

## Capability of Polymeric Product Development Via Vacuum Casting Process Using Native Drawing

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### ABSTRACT

New products that want to produce based on the native drawing may involve some difficulties in the way to get exact features. This happens because lack of efficiency in the sequence of the process. Thus, this project has been conducted to identify the capability of the vacuum casting process to produce the product based on the native drawing. This project focused on producing medal using vacuum casting technique start from understanding the design process, designing the prototype using CAD software, studying the capability of the 3D printer RP machine to produce the prototype based on the analysis that have been done using MAGICS RP software and directly continue the process by making the mold and finally pour to get the product. The result from this project showed the finish products and original drawing are the change of the shape and surface based on diagnostic that have been detected using MAGICS RP software. From that, it was clearly illustrated about the product development which may consist some difficulties to produce the product same as the original drawing. This project also can be used as a basic reference to the product maker and another researcher to develop new native product easily.

**KEYWORDS:** Vacuum Casting Technique, Rapid Prototyping Machine, Design Process, Silicone Rubber Mold, Polymer Product Development.

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### INTRODUCTION

This paper will present the Capabilities of product development using vacuum casting technique based on the native drawing. The ideas of the native drawing actually are transferred from the requirements and needs of customers. This project is planned to develop a new product which is a form of medal or trophy as recognition. Actually, new product development is the term used to describe the complete process of bringing a new product or service to a user. There are two parallel paths involved in the product development process: one involves the idea generation, product design and detail engineering; the other involves market research and marketing analysis. The initial stage in the new product development process is an opening classification, which is the ideas for new products are generated. The ideas actually are the raw materials for product development and the whole planning process depends on the quality of the exploration and selection process [1]. The opening classification basically consists of two processes: identifying and collecting new product ideas and also evaluation of the ideas. These two processes will be clearly explained in this paper.

#### Design Process

A design process may be defined as the series of activities that take a design problem from an initial requirement to a finished artifact or object that meets all the requirements of the specification [2]. Design research began in the 1960's, with so-called "first-generation" models created by investigators trying to find generic optimization routines that could be applied to any type of problem [3]. Most engineering designs can be classified as a system that are created by human try and did not exist before or else are improvements over the existing system or device [4]. Designs are not suddenly existing from nowhere but they are the result of taking together technologies to meet up human needs or to solve problems. For a while, design is the result of someone trying to do a task more quickly or efficiently. Design activity requires a step-by-step methodology and come over a period of time. The design of a new product consists of the following stages as shown in Figure 1.



Figure1: Design process[4]

### Define Problem

The initial stage of the design process for this project is a definition about the problem. The problem for this project may need the creation of the new ideas based on the requirement from the customers that need to determine the relevant design constraint, but those constraints may involve some difficulties and hard to determine without the clear features of the concept. This definition generally restrains a listing of customer requirements and information about product function. This research should clearly understand about the problem definition to construct the good ideas to fulfill the concept of the product. As mentioned before by the [5] a well definition of the problem is critical to finding the workable solution. The problem definition must consist of several criteria to guide the process of generating the ideas. The criteria that relate to a detailed design problem are must be depends on base knowledge and the research that need to be done. The criteria that usually use to get the better design solution are such as safety, easy to operate, low for the cost, ease of use and others. For this project, the value of criteria depends on several factors including design complexity, type of material, desired finish and cost involved. In this project, the problem was coming from the needs and requirement from the customers.

### Gathering Information

Before further in the design process, the designer need to collect all the information available that relates to the problem. Gathering related information can expose details about the problem. Designers may discover mistakes and false that made by other designers. When beginning a search for information relating to a design problem, designers must be prepared to go to many different sources. In [6] mentioned that method of gathering information is researching on many different sources such as existing product, what is already for sale, find out the information from magazines, television and will be better by going through the market. For this project, the information is normally came from existing product in the market, internet website, newspaper and form the games that shown in the television programmed such as 2008 Beijing Olympic Games, Football World Cup, World Badminton Grand Prix and others. From that information, the initial idea will be build before going through the detail concept of the creation of ideas. Normally, the type of recognition that be awarded to the athletic is in the form of cups, rope medal, bowls, stand medal, trophy, badges and others. A medal usually has three basic parts which are front surface of the medal (which will contain the portrait), second is the back surface of the medal (which may be blank or engraved with a design) and lastly the outer edge of the medal. These medals might be gilded, silvered, chased or finished in a variety of other ways. More interesting materials that have been used to fashion art medals include glass, porcelain, coal, wood, paper and others. Those medals that have been produced will describe about the organization, the symbol or the concept of the ceremony or contest and also the trademark to commemorate specific events. Trophy also has similarities with the medal in terms of value description, but it totally different in shape and basic part.

### Generating Multiple Solution

After gathering information about the problem definition, the info should be present in the form of sketching to identify the ideas that capable for the next process. In this stage, brainstorming of the idea need to be open and not just to concentrate on one type solution. In the process of generating the ideas, avoid from thinking about the failure because its may contribute to the block or dead end of creativity. The all ideas that have been generated will be assessed and analyzed to relate with the expected of the product concept and product description. On these stages, this project proposed nine kinds of ideas in the form of a medal and trophy. These all nine ideas have been sketched based on the characteristic or requirement of the customers. This sketching process was done in the slices of A4 paper by free hand sketching using a 2B pencil.

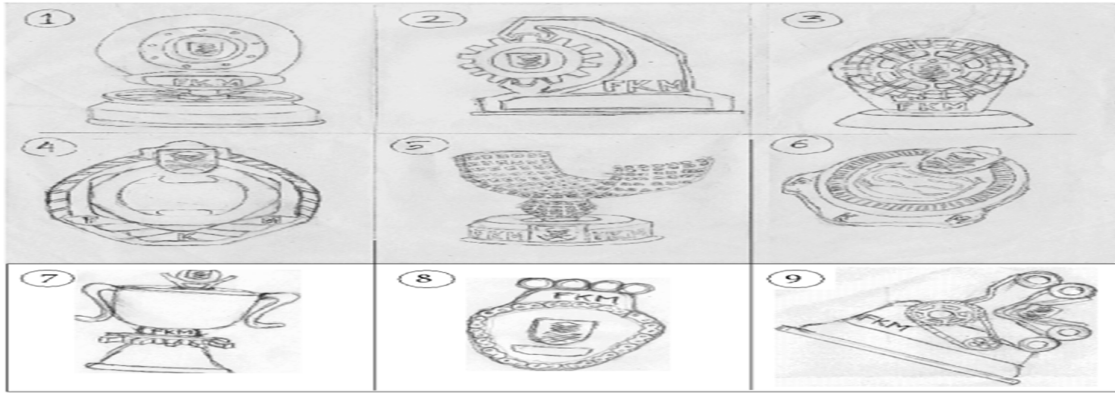


Figure2: Nine ideas consist of requirement from customers

These six ideas will be analyzed in the next stages using matrix analysis or usually known as a decision matrix to select the best three. This best three ideas will further process on the next stages starting on developing the prototype until it will be produced by using the sand casting technique. Why choose three is because it will be analyzed again in terms of the capabilities of the process and process parameters that involved producing the presents for the tournament.

**METHODOLOGY**

After getting the multiple solution which is form of ideas about the design problem, those solutions will be analyze and then will be selected which solution is best appropriate for completion. Before going into the next stage which is machining process, the nine samples of drawing will be checked in the matrix analysis based on the several criteria that have been stated by the customers. For this project, decision matrix or matrix analysis will be used as a decision method which consists of establishing a set of weighted criteria upon which the potential options can be decomposed, scored and summed to gain a total score which can then be ranked. This decision matrix will produce the subjective opinion about one alternative versus another can be made more objective. From that, the designer is able to see able to see how the opinion would have to change in order for a lower ranked alternative to out rank a challenging alternative. For this project the designer decides to produce three types of product which are in the form of rope medal, medal stand and trophy. This analysis is very important because it will evaluate and prioritizes a list of options that contribute to the success of the next process. Once get the alternative solutions to the design problem, those solutions need to be analyzed and then deciding which solution is best suitable for completion based on those criteria. This matrix can be used to compare opinions. When possible, however, it is better used to summarize data that have been collected about the various criteria. Several criteria for selecting a problem or improvement opportunity require guesses about the ultimate solution. For example, the nice appearance, style to present the trademark of UiTM, concept of mechanical and the size of the product is it easy to hold or not. Therefore, the rating of the options will be only as good as the assumptions about the solutions. For each criterion, rate each other alternative in comparison to the baseline, using scores of poor, average and finer rating scales as shown in Table1.

Table 1: Criteria for matrix analysis

Item	Poor		Average		Excellent	
	1	2	3	4	5	6
Presentation style (UiTM logo)	Too small and not clear		Clearly illustrate but at the poor position		Clearly illustrated at the nice place	
Mechanical trademark	Dim		Fair		Illumination very clear	
Size	Too big or too small		Fair		Easy to hold	
Nice appearance	Accepted		Attractive but too complex		Interesting design	

**Test and Implement the Solution**

The final stage of the design process for this project research is an analysis and completion of the solution. This completion may be present in the form of a prototype. This prototype will provide the chance to test the look and feel of a product’s potential. A functional prototype does not have the final customer interface, but enables customers to figure out the various features of the product developed. The designer will start with understanding the developed idea of a new product in terms of shape, size and operation involved to create the initial design and then transfer it into the CAD software to create a preliminary design. With the suitable software, the initial design can also be analyzed for functionality and process capabilities as the design is being

created. Based on the result that have been calculated using matrix analysis, this project decides to produce three types of the product which come from ideas 1, 2 and 6.

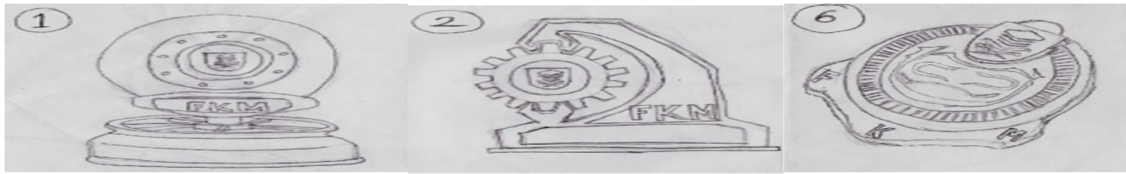


Figure3: Selected ideas

The selected ideas may involve some modification before proceed to the next process. This modification needs because to avoid from mistakes at the final stages of this project research such as unclear about the concept, trademark of the product and another specification that have been mentioned.

**Design Using Catia V5**

Catia V5 software is drawing tool that provides the operation to develop actual product start from sketching in the 2D profiles until overall of the product view, which can be called 3D projection view will be developed. The process was started by using sketching workbench and part design workbench. In this workbench, the based structure of the product will be created. In this project, the design of the three ideas will be compared in terms of body structure and operation involved to develop the ideas into 3D projection view. Actually, sketching workbench was combined with the part design workbench. All of the drawing that has been created in the sketching workbench will be transferred directly through the part design to generate solid part or 3D dimension of the part as shown in Figure4.

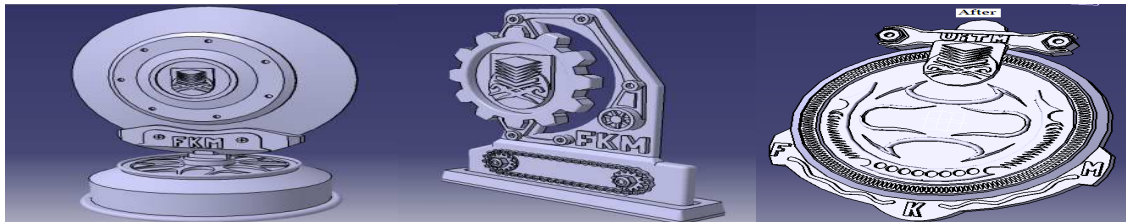


Figure4: CAD modelling for the selected ideas

**Magic RP Software Analysis**

In this software, there are several operations that need to be familiar with by the manufacturer before start the process of repairing. In this stage of the process, designer will do the analysis of the three ideas. The result of this analysis will be compiled into the matrix analysis to identify and compared between each others in terms of the operation involved, errors detected, and changes of the product after repairing. This software is very important for this project because it has been used as a safety method to avoid from developing the poor features of the product. In this software, the part operations that are usually used in this software are such as import part, saving part and unloading parts. For this project, the part operations need to be considered to facilitate the sequences of the process and avoiding from mistakes. At these stages of the project, the three designs will analyze one by one and then will be compiled in the table same as in the previous subsection.

Table2: Fix wizard result

Type of error detected	Rope Medal	Stand Medal	Disc Brake Trophy
1. Inverted normal	0	0	0
2. Bad edges	3	0	0
3. Bad contours	1	0	0
4. Near bad edges	3	0	0
5. Planar holes	0	0	0
6. Shells	1	2	2
7. Noise shells	0	0	0
8. Overlapping triangles	13	1	0
9. Intersecting triangles	0	0	0

This diagnosis very important as a protection system before further for the next process. In this process, the researcher has separated the assembled parts to make easy for the repairing process. This all product will be checked in the fix wizard toolbar and then the result will be shown in the fix wizard toolbox. The result was

clearly illustrated in Table2 showing the detected errors that need to be repaired by using the tool that have been provided by the MAGICS RP software.

**3D Printer RP Machine**

Before this project further process on prototype building using the 3D Printer RP machine, manual operation of the machine and the specification of the machine should be understood first. It will assist the flow of process sequences. The manual operation such as operator panel, build chamber, process to print the job on the PC is important to be understand first to avoid from the problem during the process that contribute to the waste of the material. Before submitting the job to the printer, this project needs to preview the print job first to identify and analysis of the prototype that will be produced in terms of material used, process time, the volume of the product and others. In this InVision client preview window, the part of STL files can be added and remove, change and rearrange part, and submit the modified job directly to the printer’s job queue. This window will show the part in many position of view such as side, plan, bottom, front and in the isometric view as shown in the Figure5.

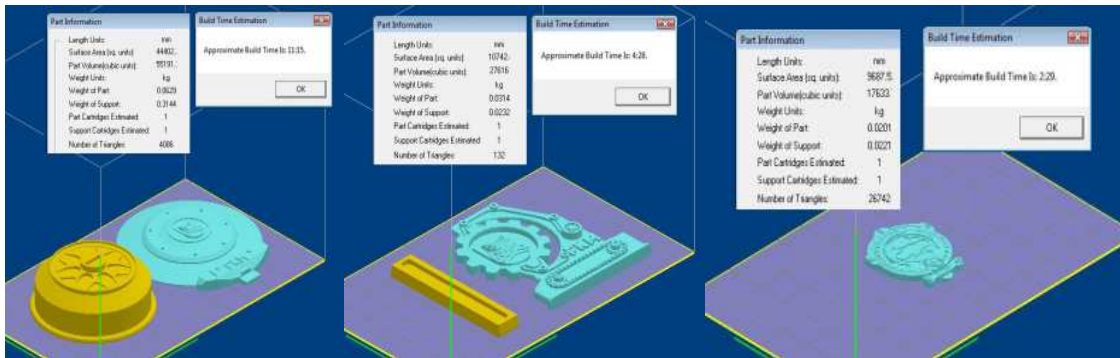


Figure5:Part arrangement and part information

This position view will guide the user to arrange the product. The position of the product is important to be considered in this project because the material used, time processing and others parameters depend on the part arrangement. As the part arrangement not accurate or not suitable, it will totally affect on the processing time and the amount of material used.



Figure 6: Prototype of the selected ideas

After finished print the job in the 3D RP machine as shown in the Figure 6, all of the ideas will enter the next stages of process before it can perform in the vacuum casting process. The produced ideas or are known as a prototype will be clean first. This support was made from wax and used as a support material printed. This support needs to be clean by heating the part in the oven for several hour,then dip the part in the heated bath to remove the bulk material after that put out and clean the part and leave it in the room temperature for a few minutes.

**Vacuum Casting Technique**

The last stage of the product development is a casting process. For this project, vacuum casting technique will be used as a casting process because it is an accurate copy of the patterns without stripes and all of the pattern shape will exactly reproduce. This technique is a replication technique distinguished by applying the vacuum during the processes of mold making and material pouring to produce the parts. Before further the step of producing the product, the manufacturer should read and understand the manual to avoid from mistakes and

wasting material. The manual will cover all process parameters and process sequences that should be considered before start producing the product.

### Silicon Rubber Mold

Silicone rubber (Figure 7) is a polymer that has a "backbone" of silicon-oxygen linkages, the same bond that is found in quartz, glass and sand. Normally, heat is required to vulcanize (set) the silicone rubber. This is normally carried out in a two stage process at the point of manufacture into the desired shape, and then in an extended post-cure process. It can also be injection molded. Silicone rubber liquid is mixed with a suitable catalyst in the right mixing ratio and then slowly solidifies to a rubbery solid. The mixing ratio must be accurate for it to be applied as a mold material. Whilst liquid, it can be poured over the original to form either a solid mould, or a skin mould with backing to be added later. Because of the flexibility, silicone rubber offers good resistance to extreme temperatures, being able to operate normally from (300°F/204°C or higher) makes as the best release properties among rubber mold. So, the silicone rubber can be used for casting resin and low melting metal alloys such as tin, pewter, lead and etc. This silicone rubber mold also has limitation such as high cost and high viscosity that requires a degassing process in the vacuum chamber to remove the bubble.



Figure 7: Silicon rubber mold

### Cast Material Preparation

The amount of resin in the casting process depends on a calculation that based on the weight of the master pattern, weight of the gate and riser, the mixing ratio between the resins used. The calculation of the resin quantity is as follows:

Weight of resin =  $(1+0.3) \times$  weight of pattern (if pattern made from plastic)

Volume of resin =  $(1+0.3) \times$  weight of pattern (for any material of pattern)



Figure 8: Cast material preparation

### Pouring Process of Vacuum Casting

Before pouring the product into the mold, the resin in Cup A and Cup B must be evacuated for 15 to 30 minutes depends on the type of resin. The initial degassing of the resin must be done not including the silicone mold in a vacuum chamber. After the main evacuation, the vacuum chamber is leaked and silicone mold is then placed inside the vacuum chamber. The resin was degassed at the second time for 5 to 8 minutes. Then, it will be mixed until 15-20 seconds before it will be poured through the silicone mold rubber. The leaking process must do continuously during the pouring process to make sure the bubble not trapped in the cavity that will affect the product features. After finishing the pouring process, waiting for vacuum pressure stops degassed before open the vacuum machine. Then the cast product will be placed in the oven until completely cured. After the product completely cured and hardened in the oven, the product will be injected from the mold by using compressed air. This is because many resins are quite sultry and viscous at high temperature. After the products have been released from the mold (Figure 9), the researcher may need some finishing process to improve the appearance of the product (Figure 10) before it can be displayed to the customer.



Figure 9: Pouring process and casting removal



Figure 10: Finished product

## RESULTS AND DISCUSSION

In the rapid prototyping process, from the result that have been determined in the MAGICS RP software, the highest number of errors has been detected from the rope medal compared to the other product. The diagnostic will show the type of error after updating the fix wizard such as bad edges, bad contours, near bad edges, shells, overlapping triangles and intersecting triangles. These all errors will be repaired by following the advice steps on the fix wizard toolbox. This toolbox will initially advise the user to repair the product using 'Automatic Fixing' which provides more benefit to the new user for this software. Automatic fixing will automatically repair the product and the result will be displayed in the same toolbox. The automatic fixing will remove the errors that do not affect the overall shape and surfaces of the product. After the products have been repaired using automatic fixing, the product updates again to detect error until the all existing error have been removed. If the product still shows the error, then proceed to the next step which is manually operations to overcome the problem. In the manual fixing, a function of this toolbar is to remove double surfaces and long thin triangles, detect double surfaces for analysis and also perform some triangle. Based on their result, overlapping triangle detector is used, the triangles that meet the detection parameters will have color added to them. This problem also can be overcome by using Fix pages that contains of autofix, basic, hole, triangle, shell, overlap and point. However, the overlapping triangles may not be completely clear by this software. It still exists even it repaired in many times, but this error does not affect the product produced because this type of errors was in the form of the thin layer that generated by the design format files. Based on those used by the software, it becomes a protector or safety procedure before the product will be produced to avoid from waste of cost, material, time processing and others.

In the casting process, the process of making the molding box needs some calculation to determine the value of the box volume. This value was very important to be considered because the amount of the silicone rubber and catalyst used was depending on this volume. Based on this calculation, the amount of the material used surely correct and wasting practice will be avoided. It also can be used as a basic reference for the new developer easily. The last process with the vacuum casting technique is a casting process, which covers the overall process involved in developing the product for this project paper. As mentioned before, this technique is an exact copy of the pattern. So, whatever false that occurred in the initial stages of the process, it can be the result of the produced product. In this process, the problem that occurred is coming from the lack of process sequences and also from the condition of the surrounding area at the working place. From the product that have been produced, there are several defects occurred in the product as shown in Figure 11 such as shortcast, miscast, bubble, misrun, flash and others. Actually, each product was produced three times to evaluate and analyzed the capabilities of the process to develop the product.

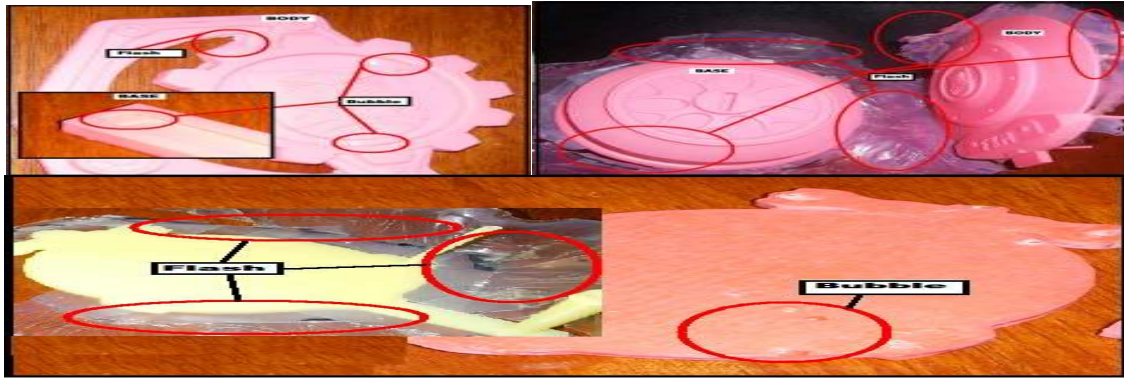


Figure 11: Types of defect

### CONCLUSION

With increased emphasis on customer satisfaction, theory development and effectiveness process to develop new product have become crucially important. From this study, it can be concluded that the new product development should consist of many important criteria such as concept of the product development, screening idea, analysis and testing method, capabilities of the process to produce the product and the market analysis to commercialize the product. For this study, the product development consists of many significant stages starting from generating ideas until fabrication of the product. This all stages should be control continuously to avoid from mistakes that may contribute to the loss of money, material, times and others. The new product development usually begins with research and generating the ideas. Then, follow by product design to concept testing to building prototypes and to produce the actual product that can be accepted by the customer. Based on this project, it can be accomplished that the likelihood of the product success was depends on the continues analysis of process capabilities start from designing the product, testing and implementation of the prototype until the last stages which is producing the product that can meet all the requirement of the customers. From this analysis, it can be used as references or project postmortem in the next process that contribute to the improvement of the product quality. It also was very important to be documented to develop new product easily into the challenging future life.

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