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Bachelor of Science
Mechanical Engineering and Production Technology

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Design really matters,
Plastic pallets in food industry

Thesis 2019

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Abstract

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The world is increasingly more mobile than ever, the need to transfer products between producers and consumers is already on a rapid growth. There are many elements involved in the transportation of goods such as logistics, packaging, containers, and above all the pallets. Although 95% of the world produced pallets are made of wood-based materials, the other non-wooden pallets such as metal, and plastic pallets are growing as well. There is an actual need for plastic pallets especially in the food industry, the reason is that the wooden pallets are less hygiene friendly than plastic ones.

To understand the customer's need, the door should be opened for more developments in plastic pallets not only in material used but also in the design. The variety of designs in plastic pallets can allow customers to have more choices to meet their needs. There are many advantages to use plastic pallets compared to wooden pallets, one of them is the plastic pallets are lighter than wooden ones, but the case in food industry, the main reason is the plastic pallets is preferred over the wooden pallets, that plastic pallets are more hygiene friendly than wooden pallets. it is obvious to conclude that weight is not the main reason to switch to plastic pallets.

The research studied two different plastic pallets with the same material. The result shows that change in design leads to different load carrying, also each design has its own advantages but thinking about better hygiene the study suggested one design over the other.

Keywords: pallets, food industry, plastic

1 Introduction

The world is increasingly more mobile than ever, the need to move products involves more logistics tools, container boxes and above all pallets.

The importance of pallets started with a container ship. It is simply a specialized type of cargo ship, and it is designed to carry the standardized container which really revolutionized transport and international trade since the 1950s until now and its growth is expected to continue as well in the future.

Although goods can be transported as bulk fluids, oil and liquified gas and also food products as wheat or beans in a non-containerized cargo which means no pallets involved, the demand for pallets is growing still due to the overall containerization global growth (The economist, 2013).

This use of these standardized containers or ‘Containerization’ pushed for more major reduction in the cost of freight transportation costs. containers are not only carried on ships, but also by road and rail, and air transport.

1.1 Purpose

The main goal behind developing this research is to demonstrate the importance of design and its impact on the static load carrying of plastic pallets utilization especially for food industry where good hygiene is needed.

The research focuses on the plastic pallets which play an important role nowadays in the food industry for many reasons. one of them is the need for a good hygiene which wooden pallets cannot fully give to this industry.

The question which the research will try to answer is, does design really matter in plastic pallets regarding its weight vs the static load.

1.2 Research Reliability

Since most of the cited and stated expressions and information are based upon previous researches and findings then the reliability issue regarding this thesis is justifiable.

The practical part is based on Solidworks test of static load, on different specific materials.

1.3 Limitations

The research is limited to only specific materials, and also studying the static load effect, not taking into consideration other load or non-static load effects. The main purpose is to focus on the effect of design on the product, its weight and the materials cost.

1.4 Pallet definition

Pallets are generally defined as a load bearing structure that are used to provide a rigid base for shipping and storage of goods and products that are termed as a unit load. According to T.S. Khoo. (2008, p. 1733-1744). “pallets are designed so that products and goods can easily be retrieved and delivered using lift trucks such as forklift and pallet jacks.”

Pallet as a definition is a flat wooden structure that heavy goods are put onto so that they can be moved using a fork-lift truck (= a small vehicle with two strong bars of metal on the front that is used for lifting heavy goods) (Cambridge dictionary).

The definition is mentioned in a clear way as a description of the pallet and its function and how it is being handled, but it does not mention the many types of pallets.

Pallets provide a safe, effective transport and storage platform throughout the handling and distribution process. Although there are standardized versions, pallets are produced in many sizes and configurations to accommodate different handling equipment (generally forklifts), cargoes, space constraints and required longevity (i.e. single or multiple use).

1.5 Development of the pallet

Pallets were first used for handling finished goods in the distribution environment in the 1930s. Modern wooden pallets were introduced on a larger scale during World War II by the military. Then, in 1946, the food-processing

industry along with transportation companies, as well as the pallet manufacturing industry, recommended the adoption of the 40-inch x 32-inch. and the 48-inch x 40-inch pallets.

Today, hundreds of millions of pallets are sold each year to support the handling and movement of all types of manufactured products. Pallets are produced in many shapes and sizes; The most common materials are wood, plastic, corrugated board, and metal.

2 Why Plastic pallets and why now

2.1 Waste reduction

There is a global trend to put more efforts in waste reduction, or source reduction, which is an action that prevents generation of waste. to use less material in a package means that less will be disposed at the end of the package life, pallet is part of the packaging and It is not an exception, moreover it results in savings in production, processing.

This must be balanced against the function of the pallet which ensures the safety of the product the pallets carry. The packaging industry has a long tradition of source reduction, accomplished for the most part with the goal of saving money by using less material for packages. Glass bottles, plastic bottles, metal cans, and many other package forms have become thinner and lighter over the years.

Reuse of pallets is another form of waste reduction, the last decade or so. Some industries have switched from corrugated boxes to plastic or metal crates or bins.

One-way wood pallets have been replaced by reusable plastic pallets in several applications. (Yam 2009)

Over the last few decades, companies have been switching from wood pallets to plastic pallets. There are many different reasons for this switch, including cost, function, and environmental reasons. Although the initial cost of a plastic pallet may be higher than that of a wood pallet, recyclable plastic pallets last much longer. This allows companies to purchase fewer pallets over time and ultimately saves them money. Plastic pallets can also be designed for almost any function.

3 Types of plastic pallets

There are many types of plastic pallets and they can be sorted based on the design or material etc.

3.1 Plastic pallet types based on the Design

Stackable plastic pallets

Rack-able plastic pallets

Nestabl plastic pallets,

Double side plastic pallets

Nine legs plastic pallets

Picture frame plastic pallets

Three runner plastic pallets

3.2 Plastic Pallets types based on the type of material

There are many types of plastics to be used to manufacture plastic pallets. The most commonly used plastic types are:

High-density polyethylene (HDPE)

Polypropylene (PP) as the most common plastic material in the industry.

HDPE and PP can also be blended together

Advanced Composite Material (ACM)

3.3 Types of Plastic Pallets Based on Application

As marketing strategy to the nonprofessional users and buyers there are many categories to select the plastic pallets one of those ways is to differentiate the plastic pallet based on the application such as:

3.3.1 Export Industrial Plastic Pallets

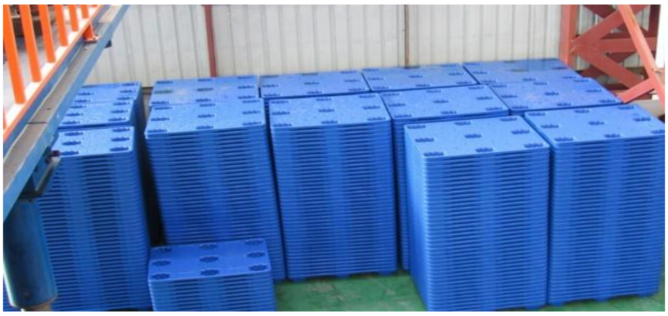


Figure #01

Plastic pallets stacked

These pallets are molded from recycled plastic, which is cost competitive.

Those designs are industrial plastic pallets only for export. That is, they are for one-way shipping.

Therefore, using 100% virgin high density polyethylene (HDPE) material or polypropylene (PP) material does not make any economic sense.

3.3.2 Spill Control Industrial Plastic Pallets

Figure #02

Plastic pallets stacked

The design of these plastic pallets aims to contain any leaks or spillages during storage and shipping. You can use them to store and transport hazardous substances.

This way, the fluid will not leak on the floor or shipping container. Like other industrial plastic pallets, these pallets come in a wide range of sizes and unique features. For instance, those used to transport drums may have recessed rings.

Here, will be recommend 100% virgin HDPE material. This is because it is resistant to most chemicals and absorbs less moisture.

3.3.3 Industrial Hygienic Plastic Pallets

Hygiene is a fundamental aspect in some industries such as: pharmaceutical, foodstuff, drug and beverage industries. For a fact, plastic pallets are more hygienic than wooden pallets.

Figure #03

Plastic pallets heavy load

Moreover, they are not subjected to strict regulations.

Industrial hygienic plastic pallets are easy to clean with no corners or edges that can accumulate dirt. Their surface is completely smooth. Furthermore, we may sterilize the pallets on request. This ensures the pallets are safe and do not hide any bacterial hence, reducing chances of infection.

4 Plastic pallet manufacturing process

Traditionally, companies used laborious manual methods for calculating pallet patterns, and they used ‘‘pallet pattern charts’’ and lookup tables to create very basic styles. This manual method of calculation was slow and inaccurate. Manual methods also proved to be inconsistent. They considered only a few alternatives and were narrow in scope, and communicating the results made preplanning difficult. With increasing mass-production techniques and the growth of product distribution on a nationwide basis, manual methods were simply inadequate (Broday, A. L, 1997).

Before manufacturing new molding tools, a simulation of the mold process can reduce the time of the product development process both by ensuring that the additively manufactured inserts will not break but also by providing valuable information about the part itself.

Simulations can provide information such as warpage, shrinkage and sink marks. By recognizing these problems in an early stage, the product development lead time can be reduced. (Kazmer, 2007)

The current methods to manufacture plastic pallets can be narrowed to the following ones:

4.1 Injection molding

The injection molding process is defined as shown in Figure #004 a cyclic manufacturing process for producing identical parts. The process also enables the production of these identical parts with high dimensional accuracy as well as a relatively short cycle time.

To ensure that the mold is according to the specifications, test runs and improvements are made before the mold is taken into production. The testing and modification processes further prolongs the lead time for producing injection molds. (Zheng, et al., 2011; Barkoula, et al., 2010; Kazmer, 2007).

Normally a common practice for minimizing the risks for failure during the molding process, is to analyze the process by using simulation software.

There is still a risk of not being able to replicate all the conditions accurately in the simulation, which leads to the need of physical prototype testing.

High performance pallets are usually injection molded as seen in Figure #04. Most injection molding is done using virgin or high-quality reprocessed resin. Injection molding is expensive, but it is also the highest speed process, and pallets can be made very quickly once the mold goes to press. Due to these factors, it recommended to choose injection molding when ordering a large volume of pallets. Most large orders or standardized orders are injection molded.

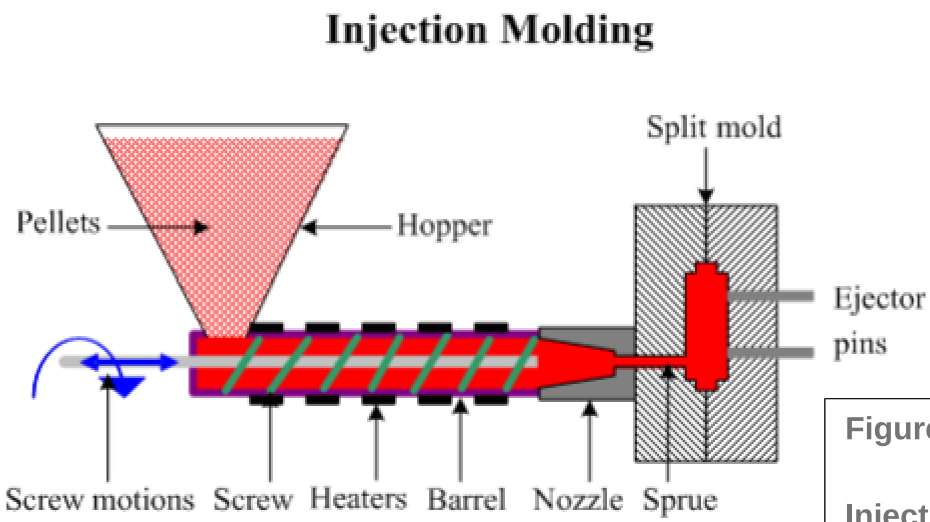


Figure #04

Injection molding

Injection molded pallets offer quality dimensions and high impact resistance from fork tine abuse. A cost to injection molded pallets limited choosing to a fairly standard type of pallet. From the marketing point of view if the pallet is unique, more than likely a manufacturer will not invest in the equipment to make it, since it is not a design they will be likely to implement often. In order to justify the investment, orders must typically exceed 50,000 units.

4.2 Rotational molding

4.2.1 History

Rotational molding, also called roto-molding or roto-cast, is a thermoplastic process for producing hollow parts by placing powder or liquid resin into a hollow mold and then rotating that tool bi-axially in an oven until the resin melts and coats the inside of the mold cavity. Next the tool is cooled, and the part is removed from the mold.

Historically Rotational molding was first developed in early the 20th century. On the other hand it was not widely used until the early 1960s, when Lyondell Basell replaced vinyl plastisol resins with polyolefin resins, that roto-molding gained wide acceptance.

4.2.2 Rotational molding as a unique method

• Resin powder is used instead of pellets

• The resin melts in the molds instead of being forced under pressure into the molds in a molten state

• The mold has a biaxial rotation

• Roto-molding molds are less expensive because of their simplicity

• Finally the operating pressures are relatively low, allowing molds to be made from less expensive materials.

It’s expected within a few years, the development of low and high-density polyethylene specifically designed for roto-molding enabled rotational molders to enter markets where vinyl parts and processes could not compete. In the early 1970s, cross linkable and modified polyethylene grades made their way into the rotational molding market. These new resins opened more new market areas, especially production of large tanks. Linear low-density polyethylene for roto molding was developed in the late 1970s, while the 1980s brought a surge of non-polyethylene resins, including nylon, polypropylene and polycarbonate for roto-molding.

4.2.3 Manufacturing a rotational molded part

1. Fill the mold with a polymer material

2. Heat the tool in the oven to melt material

3. Cool the tool to solidify the part

4. Remove the part from the tools

4.2.4 Materials used in rotational molded part

Currently polyethylene, in its many forms, represents about 85% to 90% of all polymers that are rotationally molded. Crosslinked grades of polyethylene are also commonly used in rotational molding.

4.2.5 Advantages and Disadvantages

The main advantages of rotational molding are:

- A hollow part can be made in one piece with no weld lines or joints
- The final product is essentially stress-free
- The molds are relatively inexpensive
- The lead time for the manufacture of a mold is relatively short
- Short production runs can be economically viable
- There is no material wastage in that the full charge of material is normally consumed in making the part
- It is possible to make multilayer products
- Different types of products can be molded together on one machine
- Inserts are relatively easy to mold in
- High quality graphics can be molded in

The main disadvantages of rotational molding are:

- The manufacturing times are long
- The choice of molding materials is limited
- The material costs are relatively high due to the need for special additive
- packages and the fact that the material must be ground to a fine powder
- Some geometrical features (such as ribs) are difficult to mold

4.3 Structural Foam

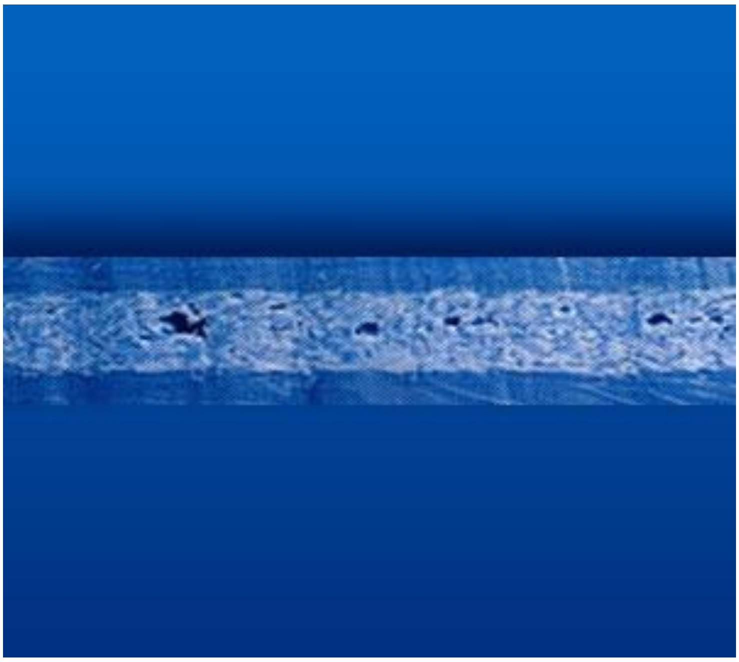


Figure #05

Cross section of

structural foam

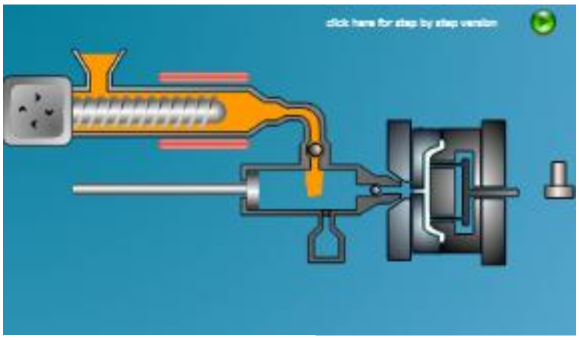
Structural foam molding is another process that is widely used for manufacturing plastic pallets because it is a process that costs less than injection molding, while offering many of the same benefits.

Structural foam is manufactured as in the process steps in Figure s #06, under lower pressure than injection molding, and uses gas in the process, rendering the inside of the plastic part porous instead of solid. This porosity allows for more rigid platforms (imagine thousands of bridges inside the plastic) making structural foam a good option for ensuring high weight capacity in racking.

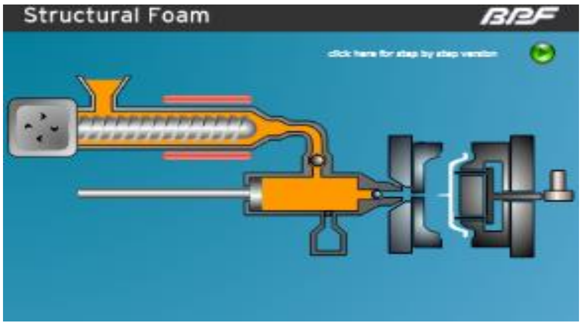
The trade-off is that the porosity renders the plastic more susceptible to damage at impact. When hit with force, pallets made from structural foam will chunk off in pieces. This is a problem for sensitive operations that cannot afford to have foreign particles introduced.

Structural foam yields parts that are larger and sturdier than injection molding, which can be considered as an advantage for pallets manufacturing.

Process steps:



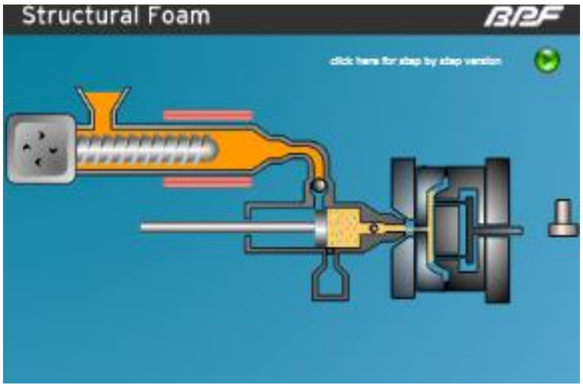
Step #1



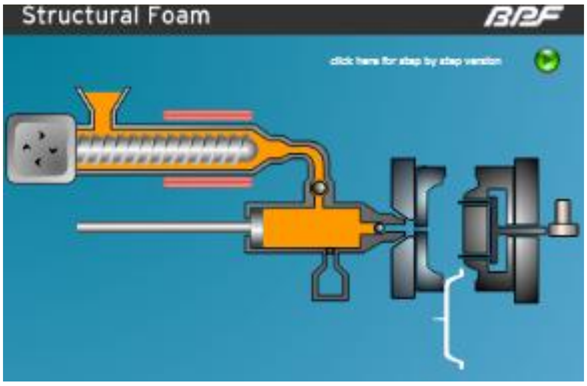
Step #2

Figure #06

structural foam manufacturing steps



Step #3



Step #4

the molding cavity is injected with plastic pallet material and an inert gas. That is, a gas that does not react chemically with the material.

4.3.1 Typical material

In general, the typical materials used are:

- Acrylonitrile-Butadiene-Styrene ABS
- Polystyrene PS
- Polycarbonate PC
- Polypropylene PP
- Polyvinyl chloride PVC

4.3.2 Methods of Producing Structural Foam

4.3.2.1 The Low Pressure Process

To achieve consistent quality moldings, it is recommended to use dedicated special purpose injection molding machines. The machines introduce a gas into the melted plastic which when injected into the closed mold tool subsequently foams the plastic material of the component being produced.

4.3.2.2 Conventional Molding Machines

Another widely used method is the use of standard injection molding machines with added "blowing agents" incorporated into the material. Using dry chemical blowing agents mixed in with the granules of plastic, the plastic is melted in the barrel of the machine. A measured charge is injected into the mold tool. The heat of the melted plastic causes the blowing agent to react, which forms a gas, which in turn foams the plastic.

4.3.3 Benefits of Structural Foam Molding

The use of structural foam as a manufacturing material comes with a large number of advantages and almost nonexistent drawbacks. Of course, structural foam initially became known for its ability to create parts of unparalleled size, such as the roofs or body panels of vehicles. However, it soon became apparent that structural foam promised a number of additional benefits.

Structural foam parts are extremely lightweight, In addition to this decrease in weight, structural foam is strong, durable, and extremely stiff – in fact, up to 8 times stiffer than similar materials such as solid polymers.

Structural foam is also highly moldable; it is able to produce variant wall thicknesses across a single part. In some cases, structural foam has even been able to generate wall thicknesses greater than the previous maximum of ½ inch

(13 mm). It also allows for thick ribs and bosses and reduces the risk of “sinks” over ribs or heavy cross-sections due to the lower viscosity of the mixture. Structural foam products experience less stresses overall during the molding process, and are highly resistant to warpage or deformation.

In addition, structural foam retains the impact, element and temperature resistance common to thermoplastic and thermoset polymers. It experiences minimal to no thermal expansion, making it perfect for products which will be utilized in a wide variety of climates or temperatures. The acoustic and sound dampening properties of structural foam are also superior to those of standard solid polymers.

Structural foam molding is also a highly cost-efficient process. Lower pressures and clamping forces are required during the injection and curing periods, allowing the tooling and molds to be made from lower cost materials such as aluminum. Cycle times are competitive with those of injection and reaction injection molding, making this a time-saving process as well as a money-saving one.

Structural foam products have a lower than average risk of damage in the mold or during the removal process, making it a highly efficient and easily repeatable method. In addition, structural foam produces no potentially harmful styrene fumes, lowering the health risks for workers involved in the molding process.

Lastly, structural foam also features highly paintable, aesthetically pleasing surfaces with a distinctive “swirly” appearance. In-mold painting (IMP) is possible for all structural foam products, further saving time and money. Multiple colors can also be applied to a single part in-mold. The surface is easy to clean and can be sawn, screwed, nailed or stapled without experiencing any problems. Structural foam is even more environmentally friendly than similar materials, as it is highly recyclable and reusable.

If you need large parts manufactured without sacrificing quality, structural foam is the way to go.

4.4 Thermoforming

In general Plastic thermoforming is one of the fastest growing methods of producing plastic packaging. With thermoforming technology, pallets can be created in almost any size that a company requires and they can also be designed to be nest-able and stackable. Since plastic pallets are typically designed to be nest-able, empty pallets take up less room on the shop floor than wood pallets. Plastic pallets are also an environmentally friendly option. Most pallets are made with at least some, if not 100%, recycled material and are fully recyclable as well.

Plastic pallets are not simply used for single use and then recycled; they are also used for returnable packing. Returnable packing allows a company to purchase the pallet once and reuse them for years. Since the pallets are nestable, the pallets take up less space on the return trip, often equating to less freight costs. This means that plastic pallets will directly reduce shipping costs for most companies. Therefore, plastic pallets in general is a better value than wood pallets because plastic pallets are a more durable, cost-efficient, and environmental sound than wood pallets.

4.4.1 Thermoforming Materials

The most widely used plastic materials in thermoforming are the amorphous or non-crystalline types, with the most popular including:

- PVC or Polyvinyl Chloride
- Polyethylene
- Impact Modified Polystyrene
- Acrylic
- ABS or Acrylonitrile Butadiene Styrene
- Polycarbonate

Material stock for thermoforming is available in two different forms, cut sheet, which is primarily used for heavier gauge products requiring thicker wall sections, and thinner gauge roll-fed sheet, which is used in high-volume, light weight packaging applications.

These materials often incorporate colors, anti-static agents, ultraviolet inhibitors, fire retardants, and other additives to enhance the final product use and packaging requirements. Additionally, thermoplastic sheets with multiple layers may be used. These can provide efficient barriers to oxygen and moisture and other attributes in critical packaging applications.

4.4.2 Thermoforming Molds

Typically, thermoforming molds have protruded, or convex surfaces, and are referred to as male, or positive, molds; or they have concave, cavity surfaces, and are referred to as female, or negative, molds. Molds can be further defined as being single cavity or 'one-up' molds for single or short run production, and multiple cavity, and or 'family' molds for volume production. Family molds are multiple cavity molds used to produce more than one part design simultaneously from a single sheet of plastic stock.

Thermoforming molds for short run production or prototype work use molds made of wood, plastic, epoxy, or other relatively inexpensive material. These molds are not temperature controlled.

High production thermoforming molds are always made of aluminum because of its lightweight, machine ability, and high thermal conductivity. Aluminum molds contain channels through which water, the primary cooling medium, is pumped. Cooling rate and temperature control affect the shrinkage and other attributes of the thermoformed part.

To achieve part detail, molds must also be able to evacuate all air trapped between the plastic and mold surfaces. This is done through the use of a vacuum or providing vent holes at specific locations within the thermoforming mold.

4.4.3 Methods of thermoforming

• Drape Thermoforming, in which the plastic sheet is stretched over a positive mold. Once the plastic seals against the mold edges, a vacuum is introduced pulling the material tightly against the mold contour.

• Cavity Thermoforming, in which a heated sheet of plastic is laid over a negative or concave mold. Once the materials seals at the mold edges, it is subjected to a vacuum pulling the material tightly into the mold.

• Pressure Thermoforming, in which material is positioned between a pressure plate and a mold. Air pressure is then introduced through the pressure plate forcing the plastic against the mold surface. Pressure thermoforming is used for finely detailed parts and requires strongly made molds.

• Plug Assist Thermoforming, which is similar to cavity forming but with a male plug forcing the material partially into the mold cavity. A vacuuming completes the thermoforming and is sometimes aided by positive air pressure. This thermoforming method is particularly fast and helps maintain consistent wall thicknesses.

• Twin Sheet Thermoforming, which is used to produce hollow parts. Typically two preheated thermoplastic sheets are positioned between mold halves. These mold halves are brought into position with their respective preheated sheets, sealing their top edges. A vacuum is then applied, forming the two individual part halves. Before the thermoformed sheets cool, the mold halves are brought together welding the halves into a hollow construction.

4.4.4 Advantages of thermoforming

Thermoforming has a number of advantages. One of its main draws is that it is very adaptable to a customer’s design needs. With a fast turnaround time, it can be used for last-minute shipments or as a quick way to develop a prototype.

It is also a relatively low-cost means of production: the materials are optimized for cost effectiveness and can lead to lower tooling costs.

Finally, the results can be very aesthetically pleasing. Colored and paintable plastics are available, allowing for a wide range of customization to meet customer needs.

4.4.5 Disadvantages of thermoforming

There are also several disadvantages associated with thermoforming. This process is limited to thin walled parts and there are limitations to the complexity of shapes it can be used to create. Each piece requires trimming, which adds time to the process.

Despite of its disadvantages, thermoforming provides a flexible and cost effective method for creating a huge variety of products.

5 IOT in Plastic pallets

IOT has been used in wooden plastic pallets a while ago, but plastic pallets have opened the door wider for the following reasons.

5.1 Durability of plastic pallets

plastic pallets are not as before intended for one-time use, that is not the case now anymore. The durability of plastic pallets vs wooden pallets allows the IOT to utilize pallets for more purposes than just logistics usages.

5.2 Consistency of plastic pallets

In the Automated systems plastic pallets are highly-engineered and manufactured in a mold, it is more consistent than new wood pallets, it makes them ideal for automated storage and conveyor systems, Since there are no deck boards to break or stringers to collapse, plastic pallets are less likely to fail during use and stop the line.

There are many special types of pallets designed to match customers' needs such as:

1. Anti-static industrial plastic pallet; they are common in electronic industry. These industrial pallets are designed to discharge static charges. This prevents any accumulation static charges on the industrial plastic surface.
2. RFID industrial plastic pallet; these pallets come with radio frequency identification (RFID).

6 Design really matters

As explained earlier in the research there are many elements affecting the selection of material and manufacturing process. The design itself has its own effect on how durable it is from the point of view of the mechanical engineering.

Depending on the application and the actual usage of the pallet in practice, the design can play an important role to save the material.

To achieve the material saving, clear steps should be taken, here in the research a static load testing will be conducted with the help of simulation 3D program to show the difference between 2 pallets design and what is the difference.

6.1 Material selection

The research focused to compare between 2 different designs and the material selected is plastic material PEHD.

6.2 Type of load applied

The static load on the surface of the pallet, for simplicity, and the bottom of the pallet are totally fixed.

6.3 Design option number one

The first design option of the pallet is seen in Figure Figure #7

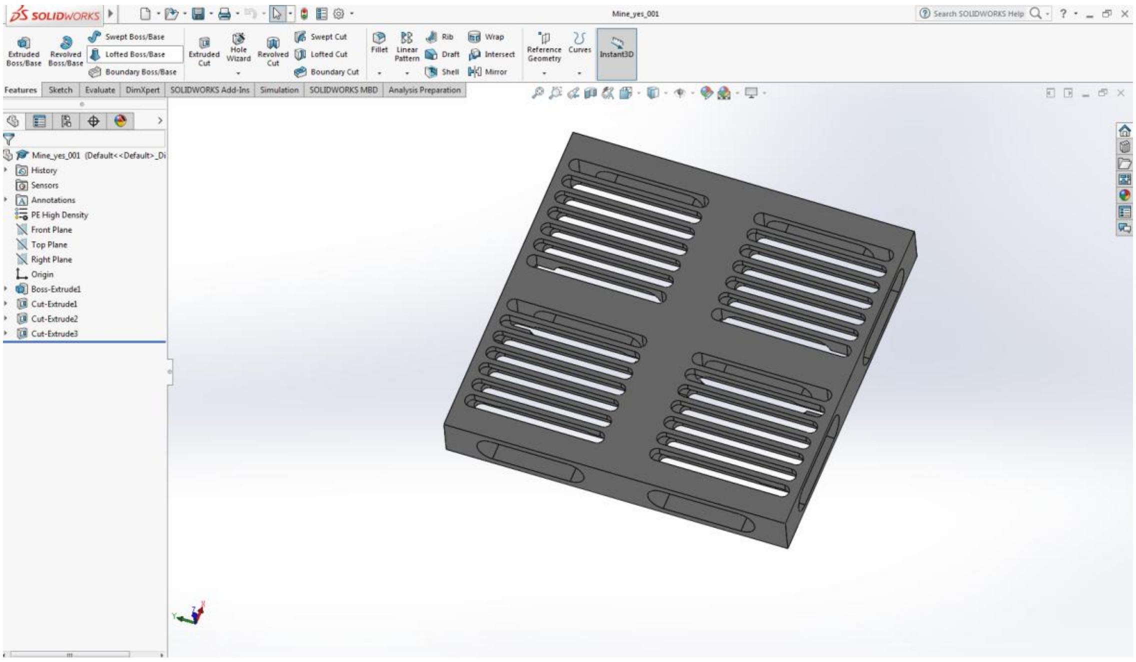
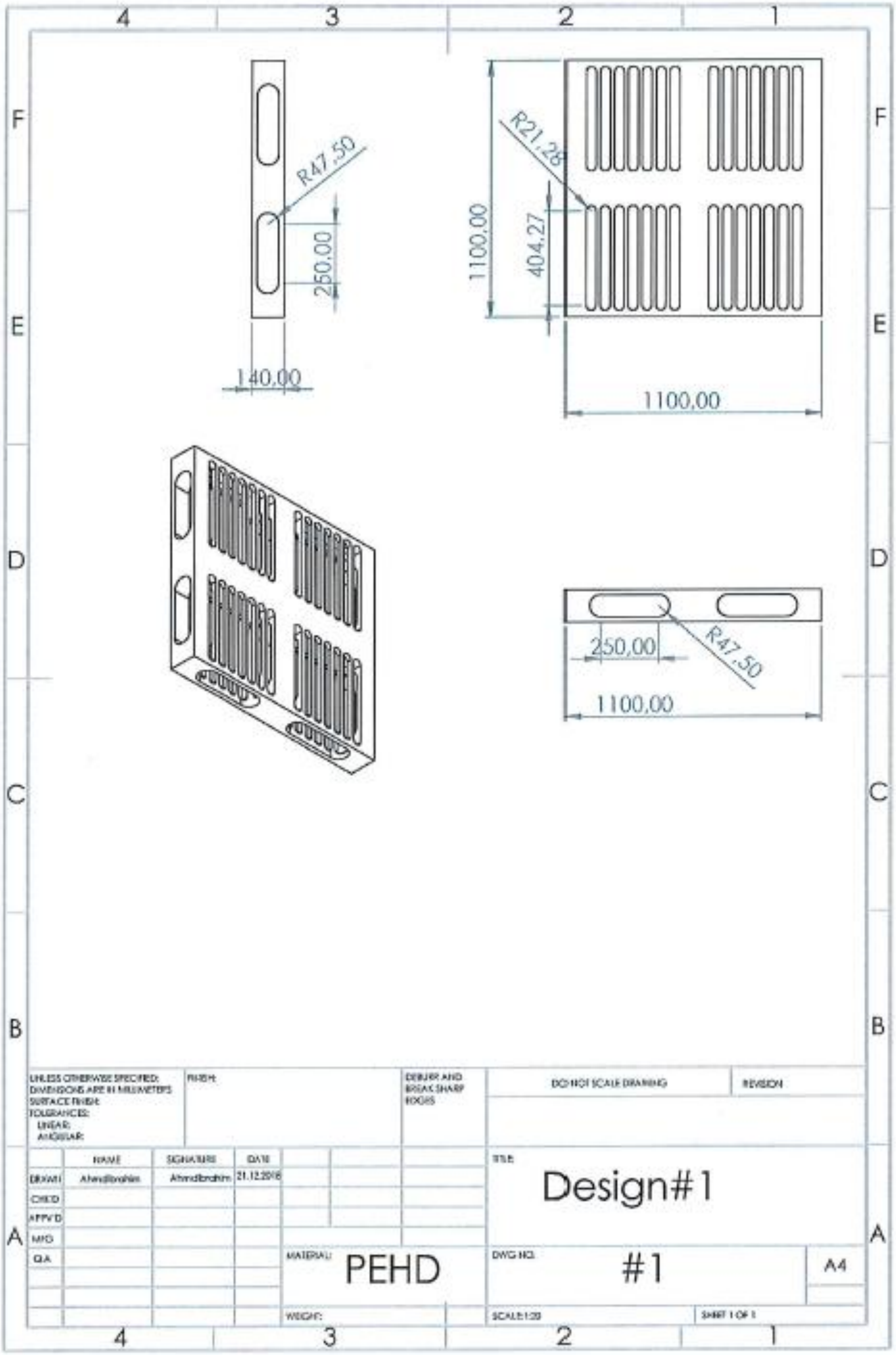


Figure #07

The diminutions of the pallets as seen in the drawing sheet from soldiworks program are 1100 mm X 1100 mm and the details in the Figure #8.


R47,50
250,00
140,00
R21,28
1100,00
404,27
1100,00
250,00
R47,50
1100,00
DO NOT SCALE DRAWING
REVISION
TITLE:
Design#1
MATERIAL:
PEHD
DWG NO.
#1
A4
WEIGHT:
SCALE:1:20
SHEET 1 OF 1
NAME
SIGNATURE
DATE
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AhmdIbrahim
AhmdIbrahim
21.12.2016

Figure 08

The material is high-density polyethylene (PEHD). the details as seen in Figure #09

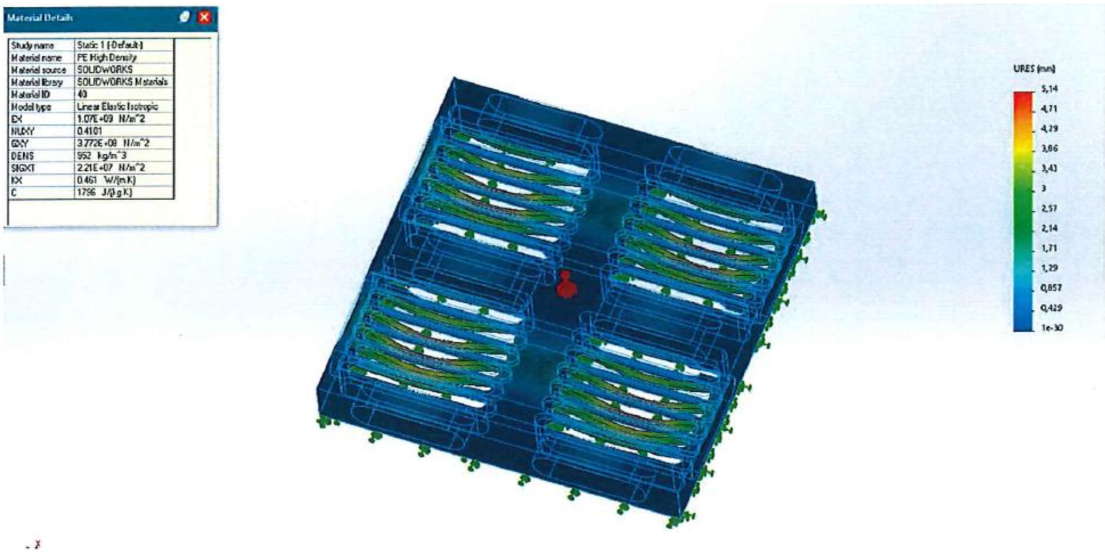

Figure 09

The load applied is static load to mimic the reality, it has been chosen to be pressure load.

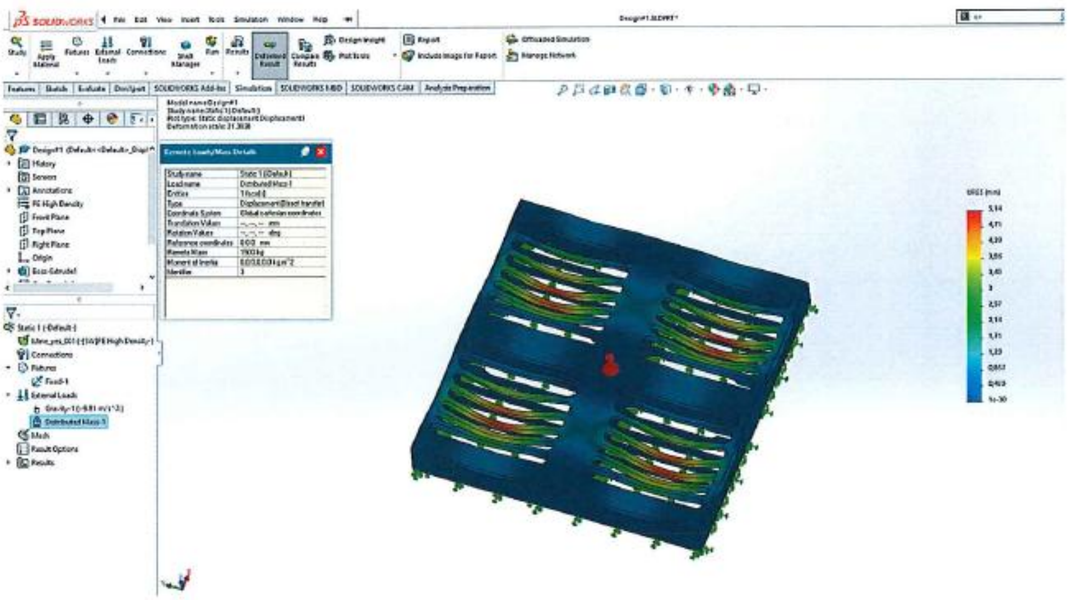

Figure 10

The results show the maximum displacement 5,14 mm under 1500kg pressurised static as seen in Figure 10.

The mass of the design is 45,06 kg as seen in Figure 11.

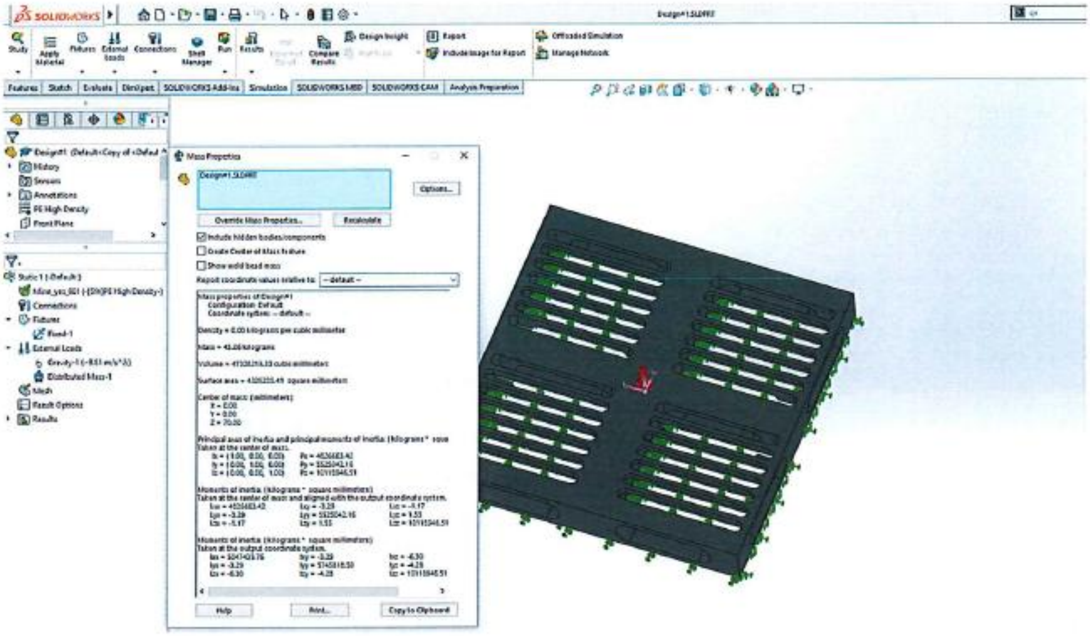

Figure 11

6.4 Design option number two

The second design option of the pallet is seen in Figure 12.

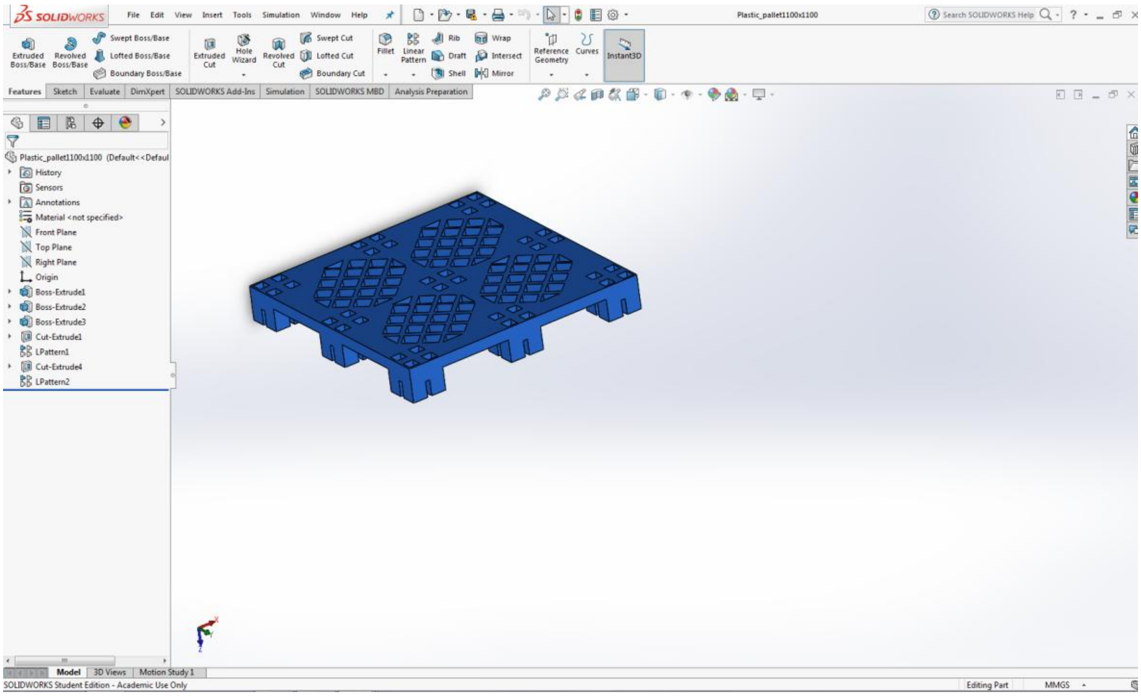

Figure 12

The design dimensions are the same as in deign number one 1100 mm X 1100 mm as shown in Figure 13

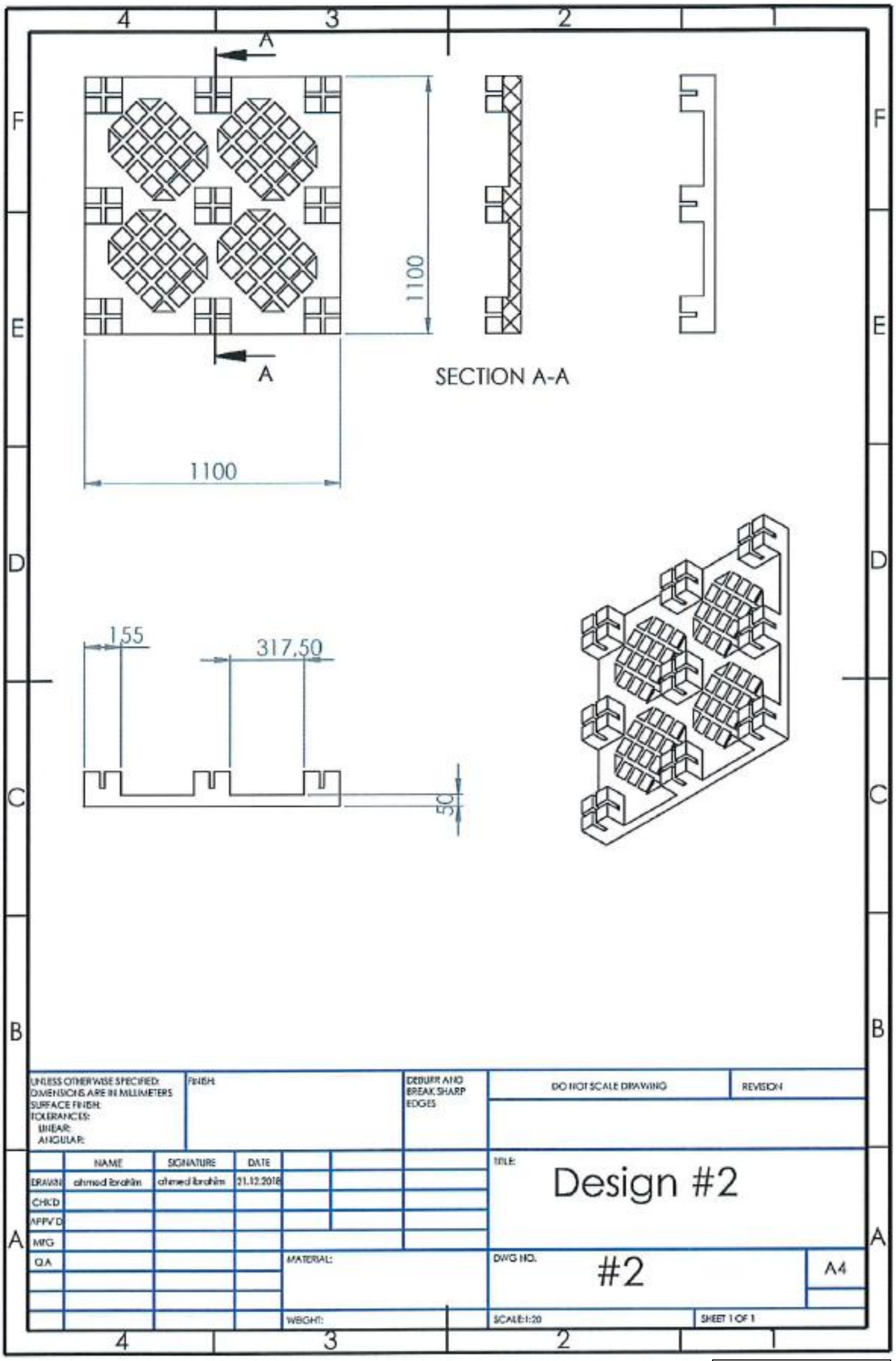

Figure 13

The weight is 49,24 kg as seen in Figure 14

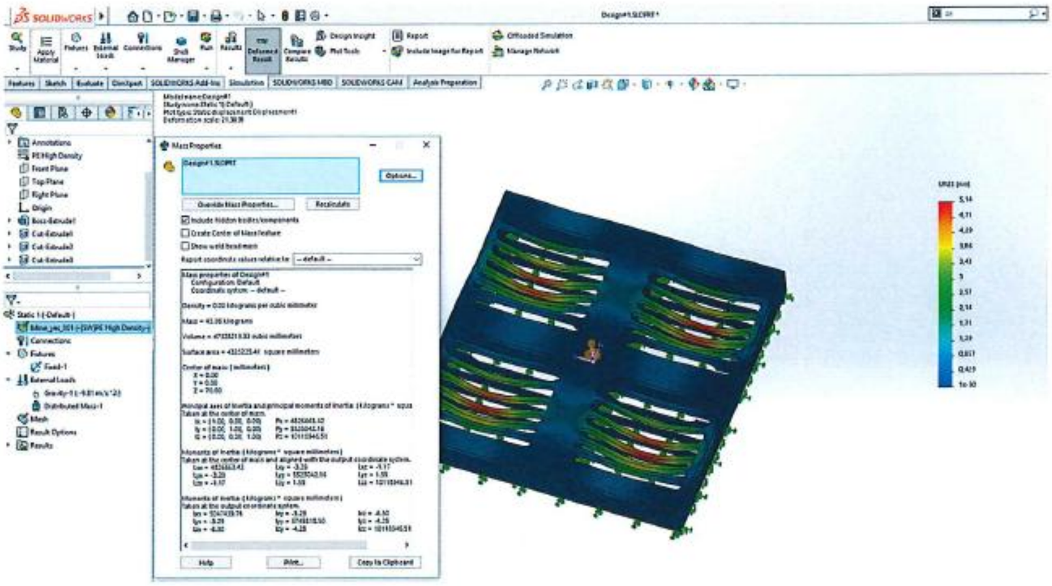

Figure 14

The Load applied is the exact same load which is a pressurised weight of 1500 kg static load.

The result is different. The maximum displacement shows only 0,30 mm as in Figure 15

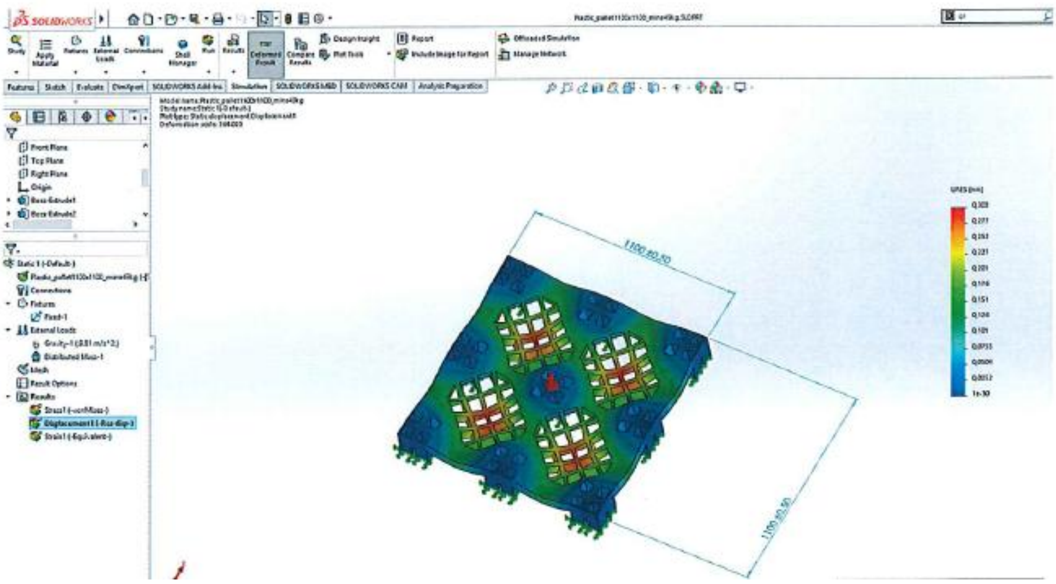

Figure 15

7 Result analysis

The designs number one and design number two both of them are from the same material PEHD. Both designs are the same dimensions 1100 mm X 1100 mm. Both designs have the same load 1500 kg steric pressurised. The displacement of the design number one is huge compared to design number two.

it means with innovative design and without using much materials, there is a way to increase the efficiency and reduce the cost in pallet manufacturing.

8 Recommendations for Further Development

When it comes to the pallet usage, so many possible aspects of recommendations can be done. in fact, according to what has been discussed in

the theoretical and analysis parts, possible outcomes in the pallet research are totally laid on the unitized tendencies in the market and the related demands and requirements for them. It is strongly recommended to consider the pallet basic raw materials and affiliated costs as the basis for the future development and researches.

Dealing with cost and raw materials can create other issues to defy with creating a model for efficient and effective pallet pool systems and managing them is the other interesting area of concentration.

The Design, the structure and the ergonomics factors are following the market requirements which at this scale is negligible in comparison with factors such as cost and raw materials.

The sustainable achievement towards the substitute raw materials and the best

possible option from recycling, reusing, waste reduction and on the whole sustainability is also recommended for the future studies and researches in this area.

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