DESIGN, ANALYSIS AND FABRICATION OF BOTTLE NECK ELECTRODE

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ABSTRACT

Bottle mould making technology has become one of the most important industries nowadays. However, the bottle necks mould making process is given less attention and special tooling is needed in order to shape the mould. Bottle neck tool making process involves features consideration of its complex geometry. This project is aim to design and manufacture the bottle neck tool. This tool will be use to form a shape the workpiece to become bottle neck mould. For that, the tool design was done using Solidworks and Cimatron. The FEA method was used in electrostatic current and voltage analysis on the tool. Finally, the DFM Concurrent Costing was applied to estimate the machining cost before it proceeds into the machining stages. The results show that after FEA analysis, the values of the electrical current magnitude were stated as 1936.07A/m^2 (highest) and 11.1649A/m^2 (lowest) respectively. Meanwhile, the estimated machining cost generated from DFM software was RM 867.19. A prototype of the neck finish electrode was fabricated at the end of this project. As a conclusion, the electrode design, analysis and fabrication have achieved by using tools such as Solidworks, Cimatron, ALGOR, DFM Concurrent Costing and MasterCAM.

ABSTRAK

Teknologi membuat acuan alur botol telah menjadi satu keperluan khususnya dalam indutri botol platik pada masa kini. Walau bagaimanapun, proses membuat acuan alur botol plastik tersebut kurang mendapat perhatian di kalangan industri tempatan di mana ianya memerlukan suatu alat untuk membentuknya kepada bentuk alur botol pada "workpiece". Pembuatan acuan alur botol memerlukan pertimbangan dari sudut segi rupa atau bentuknya yang kompleks. Projek ini dijalankan berdasarkan reka bentuk dan pembuatan elektrod untuk acuan alur botol. Untuk itu, elektrod tersebut direka dengan menggunakan Solidworks dan Cimatron. Kaedah "Finite Element Analysis" (FEA) digunaka untuk mengkaji kesan elektrostatik dari segi arus dan voltan yang dikenakan pada elektrod berkenaan. Akhir sekali, "DFM Concurrent Costing" digunakan untuk menganggar kos mesin untuk elektrod tersebut sebelum ia masuk ke tahap pemesinan. Keputusan dari FEA mencatatkan nilai-nilai untuk magnitud arus pada electrod sebagai $1936.07 A/m^2$ (tertinggi) and $11.1649 A/m^2$ (terendah). Manakala, keputusan daripada DFM concurrent Costing menunjukan bahawa kos pembuatan bagi eletrod tersebut adalah berjumlah RM 867.19. Prototaip untuk electrod bagi acuan alur botol kemudiannya difabrikasi menggunakan mesin CNC milling. Sebagai kesimpulannya, projek ini berjaya dilaksanakan dengan sokongon daripada "software" seperti Solidworks, Cimatron, ALGOR, DFM Concurrent Costing and MasterCAM.

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f	Feed
t_m	Machining time
l_w	Cylindrical surface of length
n_w	Number of revolution of the workpiece
l_t	Length of the broach
v	Cutting speed
R_a	Surface roughness
r_ε	Tool corner radius
a_e	Depth of cut
d_t	Diameter of cutter
v_f	Feed speed of the workpiece
Z_w	Metal removal rate
a_p	Workpiece width

CHAPTER 1

INTRODUCTION

This chapter discuss about the project background, problem statement, project objectives, and scopes. The structure of the thesis is also explain briefly in this chapter.

1.1 Project Background

The design and manufacturing of high-technology product such as mould, tool and dies have been a great challenge for the engineers nowadays. With the high demand in the global market, manufacturing and production sectors had grown rapidly. Eventually, products have to produce faster and efficiently. For that, creation and design of tooling is the most critical part.

Bottle or galloon plays an important role in human daily life and usually used as storage for water, oil, etc. As the needs from the customers increase by years, changes had been made in terms of its design, materials, and ergonomics. Improvement of bottle 's physical properties such as durability and reliability

This project focuses on the blown molded 4L bottle mould tool, which will cover from the mouth until the neck of the bottle. A part of that, a special tool is needed to form the threads on the mould itself. The aims of this project are design for the bottle mould tool and do analysis regarding the material selection and how to minimize the manufacturing cost.

One of the world most powerful CAD/CAM solutions for mould making software - Cimatron is being used in this project. Cimatron solutions are designed for concurrent engineering in which the functions carried out from design until production. Computer simulation on material selection and cost is done by Design for Machining (DFM).

1.2 Problems Statements

According to the current situation, the blow mould for the bottle neck finish is recently only got one in the FKM lab which was supplied by the blow molding machine manufacturer. The design and the dimension of the neck finish are depending on the capacity of the bottle, and thus might cause an undesirable and unreliable outcome.

For that, a special tool is needed to be design for the neck. Although there are various types of mould making techniques, EDM (Electrode Discharge Machine) Electrode is considered to be more flexible and reliable and the practical way for the mould making nowadays.

In the mould making industry, the manufacturing of a single EDM electrode will be very costly due to the quality of the product, hi-tech machining, and use high level software such as UG, MasterCAM, and Cimatron. Therefore, a study has to be carryout in order to minimize the manufacturing cost and eliminate long time consumption.

1.3 Project objective

The objectives of this project are to design, analysis and fabrication of the bottle neck electrode.

1.4 Project Scope

In order to achieve the objectives stated above, the following scopes have been defined:

1. Identify the literature review of the project.
2. Bottle neck design by using Solidworks and modeling using Cimatron.
3. FEA design analysis of the electrostatic current and voltage on the tool.
4. Fabrication cost analysis by using Design for Manufacturing (DFM) Concurrent Costing.
5. Prototype fabrication.
6. Product verification
7. Thesis documentation

1.5 Thesis Structure

Thesis structure is the brief explanation to every chapter in this thesis. The structures of thesis are as below:

1. **Chapter 1**

   This chapter discuss briefly on the project background, problem statement, project objectives, and project scopes. The main purpose of this chapter is to give an early understanding of the overall project.

2. **Chapter 2**

   This chapter includes all the information acquired regarding on the project which includes the quotes and summary from the journals, reference books and other types of article review. All the information including the principles, explanations and parameters related to this project were shown in this chapter for future reference.

3. **Chapter 3**

   All the methodologies are discuss clearly in this chapter and was illustrated in flow chart for better understanding. A part of that, this chapter also explain on the software been used for this project such as Solidworks, Cimatron, ALGOR and DFM Concurrent Costing.

4. Chapter 4

All the data which were generated from the design and modeling will be further to result analysis. The analysis was first carryout using Cimatron where the blank size and the tool holder were determined. After that, FEA analysis in terms of electrostatic current and voltage on the designed tool was carryout using ALGOR. The result from FEA will determine whether the design tool can be EDM or not. After that DFM Concurrent Costing was used to analyze the machining processes and cost estimation for the project outcome. Finally, machining simulation result will show the ideal machining time according to the parameters such as feed rate, spindle speed and retract rate that have set in the program. After all the process had gone through, verification will be made on the product and it will be tested.

5. Chapter 5

This chapter is the conclusion for the whole project and determines whether this project had achieved its objectives as stated in chapter 1. Further work such as design improvement also has been discussed in this chapter for future project development.

1.6 Summary

This chapter has been discussed generally on the project background, problem statement, project objectives, and scope of the project as mentioned early in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains about the basic principle of the related manufacturing process, design process and parameters that important in tool designing which taken from the journals, reference books, and other related resources.

2.2 Extrusion Blow Molding

Extrusion blow molding is a manufacturing method used in the plastics and polymers industries to create hollow but strong containers for their clients. Plastic beverage bottles and fuel tanks are commonly created through blow molding. A typical blow molding machine set-up uses an extruded plastic preform and compressed air to fill the chamber of a divided mold. The two halves of the mold separate and the finished container are released.

A preformed piece called a parison is usually extruded from a plastic injection mold placed very close to the blow molding machinery. The parison is mechanically loaded onto a stand and two sides of a bottle-shaped metal mold come together around it.

Before the parison cools down, a hollow ramrod is injected into its center and pushed to the top of the mold, stretching out the warm plastic preform as it goes.. Compressed air is then forced out in controlled low-pressure stages through the hollow ramrod. The plastic form is forced out to the sides of the mold. Because the stretching is performed evenly, the plastic remains uniformly thin and strong. The bottle assumes the shape of the mold and is dropped out of the blow molding machine as the two mold halves separate. A new parison is extruded and the entire blow molding process begins again. The actual manufacture of a bottle takes only a few seconds. (What is blow molding, URL: http://www.wisegeek.com/what-is-blow-molding.htm?)

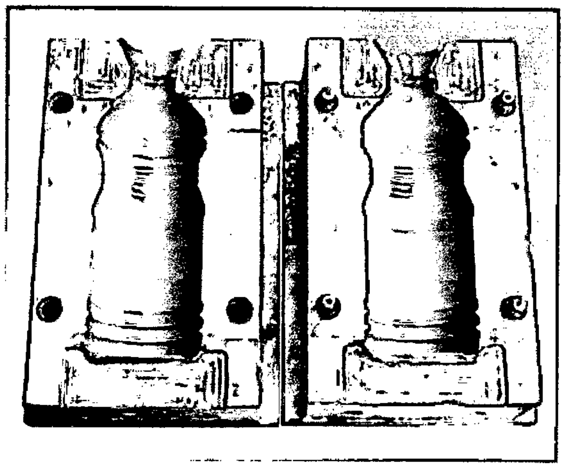


Figure 2.1: Common type of Extrusion blow mold (Made of P20 steel), (Kenplas plastic mold, URL: http://www.kenplas.com/mold/preformmold/)

2.3 Electric Discharge Machine (EDM)

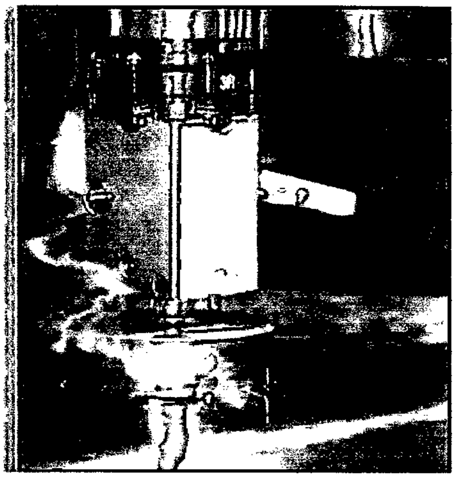


Figure 2.2: EDM Die Sinking Machine

EDM stands for electrical discharge machining also called spark-erosion machining, the applications best suited for this metal remval process are those require high tolerances and situations that difficult or impossible to handle with common machining. EDM is considered to be one of the most accurate manufacturing processes for creating complex or simple shapes and geometries within parts and assemblies.

EDM works by eroding the material in the path of electrical discharges that form an arc between an electrode tool and the work piece itself. Electrical Discharge Machining manufacturing is affordable and a desirable manufacturing process when low unit volume or high accuracy is required.

The EDM process can be used only if the material is an electrical conductor. The metal removal rate per discharge was determined by melting point and the latent heat of the material. Both physical properties act as the constraint for EDM machining. The volume of material removed per discharged typically in the range of 10^{-6} to 10^{-4} mm^3 (10^{-10} to10^{-8} in^3).

Metal removal rates for EDM usually range from 2-400 mm^3/min. Due to the molten and re-solidified surface structure, high rates produce a very rough surface finish with poor surface integrity and low fatigue properties. Hence, finishing cuts are made at low removal rates, or the recast layer is removed subsequently by finishing operation. (Kalpakjian & Schmid, 2000)

Since the shaped electrode defines the area in which the spark erosion will occur, the accuracy of the part produced after EDM is fairly high. After all, EDM is a reproductive shaping process in which the form of the electrode is mirrored in the workpiece. The cutting pattern is usually CNC controlled. Many Electrical Discharge Machine electrodes can rotate about multiple axes allowing for cutting of internal cavities. This makes EDM a highly capable manufacturing process.
(Mercatech, URL: http://www.mercatech.com)

EDM machine is different compare to common traditional machining. Below are the advantages of using sinker EDM machining:
(H.C. Moser,URL: http://www.charmillesus.com/index.cfm)

1. Much faster and more accurate.
2. EDM die sinking are generally used for complex geometries.
3. Sinker EDM can cut a hole in the part without having the hole pre-drilled for the electrode.
4. The cutting pattern is usually CNC controlled (much more automated) - Automatic wire threading, robots, automatic slug eject, easier programming and maintenance.
5. Many EDM electrodes can rotate about multiple axes allowing for cutting of internal cavities.
6. Better surface finish and surface integrity.
7. Carbide: 0% cobalt depletion on wire, better cutting on sinker.
8. No external flushing required on sinker.

9. More effective in difficult flushing conditions.
10. Much more user friendly (less training needed, less programming time).
11. Better training and customer support (easier for first time user).
12. Machine prices and operating costs down.
13. Operating cost is reduced and shortens the cycle times.

2.3.1 Principle Operation of EDM Die Sinking

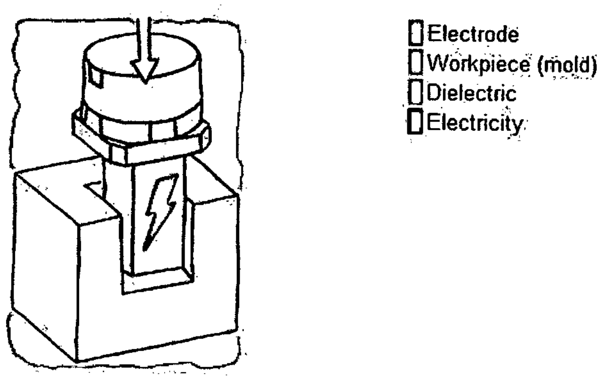


Figure 2.3: Cross section of an electrode and workpiece,
(Charmilles Technologies Corp, URL: www.charmillesus.com)

During the EDM process, a series of non-stationary, timed electrical pulses remove material from a workpiece. The electrode and the workpiece are held by the machine tool, which also contains the dielectric (electrically non-conducting). A power supply controls the timing and intensity of the electrical charges and the movement of the electrode in relation to the workpiece.

The most common dielectric fluids are mineral oils, although kerosene and distilled and deionized water are also being used in specialized applications.

The functions of dielectric fluid are;

1) Act as an insulator until the potential is sufficiently high.
2) Act as a flushing medium and carry away the debris in the gap.
3) Provide cooling medium. (Kalpakjian & R.Schmid, 2000)

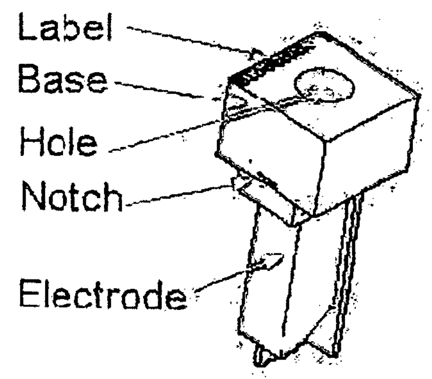
At the spot where the electric field is strongest, a discharge is initiated. Under the effect of this field, electrons and positive free ions are accelerated to high velocities and rapidly form an ionized channel that conducts electricity. At this stage current can flow and the spark forms between the electrode and workpiece, causing a great number of collisions between the particles. During this process a bubble of gas develops and its pressure rises very steadily until a plasma zone is formed. The plasma zone quickly reaches very high temperatures, in the region of 8,000 to 12,000' Centigrade, due to the effect of the ever-increasing number of collisions. This causes instantaneous local melting of a certain amount of the material at the surface of the two conductors.

When the current is cut off, the sudden reduction in temperature causes the bubble to implode, which projects the melted material away from the workpiece, leaving a tiny crater. The eroded material then re-solidifies in the dielectric in the form of small spheres and is removed by the dielectric. EDM is a non-contact machining process which allows achieving tighter tolerances and better finishes in a wide range of materials that are otherwise difficult or impossible to machine with traditional processes.
(Mercatech, URL: http://www.mercatech.com)

2.4 EDM Electrode

Generally, an electrode is usually machined to the reverse shape of the workpiece geometry to improve the efficiency and accuracy. The dimensions of the electrode are determined such that a spark gap between the surfaces to be generated and the electrode is maintained. Generally, a high material removal rate in EDM requires a large spark gap but results in a lower accuracy and surface quality.

An electrode usually includes two parts, i.e. electrode tool and holder. The electrode tool forms the shape of the workpiece geometry in EDM. The electrode holder holds the electrode tool during EDM. Electrode tool and holder are often designed and constructed in one piece. (Who is afraid of EDM design, URL: http://www.materialise.com/magics-tooling/edm_ENG.html)



Item	Explanation
Label	Each electrode is labeled to avoid confusion
Hole	The hole can be threaded to fit the electrode in the spark erosion machine
Base	This is the base block of the electrode
Electrode	Actual part of the electrode where the erosion process takes place
Notch	The notch is a mark that assists the toolmaker in orienting the electrode

Figure 2.4: Cross-section of an EDM electrode, (Materialise, URL: http://www.materialise.com/magics-tooling/edm_ENG.html

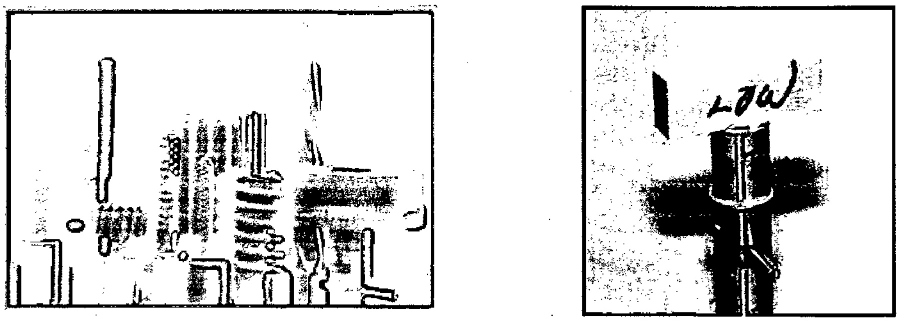


Figure 2.5: Various types of EDM electrode, (Unicor Inc,
URL: http://www.unicor.net/principal.htm)

2.4.1 Principles of Electrode Design

Electrodes are used in EDM to improve the machining efficiency, roughing, finishing and even semi-finishing. Different types of electrode will have different spark gap and surface finish. By setting different stock values (equal to the spark gaps) when preparing the CNC milling program for machining the electrode, roughing, semi-finishing and finishing electrodes can be generated from the same electrode model. Therefore, only one electrode model will be used for the roughing, semi-finishing and finishing electrodes, and the designed dimension of the electrode is the same as the workpiece.

Extra material (uncut material) left on an electrode will cause over-cut to the workpiece in EDM, thus an electrode should be machined to shape before it is used in EDM. The surface area that needs EDM may be very small, but the electrode cannot be too small. Raw material of an electrode should possibly be of a standard size. When an electrode is used in EDM, the positional relationship between the electrode and the workpiece becomes very important. A clear reference point on an electrode is necessary. In practice, the origin point of the electrode working coordinate system