UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY OF COOLING SYSTEM DESIGN FOR IPHONE CASE

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

by

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930920-04-5473

FACULTY OF ENGINEERING TECHNOLOGY

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Study of cooling system design for IPhone case.**

SESI PENGAJIAN: **2018/2019**

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APPROVAL

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

……………………………………

(Mr. Salleh bin Aboo Hassan)

ABSTRAK

Tahap pengisi dan pembungkusan, tahap penyejukan, dan tahap penyuntikan adalah tiga tahap penting dalam proses acuan plastik. Tahap pendinginan adalah yang paling penting di antara tahap-tahap lain kerana ia mempengaruhi kualiti dan produktiviti proses. Fakta diketahui bahawa lebih daripada enam puluh (60) peratus daripada kitaran acuan dibuat dengan proses penyejukan. Memandangkan terdapat dua jenis penyejukan utama yang merupakan penyejukan konvensional dan konformal, dengan itu timbul isu yang mana kaedah penyejukan ini dapat memberikan masa, aliran, liputan dan keluaran kitaran terbaik untuk produk sarung Iphone. Laporan ini bertujuan untuk menganalisis reka bentuk sistem penyejuk dalam proses suntikan acuan untuk produk sarung Iphone dan mengenalpasti reka bentuk sistem penyejukan terbaik dalam proses suntikan acuan produk sarung Iphone. Parameter untuk analisis ini ditetapkan sama dengan satu sama lain untuk memastikan hasil yang adil dan tidak berat sebelah. Hasil daripada analisis menunjukkan bahawa sistem pendinginan konformal lebih efisien dalam memberikan hasil terbaik dalam penghasilan acuan plastik dan produktiviti terbaik dalam pengeluaran. Saluran penyejuk konformal menyediakan masa yang lebih pendek untuk produk membekukan, pengecutan volumetrik yang lebih rendah, dan refleksi kilat yang lebih rendah berbanding saluran penyejukan siri.

ABSTRACT

Filling and packing stage, cooling stage, and ejection stage are the injection moulding three significant stages. Cooling stage is the upmost important one among the other stages because it primarily affects the quality and the productivity of the process. It is well known fact that more than sixty (60) percent of the moulding cycle are made up by cooling process. Since there are two main types of cooling which is the conventional and conformal cooling, thus comes the issue of which of this cooling method can provide the best cycle time, flow, area of coverage and output for the Iphone case product. This report aims is to analyse the cooling system design in mould injection process for Iphone case product and identify the best cooling system design in mould injection process of Iphone case product. The parameters for this analysis was set to be the same with one another to ensure a fair and non-bias results. The result from the analysis shown that the conformal cooling system is more efficient in providing the best outcome in plastic injection moulding and the best productivity in the production. Conformal cooling channel provide the shorter time for the product to freeze, lower volumetric shrinkage, and lesser warpage reflection compared to the series cooling channel.

ACKNOWLEDGEMENTS

Praise to Allah for giving me the opportunity to complete my degree.

First and foremost, my utmost gratitude to my supervisor, Mr. Salleh bin Aboo Hassan for his supervision, guidance and information throughout this journey that I had gained.

A lot of thanks also to my beloved parents, Mazlan bin Abdul Wahid and Zubaidah binti Wahi for their support and encourage. Not forgotten, to all lecturers and staffs of Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka. Finally, thanks to all my course mates, those have been supporting me in finishing this research.

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CHAPTER 1

INTRODUCTION

This chapter is an introduction to the background of study which focuses on the study of cooling system for Iphone case. Problem statement, objectives, and scope are then discussed in this chapter.

1.0 Introduction

Filling and packing stage, cooling stage, and ejection stage are the injection moulding three significant stages. Cooling stage is the upmost important one among the other stages because it primarily affects the quality and the productivity of the process. It is well known fact that more than sixty (60) percent of the moulding cycle are made up by cooling process (Park & Dang, 2017). An efficient cooling system design aiming at minimizing such unwanted defects such as differential shrinkage, sink marks and part warpage by reducing the cycle time (Tang, Chassapis, & Manoochehri, 1997). As a result, to obtain a uniform temperature distribution at minimum cooling cycle time, a suitable cooling system design must be identified.

There are three (3) types of cooling system in injection moulding, which is; parallel, series and conformal cooling system. The aspects that can be measured within these types of cooling system is its flow rate and its flexibility. Among these systems, conformal cooling system has the highest usage among the industry. This is due to the fact that the conformal cooling system is flexible, and its cooling channel is easy to produce.

1.1 Problem statement

The product that has been chosen to be analyse in this study or analysis is Iphone case. The Iphone case chosen for this analysis is made from mixture of polycarbonate (PC) and ABS (Acrylonitrile Butadiene Styrene) plastic material. The correct method of cooling needs to be identified to ensure good cycle time, flow, area of coverage and output. In injection moulding, cooling comprises as one of the important aspects to ensure shorter cycle time because shorter cycle time means higher productivity. Since there are two main types of cooling which is the conventional and conformal cooling, thus comes the issue of which of this cooling method can provide the best cycle time, flow, area of coverage and output for the Iphone case product. Therefore, a study needs to be done to identify which is the best cooling method for the Iphone case product to ensure good productivity.

1.2 Objectives

This study embarks on the following objectives:

1. To analyse the cooling system design in mould injection process for Iphone case product.
2. To identify the best cooling system design in mould injection process of Iphone case product.

1.3 Scope of research

The study of this research only covers the following aspect, which is only;

- two methods of cooling system in injection moulding which is series and conformal cooling system.
- The design of Iphone case product and will be produce by using Solidworks software.
- The analysis will be conducted on Solidwork Plastics.
- The result of the analysis will be on the warpage reflection, time to freeze and volumetric shrinkage value.

- The material will be chosen for this analysis is PC (Polycarbonate) + ABS (Acrylonitrile Butadiene Styrene) plastic.

CHAPTER 2

LITERATURE REVIEW

2.0 **Literature Review**

According to Rees (2002), “An injection mould is an arrangement, in one assembly, of one (or several) hollow *cavity spaces* built to the shape of the desired product, with the purpose of producing plastic parts, or *products*.”. Injection moulding is an economically capable process in producing extremely complex parts to high tolerance. A suitable injection mould must be designed, manufactured and produced before any parts can be moulded (Kazmer,2007). Injection moulding is called a net shape manufacturing process because it involves in filling the evacuated mould cavity by forcing the polymer melt into it, after which it will cools down to form to the final desired design (Kazmer,2007). Based on Rees (2002), the mould mounted in an injection moulding machine is timed to fill the cavity space to:

- Close the mould
- Inject the plastic into the cavity space
- Mould will be kept closed until the plastic is finish cooling down and prepared for extraction
- Open the mould
- Eject the finished product
- The machine may stay open an additional *mould open (MO) time* if necessary, to ensure that the next injection cycle before closing.

2.1 Mould function

There are three (3) primary function of mould; first primary function, is to fill the polymer melt within the mould cavity so that the mould cavity can be filled to form a plastic component whose shapes replicates the mould cavity. The second primary function is to transfer heat from the hot polymer melt to the cooler mould steel efficiently (Kazmer,2007). However, according to Glanvill (1965), “it is a prime function of the mould design satisfactorily to produce plastic mouldings from the completed tool, it is clearly also paramount that the design adopted should capable of economic and sound manufacture by the most suitable methods and facilities available.”.

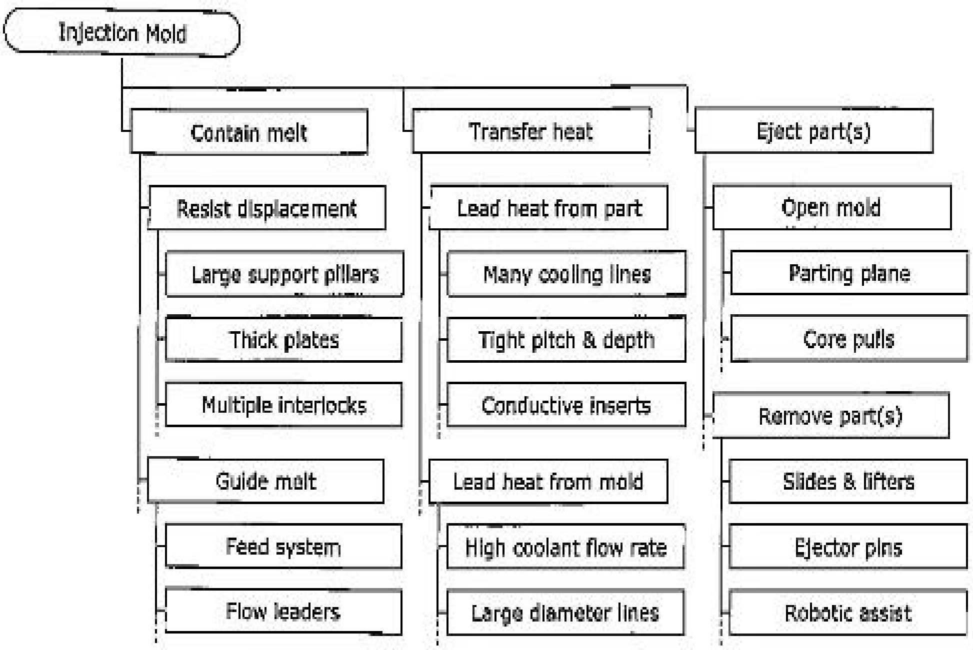

Figure 2.0: Overview of mould function

2.2 Injection Moulding Machine

According to Rees (2002), an injection moulding consists of four (4) essential elements, which is:

1. Clamping mechanism
2. Plasticizing unit
3. Injection unit
4. Controls

However, Rosato (2012) states that "injection moulding machine has three basic components; the injection unit, the mould, and the clamping system.". Both researchers have the same resemblance for the elements in the injection moulding machine but only have one different element which is the controls. This element will be explained later in this section.

2.2.1 Clamping mechanism

The process of rapid opening and closing of the mould during the cycle is the function of clamping. To keep the mould closed during the injection process a necessary clamping force is needed due to the pressure from the injection pressure acting on the internal, or surface of the cavity space. The cavity has the tendency to open the mould at the parting plane or *parting line.*

2.2.2 Plasticizing unit

Plasticizing is the process that melts the plastics. The process involves an *extruder* that heats the cold plastic until it meets the required melting temperature to make it flow for the injection. The extruder screw rotates in the barrel by mechanical energy and it also generates heat simultaneously to work the plastic. Then, the plastic advance to the tip of the screw by the mechanical energy. Heaters around the barrel is mainly required during start-up of the machine usually in three or more heating zones to provide additional heating, but to plasticize the amount of plastic required for each shot also by mechanical working of the screw alone would not suffice (Rees,2002).

2.2.3 Injection unit

An injection unit forces the melt (under pressure) into the mould. There are two injection methods that is currently being used which is the single-stage and the two-stage. The two methods of injection will be discussed below:

2.2.3.1 Single-stage

The single-stage methods are applied on the Reciprocating Screw Machine. This method is currently being applied on most of the injection moulding machine where the injection unit and the reciprocating screw combined to be in one unit.

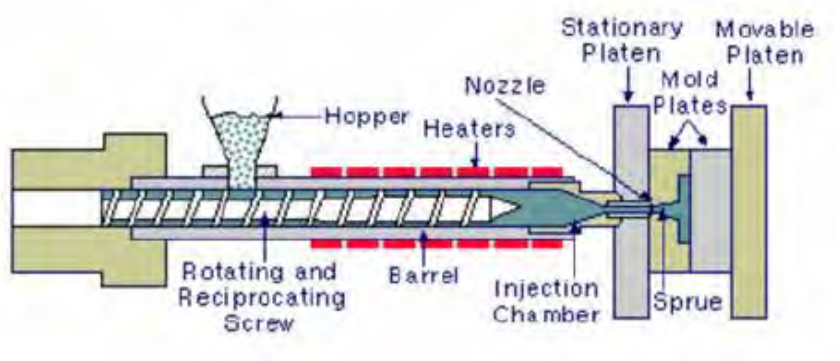

Figure 2.1: Single stage method

2.2.3.2 Two-stage method

The two-stage method can be identified as a pre-plasticizing machine system that separates the functions of the extruder and the injection unit. The extruder plasticizes the material and fills an injection cylinder of the injection unit (Rees,2002). The advantages of two-stage method are:

- The plasticizing process 100% of the available time because the screw can run endlessly.
- The shot volume in the injection pot is mechanically measured, and the repeatability and accuracy of the shot size is greater than the single-stage method
- The filter in the path of the plastic to remove any dirt in the plastic is easy to place.

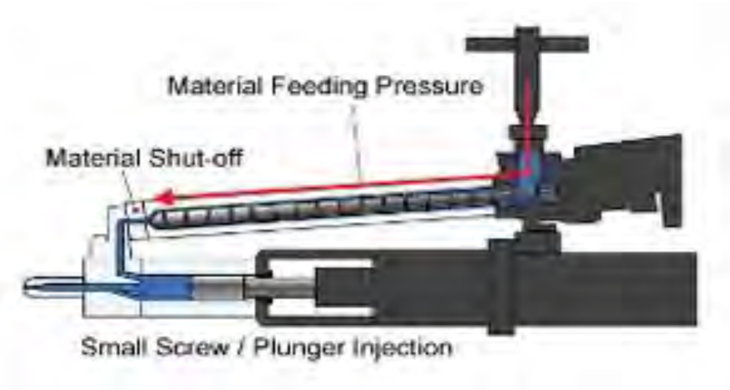

Figure 2.2: Two-stage method

2.2.4 Controls

According to Rees (2002), there are four (4) basic elements of moulding machine controls:

- The operator can observe the mould by *command module* located near the safety gate of the clamp,
- the machine settings and manipulation of the signals from positional sensors, and timers are executed by the *control logic*.
- The *power supply* and distribution to the motors and heaters.
- The *heat controls* for the machine and mould heaters.

The *heat controls* function according to Vojnová (2016) is optimizing time of production cycle of injection by to maintaining all technological requirements on the production and on the final product.

2.3 Feed System Types

Findings from Kazmer (2012), list a few types of feed system and its functions, which is;

2.3.1 Two-plate mould (Cold Runner)

The two-plate mould feed system consist of two assembled sections that sandwich the melt; each half of the mould can consist of one or more mould plates. Moreover, based on Rees (2002), the general rules for two-plate system is to apply any number of cavities necessary to produce the part. For example, when we talk about multicavity product, the process is usually for the same as petri dish base and cover or two matching halves of video and audio cassettes. The number of cavities that can be done in two-plate mould is up to thirty-two (32) cavities.

2.3.2 Three-plate mould

Three plates mould are comprised of three mould sections that move relatives to each other, with each section consisting of one or more plates (Kazmer,2012). The main feature of three-plate moulds according to Rees (2002), are listed below;

- The cavities can be positioned closer to each other, because there is no need to provide space between them for sprue and runenrs.
- The mould is inherently self-degating.
- The gate vestige is usually very good.
- Total runner length can be smaller, equal to, or greater than for an equivalent two-plate mould, because the length of drops must be considered as part of the runner length.

2.3.3 Hot runner

The layout for hot runner is a little like the three-plate mould on the cavity arrangement. Gating flexibility, cycle efficiency, and material efficiency should be a matter of importance when considering using hot runner moulds. This is due to the general rules based on experience from Rees (2002), which is;

- Fully balanced hot runner mould is necessary where mass of the product is significant, and each cavity requires a large volume.
- Unbalanced runner moulds particularly for lightweight product

2.4 Product Shape

Rees (2002) states that the product that is produced from injection usually follows this three (3) shapes; which is *plain utility shape, artistic shape* or *engineering (functional) shape.*

2.4.1 Plain utility shape

Product that does its job without giving total attention towards its shape are known as plain utility shape product. The type of product that can be classified in this category such as plain containers, toys, household wares etc.

2.4.2 Artistic shape

The concept of artistic shape is quite the same with the plain utility shape except that the artistic shape design is quite difficult to produce, and its sole purpose is to have the product more appealing.

2.4.3 Engineering (Functional) shape

The function of the engineering shape is the key requirement. The demand for accuracy and the product finishes from the designer is important. The type of product that can be categorized in the engineering shape such as computer hardware, cassette box, shaft etc.

2.5 Cooling System

Cooling system design is the upmost important aspect for plastic injection moulding because it tremendously affects the productivity and quality of the final product. *Cooling is known to be the governing stage that affects the quality and the productivity of the moulded parts* (Shayfull, Sharif, Zain, Saad, & Fairuz, 2013). The cooling system design is regarded to be the important factor by the cooling phase since about 80% of the cycle time is taken up by it (Qiao, 2006). According to Hsu F.H (2013), most advanced technologies focus on issues such as minimizing manufacturing cost and improving product quality nowadays. As more geometrically intricate part are produced, an experience-based approach becomes less and less feasible (Tang et al., 1997). Thus, having a suitable cooling system can help achieving what the current advance technologies wanted and achieving the main objective of mould design.

2.5.1 Conventional Cooling System

Based on Park & Xuan (2011), the common types of straight-drilled cooling channels are parallel and series.

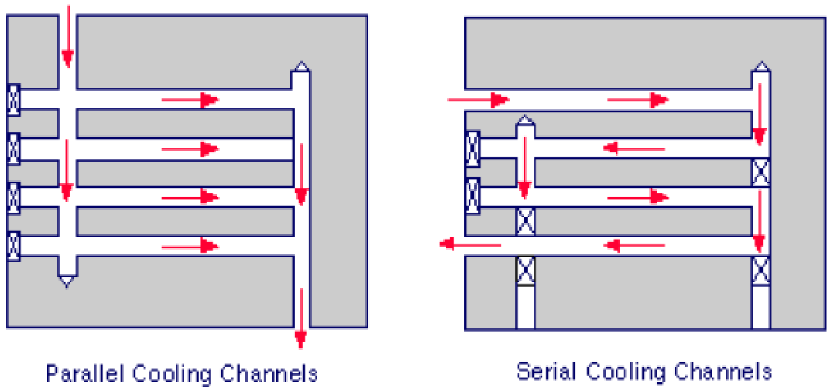

Figure 2.3: Types of conventional cooling channel.

2.5.1.1 *Parallel cooling channels*

Parallel cooling channels are drilled straight channels that the coolant flows from a supply manifold to a collection manifold. The flow rate along various cooling channels may be different, depending on the flow resistance of each individual cooling channel, due to the flow characteristics of the parallel cooling channels. This variation of the flow rate causes the heat transfer efficiency of the cooling channels to be varied from one another. As a result, cooling of the mould considered to be not uniform with a parallel cooling- channel configuration.

2.5.1.2 *Serial cooling channels*

Cooling channels that are connected in a single loop from the coolant inlet to its outlet are called serial cooling. This type of cooling channel commonly used in practice nowadays. By design, the coolant can maintain its turbulent flow rate through its entire length if the cooling channels are uniform in size. Turbulent flow enables the heat to be transferred more effectively. For large moulds, more than one serial cooling channel may be required to assure a uniform coolant temperature and thus uniform mould cooling.

2.5.1.3 Conformal Cooling System

A general trend in injection moulding industry is to reduce manufacturing cost and improve product quality. The best methods to be implemented to achieve this is by using techniques such as three-dimensional printing and laser sintering processes to form the conformal cooling channel. To reduce the amount of warping and defects and so on, conformal cooling channels have the potential to improve the performance of moulding dies in terms of uniform and fast cooling(Jahan & El-mounayri, 2016).

2.6 Analysis of Conformal Cooling System

2.6.1 Tempering

Vojnová (2016) conducted a study on how tempering can ensure an even distribution of temperature throughout the entire surface of the form cavity and how it can extract the heat from the form cavity filled with melt that the entire process cycle has an economic length. Vojnová (2016) states that "the form tempering affects shrinkage and changes in shape, surface quality and mechanical features of the moulds, as well as filling up the form cavity, and the length of the injection cycle time". The study continues with Vojnová (2016) produce two (2) cooling channels which is the conventional and conformal cooling channel to be analyse. Before starting the analysis, she identifies several factors that can affect the result of tempering, which is; type of material injected, the shape of the mould, the size of the mould, the inflow trajectory, the mould wall thickness, and mould precision requirements.