# Design and Development of mould of UTP souvenir photo frame using Rapid Prototyping and Rapid Tooling technique

By

MAGHFARAH BINTI CHE MANSHOR

Dissertation submitted in partial fulfillment of
The requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

JUNE 2008

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFIATON OF APPROVAL

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Approved by,

(Dr. Ahmad Majdi Abdul Rani)

UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MAGHFARAH BINTI CHE MANSOR)

ABSTRACT

This project is to design and develop a case study prototype using Rapid Prototyping and Rapid Tooling process. Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. Rapid tooling is a TCT that reduce time to market by streamlining product development cycle. Due to high demand of the souvenir especially during convocation ceremony, this university should have their souvenir that is practical, elegant and not too expensive in a short period. The objective of the study is to study prototyping and rapid tooling and to develop mould using Investment Casting technique This study will involve designing and developing mould product besides doing cost analysis and time management. This project commenced with research phase analysis of rapid tooling technique proceeds my mould development and conclude with analysis phase. Extensive study and method analysis and tool identification were carried out during research phase. The mould development phase began with designing 3D CAD drawing of photo frame souvenir followed by producing prototype using RP machine and proceed with investment casting. The analysis was made based on observation comparison of time completion, cost and the quality of the mold. From the analysis, we find that the investment casting is good for low cost production, with high accuracy, and high production product, but not for complicated shape design.

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# CHAPTER 1

## INTRODUCTION

### 1.0 BACKGROUND

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. Rapid Prototyping has also been referred to as solid free-form manufacturing; computer automated manufacturing, and layered manufacturing.

Rapid prototyping techniques are time compression technology (TCT). In the fast evolving technological environment, products become absolute sooner. The reduced time between product lunch and time retirement erodes sales revenues and the only way it can lengthen a product life by getting it to market as soon as possible.

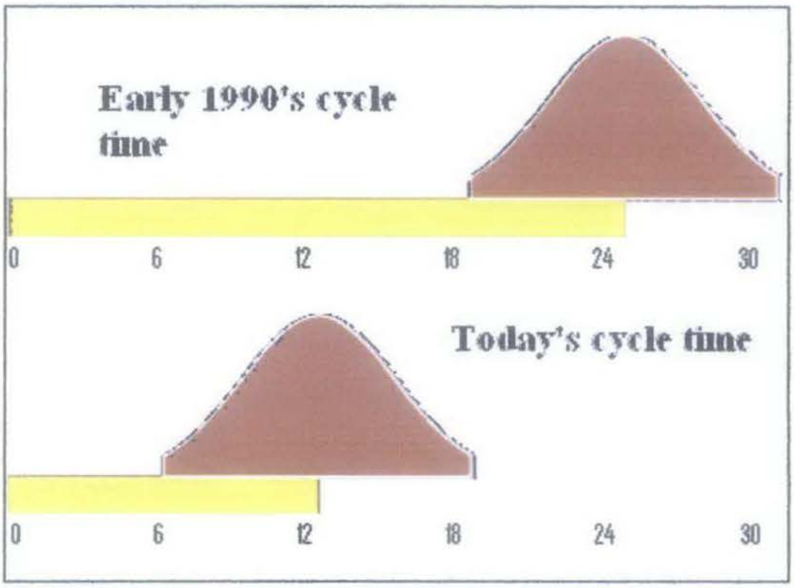



Figure 1-0: product development cycle time (source: http://.newproductdynamics.com/index.htm)

To bring product to market earlier, less time should be spend in product development. Companies respond quicker to costumer will get more sales and will set the pace of innovation. Companies which are good at developing new product can use advantage to gain market share.

TCT is common term to use in referring technology that reduces product development cycle time. Rapid prototyping, rapid tooling, CAD/CAM and reverse engineering are minor to TCT.

## 1.1 PROBLEM STATEMENT

Due to high demand of the souvenir especially during convocation ceremony, this university should have their souvenir that is practical, elegant and not too expensive in a short period. This study will involve designing and developing mould product besides doing cost analysis and time management.

The significant of this study to apply theoretical knowledge learn in various courses such as Engineering Economic, Advanced Manufacturing Technology, and Mechanical Engineering Design.

## 1.2 OBJECTIVES OF STUDY

The objectives and of the project are as follows:

1. To study prototyping and rapid tooling
2. To develop mould using Investment Casting technique

## 1.3 SCOPE OF STUDY

The scope of study will involve prototype development of the souvenir using rapid prototyping method and develop a mould using rapid tooling method. The study will also cover the cost analysis for mould production.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Time Compression Technology

The time to get new product to market faster is more compelling nowadays since was once considered fast development in now commonplace [2]. Product development can be accelerated by

- Launching the product as soon as possible
- Minimizing rework and wasted effort
- Minimizing development expense
- Agility (ability to make late change easily)

This is why prototyping has becoming an essential element in product development nowadays. TCT has been recognized as a most successful method in product development nowadays where it reduces 'time to market' by streamlining product development cycles.

TCT is common term used to referring technologies that reduce product development cycle time. TCT encompass a wide variety of technology field covering RP, Rapid Tooling, reverse engineering, CAD/CAM and other type of technology that can be said that the biggest benefit of TCT is accelerating product development by reducing 'time to market'.

## 2.2 Rapid Prototyping

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. What is commonly considered to be the first RP technique, Stereo lithography, was developed by 3D Systems of Valencia, CA, USA. The company was founded in 1986, and since then, a number of different RP techniques have become available.

Rapid Prototyping has also been referred to as solid free-form manufacturing; computer automated manufacturing, and layered manufacturing. RP has obvious use as a vehicle for visualization. In addition, RP models can be used for testing, such as when an airfoil shape is put into a wind tunnel. RP models can be used to create male models for tooling, such as silicone rubber molds and investment casts. In some cases, the RP part can be the final part, but typically the RP material is not strong or accurate enough. When the RP material is suitable, highly convoluted shapes (including parts nested within parts) can be produced because of the nature of RP.

There is a multitude of experimental RP methodologies either in development or used by small groups of individuals. This section will focus on RP techniques that are currently commercially available, including:

- Stereo lithography
- Selective Laser Sintering
- Laminated Object Manufacturing
- Fused Deposition Modeling
- Solid Ground Curing
- Ink Jet printing techniques.

The reasons of Rapid Prototyping are

- To increase effective communication
- To decrease development time.
- To decrease costly mistakes

- To minimize sustaining engineering changes.
- To extend product lifetime by adding necessary features and eliminating redundant features early in the design

Rapid Prototyping decreases development time by allowing corrections to a product to be made early in the process. By giving engineering, manufacturing, marketing, and purchasing a look at the product early in the design process, mistakes can be corrected and changes can be made while they are still inexpensive. The trends in manufacturing industries continue to emphasize the following:

- Increasing number of variants of products
- Increasing product complexity
- Decreasing product lifetime before obsolescence
- Decreasing delivery time
- Rapid Prototyping improves product development by enabling better communication in a concurrent engineering environment

The basic methodology for all current rapid prototyping techniques can be summarized as follows:

1) A CAD model is constructed, then converted to STL format. The resolution can be set to minimize stair stepping
2) The RP machine processes the .STL file by creating sliced layers of the model.
3) The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the model.
4) The model and any supports are removed. The surface of the model is then finished and cleaned.

2.2.1 Rapid Prototyping Application: Rapid Prototyping and Tooling Technology in Jewelry CAD

This study carried by Somlak Wannarumon and Erik L. J. Bohez presents the investigation of computer-aided design and rapid prototyping technologies in jewelry design and manufacturing. Computer-aided design (CAD) and Rapid prototyping (RP) technologies play important roles in many industries including the jewelry industry. In this paper, CAD and RP technology is applied to design and build jewelry prototypes, and Rapid Tooling to build molds. The main aim of this paper is to describe the implementation of CAD and RP processes in the jewelry design and manufacturing. The applicability and effectiveness of RP, using Stereolithography Apparatus (SLA), is investigated in the field of jewelry model and mold making, moreover, the methodology is compared to conventional methods in term of time requiring, quality and manufacturing factors.

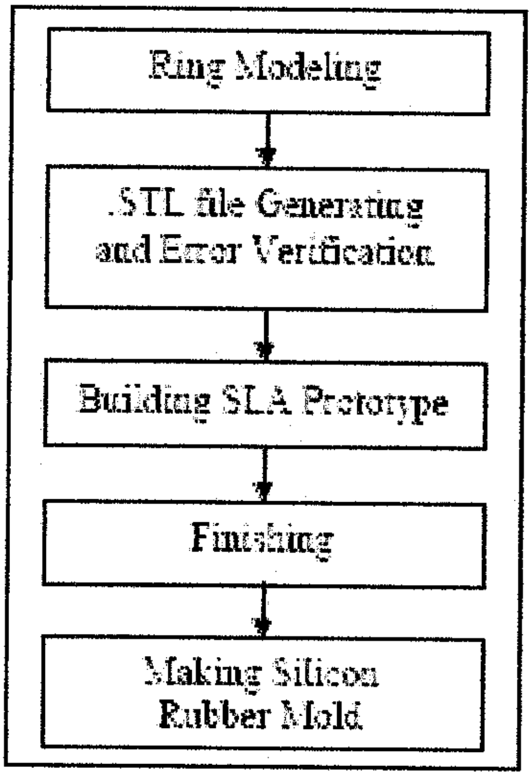



Figure 2-1: The overall procedure for building jewelry prototypes and molds by RP.

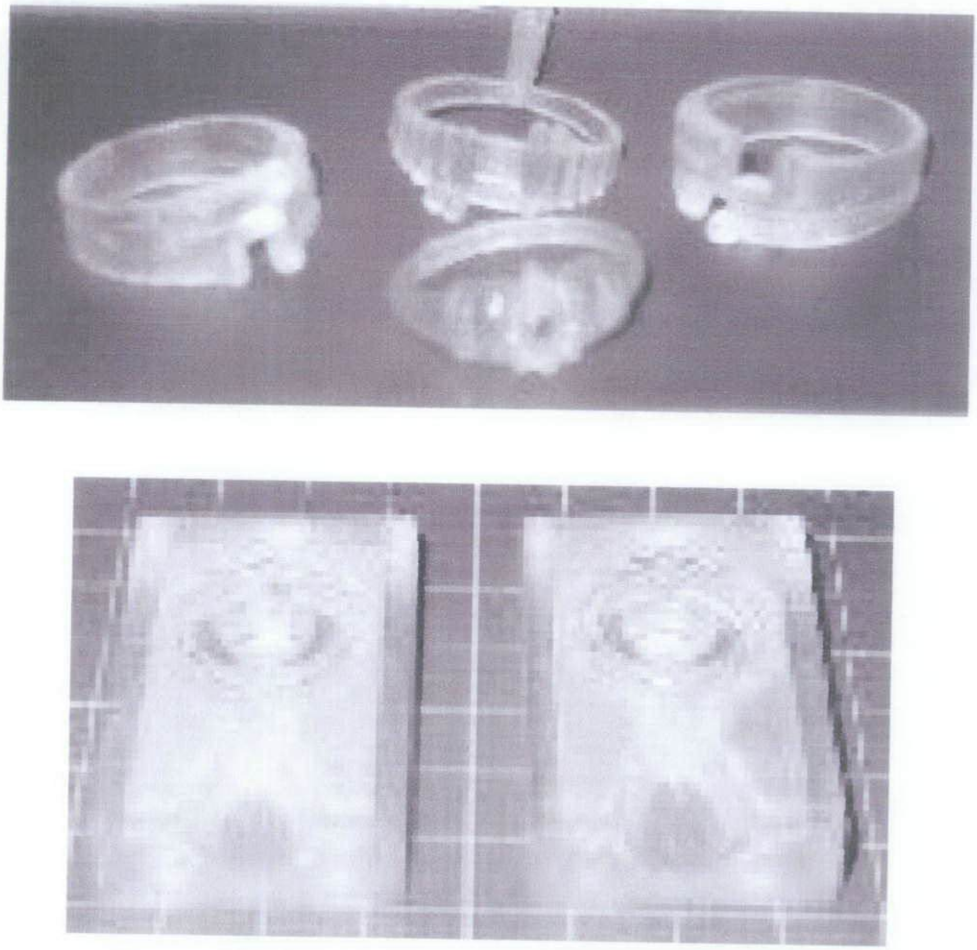


Figure 2-2: SLA ring prototypes (top) and molds (below).

## 2.3 Rapid tooling

RP part are frequently used as the basis for rapid tooling. The RP system creates a positive and negative pattern which is use to generate injection molding, investment casting or other tooling for short to medium volume productions runs. A lot of techniques exist for transferring pattern created by RP system in plastic and other soft materials into hard metal tools and products. Some methods of rapid prototyping are capable of producing metal part and tools directly [3].

Comparison between rapid tooling and conventional tooling:

- Production time shorter than conventional tools.
- Cost for rapid tooling shorter than conventional tools. (Cost can be below 5% of cost for conventional tool).
- Tool life is considerably less than a conventional tool.
- Tolerances are wider for conventional tool

### 2.3.1 Application of rapid tooling

RTV silicone rubber molding is the process where the moulds are made of silicone rubber material used by Nurul Huda binti Karim to produce twin tower souvenir. The process involves making the prototype pattern using any available rapid prototyping techniques [4]. This pattern is then finished to the quality in which final part are required. It is then suspended in enclosed box and liquid silicon rubber is poured around it. This sets with time and becomes a solid rubbery mass with the pattern inside. Now the mould is cut along the parting line and the pattern is removed. This results in formation of the core and the cavity. Because the material is flexible, undercut release is not a problem. This mould is good enough for 25-30 pieces in materials replicating properties of thermoplastics. But for highly complicated part with numerous sharp edge and extended thin wall, only 10 to 15 acceptable parts can typically be produced.

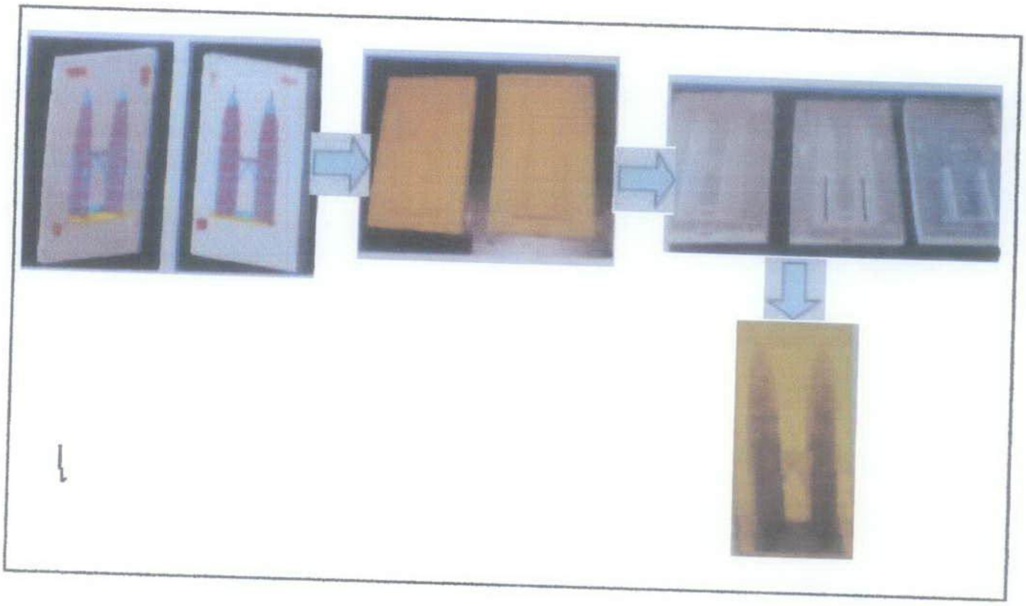


Figure 2-3: process flow of Rapid prototyping technique

2.4 Investment casting technique

Investment casting is also known as the "lost-wax" process, is regarded as a precision casting process to fabricate near-net-shaped metal parts from almost any alloy.

2.4.1Dimension accuracy

Today, the productivity of investment casting has been improved so much with digital process controls and robotics that is more often associated with precision processes such as CNC machining and injection molding than with conventional casting. And quality continues to improve. The technology can produce as-cast parts with normal tolerances of Â±0.005 in. /in. and surface finishes of 125 in., rms. Premium tolerances can be held even closer. But for the traditional investment casting, the Theoretical value for investment casting dimension accuracy ~ (-/+ 0.2mm)

2.4.2 Material for casting and product

*For this mould, we use S50C. the material composition that contain in this material are present in* table 2-1. The melting temperature for this nonferrous metal is 1610°C. Because of high melting temperature compare silicone rubber (246.11°C), the mould that produce by investment casting variety of material that can use for producing final product as long as the material has below S50C melting point.

Table 2-1 material composition

| Composition | Percent (%) |
|---|---|
| C | ~ 0.480 |
| Mn | ~ 0.649 |
| P | ~ 0.0141 |
| S | ~ 0.0125 |
| Si | ~ 0.229 |
| Ni | ~ 0.0257 |
| Cr | ~ 0.0414 |
| Mo | ~0.0124 |
| Al | ~ 0.00484 |
| Cu | ~0.0640 |

2.4.3 Number of product can obtained from single mould

Investment casting is economically suited for small to intermediate sized lots (100 to 10,000 units or more). This is because investment casting uses material efficiently, a benefit when raw stock is expensive. Scrap rates run in the range of 3 to 5%. Tooling costs also tend to be low, particularly when compared to RTV silicone rubber that only can obtained 30-40 from single mold.

### 2.4.4 Mould profile quality

Investment casting offers several advantages over other production methods. But to make full use of the technology, designers must be aware of it limitations like avoid sharp corner, keep wall thickness uniform, avoid sharp transition, avoid sharp angle and avoid joined section.

If inserts such as ceramic cores or soluble waxes are avoided, then shape complexity becomes an expense only at the tool stage, and this is a one-time cost in the process. Many internal passages, through holes, concentric cylinders, and curved and tapered holes are as simple to cast as external forms such as bosses, flanges, or shoulders. And no draft angle has to be factored in because wax shrinkage makes it easy to remove injection dies. Therefore, gates should be placed in the largest sections of parts.

### 2.4.5 Size of the mould

Perhaps the only upper-size limit on investment castings concerns the weight that can be supported by the shells as metal is poured. Parts weighing 150 lb or more can be produced, but it's advisable not to exceed 100 lb. On the lower end, handling becomes an issue and the minimum weight of investment castings is typically 1 oz.

# CHAPTER 3

## METHODOLOGY / PROJECT WORK

### 3.1 Procedure Identification

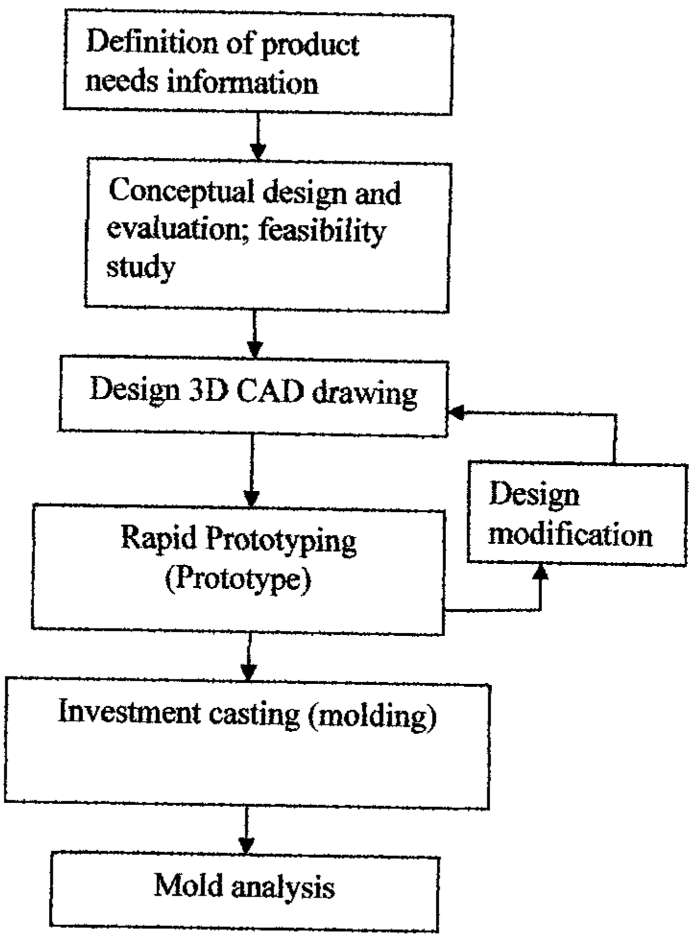



Figure 3-1: process involve to produce product

This project commenced with research phase proceeded by product development phase and concluded in the phase analysis phase.

3.1. Definition of product need

Method that has been conducted to gather marketing information is doing survey. 50 copies of 3 questions were distributed randomly to the UTP students. From the survey's result, we can conclude that majority of UTP student did not bought current souvenir that available in KOPETRO because the souvenirs are expensive. The design also not updated and the quality of the souvenir also low. The characteristic of the souvenir that meet the marketing need are they must applicable, the design updated, cheap and the souvenir its own image that symbolic UTP. From this survey, the final decision for final product is picture frame instead of letter opener. Picture's frame is selected due to possibility of the material, cost, and design.

3.1.2 Conceptual design and evaluation, feasibility study.

I. Design

Symbols that we use in this design are UTP logo and star shape chancellor hall lay out. The lay out of chancellor hall is selected because the symbol represents the quality and excellent of UTP

II. Design for manufacturability

The size of the frame should be smaller than them jet printer. It is recommended to set minimum z-axis dimensional to the build model so time fabrication n be optimize. To produce excellent surface finish, the best 3D design in design with minimum supports generation.

III. Selecting manufacturing process

A proper procedure was prepared on the method chosen in method and tools analysis. The methods were generated based on in house facilities available in UTP manufacturing laboratory.

Various approaches could be used to develop the product in a short period. The development was divided into 3 main steps which are

| Step | process |
|---|---|
| a) Producing prototype | CAD drawing → 3D printer |
| b) Producing mold | Prototype → investment casting |

Table 3-1: Experimental work

### 3.1.3 Mold development

First of all, the photo frame souvenir shape was determine from existing souvenir.3d drawing was generated by using Auto Cad, and then converted to the stl file. By using magic view software we can automatically generate negative shape of the drawing that we can use as a mold. By using this software we can control the size of the mold by control the thickness and length of the mould.

The Thermo Jet 3D printer was used to print out the prototype that we use to producing mold. The stl file was loaded to the Thermo Jet 3D printer and printed both layer according to drawing. After we remove all support connected to prototype, the proceeded process was investment casting.

### 3.1.4 Analysis phase

A number of studies have been conducted with aim of informing student local industry as to capabilities of range of rapid tooling technique. The studies have focused on time to produce, accuracy, design flexibility, and cost.

A part of feasibility studies carried out by previous FYP student [], a case study that illustrate the significant of rapid tooling technique but using RTV silicone rubber. Various stage of design process were investigated and summarized in APPENDIX.

With the consistent methodology applied to this technique, a study pertaining soft data was conducted. The analysis was made based on observation of time completion, cost of fabrication, and quality of mold and surface finish.

3.2 Tool/Equipment Required

3.2.1 3D modeling software: AutoCAD 2002

CATIA V5R6 and AutoCAD 2002 are 2 solid modeling soft wares identified and available to be used in generating 3D CAD data. After evaluating both software, AutoCAD 2002 was selected to be used based on it friendliness.

3.2.2 Rapid prototype machine: Thermo Jet Solid Object Printer by 3D system

Figure 3-2: ThermoJet Solid Object Printer by 3D system

ThermoJet solid object printer is a machined that enables printing of 3D CAD drawing into solid object. It is equipped with ThermoJet software which functioned to import and orient model on virtual platform. Describe below are some of the machine's specification:

Process: Multi-Jet Modeling (MJM)

Modeling material: thermojet 88 (thermopolymer plastic)
Material capacity: 5.9 kg
Build chamber size, x,y,z-direcion: 250 x 190 x 200 mm
Maximum resolution: 400 dpi in x-direction and 300 dpi in y-direction

The process:

Convert the data file containing 3D CAD drawing into stl format. Retrieved the stl file by using Thermojet software. Each model is verified and oriented on the virtual platform for optimum output resolution. the software will check the data for error and alert the designer if any error exists. Once the data submitted to the queue, the machine will process the job sequent.

In the build process, the MJM head is positioned above the platform to commence building the concept model from the base up. The head begins building the first layer by depositing material as it move in the x-direction.

If the width of the part is wider than MJM head, the platform is repositioned in y-direction to continue building the layer in the x-direction until the entire layer is completed.
After one layer is completed, the plat form is lowered and the building of next layer begins in the same manner. The process continues with repetition of previous steps until the part complete.

The layer are generated from small drop of thermoplastic by means of multiple print head arranged in a line and functioning on piezoelectric principle. The print head has 352 nozzle arranged in the y-direction so that per layer, the build platform need only be traversed once in x-direction. The support are generated and at the same time and can be manually removed.

As the machine selected is a concept modeler from 3D systems that has limits to the dimensions of the parts that could be printed. For that reason was necessary to divide the intake geometry into two symmetrical halves. This was the option taken, since the other alternative involved resizing the rapid tool to a smaller dimension with no interest for the objective of manufacturing real size direct soft tooling prototypes. The RT was design in 3D-CAD from the developed model but with an extended height for booth extremities of about 20mm (total RT height=190mm) necessary for composite manufacturing technique.

Since material is added to support the prototype build up its position has a strong influence on where the support ribs are fixed on the surfaces. This is important, since the necessary removal of those support ribs can damage the tooling surfaces, or at least roughen these surfaces. The build time is another factor that influences part placement. The 3D Systems' ThermoJet™ takes approximately 6min to build every millimeter in height, so by carefully examining the part orientation and other requirements one can achieve the best compromise between surface quality and RP build time.

The 3D printing is done layer by layer with "Thermojet 88" wax material from 3D systems (which properties are in APPENDIX A-3) over the apparatus metallic platform.

3.2.2 Investment casting equipment

The investment casting process was done at Prima Presision, Lahad. The process begins with preparation of the wax patterns for every casting made Wax is injected into an aluminum or steel die to produce a pattern that is an exact replica of the part to be produced. The patterns are clustered around a sprue.

The process involve dipping and coating process which is repeated again and again, (5 coating and 1 seal) using progressively coarser grades of ceramic material, until a self-supporting shell has been formed. It takes approximately 5 to10 days to make the mould including the finishing process(cut off, grind, heat treat, straightening, sand blast).

When a shell thickness of approximately 6 to 10mm has been built, the molds are dewaxed by autoclaving (pressure and steam). This leaves a ceramic shell containing cavities of the casting shape desired with passages leading to them. The hollow shells are then preheated, depending on the alloy to be poured and the molten metal cast immediately into the hot shell. After cooling, the ceramic is vibrated and blasted off the metal parts and discarded.

Material for first and second coating:

Slurry: Zircon flour,collodial silica n fuse silica

Sand: zircon sand

Material for third, fourth, fifth coating:

Slurry: mullite, collodial silica.

Sand: mullite sand with lower mesh value

Parameter control: relative humidity, temperature room, slurry density, slurry, viscosity slurry temp and pH.

Figure 3-3: slurry tank

Figure 3-4: sand tank

Figure 3-5: drying area

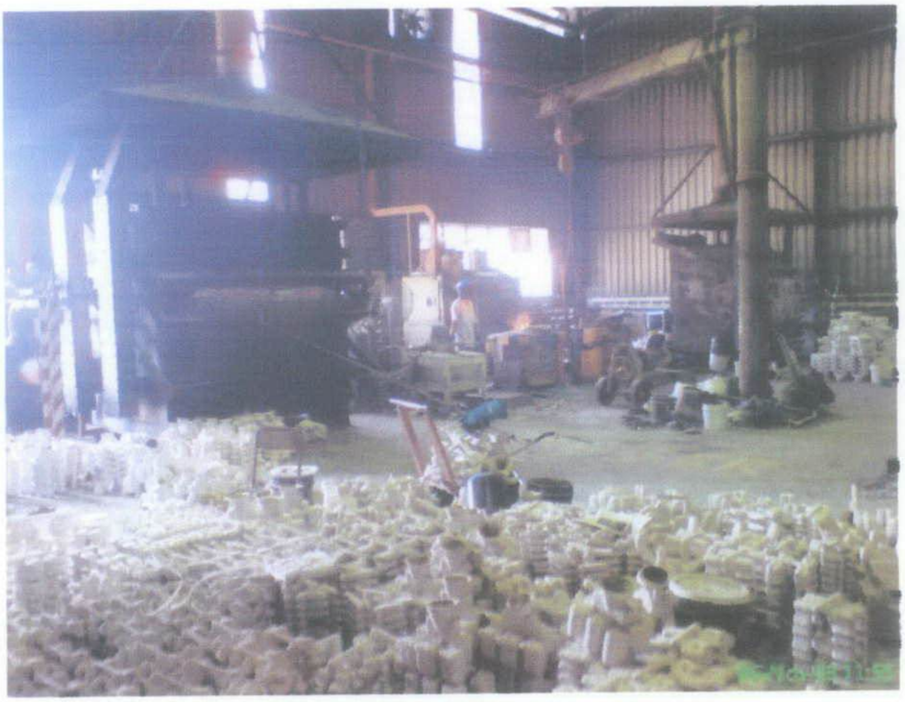


Figure 3-6: pouring area

# CHAPTER 4

## RESULTS AND DISCUSSION

### 4.1 Analysis of fabrication method

Rapid prototyping is the perfect tool to understand how a system is measured up to another. The benchmark is set to measure performance in real time, cost and quality measures where real time refers to total process time, cost refers to prototype production cost and quality refers to dimensional accuracy and surface finish.

#### 4.1.1 Experimental work

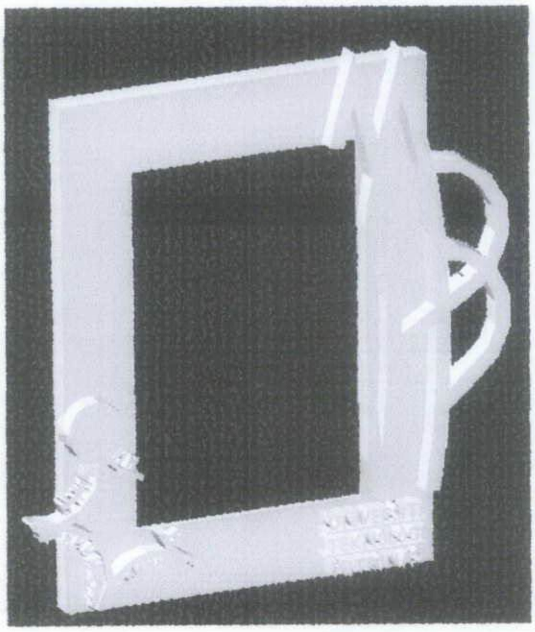
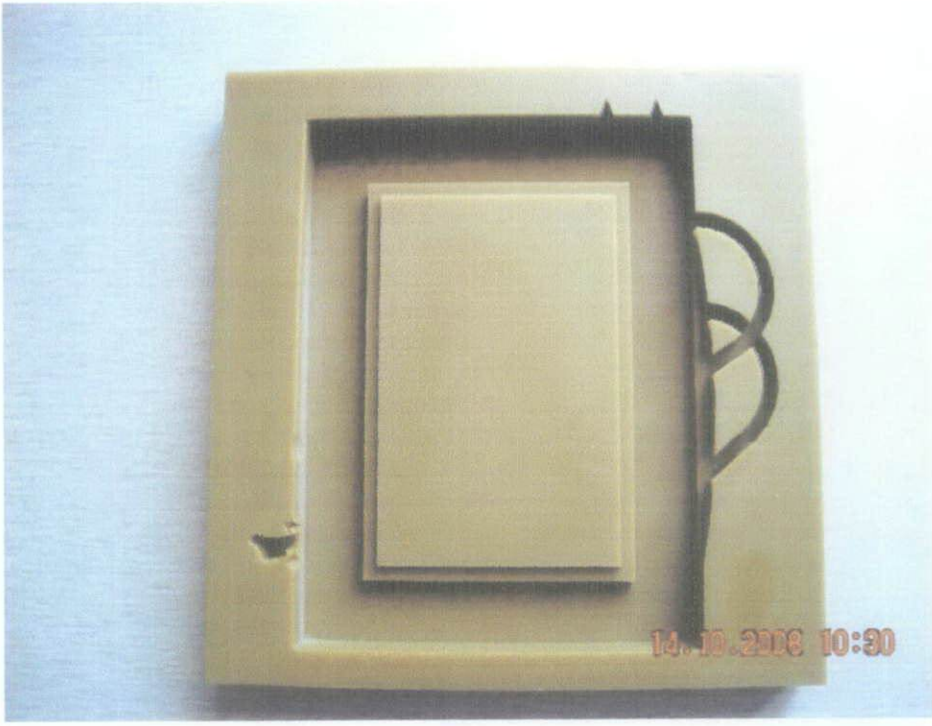


Figure 4-1: 3D drawing (shape that we use to generate mold shape)

Figure 3-3 shows the 3-D design that generate by AutoCAD. The moulds are generated from this drawing by using Magics Software.



(a)


(b)

Figure 4-2 (a) and (b): Picture of the prototype

Figure above are the first layer and second layer of mold prototype printed by Thermo Jet 3D printer. The prototypes are directly printed from 3D drawing that are generated from Magics Software that are converted to STl format file.

(a)

(b)

Figure4-3: first and second layer of mould.

Figure (a) and (b) are the first layer and second layer of mould that produced by investment casting technique.

4.1.2 Time completion

Timing for every step taken to complete each process was carefully observed and measured. Every process and step timing is tabulated in table 4-1.

Table 4-1: time of completion for each process

| Process | Steps | 1st layer mould (hour) | 2nd layer mould(hour) |
|---|---|---|---|
| designing | 3D CAD drawing | 15 | |
| | Check validity | | |
| | Magics software | 0.5 | 0.75 |
| | Total | 16.25 hours | |
| Rapid prototyping | Model construction | 2.25 | 2.45 |
| | Chilling | 1 | 1 |
| | Support removal | 0.5 | 0.5 |
| | total | 3.75 | 3.95 |
| Investment casting | Coating (5x) | 15 | 15 |
| | Seal | 3 | 3 |
| | Pouring | 3 | 5 |
| | finishing | 0.5 | 0.5 |
| | total | 23.5 | 23.5 |
| | TOTAL | 35.38 | 35.58 |

In the design process, only one time measure for both layers because both layer using same design. 35 hours and 23 minutes need to complete the 1st layer mould and 35 hours 35 minutes need to complete the second layer. Total time for investment casting process for both layer is 70 hours and 58 minutes. The total time this whole process are high because investment casting take a lot of time to completed the whole process. This is because dipping and coating process must be repeated for 5 times until the thickness of the shell approximately 6-10 mm. or every coating an dipping, the pattern should be dried first before continue with another layer of coating.

4.1.3 Cost of material and fabrication

Table 4-2: cost of material

| Material | Cost material | quantity | cost |
|---|---|---|---|
| Thermojet 88 material neutral | RM 308.60/kg | 0.605 kg | RM 186.70 |
| S50C | RM 12/kg | 10 kg | RM 120.00 |
| Total | | | RM 306.70 |

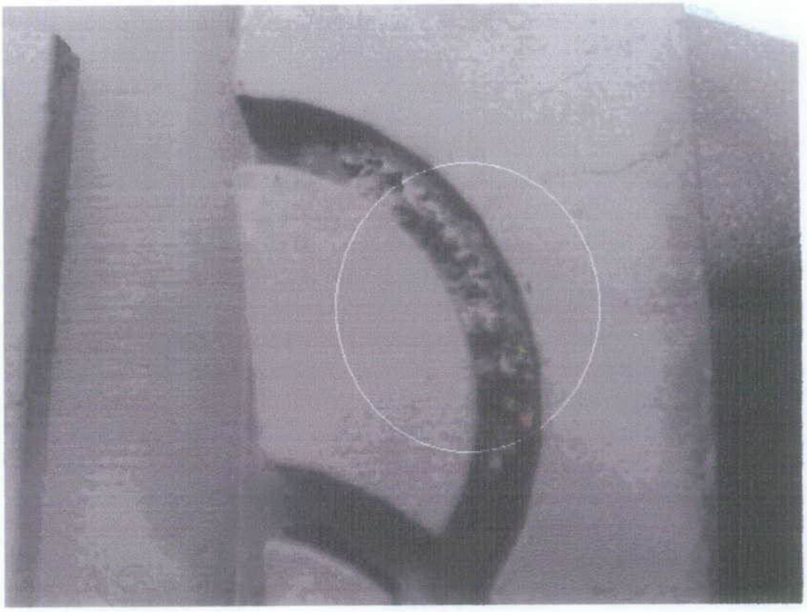
The cost of the material was obtained from the manufacturing laboratory based on cost charged to laboratory when purchase the material. The cost then calculated to give the indication of the money spent per kg of mass each material. The values were than manipulated to compute the cost of fabrication as present in table 4-2. Quantity of each material consumed in each technique was acquired from computation made on the volume recorded for each material.

4.1.4 Dimension accuracy

Table 4-3: dimension accuracy.

| Dimension | layer | Wide | Percent of error (%) | Length | Percent of error (%) | Thickness | Percent of error (%) |
|---|---|---|---|---|---|---|---|
| 3D drawing | 1 | 168.00 | - | 178.00 | - | 20.00 | - |
| | 2 | 168.00 | - | 178.00 | - | 4.00 | - |
| Prototype | 1 | 167.95 | 0.03 | 177.97 | 0.02 | 19.96 | 0.20 |
| | 2 | 167.93 | 0.04 | 177.96 | 0.02 | 3.98 | 0.50 |
| Mould | 1 | 167.59 | 0.24 | 177.73 | 0.15 | 20.12 | 0.6 |
| | 2 | 168.23 | 0.14 | 178.21 | 0.18 | 4.32 | 8 |

4.1.5 Mould profile quality



(a)

(b)

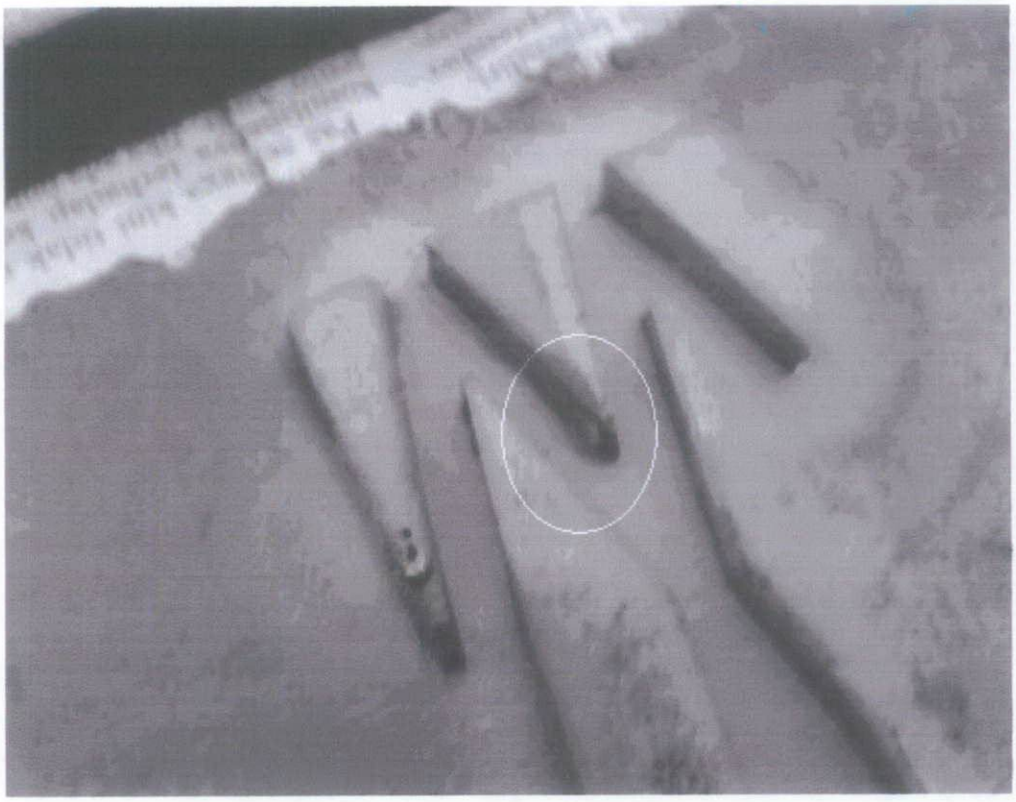


Figure 4-4 (a),(b),(c) : finishing of mold

From figure below, picture (a) shows the sand of the coating process are stuck between two gap of the mould. This is because the design gap is too small. Picture (b) shows the sand from shell stuck at the share edge of the mould. Because the shell broken during decasting process. Picture (c) shows the shell not fully removes because 90 degree designs.

# CHAPTER 5

## *CONCLUSION*

The objectives and of the project are to study rapid tooling technique, and to develop mould using rapid tooling method. The first part of the project has been accomplished in the first half of the project through research work and studies. Knowledge gained through the extensive research is applied in fabrication of the plastic prototypes.

The mould of UTP souvenir photo frame has been successfully completed within the time frame. The 2 techniques were analyzed and justified based on time completion, cost fabrication and profile quality and comparison with other rapid tooling technique.

| Analysis | Result |
|---|---|
| Time completion | 70 hours and 58 minutes. |
| Cost fabrication | RM 306.70 |

Base on this study, the investment casting is much recommended for producing low cost product with high production quantity with high accuracy dimension. This is because the cost for producing this mold is much lower compare to other technique and it can use repeatedly until up to 1000. But this technique is not suitable for the product that has complicated design with sharp edge and small gap.

Recommendation:

For smooth surface finish, the design has to change as investment casting design requirement. To make sure no sand stuck at the mould.

In the future, it is recommended for fabrication work to produce final product of the design and analysis of batch of product. Besides making souvenir product, the scope can be diversified to functional prototype as well as other type to prove that Rapid tooling can be implemented in various application and discipline.

REFERENCE


1. Kalpakjian Schemid. 2006, Manufacturing Engineer and Technology, Singapore, Pearson.
2. Somlak Wannarumon1 and Erik L. J. Bohez2.2000, Rapid Prototyping and Tooling Technology in Jewelry CAD, Thailand
3. McDonal J.A, Ryall C.J and Wimpenny D.I 2001, Rapid Prototyping Casebook, UK, Professional Engineering Publishing Limited.
4. Nurul Huda bt Abdul Karim, June 2005,' Application of time compression Technology in development of souvenir', UTP
5. August 20, 2008ust 20, 2008<http://www.newproductdynamics.com/index.htm>
6. Rapid tooling, August 20, 2008 <http://www.efunda.com/processes/rapid_prototyping/rt.cfm>
7. Castle Island Co. 2004 <http://home.att.net/~castleisland/3dprint.htm>
8. Laser design inc. May 2005. <http://www.laserdesign.com/reverseengineering.htm >
9. Machined design. November 2008 <http://machinedesign.com/ContentIndex/713/CadCamCae.aspx>

APPENDIX A-1

## 1) List price for material

| Prices Listed are Per Pound | Less than 10,000 lbs. | | | 10,000 - 100,000 lbs. | | | Greater than 100,000 lbs | | |
|---|---|---|---|---|---|---|---|---|---|
| Generic | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. |
| ABS | $2.42 | $0.83 | $1.43 | $1.25 | $0.66 | $1.44 | $1.14 | $0.68 | $0.91 |
| ABS (30% glass) | | | | $1.25 | $1.25 | $1.25 | | | |
| ABS - Medium Impact | | | | | | | $0.89 | $0.85 | $0.87 |
| ABS - High Impact | | | | $0.86 | $0.86 | $0.86 | $1.24 | $1.24 | $1.24 |
| Acetal Homopolymer | | | | $1.08 | $1.08 | $1.08 | $1.45 | $1.24 | $1.34 |
| Acetal Copolymer | $4.55 | $1.95 | $2.67 | $0.89 | $0.89 | $0.89 | $.95 | $.95 | $.95 |
| Acrylic / PMMA | $2.97 | $2.41 | $2.65 | $2.45 | $2.45 | $2.45 | $1.80 | $1.80 | $1.80 |
| ASA (Acrylonitrile Styrene Acrylate) | | | | $1.75 | $1.75 | $1.75 | | | |
| EVA (Ethylene Vinyl Acetate) | | | | $2.80 | $2.80 | $2.80 | | | |
| EVA (Wide-Spec) | | | | | | | $0.58 | $0.58 | $0.58 |
| Nylon 6 | | | | $1.82 | $1.32 | $1.50 | $1.50 | $0.85 | $1.08 |
| Nylon 6 (15% glass) | $2.00 | $2.00 | $2.00 | $1.51 | $1.38 | $1.44 | | | |
| Nylon 6 (30% glass) | $2.60 | $2.60 | $2.60 | $1.69 | $1.69 | $1.69 | $1.45 | $0.80 | $1.12 |
| Nylon 6/6 | $1.72 | $1.71 | $1.71 | $1.65 | $1.44 | $1.54 | $1.75 | $1.75 | $1.75 |
| Nylon 6/6 (10% glass) | $1.65 | $1.65 | $1.65 | | | | | | |
| Nylon 6/6 (25% glass) | $1.91 | $1.91 | $1.91 | | | | | | |
| Nylon 6/6 (30% glass) | | | | $1.65 | $1.62 | $1.63 | $1.58 | $1.45 | $1.51 |
| Nylon 4/6 | $4.64 | $4.08 | $3.54 | | | | | | |
| Nylon 4/6 (30% glass) | $3.58 | $3.58 | $3.58 | | | | $1.81 | $1.81 | $1.81 |
| Nylon 11 | $3.75 | $3.75 | $3.75 | | | | | | |
| Nylon 12 | $3.85 | $3.85 | $3.85 | $3.00 | $3.00 | $3.00 | | | |
| Polycarbonate | | | | $3.13 | $1.69 | $2.27 | $2.55 | $1.00 | $1.68 |
| Polycarbonate High Impact | | | | | | | $0.85 | $0.70 | $0.77 |
| Polycarbonate (30% glass) | $2.00 | $2.00 | $2.00 | | | | | | |
| Polcarbonate + ABS | | | | $4.25 | $3.93 | $4.09 | $2.60 | $.90 | $1.75 |
| Polycarbonate + PET (Imp. Mod) | | | | $2.87 | $2.87 | $2.87 | | | |
| HDPE | $0.82 | $0.62 | $0.68 | $0.89 | $0.49 | $0.72 | $0.79 | $0.53 | $0.64 |
| HDPE (widespec, virgin) | | | | | | | $0.42 | $0.42 | $0.42 |
| HDPE (co-pp) | | | | | | | $0.36 | $0.36 | $0.36 |
| LDPE | $0.94 | $0.94 | $0.94 | | | | $0.80 | $0.72 | $0.76 |
| LLDPE | $3.30 | $1.40 | $2.36 | $0.93 | $0.93 | $0.93 | $0.85 | $0.50 | $0.70 |
| PBT | $3.16 | $3.16 | $3.16 | | | | $1.80 | $1.80 | $1.80 |
| PEEK (30% glass) | $28.75 | $28.75 | $28.75 | | | | | | |
| PET | $1.50 | $1.28 | $1.39 | $0.67 | $0.67 | $0.67 | $0.70 | $0.45 | $0.54 |
| Polyester | $1.50 | $1.50 | $1.50 | $1.40 | $0.88 | $1.14 | $1.12 | $0.91 | $1.04 |
| Polyether Block Amide (PEBA) | $3.00 | $3.00 | $3.00 | | | | | | |
| Polypropylene | | | | $2.25 | $1.01 | $1.42 | $1.05 | $0.54 | $0.76 |
| Polypropylene Copolymer | $0.82 | $0.82 | $0.82 | $0.95 | $0.55 | $0.75 | $0.93 | $0.49 | $0.64 |
| Polypropylene Copoly (10% glass) | | | | | | | $0.68 | $0.61 | $0.62 |
| Polypropylene Copoly (20% glass) | | | | | | | $1.20 | $0.80 | $1.00 |
| Polypropylene Copoly (30% glass) | $1.17 | $1.09 | $1.13 | | | | $0.80 | $0.80 | $0.80 |
| Polypropylene Impact Copoly | | | | $4.00 | $4.00 | $4.00 | | | |
| Polypropylene Homopolymer | $0.60 | $0.60 | $0.60 | $0.68 | $0.47 | $0.56 | $0.83 | $0.50 | $0.67 |
| PP Homopoly (30% glass) | | | | $1.01 | $1.01 | $1.01 | | | |
| PPA | $3.67 | $3.67 | $3.67 | | | | | | |
| PPE+PS (PPO) | $2.50 | $2.45 | $2.47 | | | | $1.42 | $1.42 | $1.42 |
| Polystyrene (GPPS) | | | | $0.82 | $0.64 | $0.66 | $0.79 | $0.70 | $0.74 |
| Polystyrene (HIPS) | | | | $0.82 | $0.70 | $0.77 | $0.81 | $0.63 | $0.75 |
| Polystyrene (MIPS) | | | | | | | | | |
| PVC - Flexible | | | | $0.80 | $0.75 | $0.77 | $0.85 | $0.73 | $0.77 |
| PVC - Rigid | | | | $1.08 | $0.84 | $1.50 | $0.97 | $0.51 | $0.78 |
| Silicone Rubber | | | | $4.50 | $4.50 | $4.50 | | | |
| Thermoplastic Elastomer (TPE) | $3.00 | $2.00 | $2.50 | $2.5 | $1.82 | $2.16 | | | |

**Figure 1: Street Plastic Prices Report (Updated March 19, 2008)**

APPENDIX A-1

2) Survey form

Name:

Id No.:

1. Do you like UTP's souvenir that available at KOPETRO? Why?

-

______________________________________________

______________________________________________

______________________________

2. What is importance chatacteristic for souvenir?

______________________________________________

______________________________________________

______________________________

3. What are products that suitable for souvenir? Why?

______________________________________________

______________________________________________

______________________________

APPENDIX A-3

**Table I** Properties of wax material "Thermojet 88" (3D Systems)

| | |
|---|---|
| **Melt temperature (K)** | 358-368 |
| **Softening temperature (K)** | 343 |
| **Density at 413 K ($g/cm^3$)** | 0.846 |
| **Density at 403 K ($g/cm^3$)** | 0.848 |
| **Density at 296 K ($g/cm^3$)** | 0.975 |
| **Volumetric shrinkage from 413 K to room temperature (per cent)** | 12.9 |
| **Ash content (Gray wax) (per cent)** | 0.00-0.01 |