UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND FABRICATE MOLD FOR POLYMER BASED INTERLOCKING TILES

This report submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Manufacturing Engineering Technology (Product Design) with Honours

by

MUHAMMAD IZZAT IQBAL BIN SUPANDI

B071210578

900909-01-6017

FACULTY OF ENGINEERING TECHNOLOGY

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DECLARATION

I hereby, declared this report entitled “Design and Fabricate Mold for Polymer Based Interlocking Tiles” is the results of my own research except as cited in references.

Signature : ………………………

Name : Muhammad Izzat Iqbal Bin Supandi

Date : ………………………

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) (Hons.). The member of the supervisory is as follow:

…………………………………

Hairul Effendy Bin Ab Maulod

ABSTRACT

Ceramic tiles have been known for its usage for a very long time. Landmark buildings in Europe with ceramic glazed tiles still exists and on display. Though classically we have identified human civilization through the centuries from the main material that contributes to the growth. Beginning with the Stone Age, Bronze Age, Metal Age and now some scientists are in agreement that the modern age is defined by the Plastics Age. Ceramics tiles are known for its durability, anti-fungal, but most of all its aesthetic quality. The drawback that it has is that in mass production some conventional methods are still being used because it retains the high standard quality that it is famous for but with higher economical cost. Polymeric tiles was found to be a good alternative to ceramic due to its low cost of raw material, ease of production, differing design and also customizable. Same with ceramic tiles, a mould is required in order to produce the polymer tiles. Mild steel was chosen as the mould material due to its low cost and also easier to machine. The mould will be used on a hot press machine since to design and fabricate an injection mould requires complex parameters. An interlocking feature was added to facilitate assembly of the polymer tiles. The mould was designed using CAD software and analysed for its functionality. Finally the mould was fabricated using CNC machining and also a detailed drawing was produced according to the design.

ABSTRAK

Jubin seramik terkenal dengan kegunaanya sejak dari dahulu lagi. Bangunan mercu tanda di Eropah dengan menggunakan seramik masih wujud dan masih dipamerkan. Walaupun secara klasik kita telah mengenal pasti tamadun manusia sepanjang abad daripada bahan utama yang menyumbang kepada pertumbuhan. Bermula dengan Zaman Batu, Zaman Gangsa, Zaman Logam dan kini beberapa saintis bersetuju bahawa zaman moden ditakrifkan oleh Zaman Plastik. Jubin seramik terkenal dengan ketahanan, anti-kulat, tetapi yang paling penting kualiti estatiknya. Kelemahan yang dipunyai adalah bahawa dalam pengeluaran besar-besaran beberapa kaedah konvensional masih digunakan kerana ia mengekalkan kualiti yang tinggi dan standard yang terkenal dengan kos yang lebih tinggi. Jubin polimer didapati menjadi alternatif yang baik untuk seramik kerana kos bahan mentah yang rendah, kemudahan pengeluaran, reka bentuk yang berbeza dan juga disesuaikan. Sama dengan jubin seramik, acuan diperlukan untuk menghasilkan jubin polimer. Keluli lembut dipilih sebagai bahan acuan kerana kos yang rendah dan juga lebih mudah untuk dimesin. Acuan ini akan digunakan pada mesin tekanan panas kerana untuk mereka bentuk dan reka acuan suntikan memerlukan parameter kompleks. Satu ciri yang saling bertaut telah ditambah untuk memudahkan pemasangan jubin polimer. Acuan ini telah direka menggunakan perisian CAD dan dianalisis untuk fungsinya. Akhirnya acuan telah direka menggunakan pemesinan CNC dan juga lukisan terperinci telah dihasilkan mengikut reka bentuk.

DEDICATIONS

To my beloved family, friends and lecturers which have been the source of my inspiration to undergo this project to a success. Thank you for all the support and encouragement from the start until end.

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I would like to express my appreciation to Allah S.W.T. for giving me grace, love and blessing, to help me to pursue my ambition up to this point of my life.

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

This chapter will explain the overview of the study and the purpose of this study. The chapter includes the background of the study, problem statement, objectives that is expected to be achieved and the scope of the study that is going to be conducted.

1.1 Background of Study

Interlocking tiles is a product that cover cement floors with an added aesthetic look and comes with safety measures as it minimizes tripping hazard due to uneven floor surface and as an aid in water drainage which keep areas both dry and safe. Furthermore, interlocking tiles are easy to install, customizable and affordable. Interlocking tiles can be divided into two main categories which are rubber tiles and polymeric tiles. Polymeric tiles are chosen in this research because it is on option for ceramic tiles that have been used widely around the world.

The most common material used to manufacture interlocking tiles is polymer. Polymer is a plastic resin that can be enhance by adding color and other additive to fortify the properties of the resin such as strength and flexibility before it undergoes molding process (Ibeh C.C., 2011). For this project, polypropylene is selected because the material is easy to obtain.

In molding process, hot press method is used to make this product. It is because hot press method is cost saving as this product does not require complex geometry in its design (Zhang et al., 2011). The material for the mold is mild steel because of prototype purpose only, not for mass production.

Hot press molding is a type of manufacturing process where plastic pellets is heated to certain temperature inside the mold cavity until the plastic melts and give the desired shape based on the mold itself. As for the hot press mold, it refers to an arrangement of hollow cavity spaces built to the shape of preferred product in one assembly to produce plastic product in mass production. The cavity space consists of female mold part known as cavity and male mold part known as core. There are limits in what material should be used for making hot press molding as this process usually use thermoplastic materials and also applicable to certain thermoset material (Rees H., 2002).

Hot press molding consists of multiple part as shown on Figure 1.1 such as (1) pressure head, (2) upper shell, (3) upper heat retainer, (4) guide sleeve, (5) upper asbestos insulation, (6) heating room, (7) die orifice, (8) female die, (9) roof plate, (10) punch, (11) billet, (12) workbench, (13) lower template, (14) guide pin, (15) ejector pin, (16) electric iron core, (17) lower shell, (18) lower asbestos insulation, (19) lower heat retainer, (20) fixed plate, (21) guide sleeve, (22) upper insulation cushion, (23) movable beam and (24) upper template (Zhang, et al., 2011).

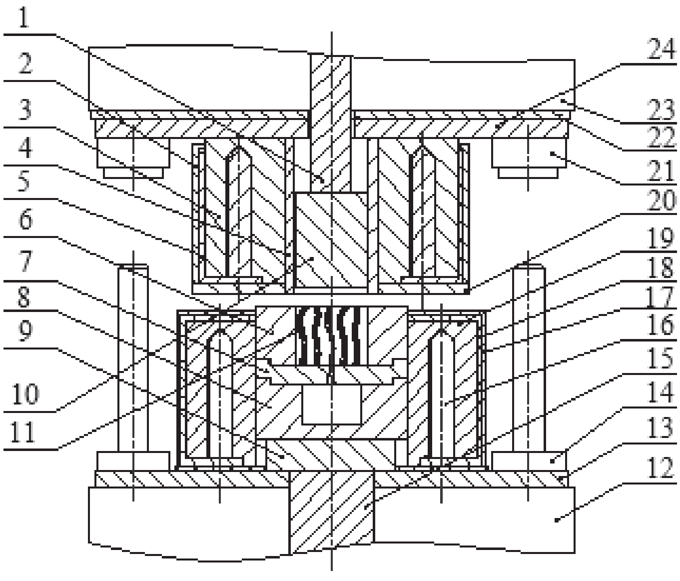


Figure 1.1: The cross sectional of a hot press mold

1.2 Problem Statement

Ceramic tiles were applied for many purposes since the early time. Some of its example was the Great Pyramid in Egypt and the ancient Babylon. The structure made of ceramic still exist and in good condition. This shows how durable this material is. Material to make ceramic is really easy to obtain as different types of clays can be found nearly everywhere on earth. However, to make this ceramic tile uses massive amount of energy as the clay need to be fired at least once at typical firing temperature of 1204°C (Abraham et al., 2010).

Polymeric tiles in the other way, is easy to manufacture as it has low melting point. Besides that, most of polymers can be recycle and reproduce. Polymer can also blends with other material to improve its mechanical properties which may result to improvement of wear resistance and improve friction (El-Abden et al.,2014).

There are basic steps to install a ceramic tile that is preparing the surface, creates layout lines, tile fitting and cutting, setting the tiles with adhesive, filling joints with grout and in some cases, sealing the grout joints or tile (Barret J., 1993).

Although ceramic tiles installation can be done by certain individual, it takes technical skills such as measuring to draw layout for floor design, mark reference lines and test corners for square. After all the measuring, the floor needs to be spread mortar evenly before the tiles can be place on top of it. This requires skills and experience to make sure that the surface of the tile flooring is even on all side. The final process is applying grout between the gaps to make sure the tile floor is waterproof. This process is a quite messy and cleaning is required to remove any excessive grout (Farris J., 2007).

Table 1.1 state the price report of floor tiles obtained from Construction Industry Development Board (CIDB), Malaysia from January 2014 to December 2014.

Table 1.1: Price report of floor tiles January 2014 to December 2014, CIDB.

Building Materials	Jubin Lantai dan Dinding / Walls and Floor Tiles			
	Plain Homogeneous Floor Tiles, Standard light Colour, 200mm x 200mm x 8mm - Grade 1	Plain Homogeneous Floor Tiles, Standard light Colour, 300mm x 300mm x 8mm - Grade 1	Glazed Ceramic Wall Tiles, Standard light Colour, 200mm x 200mm x 6mm - Grade 1	Glazed Ceramic Wall Tiles, Standard light Colour, 200mm x 250mm x 6mm - Grade 1
	RM / piece	RM / piece	RM / piece	RM / piece
	60 Del	60 Del	60 Del	60 Del
Jan-14	1.85	2.78	1.00	1.40
Feb-14	1.85	2.78	1.00	1.40
Mar-14	1.85	2.78	1.00	1.40
Apr-14	1.85	2.78	1.00	1.40
May-14	1.85	2.78	1.00	1.40
Jun-14	1.85	2.78	1.00	1.40
Jul-14	1.85	2.78	1.00	1.40
Aug-14	1.85	2.80	1.03	1.40
Sep-14	1.85	2.80	1.03	1.40
Oct-14	1.85	2.80	1.03	1.43
Nov-14	1.85	2.80	1.03	1.43
Dec-14				

MT=Matric Tonne, m2=Square Metre, m3=Cubic Metre, Del=Delivered, Ex=Ex-Factory, E

1.3 Objectives

The general objective of this project is to design and fabricate mold for hot press to produce polymer based interlocking tiles. For the specific objective, this project aims;

1) To obtain the best design for polymeric interlocking tiles.
2) To determine the core and die design and fabricate specifically for hot press.
3) To fabricate mold prototype for hot press.

1.4 Scope

The scope for this project is only focused on;

1) Design interlock pattern for the tile.
2) Select suitable material for the tile.
3) Design the mold core and die.
4) Select material for mold.
5) Fabricate the mold prototype.

CHAPTER 2

LITERATURE REVIEW

This chapter explains about all findings obtained from many literature reviews, which may come from the internet, journals, article and books about the topic related to this study. This section includes findings about the overview of interlocking tiles design, hot press molding, mold design and mold making process.

2.1 Issues

The ceramic tile is giving a bad influence to the environment due to consumption of energy sources, raw material, emission and waste that emerged throughout the production (Hocenski et al., 2006). Figure 2.1 shows the schematic diagram of making a ceramic tile.

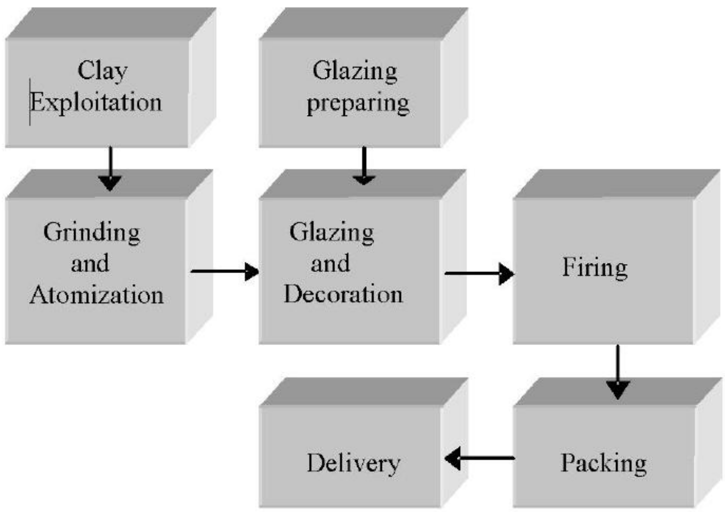


Figure 2.1: Ceramic tile manufacturing process.

2.2 Part design process

To design a plastic part, there are several approach and methods available. One of the method that is widely been used in industry is the concurrent engineering. This method is a time and cost saving method as the development process is team oriented with improved communication between different groups which is marketing, design engineering, and manufacturing groups as shown in Figure 2.2 (Malloy R.A., 2011).

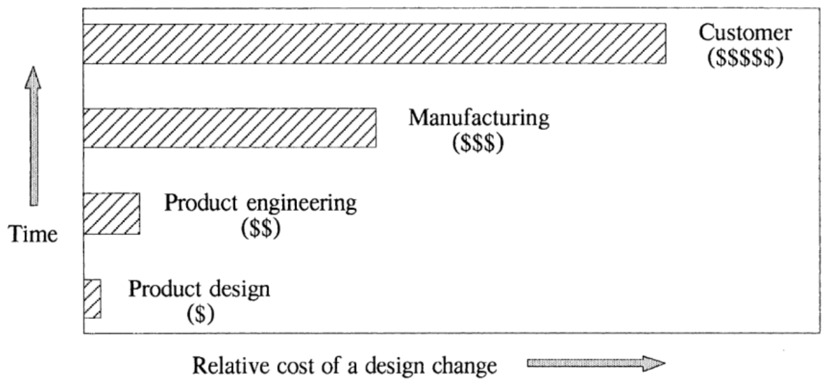


Figure 2.2: Relative cost of a design change vs time in concurrent engineering.

Concurrent engineering to product design is to reduce development time, increasing quality, and minimize potential for unexpected production or performance problems. Figure 2.3 shows the concurrent engineering flow chart (Malloy R.A., 2011).

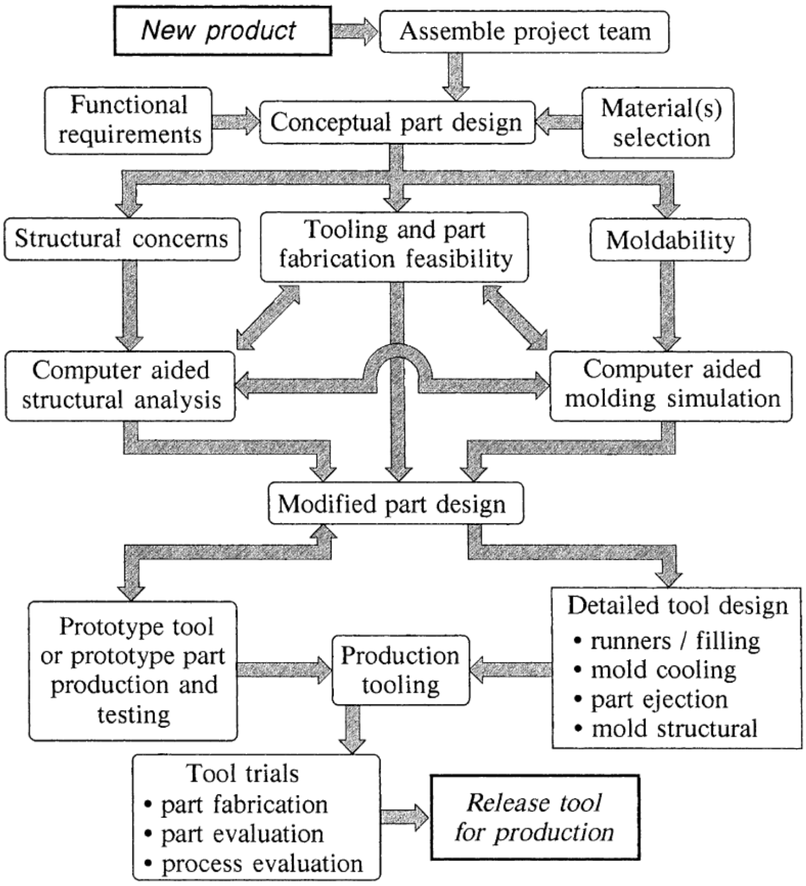


Figure 2.3: Concurrent engineering flow chart.

Plastic part design is best accomplished using the practice of concurrent engineering. These are steps to accomplished plastic part design and fabrication which is:

1) Defining end-use requirements
2) Create preliminary concept sketch
3) Initial materials selection
4) Design part in accordance with material properties
5) Final materials selection
6) Modify design for manufacturing
7) Prototyping
8) Tooling
9) Production

2.3 Part design

The design sketched is turned into computer aided drawing (CAD) using SolidWorks software. It is one of the most popular 3D CAD software. It has become favorite design tool among engineers, mechanical designers and industrial designer. This is because of its easy-to-learn graphical user interface and tremendous tool set. Its ability to create 3D solid geometric is later transformed into technical drawings, manufacturing instructions, animation, instruction manual, vivid renderings, and other types of document. Other features such as simulation and analysis have become an extra as the designer can evaluate whether his product is good enough (Ruiz A.R., 2010).

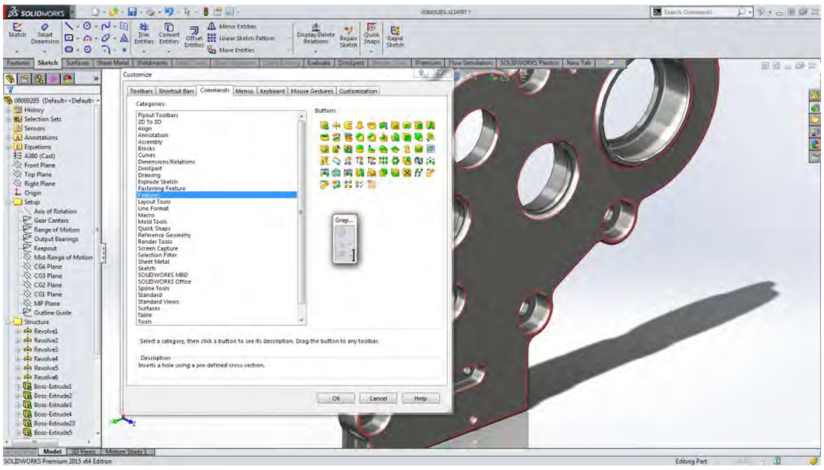
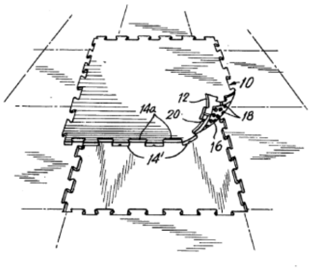
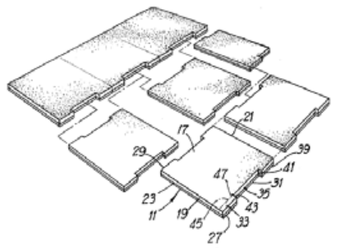
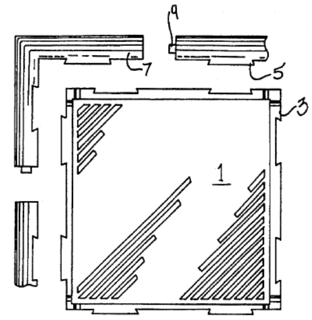
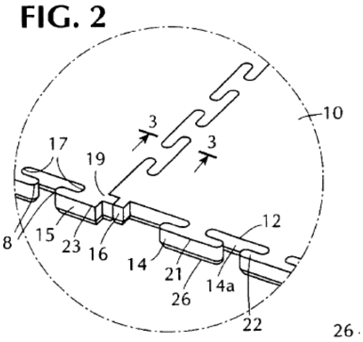
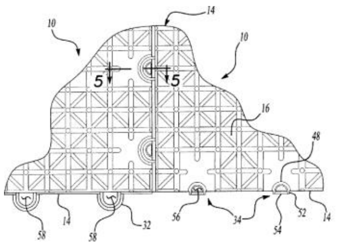
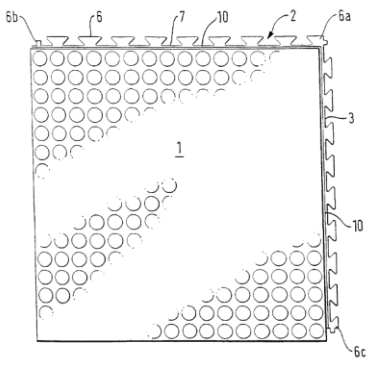
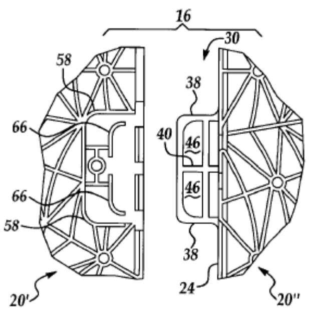
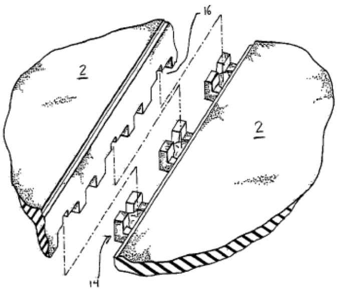


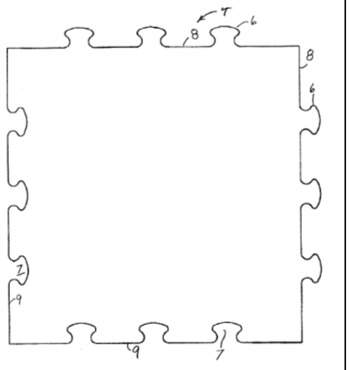
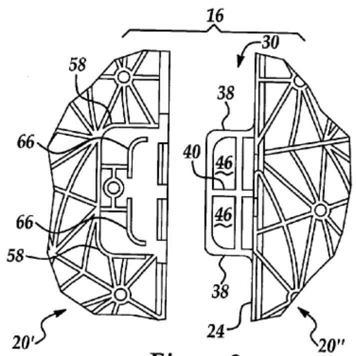
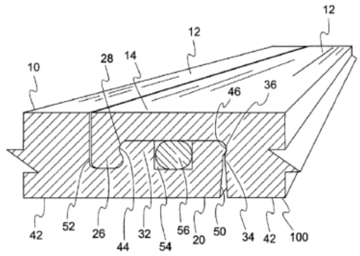
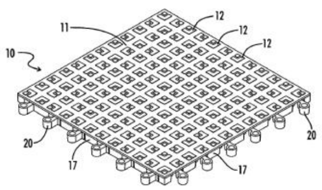
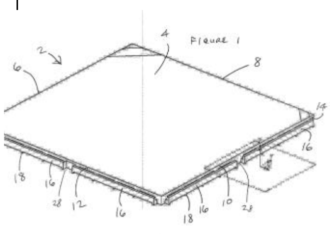
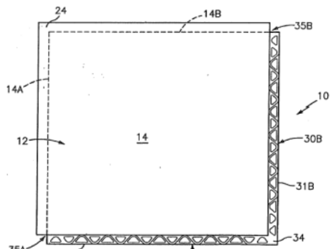
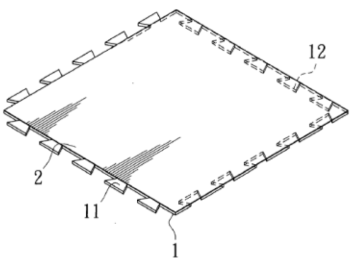
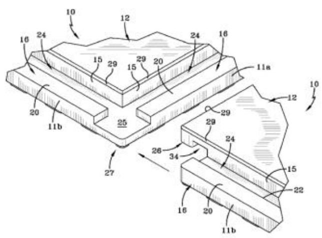
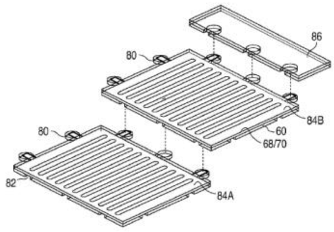
Figure 2.4: SolidWorks user interface.

SolidWorks is used to make virtual prototype. It helps you to visualize the product in most realistic way without producing the real physical part. This term is called modelling. Feature-based modelling is a term where model building is created incrementally identifying functional shape and applying process to create the desired shape. For example, a simple box can be created by using the Extrude process and a sphere is created by using Revolve process. Visualizing the 3D shape is required to make the 2D sketch (Lombart M., 2007).

In Table 2.1 are some designs that have been patent. These designs were used as a restriction benchmark to make sure the final design is not similar to these patent designs.

Table 2.1: Interlocking designs that have been patent.

US4018025		US4571353	
US5630304		US5791114	FIG. 2 
US6098354		US6526705B1	
US6751912B2		US8070382B2	

US8215077B1		US20020189176A1	 Figure 9
US20020189183A1		US20050183370A1	
US20050252109A1		US20070011980A1	
US20080209840A1	 FIG. 2	US20110011020A1	
US20130139463A1		US20140226329A1	

2.4 Material selection for tile

There are various thermoplastic are available to use in the hot press molding. The typical raw materials of plastics are oil, natural gas, coal, agricultural products such as corn, soybean, etc, chemicals such as benzene, glycols, isocyanates, phenols, sodium chloride, etc. These raw materials are not directly turned into polymer as chemical treating process is required. All the process takes place in the refinery and specialized laboratory (Petrovic Z.S., 2006).

In year 1954, Carl Ziegler and Guilo Natta invented stereospecific catalysts. Their invention was commercialized by Phillips Petroleum Co. which later produced linear polyethylene (PE), medium density polyethylene (MDPE), and high density polyethylene (HDPE). Ziegler-Natta invention also spurred the development of polypropylene (PP) which is the second most popular plastic material. In the United State of America alone, annual consumption of polypropylene is approximately 37 billion pounds. This makes polypropylene (PP) second largest thermoplastic used after polyethylene (PE) (Ibeh C.C., 2011).

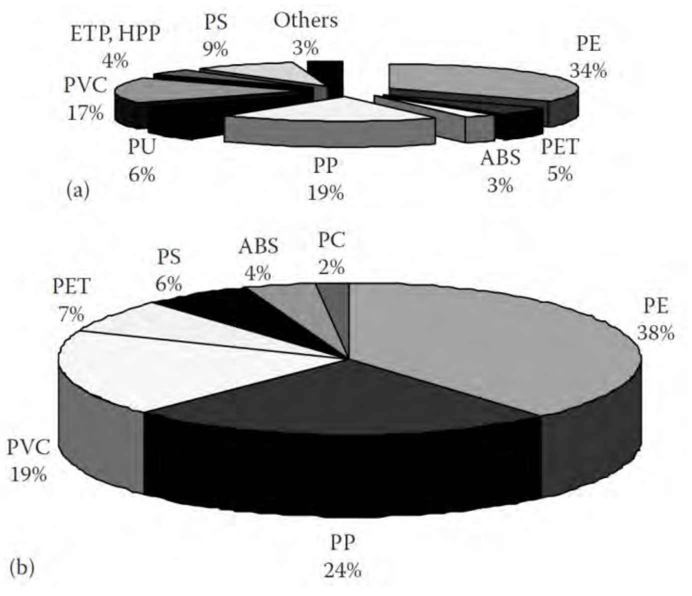


Figure 2.5: Material used in plastic industry all over US.

Polypropylene has a low glass transition temperature which is around 4°C. Besides that, it also has a relatively high melting which is around 163°C (Throne J.L., 2008).

Table 2.2: Difference of glass transition temperature, melting temperature and heat distortion temperature in polymer.

Polymer	Glass transition temperature [°F (°C)]	Melting temperature [°F (°C)]	Heat distortion temperature 66 psi (0.46 N/mm²) [°F (°C)]
Polystyrene	200 (94)	– (–)	155–204 (68–96)
PMMA	212 (100)	– (–)	165–235 (74–113)
PMMA/PVC	221 (105)	– (–)	177 (81)
ABS	190–248 (88–120)	– (–)	170–235 (77–113)
Polycarbonate	300 (150)	– (–)	280 (138)
Rigid PVC	170 (77)	– (–)	135–180 (57–82)
PETG	180 (82)	– (–)	158 (70)
LDPE	–13 (–25)	239 (115)	104–112 (40–44)
HDPE	–148 (–100)	273 (134)	175–196 (79–91)
Cellulose acetate	158,212 (70,100)	445 (230)	125–200 (52–93)
Polypropylene	41 (5)	334 (168)	225–250 (107–121)
Copolymer polypropylene	–4 (–20)	302–347 (150–175)	185–220 (85–104)
PET	158 (70)	490 (255)	120 (49)

Polypropylene basically does not react chemically, but the presence of methyl groups make it susceptible than HDPE to react with strong oxidizing agents. It also has resistance against dilute or concentrated alcohol, acids, bases and mineral oils. This is why polypropylene is a good choice to manufacture consumer products due to its chemical resistance and temperature resistance. However, polypropylene has a relatively low yield strength which is only around 4500 to 5400 psi (Ibeh C.C., 2011).

Final material selection is selected by comparing the advantage and limitation of several material selected. By rating each of the material characteristic, designers can make selection unbiased for the best material (Malloy R.A., 2011).

Table 2.3: Property or characteristic between major polymer.

Property or characteristic	Rating*		
	HDPE	PP	Nylon 6/6
Overall processability	9	8	6
Creep resistance	2	4	7
Chemical resistance	10	9	10
Manufacturing cost per part **	7	9	8
⋮	⋮	⋮	⋮
Elevated temp. performance	3	5	9
Average rating	6.3	7.1	8.0

* 10 = highest rating (best)   0 = lowest rating (worst)
** Considers both material consumption (based on part volume) and manufacturing cycle time

2.5 Compression molding

Compression molding is a cheaper way to manufacture molded part using thermoset molding compounds. It is an advantage to use this kind of mold to manufacture large, thin walled part that have tendency to warp.

The mold is heated before the molding compound is loaded into the mold manually or using loading device. After loading the molding compound, the mold is closed which tentatively build up pressure, heat and pressure exposure to the molding compound. Ventilation is created if necessary. After a period of time, the mold is opened and the preform is ejected manually or using a removal tool as shown in Figure 2.6 (Mennig et al., 2013).

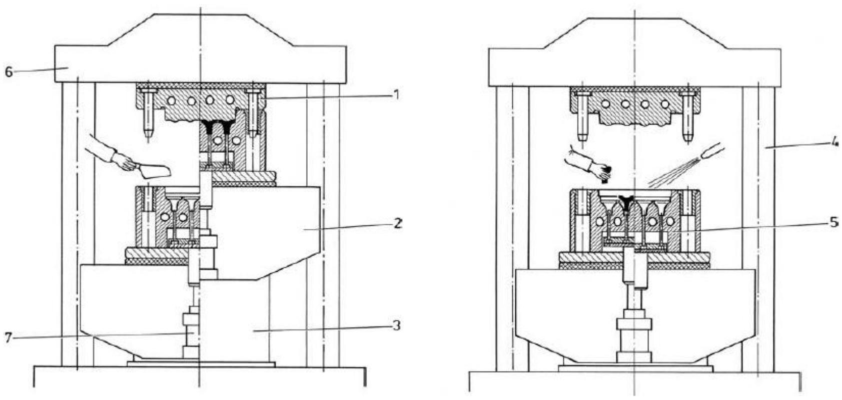


Figure 2.6: Compression molding figure and steps.

2.6 Mold design

Mold has its own purposes. The main purpose of mold is to accurately shape and hold part that meets all the desired specification. It also needs to have dimensionally stable surface so that the parts can be repeatedly produced (Throne J.L., 2008).

There are several problems need to be identified before designing a mold such as material type, machine provided, user, component requirements, customer demands and production facility. Each aspect needs to be narrowed down as early as possible in order to satisfy the aspects into the design. The design phase is basically divided into three main phases.

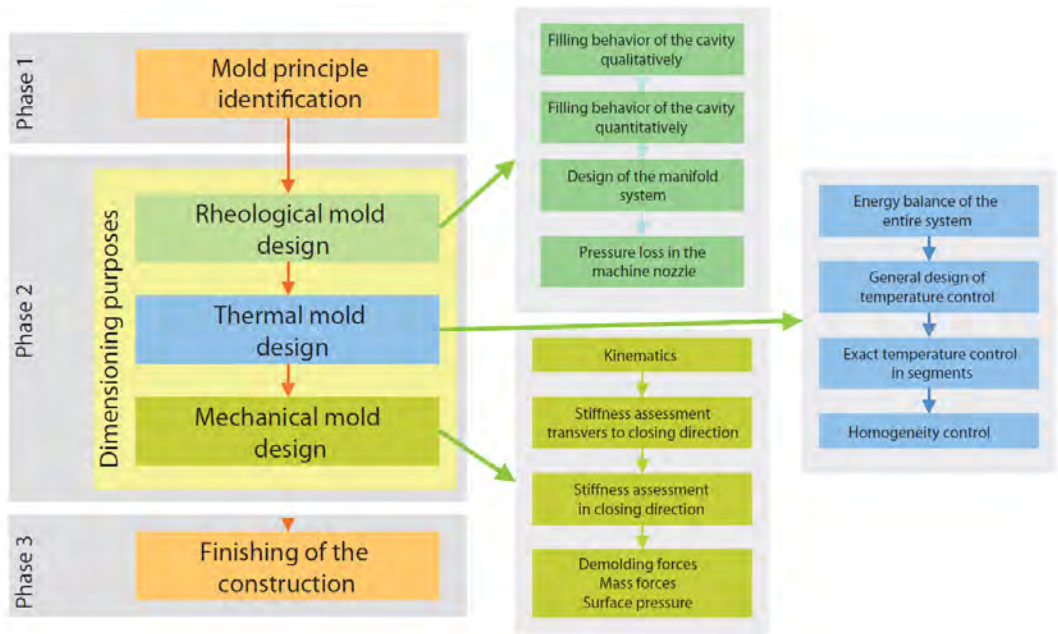


Figure 2.7: Phase of designing a mold.

Phase 1 is usually finding the basic principal. Some of them discussed about what is the specific technology are about to be used. The design need to analyse and weight with proper evaluation matrices. The second phase is basically about dimensioning. The three important tasks that need to be carried out are the rheological design, thermal design and mechanical design. All of these methods need to be weight equivalently but predominance is given to the mechanical dimensioning as it ensures functionality of the mold itself. Final phase is the mold design. In this phase, plate sizes, location and size of cooling channels, gating system and number of injection is defined as they will be implemented in the detail drawing.

To draft design of the mold, several information should be obtained such as building size, material of mold, gate system, slider position, control system, parting line position, cooling, ejector position and cycle time. This is to ensure that the mold design in 2D will be the actual design draft which later will be executed in 3D.

Detailing phase which usually developed in 3D CAD will speed up the work preparation and creation of machine program in the production process. This allows the mold designer to select standard part from various manufacturers and accelerating the design process (Mennig et al., 2013).

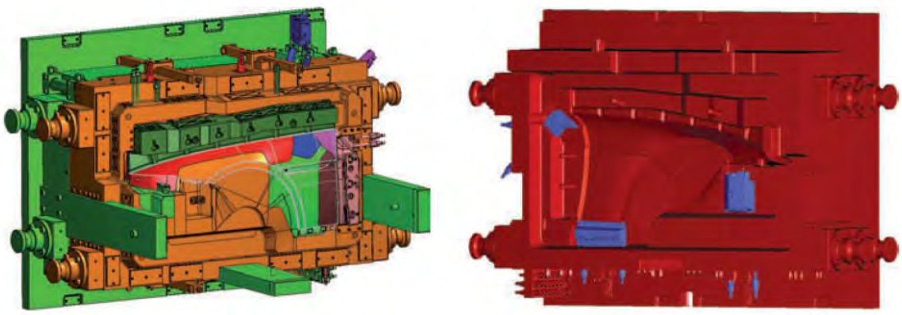


Figure 2.8: 3D CAD of a mold.

Autodesk Moldflow Analysis has been largely used to simulate the filling pattern inside a mold which results to defects detection without making any prototype. This process fully utilizing the 3D CAD data made out in the earlier process (Shin et al., 2013).

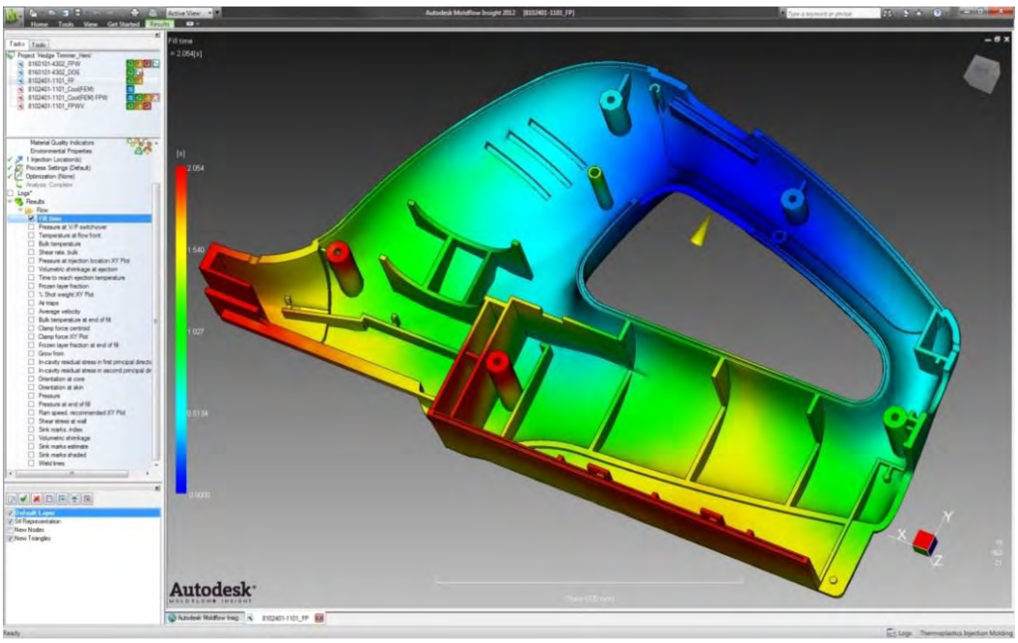


Figure 2.9: Moldflow user interface.