COMPUTER AIDED DIE DESIGN OF PLASTIC SHAMPOO BOTTLE

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ABSTRACT

Nowadays most products are produced at a very rapid phase and not forgetting their life cycle too is getting shorter and shorter. Noticeably these products are mostly produced from plastics material since this method of plastic production is not only very fast but also very accurate and flexible.

Thus the author has taken the initiative to work on a project on how to design and then to machine the shampoo bottle mould specifically for the blow moulding process both in using CAM software and Vertical Machining Center (VMC) respectively. The design of the shampoo bottle was firstly derived from the real life survey conducted and targeted at for middle age group. And the original design was translated to the 2D and then 3D drawings using CAM software. Later the simulation of machining was carried out before the program was post-processed to the VMC machine for machining verification. Proceeding with this project too is the rapid prototype of the hinged cap of the shampoo bottle, which was first designed and developed using CAM software and then translated to the FDM 2000 rapid prototyping machine for rapid modeling.

A shampoo bottle mould cavity was successfully machined using the VMC machine and a prototype of the shampoo bottle's hinged cap was produced from the FDM 2000 machine.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND STUDY

Since the early history of man, metal has played an important part of their daily lives. Metal was used in most of their activities i.e. hunting, cooking, cutting, constructing etc. Even weapons of war were made from metal ranging from the basic spear to the more sophisticated guns and cannons.

However, with the turn of this century plastic is now modern mans daily usage. It would be difficult to imagine our modern world without plastics. Today they are an integral part of everyone's lifestyle with applications varying from commonplace domestic articles to sophisticated scientific and medical instruments. It has taken over most of the products initially made from metal due to its lightweight, economic cost and abundance. It can be easily transformed from one form to another without involving high cost. Also, from certain aspects, plastic performs better than metal with certain plastic products having better physical stability compared to metals.

Nowadays designers and engineers readily turn to plastics because they offer combinations of properties that is not available in any other materials, even the metal alloys. Therefore, it was only logical to carry out a research on plastic products, as they are becoming even more important with new developments happening in this field frequently.

Plastic has become an important and useful product, especially to consumers. In all of our daily lives we come in direct contact with plastic either as a raw material, intermediate or finished product. Having such a wide range of usage, it was difficult to design a product made out of plastic without narrowing down the scope first. As such it was decided that the product to be chosen and further made research upon would fulfill the following criteria:

- Consumer oriented product;
- Used commonly and frequently by consumers;
- Targeted for every level income group of consumers; and
- Different design of the proposed product is available in the market for further assessment;

Based on the criteria set above, it was decided to choose personal hygiene products regularly used by consumers. Among these, several plastic product were assessed i.e. shower bottle, shampoo bottle, powder bottle etc. Finally, after conducting a quick market survey and consultation with the advisor, shampoo bottle was chosen as the product to be researched upon.

Here the author chooses to design on the die design of plastic shampoo bottles due to the prime fact that almost all of us use shampoos in our daily lives, thus the market is definitely out there for these shampoo bottles. Shampoos are considered a daily must for every consumer and it is far more important and definitely a favorite among the people. Thus it is worth considering to invest time in improving and refining the existing design and process used to produce this product. Furthermore, this seems suitable as almost all parts of the world are going through a recession period. Thus improvement on the die design of the shampoo bottle would not be particularly demanding or financially consuming if compared to other highly technology intensified automotive or aviation inventions.

1.2 Scope of Work

This project is intended to design a mould for the shampoo bottle by utilizing the sophisticated and advanced machines available in the Tool and Die Lab of Kulliyah of Engineering, International Islamic University Malaysia (IIUM). This entails designing and machining of the shampoo bottle mould specifically for the blow molding process both using the CAM software and VMC machine respectively. The design of the shampoo bottle was based from questionnaire which was developed and distributed at Project I (MFG 4110) level. *Section 3.1* details out further preparation and conduct of the questionnaire and survey

Included within the scope of work is also a rapid prototype of the hinged cap of the shampoo bottle, which was designed and developed using the CAM software and then translated into the FDM 2000 rapid prototyping machine which functions as a rapid modeler.

1.3 Project Methodology

The proposed project on the computer aided die design of plastic shampoo bottle was carried out in three main stages, with each stage encompassing different tasks enduring several weeks. Among other things, it ranges from literature survey right up to design of the product with complete dimensions incorporated into it. *Table 1.3-a* summarizes the three stages to this project and also lists the tasks performed for each of the stage.

Table 1.3-a   Stage and Task Level for the Proposed Project

Stage	***Tasks***
Stage 1	• Selection of Product; and • Literature Survey.
Stage 2	• Preparation of Questionnaire; • Conduct Survey; • Analyze Survey; and • Conclusion from Survey
Stage 3	• Design of Shampoo Bottle; • Design of Hinged Cap; • Modifications; and • Dimensions

Once, it was ascertained, from discussions with the project supervisor, that products made of plastic, specifically a shampoo bottle was to be designed, the next step was to carry out an extensive literature survey on the design of a plastic bottle.

Several information that required further research and relevant reading for designing a shampoo bottle and hinged cap was undertaken including accessing the internet. These information include, but not limited to, the following items listed out in *Table 1.3-b* below. Details of the literature survey is given in Chapter Two of this project.

Table 1.3-b Information Required in Designing Shampoo Bottle and Hinged Cap

Items	***Description***
Plastics	• Ascertain types, characteristics and behavior of plastics; • Recommend type of plastic suitable as a raw material for the shampoo bottle and hinged cap
Molding processes	• Discover the different molding processes available in the industry; • Recommend the process most suitable for manufacturing shampoo bottle and hinged cap
Computer Numerical Control (CNC) Machines	• Determine the various types of CNC machines (vertical, horizontal, etc.) available • List out the specifications and special functions of these machines;
Materials	• Seek out types and characteristics of materials suitable for machining; • Establish appropriate type of material to be used for machining including physical properties i.e. hardness, material strength etc.

The next step was to establish consumers design choice of a shampoo bottle which was determined by conducting a survey. Questionnaires were distributed to selected category of people to gauge the type and design of a shampoo bottle most preferred. Further details of the survey including results and discussions from the questionnaire are discussed in *Section 3.1*.

Upon completion of Stage 2, the next stage is to design the shampoo bottle and its hinged cap utilizing a proprietary software, MasterCAM. The designs of both components were done in 2D which was then transferred to 3D view. This was followed by simulation of machining process for the shampoo bottle using MasterCAM. After successfully simulating the machining process in MasterCAM, the shampoo bottle was then physically machined on a stainless steel workpiece using the VMC machine, model ZPS MCFV 1060LR.

The 3D design of MasterCAM software, has the capability of converting *.MC7 machine files to *.STL rapid prototyping files which is readable by the rapid prototyping software, QuickSlice. Design of the shampoo bottle's cap was translated via this method before modeling it with FDM 2000. During the entire design process, continuous modifications and changes to the dimensions were carried out in order to ensure smooth machining and modeling processes. Stage 3 involving design of the shampoo bottle and its hinged cap right up to the physical machining process is explained in Chapter Three of this project.

Chapter Four provides results achieved after undertaking this project. This includes a sample of the body shampoo mould which was machined using stainless steel as the cavity and a prototype of the hinged cap via rapid modeling. Discussions pertaining to the project including problems and difficulties encountered are highlighted in Chapter 5.

The final Chapter Six is devoted to providing conclusions as well as relevant recommendations from the project. Included in this chapter are suggested works for future undertaking.

CHAPTER TWO

LITERATURE SURVEY

2.1 Overview of Plastics

Pitch, amber, lac, wax, etc., are all plastics, but plastics materials as we now know them have been around since the middle 1800's. It was the Second World War that brought about the need for plastic products to be mass-produced and to replace more traditional materials such as steel, aluminum and iron. Since that time the word 'plastic' has come to mean 'imitation' or 'cheap and nasty', i.e. 'plastic food' for instance. But, as far from being either cheap or nasty, many high quality things used at home or at work cannot be made out of anything else. And the complainers would really have something to moan about if all the plastics suddenly disappeared. Half the kitchen equipment would vanish. There would be no telephones, televisions, refrigerators etc., in fact, no electricity, because most of the insulation is made from plastics. We would all have to walk to work, too – not that it would be worth going, because most industrial processes need plastics somewhere in their machinery to keep going. Therefore, the statement "everything seems to be made out of plastic these days" is not far from the truth.

2.2 Usage and Types of Plastics

More things are made of plastics, and there are now hundreds of materials, which are plastic, produced by various complicated processes which combine oil, air and other chemicals. Plastics offer advantages such as lightness, resilience, resistance to corrosion, color fastness, transparency, ease of processing, etc., and although they have their limitations, their exploitation is limited only by the ingenuity of the designer.

The term plastic refers to a family of materials, which includes nylon, polyethylene and PTFE just as zinc, aluminum and steel fall within the family of metals. This is an important point because just as it is accepted that zinc has quite different properties from steel, similarly nylon has quite different properties from PTFE. This analogy can be taken still further because in the same way that there are different grades of steel there are also different grades of, say, polypropylene. In both cases a good designer will recognize this and select the most appropriate material and grade on the basis of processability, toughness, chemical resistance, etc.

It is usual to think that plastics are a relatively recent development but in fact, as part of the larger family called polymers, they are a basic ingredient of animal and plant life. Polymers are different from metals in the sense that their structure consists of very long chain-like molecules. Natural materials such as silk, shellac, bitumen, rubber and cellulose have this type of structure. However, it was not until the nineteenth century that attempts were made to develop a synthetic polymeric material and the first success was based on cellulose. This was a material called Parkesine, after its inventor Alexander Parkes, and although it was not a commercial success it was a start and it led to the development of Celluloid. This material was an important breakthrough because it became established as a good replacement for natural materials, which were in short supply – for example ivory for billiard balls.

Plastics, more than any other design material, offer such a wide spectrum of properties that they must be given serious consideration in most component design. However, this does not imply that there is a plastic with the correct combinations of properties for every application. It simply means that the designer must have an awareness of the properties of the range of plastics available and keep an open mind. One of the most common faults in design is to be guided by pre-conceived notions. For example, an initial commitment to plastics based on an irrational approach is itself a serious design fault. A good design always involves a judicious selection of material from the whole range available, including non-plastics. Generally, in fact, it is only against a background of what other materials have to offer that the full advantages of plastics can be realized.

The various forms of plastics, commonly available in the industry today, are listed below:

- Engineering plastics or thermoplastics;
- Thermosets;
- Composites;
- Structural foam;
- Elastomers;
- Polymer alloys; and
- Liquid Crystal Polymers (LCP).

For this project, semi-crystalline plastics a sub category of engineering plastics is suggested as raw material for manufacturing of the shampoo bottle. The following section details out important elements and characteristics of this type of plastics.

2.2.1 Semi-Crystalline Plastics

It is noted from experience gained by the researcher during Industrial Training (IT) that manufacturers of consumer and daily household products prefer semi-crystalline plastics as a base for shampoo containers. However, there are various forms and grades of this type of plastic which require further evaluation prior to selection of material. *Table 2.2-a* below summarizes key characteristics and nature of each plastic material from this category.

Table 2.2-a Category and Key Attributes of Semi-Crystalline Plastics

Material Type	Description
Low density polyethylene (LDPE)	• Widely used in the UK (21% of total UK consumption of plastics); and • Very tough and flexible
Linear Low Density Polyethylene (LLDPE)	• It has a regular structure with short chain branches
High Density Polyethylene (HDPE)	• More expensive, stronger, stiffer; and • Numerous applications such as dustbins, bottle crates, general purpose fluid containers like in this project shampoo bottles and pipes.
Polypropylene (PP)	• Extremely versatile plastic, has the lowest density of all thermoplastics; and • Available in fiber form, film form.
Polyamides (nylon)	• High strength, stiffness and toughness, also known as engineering plastics.

For this project, polypropylene is recommended as plastic material for the bottle instead of polyethylene, which is preferred by manufacturers. Polypropylene (PP) is a type of synthetic polymer, which falls under the crystalline thermoplastic category. An important attribute of a thermoplastic is that it will soften and melt easily on heating but solidify upon cooling. PP together with other plastic materials, i.e. polyethylene (PE), nylon (PA) and PET materials falls under the category of partial crystalline type of chain molecules, as illustrated in *Figure 2.2-a*.

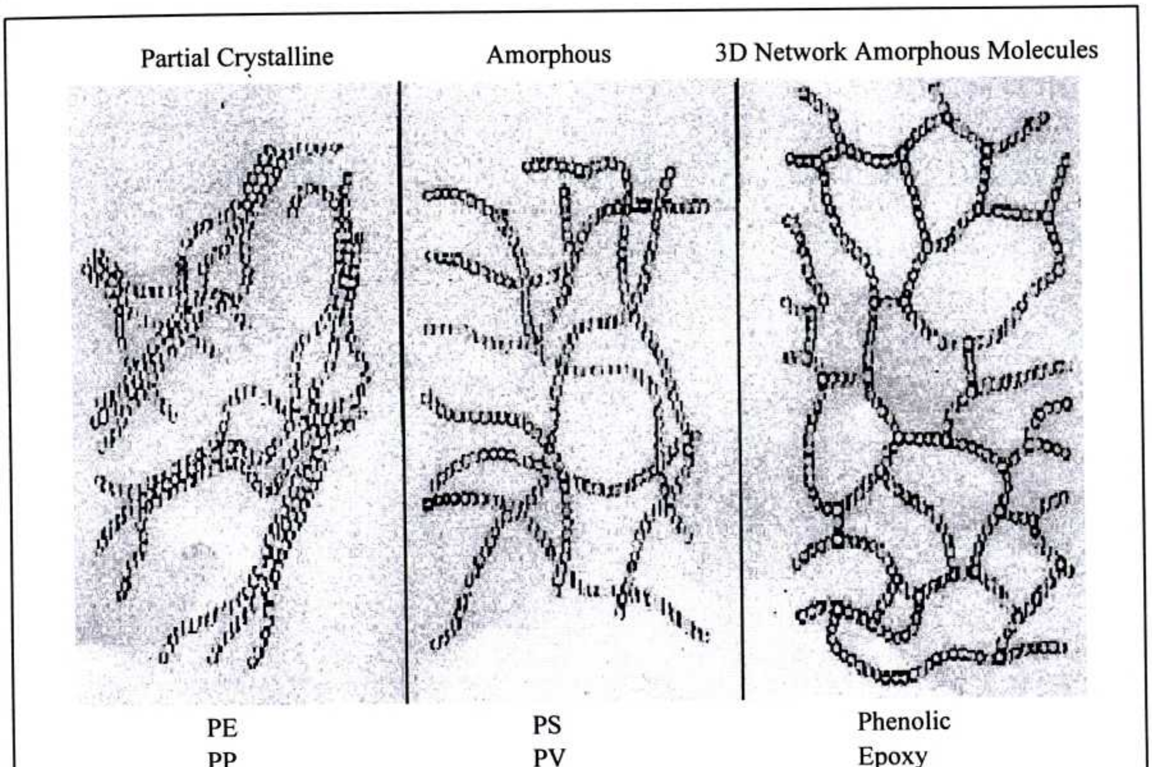

Figure 2.2-a Chain Molecules of Partial Crystalline Material

Included in *Table 2.2-b* and *Table 2.2-c* are short-term properties of some important plastcics including thermal properties of materials, which will give more insight to this suggested plastic material, polypropylene.

Table 2.2-b Thermal Properties of Selected Plastics

Material	Density (kg/m^3)	Specific Heat	Thermal Conductivity (W/m/K)	Coeff. of Therm Exp. (μm/m/K)	Thermal Diffusivity (m^2/s)x10^{-7}	Max. Operating Temp (°C)
ABS (high impact)	1040	0.35	0.3	90	1.7	70
Acetal (homopolymer)	1420	0.35	0.2	80	0.7	85
Acetal (copolymer)	1410	0.35	0.2	95	0.72	90
Acrylic	1180	0.35	0.2	70	1.09	50
Cellulose acetate	1280	0.36	0.15	100	1.04	60
CAB	1190	0.35	0.14	100	1.27	60
Epoxy	1200	-	0.23	70	-	130
Modified PPO	1060	-	0.22	60	-	120
Nylon 66	1140	0.4	0.24	90	1.01	90
Nylon 66 (33% glass)	1380	0.3	0.52	30	1.33	100
PEEK	1300	-	-	48	-	204
PEEK (30% carbon)	1400	-	-	14	-	255
PET	1360	-	0.14	90	-	110
PET (36% glass)	1630	-	-	40	-	150
Phenolic (mineral filled)	1690	-	-	22	-	185
Polyamide-imide	1400	-	-	36	-	260
Polycarbonate	1150	0.3	0.2	65	1.47	125
Polyester	1200	-	0.2	100	-	-
Polyetherimide	1270	-	0.22	56	-	170
Polyethersulphone	1370	-	1.18	55	-	180
Polyimide	1420	-	-	45	-	260
Polyphenylene sulfide (30% carbon)	1460	-	-	16	-	200