-stroke presses, it's also served as a press table.

4. Column, Nut & Chuck-nut

Round Bar or manufactured structure are used as columns. It firmly connects the top and bottom platens. Round bars are threaded at the ends and nuts are given to keep the platen in place; check-nuts are given to keep the main nuts from loosening.

5. Power Pack Units

This is the most crucial component of the machine. It pumps oil at a steady pressure and flow. Introduction to Hydraulic Presses and Pressing the Body into the Cylinder to impart desired speed and force Hydraulic valves, pumps, oil tanks, coolers, hydraulic accessories, manifold blocks, and piping are all included in the power pack. The hydraulic pump can be powered by an electric motor or an internal combustion engine.

6. Control Panel

By controlling the power pack unit, it controls the overall operation and performance of the hydraulic press. It has a motor starter, a push button, an indicator lamp, a current and voltage indication, a contractor, and a timer, among other things. The hydraulic press provides feedback to the control panel via limit switches, pressure switches, proximity switches, thermocouples, and other devices.

7. Hydraulic Piping

Suction port, delivery port, tank line [return line] port, drain line port, pilot line port, oil port [A] for forward motion of cylinder, oil port [B] for return motion of cylinder, and so on are all oil port [holes] on hydraulic valves and pumps.

8. Electric heaters

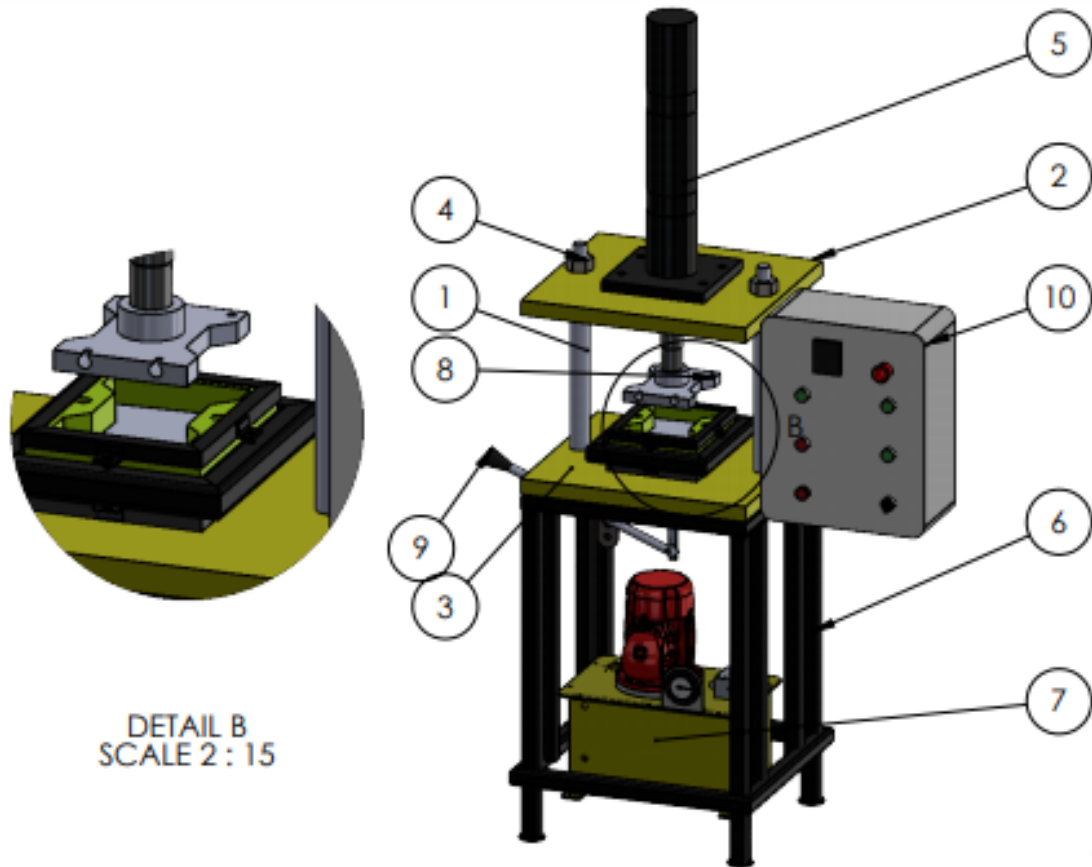
A device that converts electric energy into heat energy in order to improve molding operation

9. Mold

A hybrid 3d printed mold with metal housing

10. Ejector:

Are mounted below the bottom plate, and used to eject the tile after pressing.



PART NO	PART NAME	QTY	Material
1	RODS	2	CHROMIUM STAINLESS STEEL
2	TOP PLATE	1	ST.37
3	LOWER PLATE	1	ST37
4	NUTS	4	ST304
5	HYDRAULIC CYLINDER	1	ST304
6	STEEL FRAME	1	ST.37
7	HYDRAULIC UNIT	1	
8	DIE MALE	1	ST.42
9	EJECTOR	1	ST.37
10	CONTROL UNIT	1	

Fig 32: Machine components

6.2. Hydraulic press body design

The press body composed mainly of upper plate which holds the cylinder, lower plate in which the mold is fastened with, columns which are used in order to connect upper plate with lower plate and act as guide.

6.2.1. Design procedures

Design is a creative art, which starts with idea and ends with three dimensional solid object or a design. Between the start and obtaining the actual design, there are logical steps, the designer has to follow to achieve his goal of bringing the required design into the market. These logical steps are:

1. State the purpose of the design, considering special requirements and limitations
2. Select possible solutions using product concept with the aid of 2D/3D free hand sketching applying 3Fs and KISS concepts
3. Determine the nature of loading (static, dynamic, shock, thermal, etc..)
4. Select appropriate material for each element
5. Determine size and shape for each element through force analysis, stress analysis, applying appropriate design failure theories
6. Modify the element in shape and size to facilitate the methods of manufacturing (DFM) and assembly (DFA)
7. Make the detail drawings and assembly drawing, specifying properly all dimensions, tolerances, materials, heat treatments and levels of surface finish.

Initially, we have designed the machine with more than one product concept in order to be easy in manufacturing, simple in shape and low in cost

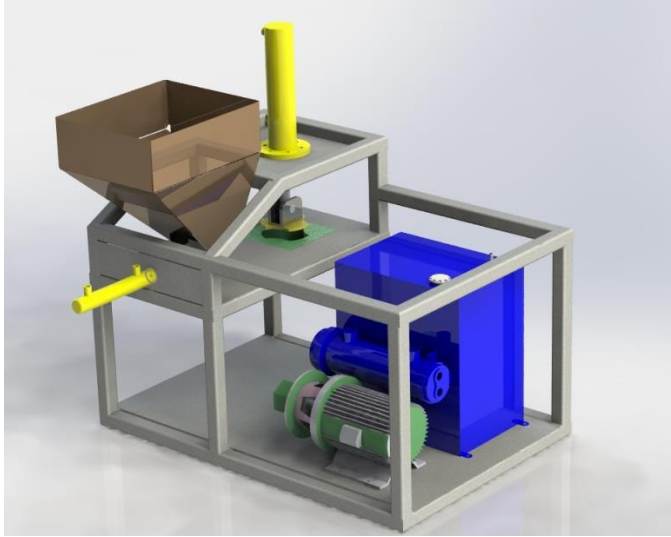


Figure 33: Version 1

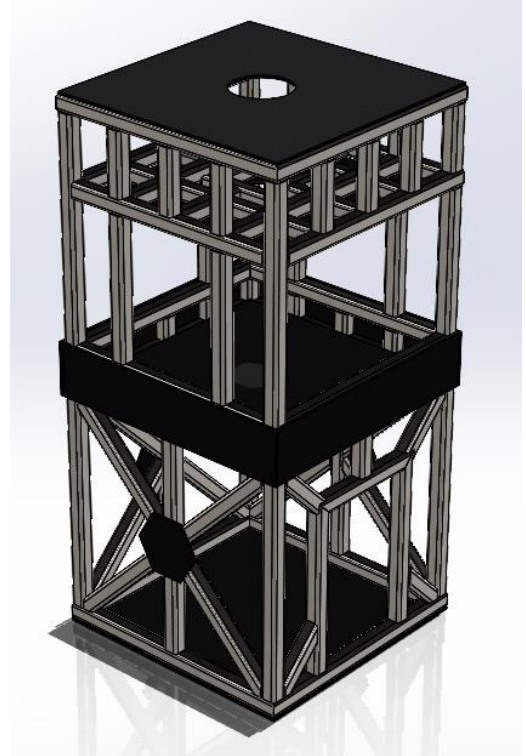


Figure 34: Version 2

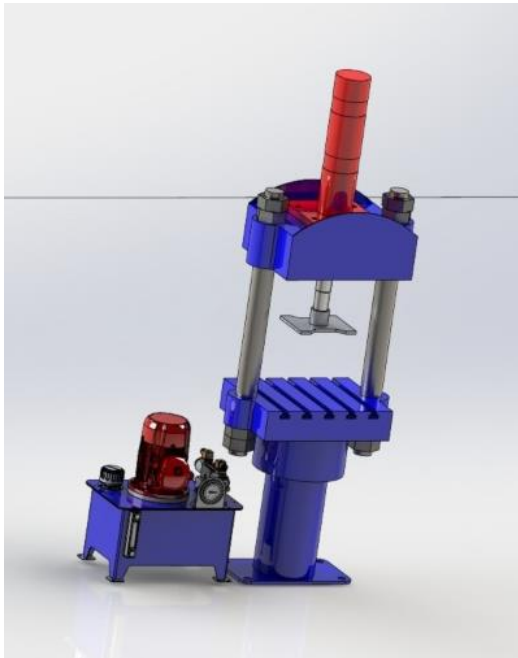


Figure 35: Version 3

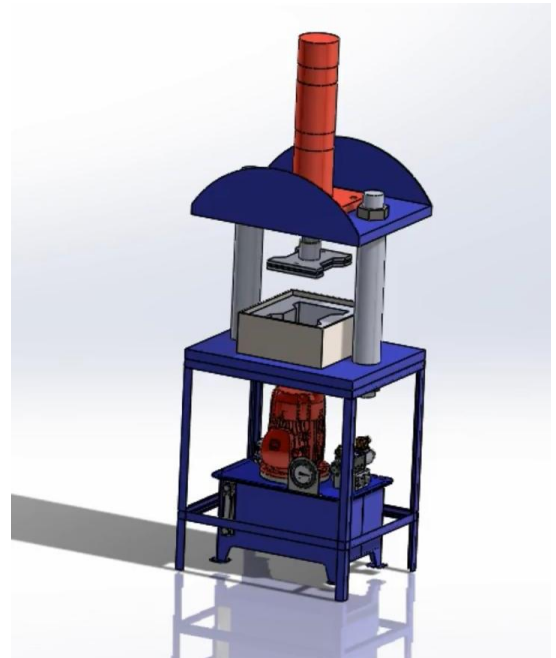


Figure 36: Last version

Due to complexity in shape and difficulty in operations, the design shown in figure 19 have been rejected. The second machine concept shown in figure 20 can achieve the minimum cost but because of difficulty in manufacturing and welding, this design has eliminated too.

Finally, we have selected the design shown in figure 21 by using two columns with little modifications in press table to reduce its cost and for easier manufacturing.

The first advantage of this design is accuracy and pressing load always remain at central axis of main cylinder, and also there is no chance of taking any eccentric load. The second one is that the press is composed of many parts (plates, columns and base) so, we have the ability to change any part of them separately.

The base of the machine is manufactured from 40*40*4 square steel tubes



Figure 37: Final machine design

6.2.2. Design of upper and lower plates

The upper plate of press is the plate which holds the main cylinder and affected by two force, on of them is the force required to press the rubber mixture which is equal to 10 ton, the other one is the weight of cylinder which can be neglected. The force acting on the plate is at its center, so we can consider the plate as a simple supported beam affected by force on its centre. Which mens that only bending stress is affecting on plate

The dimensions of the plate is $500 \times 500 \text{ mm}^2$ made of steel 37 and the unknown dimension is the thickness of the plate

The permissible tensile stress is given by:

$$\sigma_t = \frac{\text{yield strength}}{\text{factor of safety}} = \frac{225}{2.5} = 90 \text{ Mpa}$$

The bending moment is given by:

$$M = \frac{F * L}{4} = \frac{98066.5 * 500}{4} = 12258312.5 \text{ N.mm}$$

Bending stress is given by:

$$\sigma = \frac{M * y}{I} = \frac{12258312.5 * \frac{t}{2}}{\frac{500 * t^3}{12}}$$

The required thickness of the plate is:

$$t = 40 \text{ mm}$$

6.2.3. Design of coloumn:

The coloumn is made of material : Chrome stainless steel whose yield strength is 172.4 Mpa

$$\text{Force acting on each column} = \frac{F}{\text{No. of coloumns}} = \frac{98066.5}{2} = 49033.25 \text{ N}$$

$$\text{Total working stress} = \sigma_t = \frac{\text{Yield strength}}{\text{Factor of safety}} = \frac{172.4}{2.5} = 69 \text{ Mpa}$$

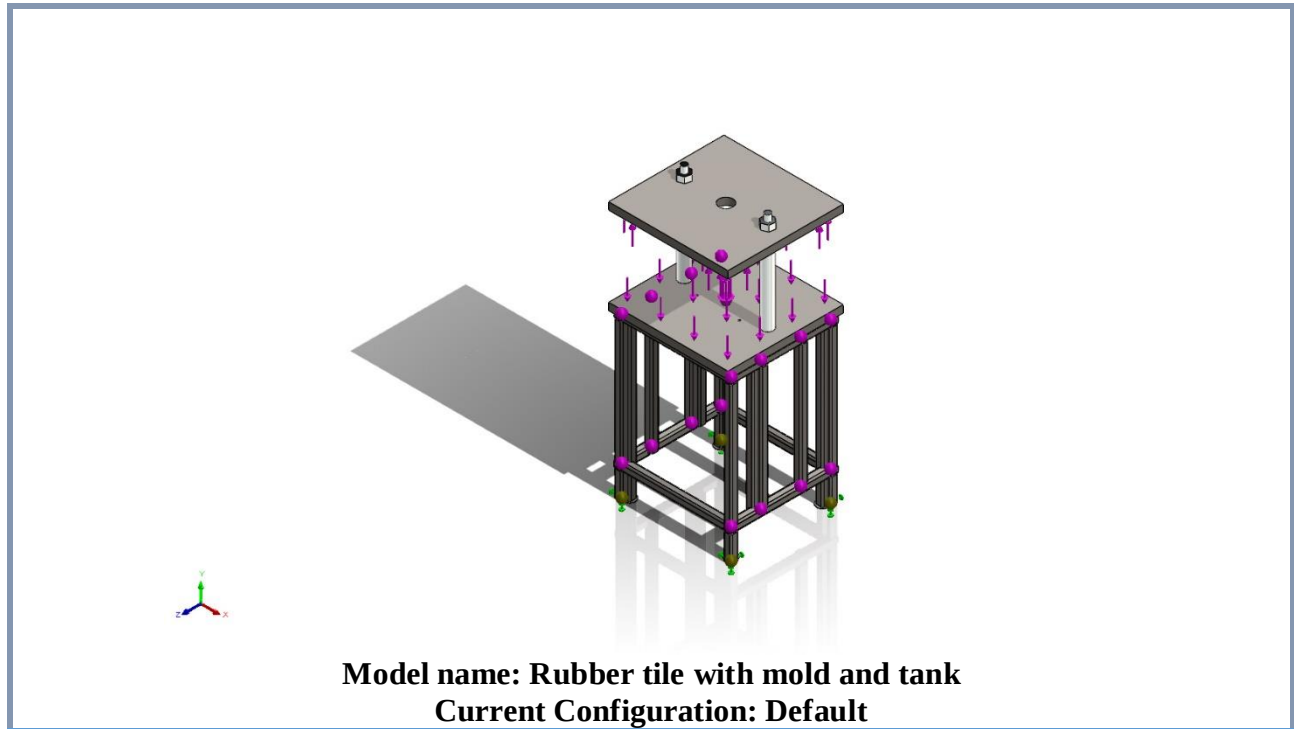
$$\text{Working stress per colomn} = \frac{69}{2} = 34.5 \text{ Mpa}$$

$$\sigma = \frac{F}{A} = \frac{4F}{\pi * d^2}$$

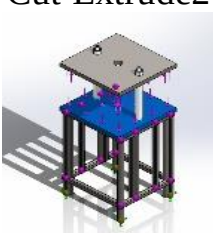
$$d^2 = \frac{4F}{\pi * \sigma} = \frac{4 * 49033.25}{\pi * 34.5} = 1809.6 \text{ mm}^2$$

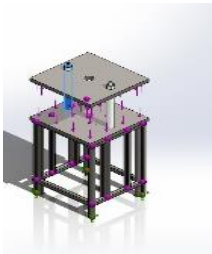
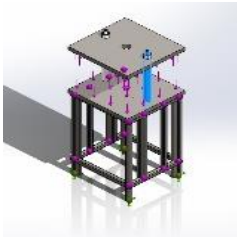
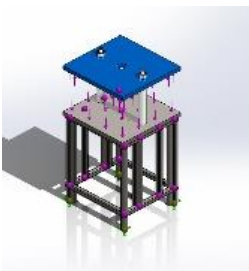
$$d = 42.5 \text{ mm}$$

6.2.4. Static stress analysis



6.2.4.1. Solid bodies

Document Name and Reference	Treated As	Volumetric Properties
Cut-Extrude2 	Solid Body	Mass:100.43 kg Volume:0.0127936 m ³ Density:7,850 kg/m ³ Weight:984.213 N

Revolve1 	Solid Body	Mass:8.51529 kg Volume:0.0010917 m³ Density:7,800 kg/m³ Weight:83.4498 N
Revolve1 	Solid Body	Mass:8.51529 kg Volume:0.0010917 m³ Density:7,800 kg/m³ Weight:83.4498 N
Boss-Extrude1 	Solid Body	Mass:99.5482 kg Volume:0.0126813 m³ Density:7,850 kg/m³ Weight:975.572 N

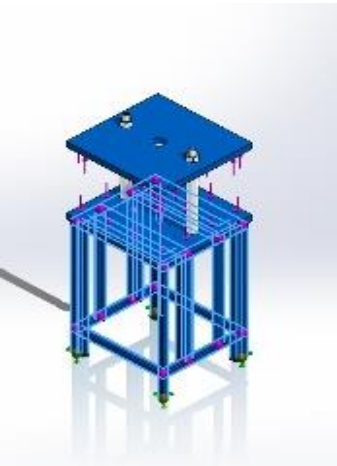
6.2.4.2. Study Properties

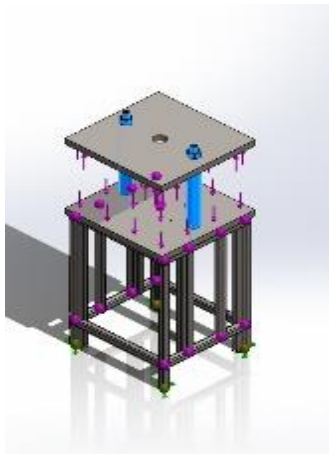
Study name	Rubber tiles machine
Analysis type	Static
Mesh type	Mixed Mesh
Thermal Effect	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off

6.2.4.3. Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m ²

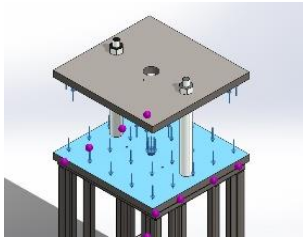
6.2.4.4. Material Properties

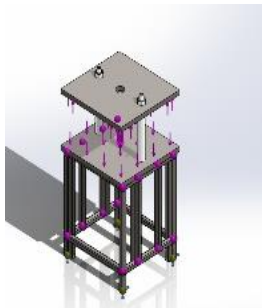
Model Reference	Properties
	Name: AISI 1035 Steel (SS) Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 2.82685e+08 N/m² Tensile strength: 5.85e+08 N/m² Elastic modulus: 2.05e+11 N/m² Poisson's ratio: 0.29 Mass density: 7,850 kg/m³ Shear modulus: 8e+10 N/m² Thermal expansion coefficient: 1.1e-05 /Kelvin



Name:	Chrome Stainless Steel
Model type:	Linear Elastic Isotropic
Default failure criterion:	Max von Mises Stress
Yield strength:	1.72339e+08 N/m²
Tensile strength:	4.13613e+08 N/m²
Elastic modulus:	2e+11 N/m²
Poisson's ratio:	0.28
Mass density:	7,800 kg/m³
Shear modulus:	7.7e+10 N/m²
Thermal expansion coefficient:	1.1e-05 /Kelvin

6.2.4.5. *Loads and Fixtures*

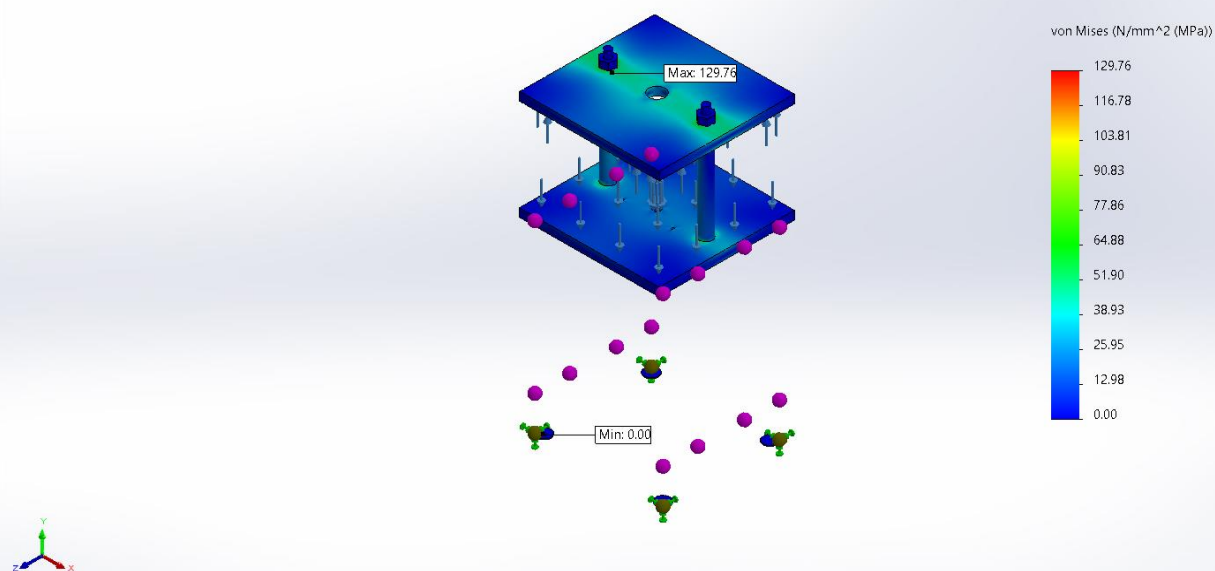
Load name	Load Image	Load Details
Force-1		Entities: 2 face(s) Type: Apply normal force Value: 100,000 N

Fixture name	Fixture Image	Fixture Details
Fixed-1		Type: Fixed Geometry

6.2.4.6. Study Results

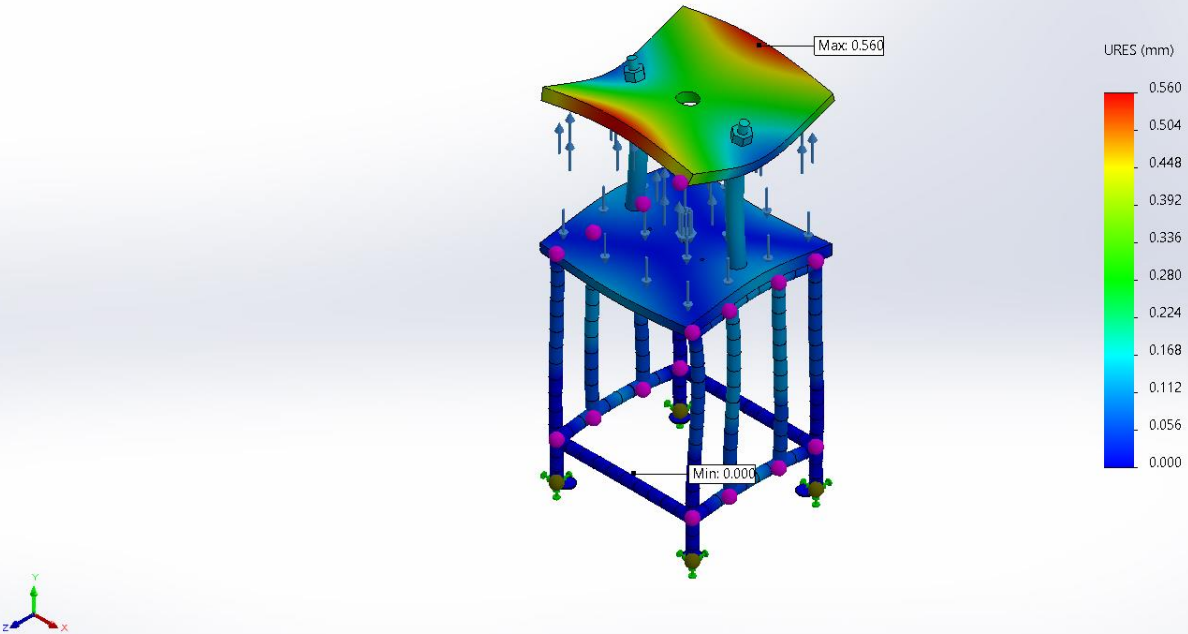
Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.00N/mm ² (MPa) Node: 123155	129.76N/mm ² (MPa) Node: 77616

Model name: Rubber tile with mold and tank
Study name: Sa3eed(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1



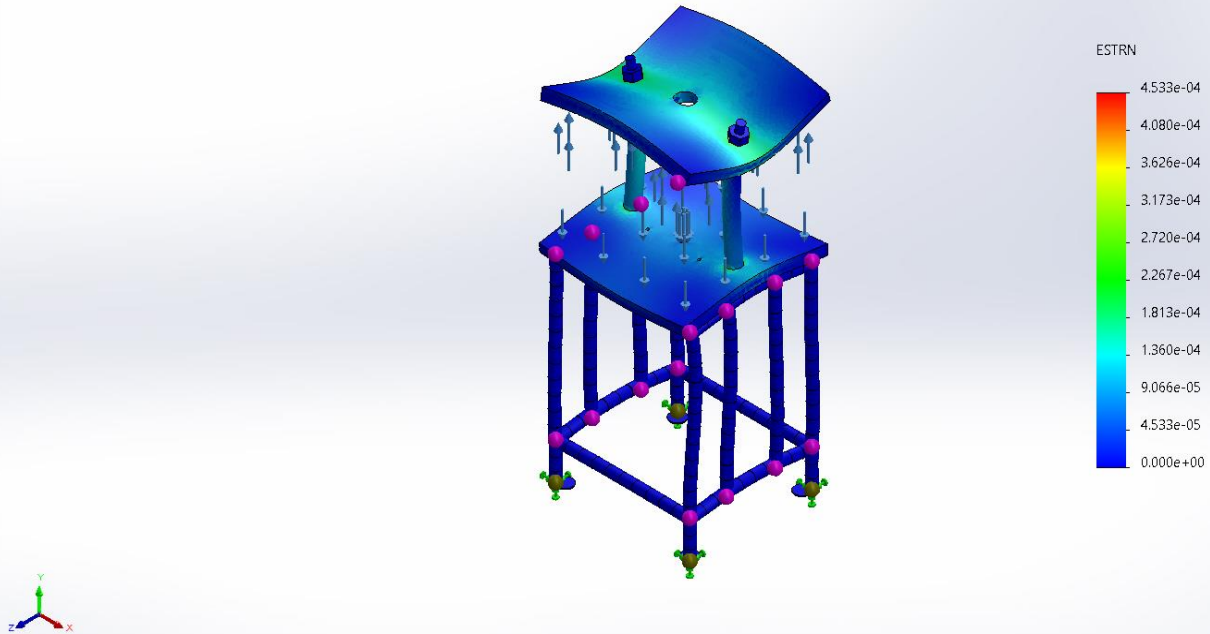
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000mm Node: 123155	0.560mm Node: 77566

Model name: Rubber tile with mold and tank
Study name: Sa3eed(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 243.717



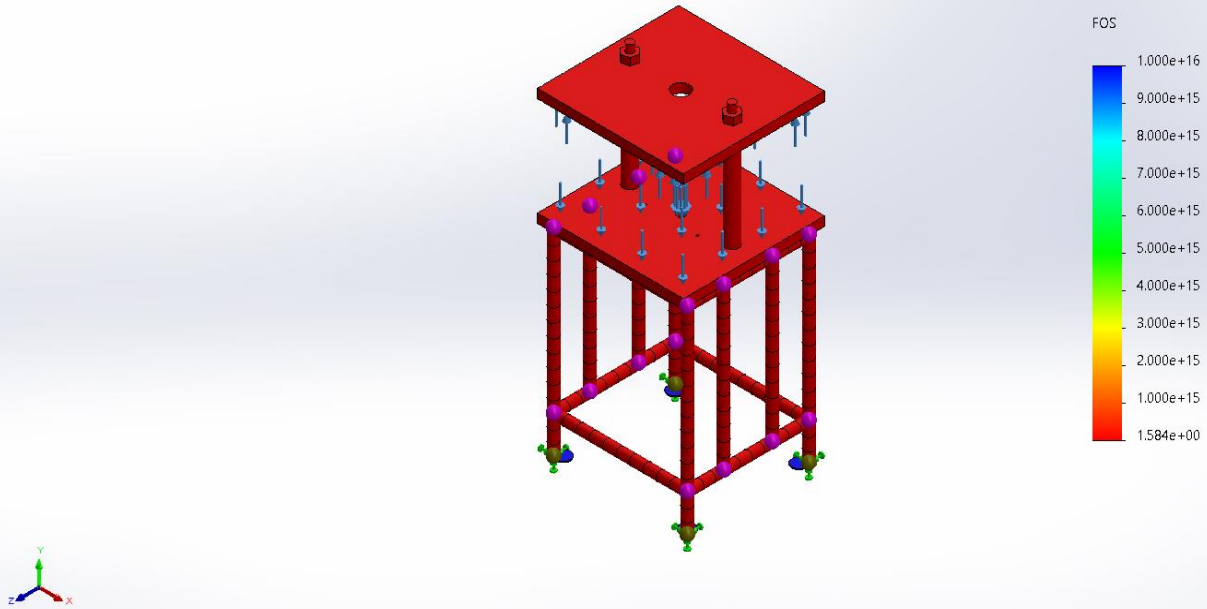
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000e+00	4.533e-04
		Element: 77157	Element: 39026

Model name: Rubber tile with mold and tank
Study name: Sa3eed(-Default-)
Plot type: Static strain Strain1
Deformation scale: 243.717



Name	Type	Min	Max
Factor of Safety1	Automatic	1.584e+00	1.000e+16
		Node: 62765	Node: 123155

Model name: Rubber tile with mold and tank
Study name: Sa3eed(-Default-)
Plot type: Factor of Safety Factor of Safety1
Criterion : Automatic
Factor of safety distribution: Min FOS = 1.6



6.3. Machine working drawing

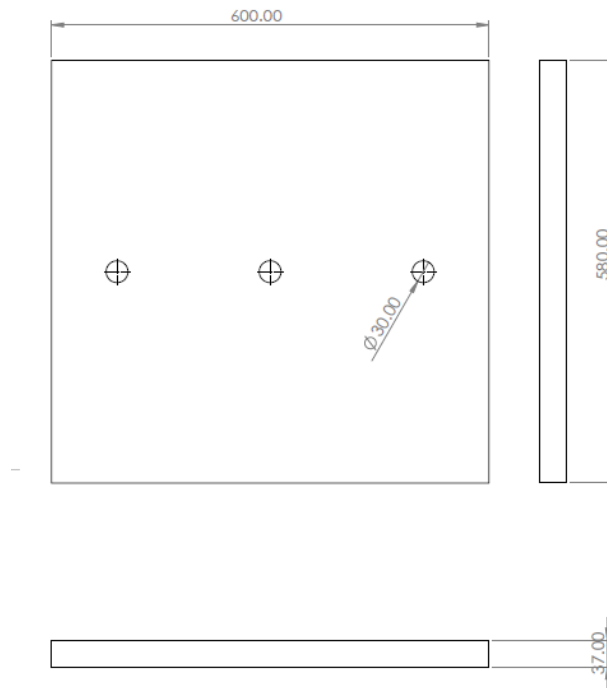


Fig 38: Plate working drawing

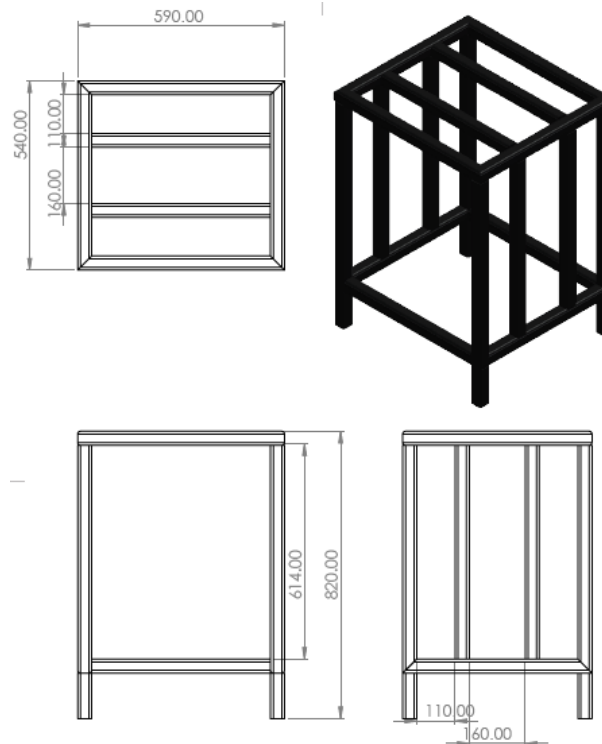


Fig 39: Base working drawing

Chapter 7

Hydraulic System Design

7.1. Fluid Power

Fluid power is a branch of engineering that deals with the generation, control, and transmission of energy using pressured fluids. Fluid power can be defined as the muscle that propels industry forward. This is because nearly all modern industrial machines employ fluid power to push, pull, control, or drive them. Fluid power, for example, steers and brakes cars, launches spacecraft, moves the earth, harvests crops, digs coal, runs machine tools, controls planes, prepares food, and even drills teeth. In reality, it's nearly impossible to locate a manufactured product that hasn't been "fluid-powered" in some way during the manufacturing or distribution process.

7.1.1. Types of Fluid Power Control Systems

- a) Closed-loop control system (servo system)
 - Based on feedback, output is compared to input first.
- b) System of open-loop control
 - Has received no feedback.
 - The vast majority of hydraulic systems are open-loop.

7.1.2. Advantages of fluid power:

7.1.2.1. Ease and accuracy of control.

The operator of a fluid power system may easily start, stop, speed up or slow down, and position forces that deliver any required horsepower with tolerances as exact as one ten-thousandth of an inch by using simple levers and pushbuttons. A fluid power system allows an aeroplane pilot to raise and lower his landing gear, as seen in Fig.19. Oil under pressure flows to one end of the cylinder when the pilot moves a small control valve in one direction to lower the landing gear. The pilot pushes the valve lever in the opposite direction to retract the landing gear, allowing oil to flow into the other end of the cylinder.

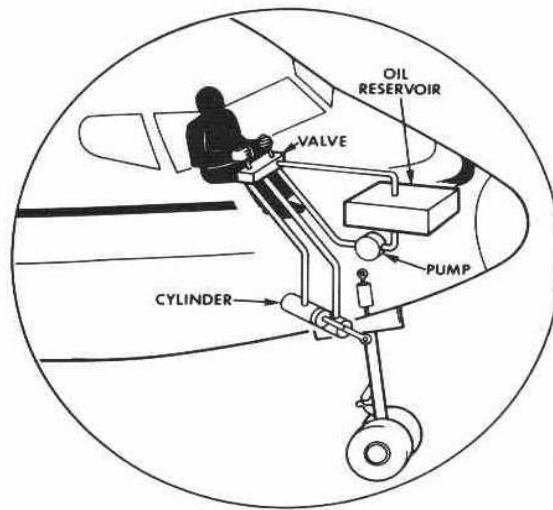


Figure 40: Hydraulic operation of landing gear

7.1.2.2. Multiplication of force

A fluid power system can multiply forces from a fraction of an ounce to several hundred tonnes of output without the use of heavy gears, pulleys, and levers. Figure 20 depicts a situation in which a tough, powerful drive is necessary to handle large logs. A turntable propelled by a hydraulic motor in this case can handle a 20,000-pound load at a 10-foot radius under difficult working conditions.

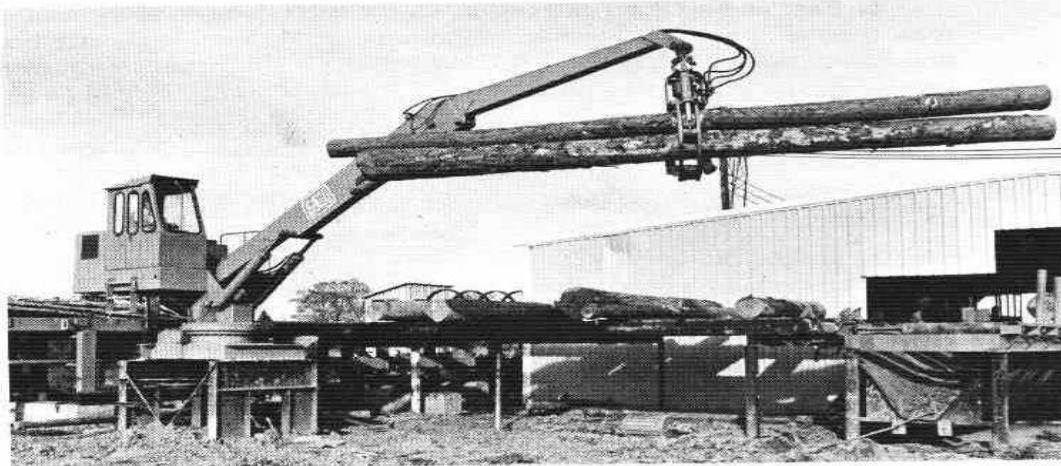


Figure 41: Hydraulically driven turntable for handling huge logs

7.1.2.3. Constant force or torque.

Fluid power systems are the only ones that can maintain constant force or torque despite speed fluctuations. Whether the work output moves a few inches per hour or a few feet per hour, this is accomplished. Several hundred inches per minute are being produced. Thousands of revolutions per minute or a few hundred per hour. Figure 21 shows an oceanographic application that entails the exploration and development of ocean resources for the benefit of humanity. In this case, it's critical for the operator to use the grappling hooks to apply a required consistent grasping force.

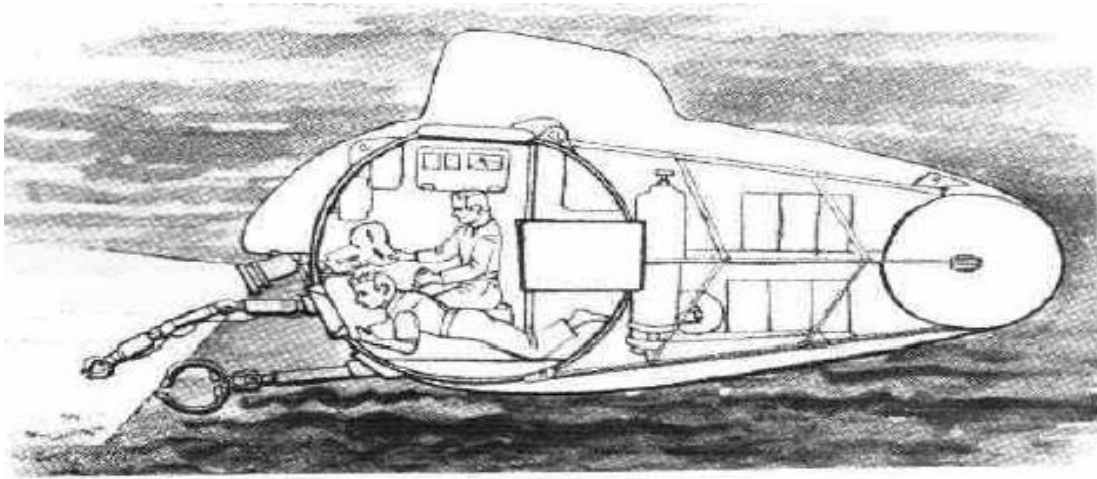


Figure 42: fluid power application in oceanography

7.1.2.4. Simplicity, safety, economy

Fluid power systems, on average, have fewer moving components than mechanical or electrical systems. As a result, they're easier to maintain and operate. As a result, safety, compactness, and dependability are all improved. A power steering control for off-highway vehicles is shown in Figure 27. The steering unit is coupled to the steering wheel column.

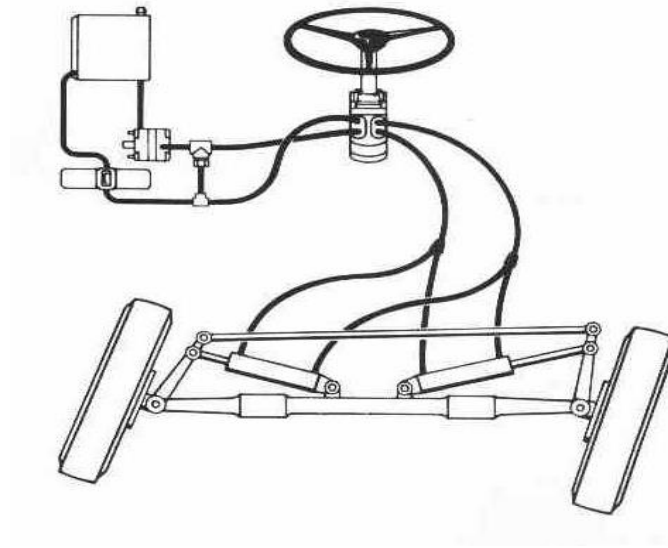


Figure 43: power steering control system for off-highway vehicles typical Orbitrol power steering systems

7.1.3. Disadvantages of fluid power systems:

- Hydraulic oils are dirty, and leaking cannot be totally avoided.
- Hydraulic lines have the potential to explode (human injury).
- If an oil spill occurs near heated equipment, most hydraulic oils can cause fires.
- The pneumatic system has a restricted range of power and cannot totally replace the hydraulic system.

7.2. Hydraulic Components and System Schematics

A hydraulic pump, a control valve, and a hydraulic cylinder are the major components of a conventional hydraulic system, as shown in Figure 28. Because the structure of many hydraulic components is complex, the industry frequently employs standardized graphical symbols to represent distinct hydraulic components in a system circuit. A system schematic is a diagram of a system circuit that is made using conventional graphical symbols. Figure 29 depicts a simplified system schematic for a hydraulic implement system often found on mobile equipment. All of the major components are depicted using graphical symbols in this circuit diagram. The symbol for a fixed-displacement pump, for example, is item 4, whereas the symbol for a directional control hydraulic valve is item 15, and the symbol for a single-rod double-action hydraulic cylinder is item 18. Hydraulic hoses are represented by the solid lines 2, 6, 7, and 8. The symbols, together with the corresponding lines, not only represent how these components are connected, but they also show the essential function of those elements, as shown in this system schematic.

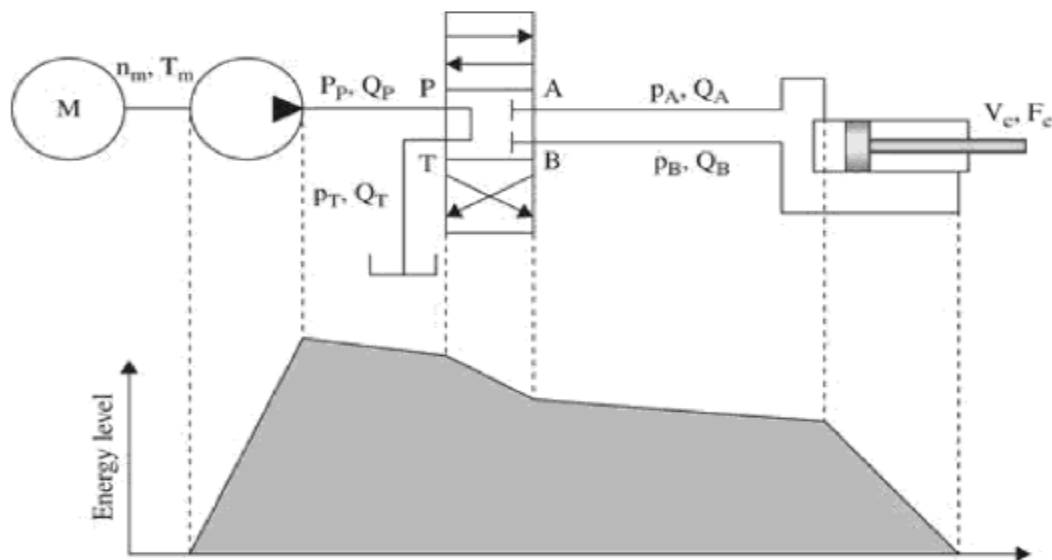


Figure 44: Hydraulic system schematic

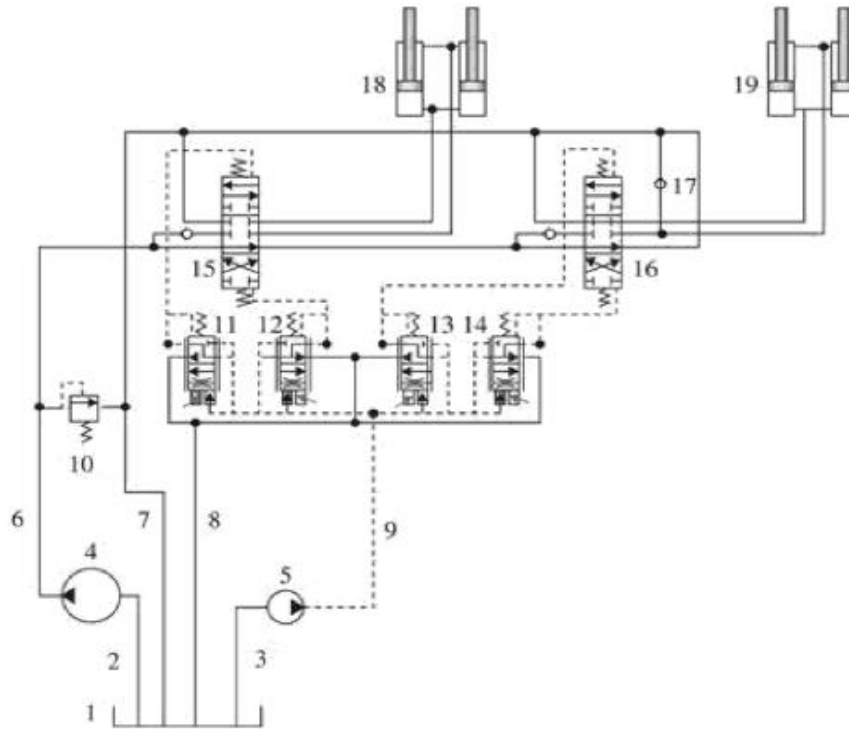


Figure 45: Hydraulic circuit components

7.3. Fundamental of Hydraulic Power Transmission

7.3.1. Multiplication of Force

Blaise Pascal, a French physicist, best explains why fluids can convey energy when enclosed (1623-1662). Pascal stated the following statement, which has become known as Pascal's law: Pressure applies equally in all directions and at right angles to the confining surfaces in a confined mass of fluid. Pascal's law is one of the fundamental rules of fluid power, and it serves as the foundation for creating the fluid static pressure transfer principle. A hydraulic jack can be used to illustrate this fundamental idea of fluid power systems.

Pascal's law defines the basic relationship between force (F), pressure (p), and area (A) in a hydraulic system: the force exerted on a surface equals the pressure exerted on the surface times the area of the surface. Mathematically, we can express the relationship as follows:

$$F = P A \quad \text{eq. (1)}$$

By Pascal's law, $P_1 = P_2$ since pressure equals force divided by area, we have

$$\frac{F_1}{F_2} = \frac{A_2}{A_1} \quad \text{eq. (2)}$$

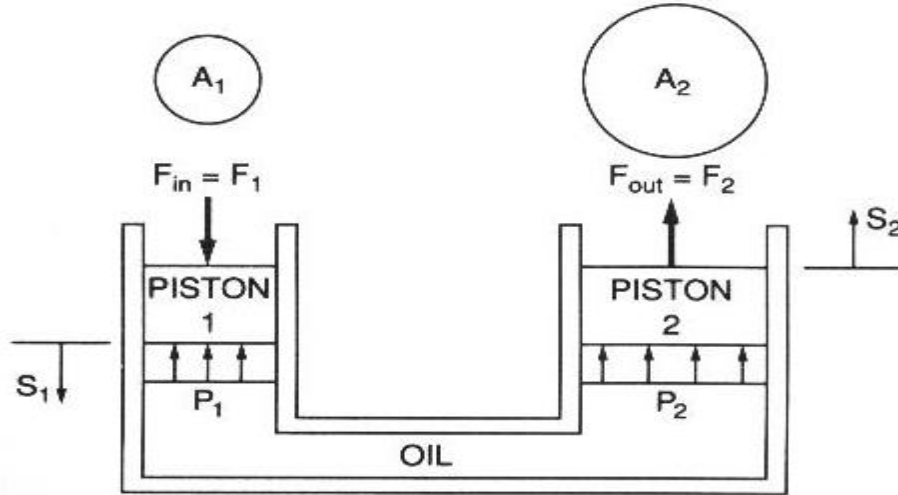


Figure 46: Pascal's law

7.3.2. Continuity of Fluids

The constant flow of fluid throughout the system is a fundamental principle of hydraulic power transmission. In hydraulic system analysis, the continuous flow principle is critical. The scenario where the total inlet flow rate is the same as the total outflow flow rate for steady flow in a control volume is commonly expressed using a flow continuity equation. In a hydraulic system, a control volume is the boundary of the section of interest that represents where and how the mass flow balance is accomplished.

$$Q = VA \quad \text{eq. (3)}$$

7.4. Energy and Power in Hydraulic Systems

7.4.1. Energy Conversion in Hydraulic Systems

The total energy carried by the pressured fluid reaches its highest level at the pump-discharge port, as shown in Figure 31. Due to a variety of energy losses, this energy level falls as the fluid travels away from the port. Energy conversions occur

during the delivery process, as evidenced by such losses. The energy flow in a typical hydraulic system during the power delivery process is depicted in Figure 31. There are different resistances and losses to overcome in order to transport the potential energy carried by the pressurised fluid to the actuator, such as line resistance, valve resistance, and friction on the actuator. A considerable quantity of energy will be expended to overcome certain resistances. Because this energy is not used to move the load—that is, it is not turned into kinetic energy to perform useful work—it is always transformed to thermal energy, causing a temperature rise in hydraulic fluids.

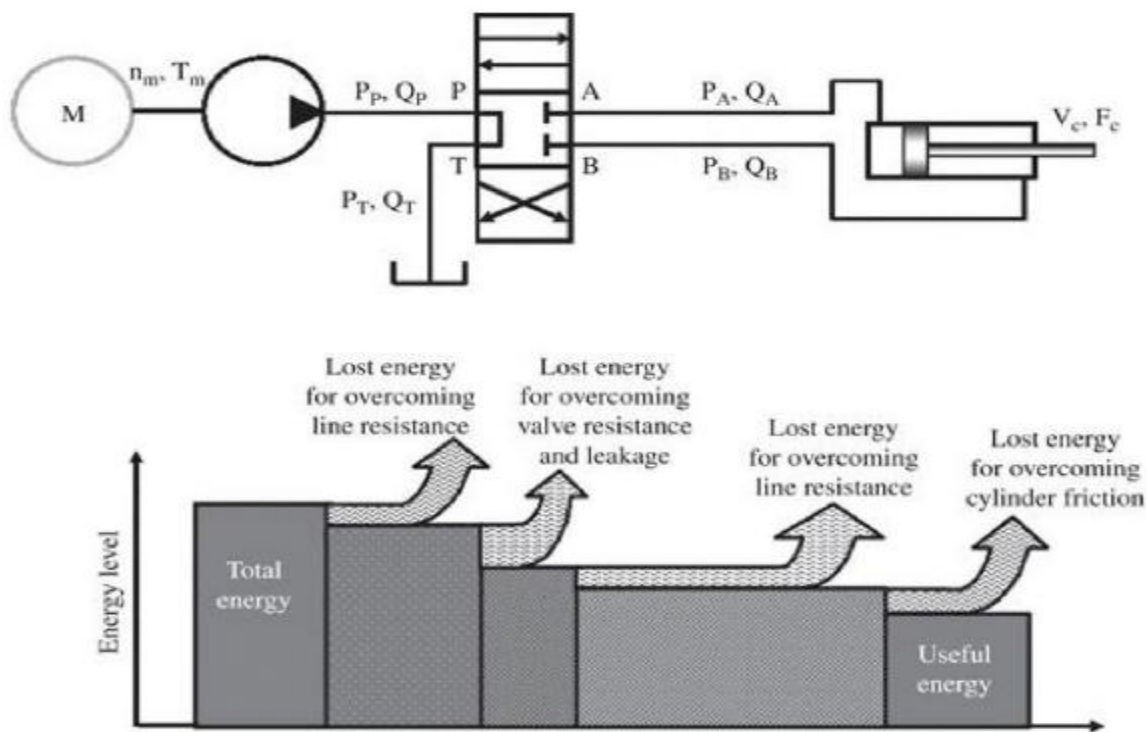


Figure 47: concept illustration of energy conversion during typical hydraulic power delivery process.

7.4.2. Hydraulic power

We learned that the power transfer in a typical hydraulic system includes the transfer from mechanical kinetic energy to hydraulic potential energy and vice versa from the previous sections' examination of energy conservation laws. The output mechanical power is always smaller than the input mechanical power,

which is a crucial point to remember when dealing with power transfer. The efficiency of a hydraulic power transmission system is defined as the ratio of output mechanical power to input value. It is necessary to understand how the mechanical and hydraulic powers in a hydraulic system are determined in order to examine the efficiency. In a typical hydraulic system, mechanical power is supplied as input power to drive the hydraulic pump and output power to drive the load via the hydraulic actuator. The torque and angular velocity are always used to determine the input power to a hydraulic pump and the output power from a hydraulic motor using the following equation.

$$P_m = T \omega \quad \text{eq. (4)}$$

where (P_m) is the mechanical power, (T) is the external torque applied on the shaft of either pump or motor, and (ω) is the angular velocity of the shaft. In eq (6-4), the torque is measured by (N. m), the angular velocity is in (s^{-1}). and the unit of power is (W in SI) units.

Different from the mechanical power, the hydraulic power is always determined by the system pressure, and the volumetric flow rate is as follows;

$$P_h = P \cdot Q \quad \text{eq. (5)}$$

where is the (P_h) hydraulic power, (P) is the system pressure, and (Q) is the volumetric flow rate. The unit of the pressure is (Pa), the flow rate is m^3 / s , and the unit of power is (W in SI) units.

7.5. Hydraulic Circuit and Components

7.5.1. Hydraulic main components

- A pump
- Valves: pressure regulation, and control
- An electric motor
- An actuator
- Piping
- A reservoir

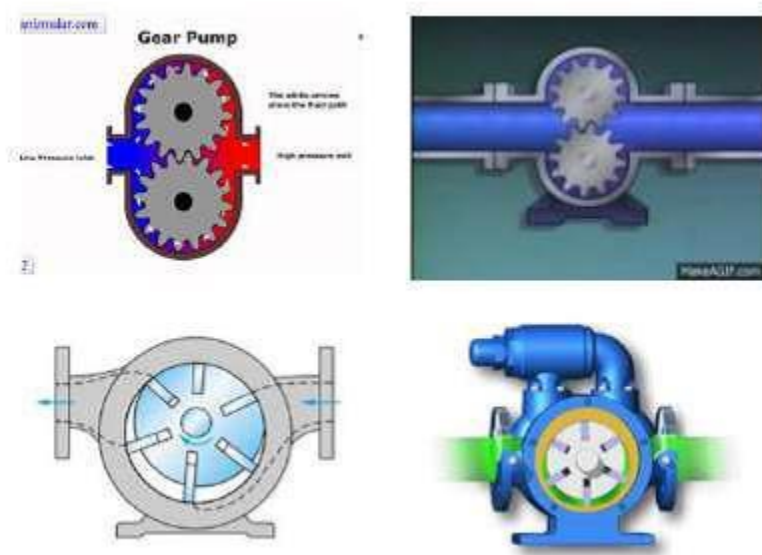


Figure 48: Pump types

7.5.1.1. Hydraulic pumps

They are machines that act to increase the energy of the flow of the liquid passing through them.

➤ **Pumps are divided into three categories.**

1. Positive displacement
2. Roto-dynamic pumps
3. special effect pumps

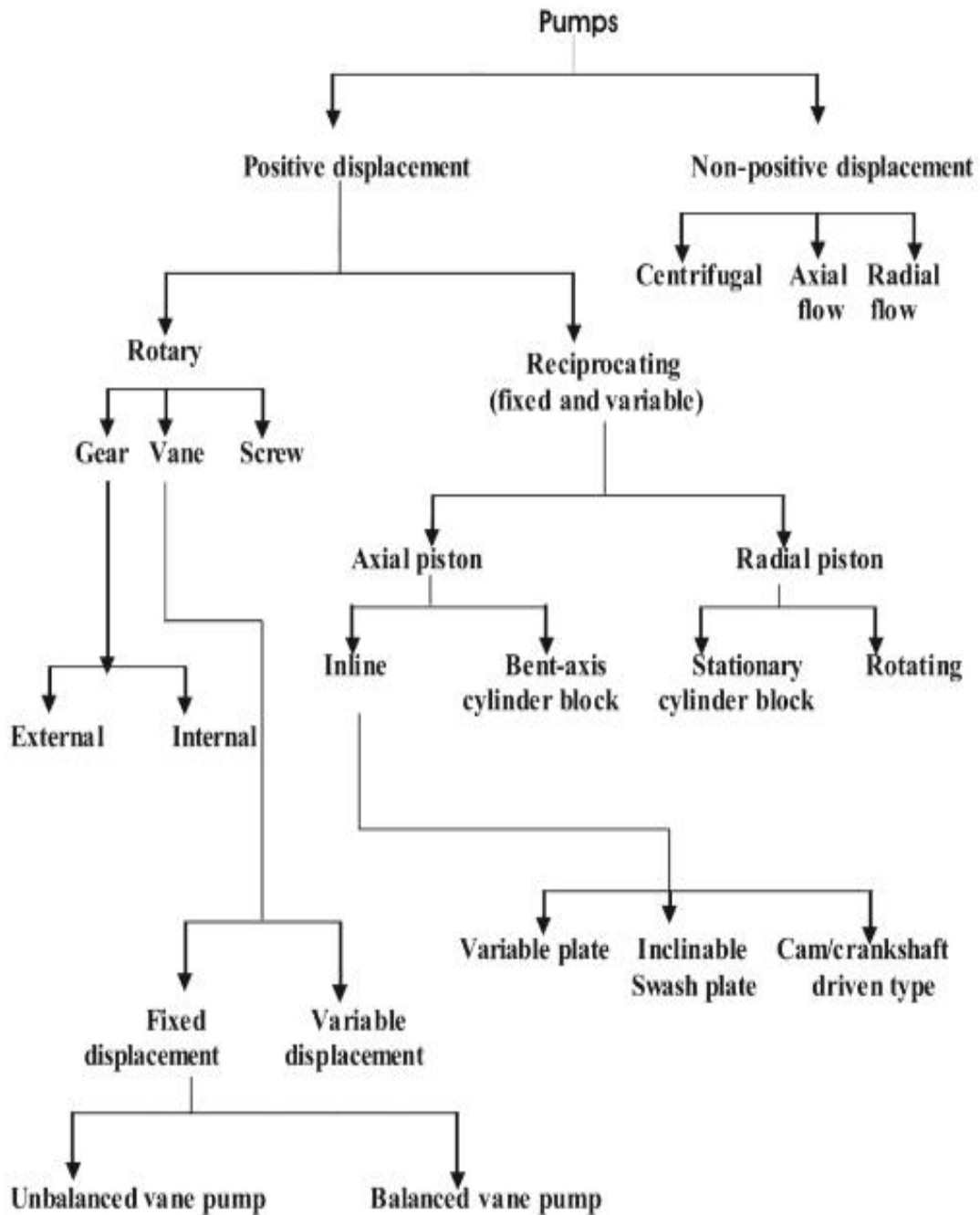


Figure 49: Classification of pumps

7.5.1.2. Valves

They help in regulating the flow rate, pressure, and direction of the liquid

➤ Type of valves:

1. Check valve
2. Pressure relief valve
3. Pressure reducing valve
4. Directional control valve

1. Check valve

Check valves are commonly employed to allow free flow in one direction while preventing (obstructing) fluid passage in the other.

➤ Types of Check valves:

a) Spring-Loaded Direct-Operated Check Valves

- If the pressure differential ($P_A - P_B$) is greater than the cracking pressure, it allows fluid to flow in the direction (A) to (B) (P_r)
- The cracking pressure (P_r) is defined as the difference in pressure that causes a pressure force equal to the spring force.

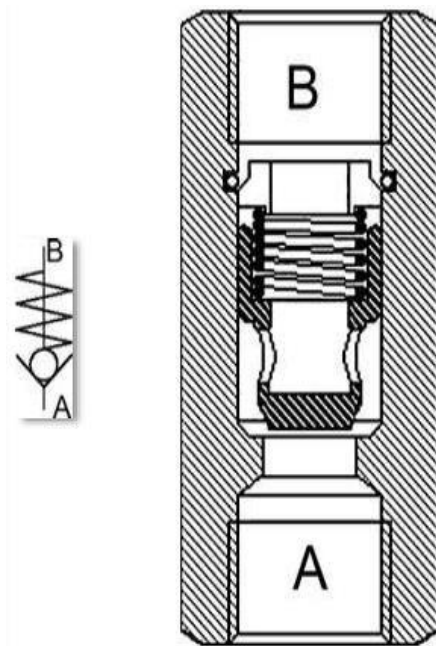


Figure 50: Spring loaded check valve

b) Direct-Operated Check Valves Without Springs

- A low cracking pressure is required in some applications. The check valve is constructed with very low stiffness springs or even without springs in this circumstance.
- The cracking pressure of these valves is less than 0.2 bar.

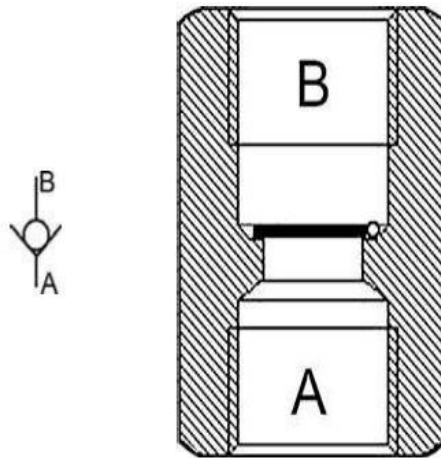


Figure 51: Direct operated Check valve

2. Pressure relief valves

- connected with high-pressure and return low pressure
- used to limit the maximum operating pressure in the high-pressure lines
- consists mainly of a poppet, loaded by a spring
- poppet is pushed by the spring to rest against its seat in the valve housing
- The spring pre-compression force is adjusted by a spring seat screw or by inserting distance rings

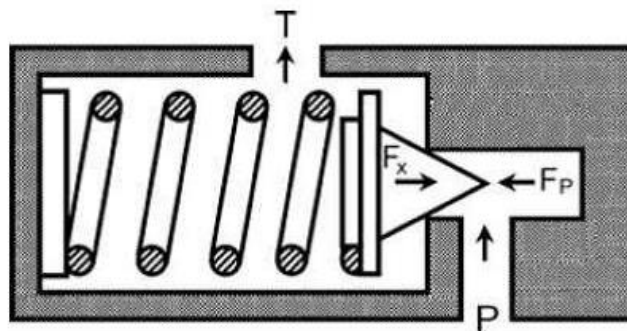


Figure 52: Pressure relief valve

3. Pressure reducing valve

- When a subsystem operates at a lower pressure than the main system, pressure reducers are used.
- Throttling elements are used to reduce and control pressure in most situations.
- By increasing the area, A_1 , or decreasing the area, A_2 , the lowered pressure, P_R , is raised, and vice versa.

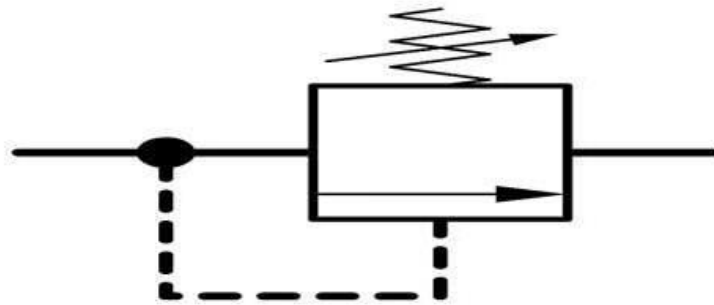
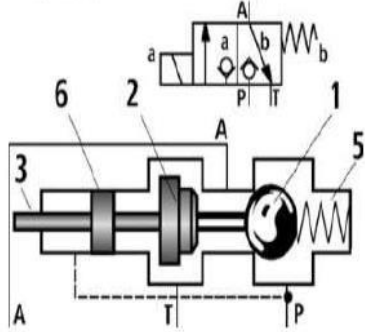
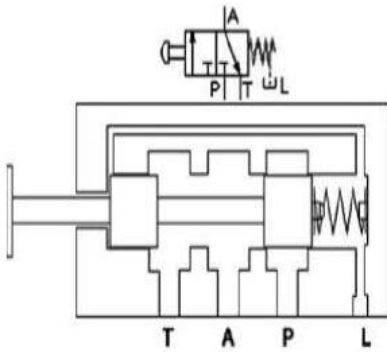


Figure 53: Pressure reducing valve

4. Directional control valves

- Directional control valves (DCVs) are used to start, stop, or change the direction of fluid flow.
- These valves are specified by the number of connected lines (ways) and the number of control positions

Table 2: Types of (DCVs)

Poppet type (DCV)	Spool type
• poppet type operates at pressure levels up to 630 (bar) and flow rate up to 40 L/min  1. Spherical poppet, 2. Main poppet, 3. Plunger, 5. Spring, 6. Pressure compensating piston A 3/2 poppet directional control valve.	• The spool valve are widely used in direction controls • Very flexible  A 3/2 DCV of spool type

7.5.1.3. Actuators

- Actuators' primary function is to transform liquid energy into mechanical force.
- According to the type of motion, hydraulic actuators are divided into three groups:
 - Hydraulic cylinders that move in a straight line
 - Hydraulic motors that rotate in a continuous loop
 - Hydraulic rotary actuators with a limited angular range of motion

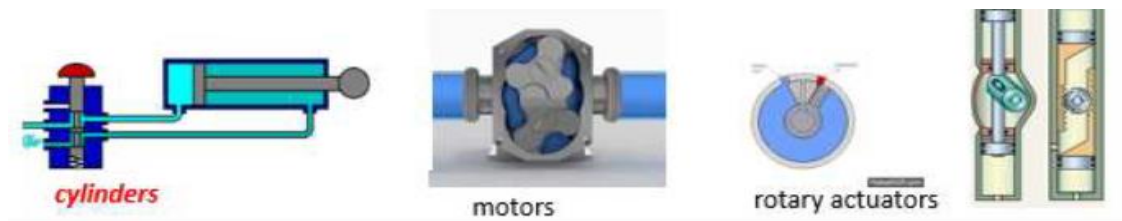


Figure 54: Types of actuators

7.5.2. Hydraulic circuit design

Figure (36) shows the hydraulic circuit of our machine that contains:

1. hyd. cylinder
2. DCV G-type
3. Relief Valve
4. check valve
5. pump
6. electric motor
7. A reservoir

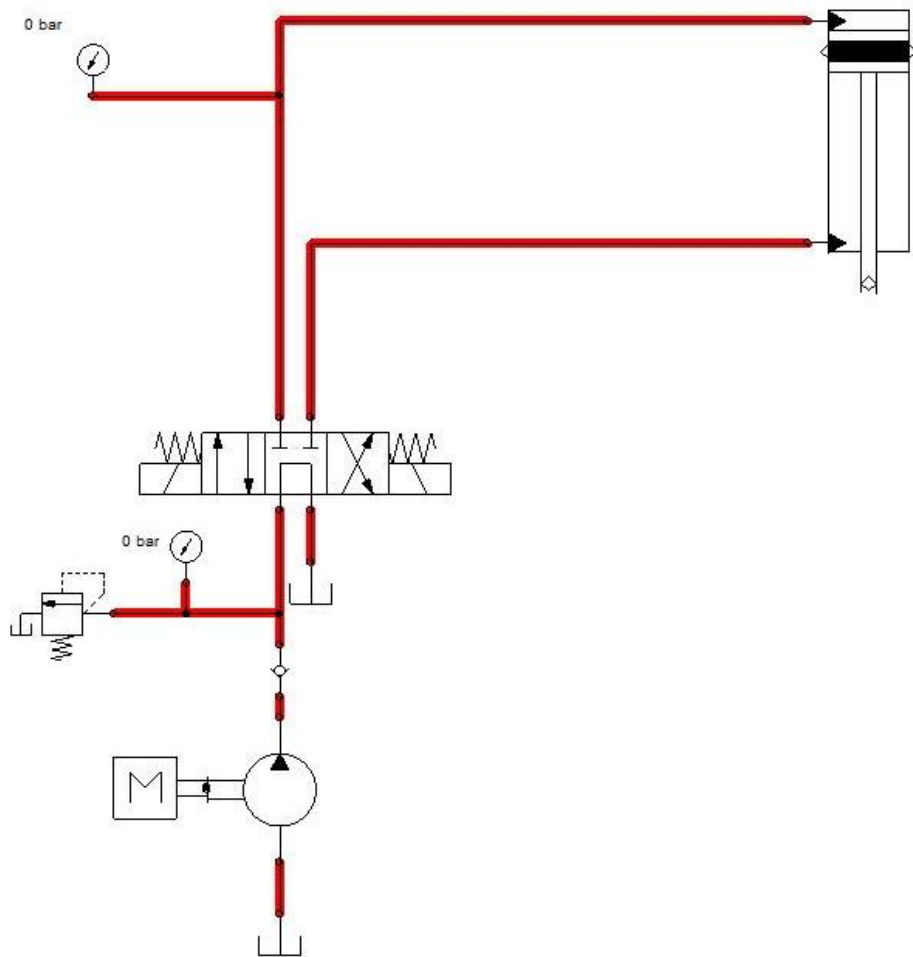


Figure 55: Machine hydraulic circuit

to design the hydraulic circuit, we have the force needed to press the tile $F = 10$ ton, and take pressure of circuit $P = 160$ bar.

7.5.2.1. Determine piston area:

From Pascal's law

$$F = P \cdot A_p \quad \text{eq. (6)}$$

$$A_p = 0.0062 \text{ M}^2 = 62 \text{ CM}^2$$

From selection sheet for available pistons

$$\text{Select } A_p \text{ actual} = 78.54 \text{ CM}^2$$

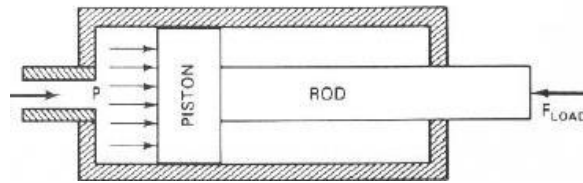


Figure 56: Piston area determination

AL Ø mm	MM Ø mm	ϕ A_1/A_3	A_1 cm ²	A_2 cm ²	A_3 cm ²	F_1 kN	F_2 kN	F_3 kN	q_{v1} l/min	q_{v2} l/min	q_{v3} l/min
25	14	1,46	4,91	1,54	3,37	7,85	2,46	5,39	2,9	0,9	2,0
32	18	1,46	8,04	2,54	5,50	12,80	4,07	8,79	4,8	1,5	3,3
40	22	1,43	12,56	3,80	8,76	20,00	6,08	14,00	7,5	2,3	5,3
50	28	1,46	19,63	6,16	13,47	31,30	9,82	21,50	11,7	3,7	8,1
63	36	1,48	31,17	10,18	20,99	49,80	25,40	24,40	18,7	9,5	9,2
80	45	1,46	50,26	15,90	34,36	80,30	25,40	54,90	30,1	9,5	20,6
100	56	1,46	78,54	24,63	53,91	125,00	39,30	86,20	47,1	14,8	32,3
125	70	1,46	122,72	38,48	84,24	196,00	61,50	134,00	73,6	23,1	50,5
160	90	1,46	201,06	63,62	137,00	321,00	101,00	219,00	121,0	38,1	82,4
200	110	1,43	314,16	95,06	219,00	502,00	151,00	350,00	188,0	57,0	131,0
220	90	1,20	380,1	63,6	316	494 ³⁾	82,8 ³⁾	506	228	38,2	190
	100	1,26		78,5	301		102 ³⁾	482		47,1	181
	110	1,33		95,0	285		123 ³⁾	456		57,0	171
250	100	1,19	490,8	78,5	412	638 ³⁾	102 ³⁾	659	294	47,2	248
	110	1,24		95,0	396		123 ³⁾	633		57,0	238
	125	1,33		123	368		159 ³⁾	589		73,7	221
280	110	1,18	615,7	95,0	520	800 ³⁾	123 ³⁾	833	369	57,0	313
	125	1,25		123	493		159 ³⁾	788		73,7	296
	140	1,33		154	462		200 ³⁾	739		92,4	277
320	125	1,18	804,2	123	681	1045 ³⁾	159 ³⁾	1090	482	73,7	409
	140	1,24		154	650		200 ³⁾	1040		92,4	390
	160	1,33		201	603		261 ³⁾	965		121	362
360	140	1,18	1017,8	154	864	1323 ³⁾	200 ³⁾	1382	610	92,4	519
	160	1,25		201	816		261 ³⁾	1306		121	490
	180	1,33		254	763		330 ³⁾	1221		153	458
400	160	1,19	1256,6	201	1055	1633 ³⁾	261 ³⁾	1688	753	121	634
	180	1,25		254	1002		330 ³⁾	1603		153	602
	200	1,33		314	942		408 ³⁾	1507		188	566
450	180	1,19	1590,4	254	1335	2067 ³⁾	330 ³⁾	2136	954	153	801
	200	1,25		314	1276		408 ³⁾	2042		188	766
	220	1,33		380	1210		494 ³⁾	1936		228	726
500	200	1,19	1963,4	314	1649	2551 ³⁾	408 ³⁾	2639	1178	188	990
	220	1,24		380	1583		494 ³⁾	2533		228	950
	250	1,33		491	1472		638 ³⁾	2356		294	884

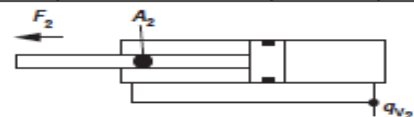
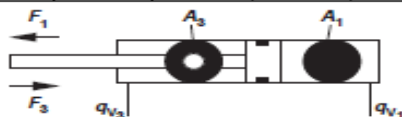


Table 3: Piston selected

piston diameter	rod diameter	piston area
100 mm	70 mm	78.54 cm ²

7.5.2.2. Determine pump flow rate

From the equation

$$Q = VA \quad \text{eq. (7)}$$

(Q) is the flow rate in the piston, (A) = (A_p) and take the moving speed of the piston

$$V = 2 \text{ cm/s}$$

$$\text{So } Q = (78.45 \times 10^{-4})(2 \times 10^{-2}) = .00015 \frac{M^2}{s} = 9 \text{ L /min.}$$

According to principle of Continuity of Fluids the pump flow rate(Q_p) = the piston flow rate (Q)

❖ To select the pump

$$Q_p = \frac{V_g \times \eta_g \times n}{1000} \quad \text{eq. (8)}$$

V_g : displacement per revolution (CM^3)

η_g : volumetric efficiency

n : rotational speed (rpm)

$$Q_p = Q = 9 \text{ L /min, Take } \eta_g = 90\% \text{ and } n = 1450 \text{ rpm}$$

$$\text{So } V_g = 6.89 \text{ CM}^3$$

From selection sheet

AZPW-1x			NG	004	005	008	011	014	016	019	022
Displacement, geometric, per revolution		V_g	cm ³	4.0	5.5	8.0	11.0	14.0	16.0	19.0	22.5
Pressure in suction port absolute		p_0	bar	0.7 to 3							
Maximum continuous pressure		p_1	bar	190	190	190	190	190	190	180	170
Maximum intermittent pressure		p_2	bar	210	210	210	210	210	210	200	190
Maximum pressure peak		p_3	bar	230	230	230	230	230	230	220	210
Minimum speed	at 12 mm ² /s and	< 100 bar	n_{min}	rpm	700	700	700	700	700	700	700
		100 to 180 bar		rpm	1200	1200	1000	1000	800	800	800
		180 bar to p_2		rpm	1400	1400	1400	1200	1000	1000	1000
	at 25 mm ² /s and	p_2		rpm	700	700	700	700	700	700	700
Maximum speed		at p_2	n_{max}	rpm	3500	3500	3500	3500	3000	3000	2500

$$V_g \text{ actual} = 8 \text{ CM}^3$$

$$\text{So, } Q_p \text{ actual} = 10.44 \text{ L /min}$$

The pump we selected (AZPW-1-008R) (gear type)

The reason for select the (gear type) is:

1. The availability on market
2. Can withstand with the pressure of the circuit
3. Cheaper than other types

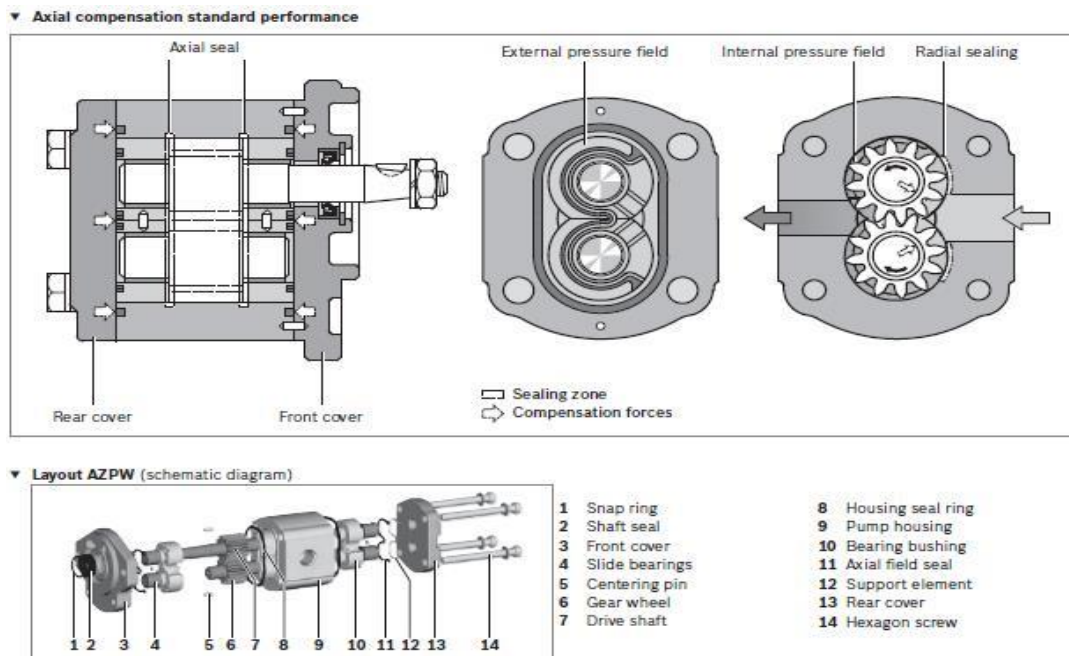


Figure 57: Gear type pump

7.5.2.3. Determine the electric motor power

From the equation

$$P_h = P \cdot Q \quad \text{eq. (9)}$$

$$= 160 \times 10^5 \times \frac{10.44}{1000 \times 60} = 2784 \text{ W} = 2.78 \text{ KW}$$

From selection sheet:

PERFORMANCE DATA Synchronous Speed 1000 r/min (6 poles) 400V/50Hz

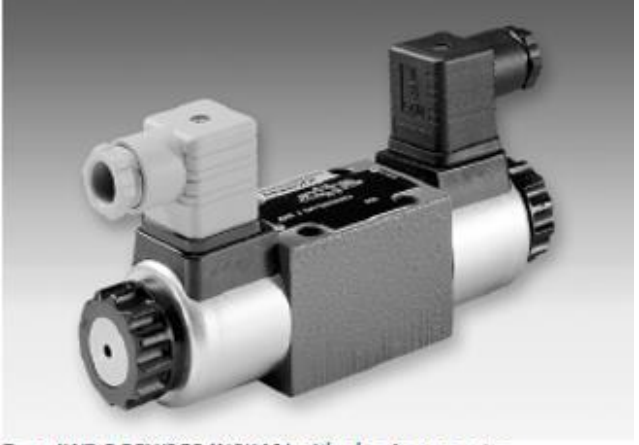
TYPE	Rated Output		Full Load				Locked Current	Locked Torque	Max. Torque	Moment of Inertia $J = \frac{1}{2}GD^2$ kgm ²	Weight kg
	Kw	Hp	Current in 400V A	Speed r/min	Eff %	Power Factor cos ϕ	Rated Current I_s/I_n	Rated Torque T_s/T_n	Rated Torque T_{max}/T_n		
M 71 K 6	0.18	0.25	0.70	900	57	0.66	4.0	1.9	2.0	0.0011	14
M 71 G 6	0.25	0.33	0.90	900	60	0.68	4.0	1.9	2.0	0.0014	14.5
M 80 K 6	0.37	0.50	1.24	900	66.5	0.70	4.7	1.9	2.0	0.0016	15
M 80 G 6	0.55	0.75	1.70	900	68.2	0.66	4.7	1.9	2.1	0.0019	16
M 90 S 6	0.75	1	2.12	910	71	0.72	5.5	2.0	2.1	0.0033	19
M 90 L 6	1.1	1.5	2.98	910	73	0.73	5.5	2.0	2.1	0.0040	22
M 100 L 6	1.5	2	3.85	920	76	0.75	5.5	2.0	2.1	0.0082	32
M 112 M 6	2.2	3	5.36	935	79	0.76	6.5	2.0	2.1	0.0147	41
M 132 S 6	3	4	6.7	960	81	0.76	6.5	2.1	2.1	0.0343	53
M 132 M 6	4	5.5	8.8	960	82	0.76	6.5	2.1	2.1	0.0429	61
M 132 MX 6	5.5	7.5	11.7	960	84	0.77	6.5	2.1	2.1	0.0543	70
M 160 M 6	7.5	10	15.9	970	86	0.77	6.5	2.0	2.1	0.1003	101
M 160 L 6	11	15	22.4	970	87.5	0.78	6.5	2.0	2.1	0.1336	120
M 180 L 6	15	20	29.2	970	89	0.81	7.0	2.0	2.1	0.2332	170
M 200 L 6	18.5	25	35.8	970	90.0	0.81	7.0	2.1	2.1	0.3532	187
M 200 LX 6	22	30	41.90	970	90.1	0.83	7.0	2.1	2.1	0.3401	210
M 225 M 6	30	40	55.50	980	91.5	0.84	7.0	2.0	2.1	0.5793	288
M 250 M 6	37	50	66.90	980	92.0	0.86	7.0	2.1	2.1	0.9524	367
M 280 S 6	45	60	81.10	980	92.5	0.86	7.0	2.1	2.0	1.31	483
M 280 M 6	55	75	98.10	980	92.8	0.86	7.0	2.1	2.0	1.54	550
M 315 S 6	75	100	133.2	990	93.5	0.86	7.0	2.0	2.0	3.55	930
M 315 M 6	90	125	158.70	990	93.8	0.86	7.0	2.0	2.0	4.17	950
M 315 L 6	110	150	192.2	990	94.0	0.86	6.7	2.0	2.0	5.10	1092
M 315 LX 6	132	180	230.2	990	94.2	0.87	6.7	2.0	2.0	6.17	1150
M 355 M 6	160	220	276.5	990	94.9	0.88	6.7	1.9	2.0	7.29	1550
M 355 MX 6	200	270	346.4	990	94.7	0.88	6.7	1.9	2.0	8.67	1600
M 355 L 6	250	340	433	990	94.7	0.88	6.7	1.9	2.0	11.04	1700

We select (M 132 S 6)

$$P_h = 3 \text{ KW}$$

7.5.2.4. Directional Control Valve

We selected 4/3 directional valve with wet pin DC solenoids

(G-type)	
• Norma size 6 • Series 6x • Max operating pressure 135 bar • Max flow 60 L / min	 Type 4WE 6 E6X/SG24N9K4/V with plug-in connector

Why We select (G-type)?

In order to avoid any increase in the temperature of the circuit's oil and increase in the pressure on the pump during holding position.

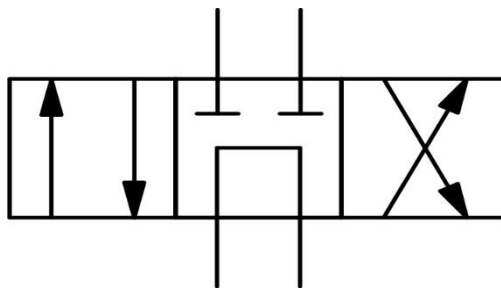


Figure 58: DCV G-type

7.5.2.5. Relief Valve

- Pressure relief valve, direct operated, type DBD
- Max operating pressure 630 bar
- Max flow 330 L/min



Figure 59: Relief valve

7.5.2.6. Reservoir volume

$$\begin{aligned}\text{The Reservoir volume} &= (3:5) \times Q \\ &= 4 \times 10.44 \approx 40\text{L}\end{aligned}$$

Chapter 8

Automatic Control

Automatic control is to give the machines the task of controlling the industrial process. Instead of the human element because of its accuracy, speed, high endurance and continuity, and this is achieved by continuous measurement of the elements involved in the change of the industrial process, such as: pressure, temperature, level, flow, etc., and then a comparison and Process Variable is the value set to set the industrial process for the correct operation of the industrial process.

8.1. The need of automatic controls:

There are three main reasons why automatic control is needed:

1. Safety

There must be sufficient safety in operating industrial production processes, especially complex and dangerous production processes that require high operating pressures and heat, and must be kept within safe limits to avoid risk of explosion and physical and human losses. It also prevents the risk of weak or uncontrolled chemical reactions resulting in toxic or hazardous substances.

2. Stability

Industrial facilities must operate consistently to prevent the recurrence of unplanned stops (Down Time)

3. Accuracy

Accuracy is the key to achieving an industrial product with standard standards and high economic efficiency

8.2. Control methods: (controllers)

8.2.1. Classic control

In classical control systems, knowledge of the controlled system (plant) is required in the form of a set of algebraic and differential equations, which analytically relate inputs and outputs. However, these models can become

complex, rely on many assumptions, may contain parameters which are difficult to measure or may change significantly during operation as in the case of the rotor flux oriented control (RFOC) induction motor drive. Classical control theory suffers from some limitations due to the assumptions made for the control system such as linearity, time-invariance, etc. These problems can be overcome by using artificial intelligence-based control techniques, and these techniques can be used, even when the analytical models are not known. Such control systems can also be less sensitive to parameter variation than classical control systems.

8.2.2. PLC

The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a PLC can monitor and record run time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application.

Table 4: The difference between PLC and classic control

Contents	PLC	Classic control
Basic	Programmable Logic Control (PLC) is a solid-state computerized industrial controller that performs software logic by using input & output modules, CPU, memory, and others.	Relay is an electro-mechanical switching hardware device (Hardware Switching Device).
Function	PLC plays a monitoring as well as controlling role in designing circuits. PLC consists of more programming functions	Relay plays only a controlling role in the designing circuit. Monitoring is not so easy with a relay. Relay gives only one fault

	like timer, counter, memory, etc.	detection function. And it does not have much-advanced functionalities.
Working	In the PLC, we can write the program using different types of programming languages.	In the Relay, we cannot write the program.
Operation (Digital & Analog Signals)	PLC is operated on the digital system. ²²	Relay is operated on the analog system.
Design	You can easily modify the designing circuit.	Modification of the electronic circuit is more difficult as compared to PLC.
I/O	PLC has more capabilities of input and output modules.	The relay does not have more capabilities.
Flexibility	PLC provides more flexibility than the relay.	The relay provides less flexibility.
Fault	You can easily find the fault by using the software.	It is very hard to find fault in the Relay circuit.
Time	PLC has a time response of nearly 50 msec and above.	Relays have less than 10 msec response time.
Memory	It consists of memory to store the program.	It does not consist of memory.
Types of PLC & Relay	There are two types of PLC as- • Compact PLC • Modular PLC	Following the list of types of the relay- • Electromagnetic Relay

		• Thermal Relay • Induction Relay
Cost	High cost	Low cost

Therefore, we are going to use PLC because it increases the reliability, flexibility, and accuracy of the automation system. Fast operation (no booting time) are the most important advantages as compared to alternative technologies.

❖ **And Now we have to Talk about our automation circuit:**

The circuit in general consists of three sub-circuits (Manual-automatic with timer-the motor control).

The First the manual one: Simple circuit with two buttons to open and close the hydraulic cylinder.

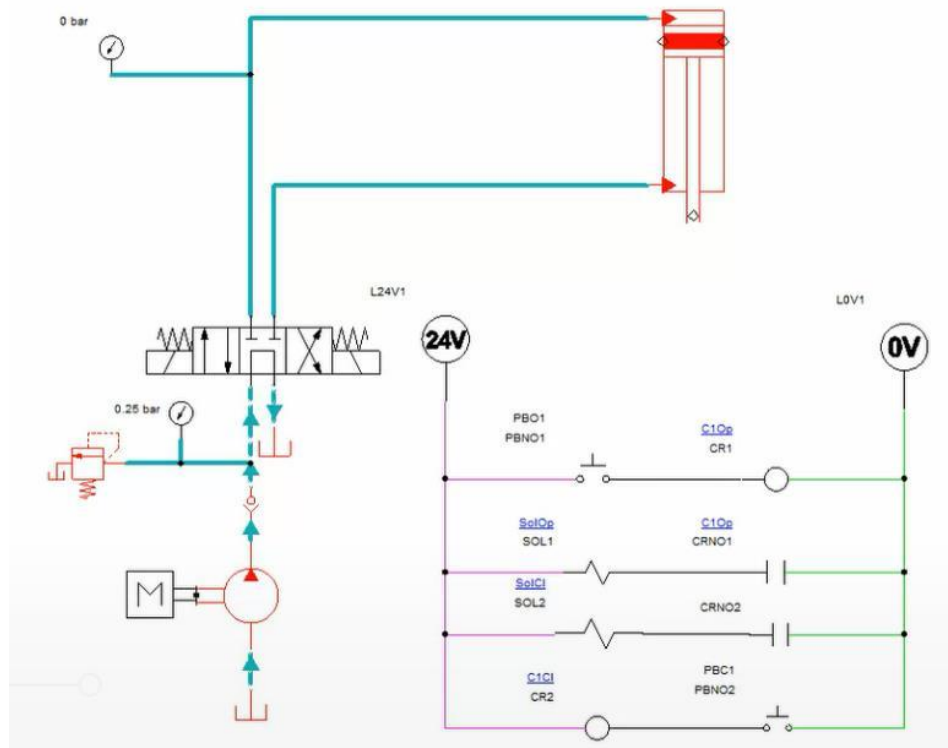


Figure 60: Automation circuit

Table 5: Components of first manual one

No	element	Quantity	Description
1	Push button	2	A push button is a simple type of switch that controls an action in a machine or some type of process.
2	Relay	2	the relay is the device that open or closes the contacts to cause the operation of the other electric control.
3	Vcc	1	220 V
4	Ground	1	Neutral

The second automatic one: more complicated circuit with one button and timer switch to open and close the hydraulic cylinder with the needed time.

Table 6: Components of the second automatic one

No	element	Quantity	Description
1	Push button	1	A push button is a simple type of switch that controls an action in a machine or some type of process.
2	Timer switch	1	the timer is the device that N/C position when start and switch after known time which can be set.
3	Vcc	1	220 V
4	Ground	1	Neutral

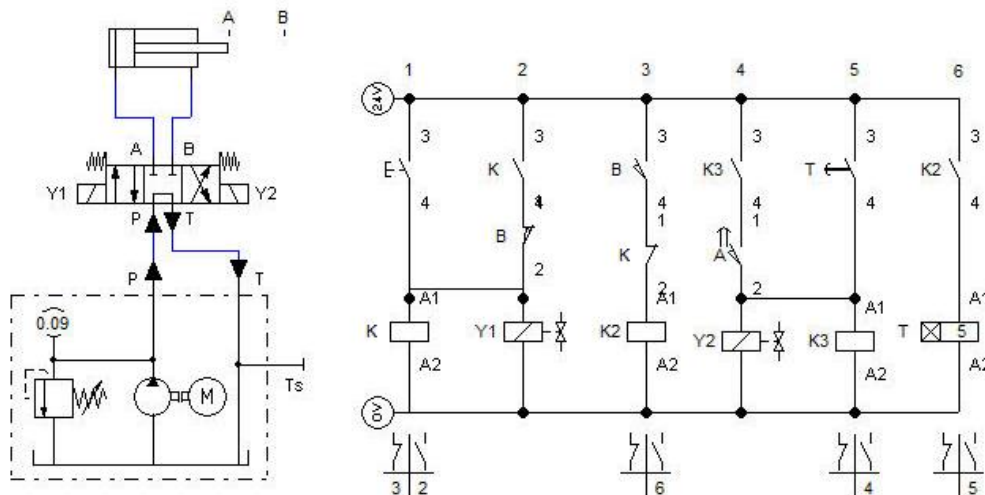
The third motor control : more complicated circuit with one contactor, circuit breaker, overload device and single phase motor.

Table 7: components of the third motor control

no	element	Quantity	Description
1	Contactor	1	A contactor is an electrical device which is used for switching an electrical circuit on or off.
2	Overload device	1	An overload relay is an electrical device used to protect an electric motor from overheating. So it is essential to have sufficient motor protection
3	circuit breaker	1	A circuit breaker is a switching device that interrupts the abnormal or fault current.
4	Single phase motor	1	Single phase motors work on the same principle as 3 phase motors except they are only run off one phase
5	Vcc	1	220 V
6	Ground	1	Neutral

➤ If we make it with Classic control:

❖ **Our electric Circuit on (FluidSIM software)**



❖ Our circuit with PLC controller

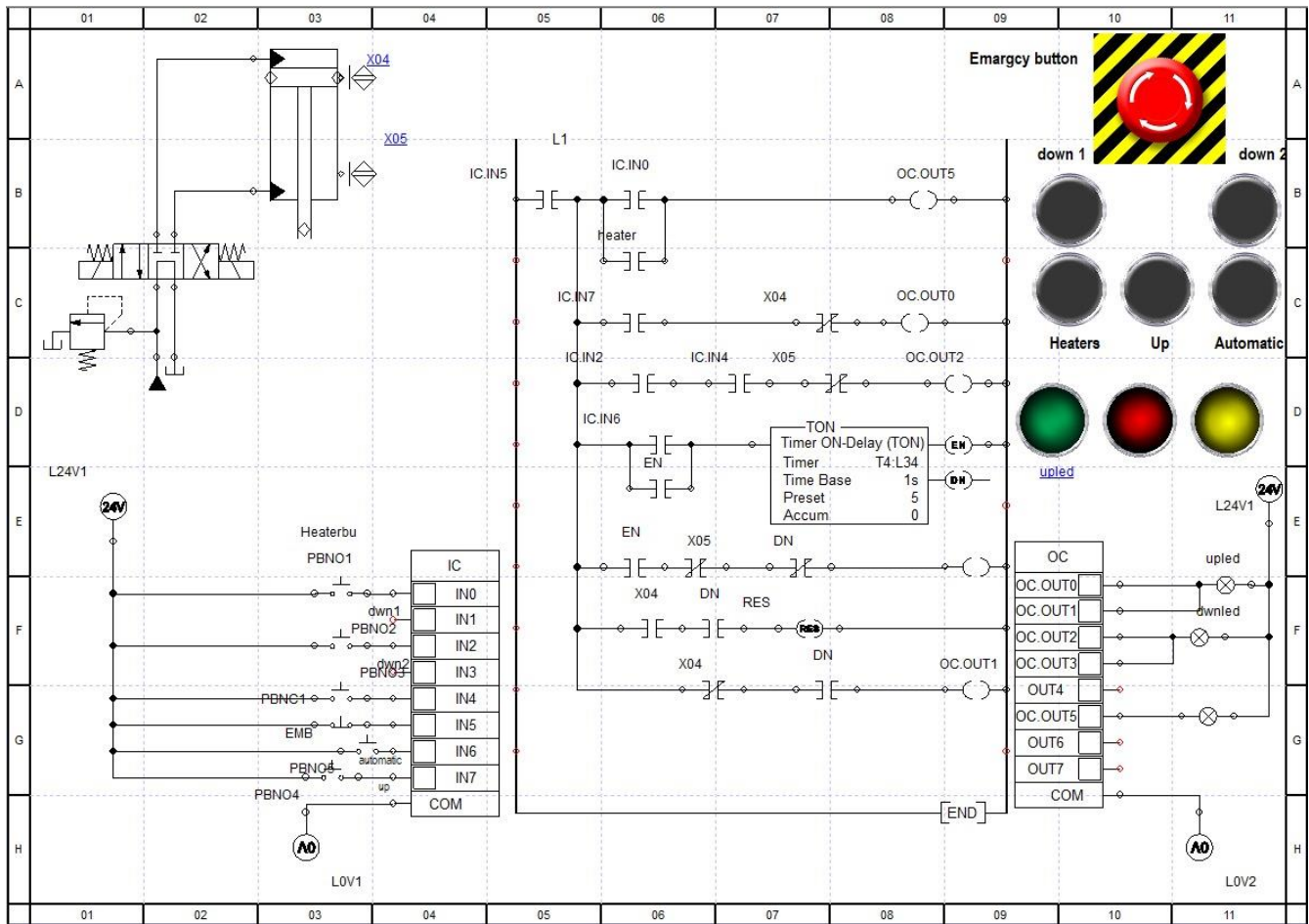
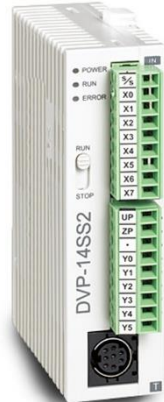


Table 8: The Final control circuit components :

No	Element	Quantity	Function	Figure
1	Contactor	2	Used for switching an electrical circuit on or off	

2	Overload device	1	Used to protect an electric motor from overheating	
3	circuit breaker	1	To protect an electrical circuit from damage caused by overcurrent/overload or short circuit. Its basic function is to interrupt current flow after protective relays detect a fault.	
4	Single phase motor	1	Turn electric energy into mechanical energy. It works by using a single-phase power supply	
5	Emergency button	1	To stop the machinery quickly when there is a risk of injury or the workflow requires stopping. It is intended to avert harm or to reduce existing hazards to people, machinery, or working.	

6	Cartridge Heater	3	Cartridge heaters provide localized and precise heating.	
7	Indicator Lamp	1	To build a mental image of the functional relationships sounds in the bridge control console and an indicator light glows on the panel	
8	Limit switch	2	They are used for controlling machinery as safety interlocks, or to count objects passing a point.	
9	Buzzer 220 V	1	To alert the workers to take immediate action whenever the system detects any fault event.	
10	Push button	3	To switch the machine either on or off	

11	Digital temperature controller	1	To control a heater or other equipment by comparing a sensor signal with a set point and performing calculations according to the deviation between those values.	
12	Thermocouple type K	1	It is a sensor that measures temperature	
13	PLC	1	It is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices.	

References

- [1] **Jain, A., 2016.** Compendium of Technologies for the Recovery of Materials/Energy from End of Life (EoL) Tires Final Report. *Nations, United Programme, Environment Environmental, International Centre, Technology.*
- [2] **Zaki, T. and Khayal, A., 2010.** Country report on the solid waste management in Egypt. *The Regional Solid Waste Exchange of the Information Expertise Network in Mashreq and Maghreb Countries.*
- [3] **Waste Management and Recycling of Tires in Europe** ISBN 90-5383-643-8
- [4] **Waste (Second Edition)** A Handbook for Management & Valerie Schulman &The European Tire Recycling Association (ETRA), Brussels, Belgium
- [5] **Pehlken, A. and Essadiqi, E., 2018.** Canmet materials technology laboratory: Scrap tire recycling in Canada. MTL2005-08(CF). August 2005.
- [6] **Health Care Without Harm (HCWH),** “Healthy & Sustainable Flooring: Choosing resilient flooring for the European healthcare sector”, September 2012
- [7] https://noharm-uscanada.org/sites/default/files/documents-files/2643/2012-09%20HCWH%20Europe%20Healthy_Sustainable_Flooring_EN%20single%20pages%20lowres.pdf_
- [8] **CHANG, L.T., TSAI, K.H. and SHIAU, J.S., 2004.** Experimental Evaluation Of The Impactabsorption Properties Of Rubber Tiles For The Playground. *Biomedical Engineering: Applications, Basis and Communications*, 16(05), pp.244-250. Shi, J., Jiang, K., Ren, D., Zou, H., Wang, Y., Lv, X. and Zhang, L., 2013. Structure and performance of reclaimed rubber obtained by different methods. *Journal of applied polymer science*, 129(3), pp.999-1007.
- [9] **Pehlken, A. and Essadiqi, E., 2005.** CANMET Materials Technology Laboratory, Scrap tire recycling in Canada. Juma M, Korenova Z, Markos J, Annus J, Jelemensky L (2006) Pyrolysis and Combustion of Scrap Tire. *Petroleum Coal*, 48, pp.15-26.

- [10] ISO 14025:2011-10 Environmental labels and declarations - Type III environmental declarations - Principles and procedures
- [11] <https://resin-expert.com/en/guide/polyurethane-glue>
- [12] **Strøbech, C., 1990.** Polyurethane adhesives. *International Journal of Adhesion and Adhesives*, 10(3), p.127.
- [13] **Quadrini, F., Gagliardi, D., Tedde, G.M., Santo, L. and Musacchi, E., 2016, October.** Direct molding of pavement tiles made of ground tire rubber. In *AIP Conference Proceedings* (Vol. 1769, No. 1, p. 050002). AIP Publishing LLC.
- [14] **Lucignano, C., Gugliemotti, A. and Quadrini, F., 2012.** Compression moulding of rubber powder from exhausted tires. *Polymer-Plastics Technology and Engineering*, 51(4), pp.340-344.
- [15] **Petrauskas, K., Žaržojūtė, V., Jukna, A. and Asadauskas, S., 2017.** Improvement of elastomer swelling measurement for sulfur cross-link density determination. *Chemija*, 28(4).
- [16] **Myhre, M., Saiwari, S., Dierkes, W. and Noordermeer, J., 2012.** Rubber recycling: chemistry, processing, and applications. *Rubber chemistry and technology*, 85(3), pp.408-449.
- [17] **Shi, J., Jiang, K., Ren, D., Zou, H., Wang, Y., Lv, X. and Zhang, L., 2013.** Structure and performance of reclaimed rubber obtained by different methods. *Journal of applied polymer science*, 129(3), pp.999-1007.
- [18] **Strakšys, A., Valsiūnas, I., Stalnionis, G., Eicher-Lorka, O., Kuodis, Z., Bražinskienė, D., Jukna, A. and Asadauskas, S., 2018.** Influence of polyurethane adhesives on tensile and compressive properties of ground rubber composites. *Chemija*, 29(2).
- [19] <https://pinshape.com/guides/3d-printing-materials/>
- [20] <https://cdn.cnetcontent.com/syndication/mediaserverredirect/e6b5204e10f48834b7bc52e4ebb89b69/original.pdf>.

[21] Manufacturing, S.D., 2016. 3D Printing Materials: Choosing the Right Material for Your Application. *Resource URL: [https://www. stratasysdirect.com/content/white_papers/S TR_7463_15_SDM_WP_3D_MATERIALS.PDF](https://www.stratasysdirect.com/content/white_papers/S TR_7463_15_SDM_WP_3D_MATERIALS.PDF)*.

[22] <https://markforged.com/resources/learn/design-for-additive-manufacturing-plastics-composites/understanding-3d-printing-strength/3d-printing-settings-impacting-part-strength>

[23] Kumar, S. and Prashanth, B., 2017. Design and fabrication of hydraulic press. *Int. J. Sci. Develop. Res*, 2(7), pp.227-230.