HONEYCOMB RIBS DESIGN ON OVERCOMING PART WARPING

NIK ZURAIDA BINTI IMRAN ADLY

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ABSTRACT

Thin walled plastic parts are subjected to warpage after injection. Warpage can be overcome by designing ribs. This experimental project is to design a suitable honeycomb ribs replacing the normal ribs to overcome part warping. The parameters included honeycomb ribs height, honeycomb ribs thickness and the honeycomb size. Finite Element Analysis (FEA) simulations for each honeycomb ribs design are analyzed with Autodesk Moldflow Insight software and the part which result the worst warping value, part with medium warping value and part with less warping value were chosen to validate them by fabricating the core and cavity inserts to produce the actual product. The part warping is measured and then compared with the data from the simulation. Thus, the best design parameters of honeycomb ribs are identified.

ABSTRAK

Produk plastik berdinding nipis mengalami pengeledingan selepas suntikan. Meleding boleh diatasi dengan mereka bentuk tetulang. Projek berunsurkan eksperimen ini adalah bertujuan untuk mereka bentuk tetulang berbentuk sarang lebah yang sesuai bagi menggantikan tetulang biasa untuk mengatasi ledingan. Parameter di dalam projek ini ialah ketinggian tetulang berbentuk sarang lebah, ketebalan tetulang yang berbentuk sarang lebah dan saiz tetulang berbentuk sarang lebah. Analysis Unsur Terhingga, "Finite Element Analysis (FEA)" bagi setiap reka bentuk tetulang berbentuk sarang lebah dianalisis dengan perisian Autodesk Moldflow Insight dan produk yang mempunyai nilai ledingan terburuk, produk yang mempunyai ledingan sederhana dan produk yang mempunyai ledingan yang paling kurang dipilih untuk disahkan bagi menghasilkan teras dan rongga untuk produk sebenar. Nilai ledingan daripada produk sebenar diukur dan kemudian dibandingkan dengan data daripada simulasi komputer. Oleh itu, parameter reka bentuk yang terbaik bagi tetulang berbentuk sarang lebah telah dikenalpasti.

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
CAD	Computer Aided Design
CNC	Computer Numerical Control
DOE	Design of Experiment
FEA	Finite Element Analysis
FEM	Finite Element Method
FYP 1	Final Year Project 1
FYP2	Final Year Project 2
PLA	Polylactic Acid
PP	Polypropylene

CHAPTER 1

INTRODUCTION

1.1 PROJECT MOTIVATION

Plastic part design plays an important role to ensure the quality of final product. During production of final product, sometimes there are qualities problems of the plastic parts that occur. One of the most quality problems is warpage. Reducing warping is one of the important requirements in producing plastic part especially thin walled part to the plastic manufacturer. One of the successful ways to overcome warping is changing the part geometry by adding ribs as ribs can increase the structural strength of a part. In addition, honeycomb structures are widely used in structural applications because of their high strength per density. Therefore, a combination of honeycombs design with ribs can produce a good quality of plastic part product. Research on honeycomb ribs design is important to help the manufacturer especially in the plastic manufacturing fields to reduce warping in their product.

1.2 PROJECT BACKGROUND

Injection moulding is a common batch process to fabricate the plastic products and has been used in more and more fields. However, the manufactured parts, especially the thin-walled ones, usually tend to be warped, which is highly desired to be addressed. Theoretical research paid attention to shrinking and stress distribution influence to the warpage deformation (X.M Cheng et al., 2009).

This project presents an experimental study of honeycomb rib design with different variables on overcoming part warping on thin walled plastic parts that subjected to a warpage after injection. In this project, honeycomb ribs are designed to replace the normal ribs to overcome the part warping. Honeycomb ribs design is about designing honeycomb pattern which is hexagonal in shaped.

The hexagonal shape act as a rib to replace the normal ribs and its pattern are tabulated on the surface of the thin walled plastic part. In this research, the parameter included the ribs height, the ribs thickness, the honeycomb size and the ribs angle will be studied to get the best parameters for the suitable design of the honeycomb ribs structure.

1.3 PROBLEM STATEMENT

Reduce warpage of the thin-walled parts becomes a major problem that limit the engineering and applications (X.M Cheng et al., 2009). Reducing warpage is one of the top priorities to improve the quality of injection moulded parts. Warping can be overcome by designing ribs. Designing ribs keep the part thickness as thin and uniform as possible. As it will shorten the cycle time, improve dimensional stability and also eliminate others surface defects.

The project is developed to experimental design a suitable honeycomb ribs replacing the normal ribs to overcome plastic part warping on thin walled plastic product. The design parameter of the honeycomb ribs varies based on ribs height, the rib thickness, the honeycomb size while rib angle is remaining constant. The project is also aimed to determine the suitable design of honeycomb ribs based on different parameters replacing the normal ribs to overcome part warping.

1.4 PROJECT OBJECTIVES

There are three objectives that had been defined to be focused on this project as stated below:

i. To overcome warping by using a suitable honeycomb ribs on plastic product.

ii. To determine the best design of honeycomb ribs based on different parameters (ribs height, ribs thickness, honeycomb size, ribs angle).

iii. To evaluate the design efficiency of honeycomb ribs compared to normal ribs based on Finite Element Analysis (FEA) simulation in computer software and by validation of real product.

1.5 PROJECT IMPACT

The impact of this project is it can help the manufacturer especially in the plastic manufacturing field to reduce warping using the honeycomb rib design instead of normal ribs on thin walled part.

1.6 PROJECT SCOPE

The following scopes of the project are determined in order to achieve the objectives of the project. The original design honeycomb ribs on thin walled plastic part product are designed by using CAD modelling software. Here, the parameters included the rib height, ribs thickness, the honeycomb size is varied while the rib angle remained constant. The analysis of the warping on the plastic part will be analyzed in Autodesk Moldflow Insight plastic injection moulding simulation software based on different parameters stated. Then the part is validated by fabricating the mould and insert (core and cavity) to produce the actual product. Based on the actual product with varying parameter on the design of honeycomb rib structures, the products' warping value then measured by using Optical Video Measuring System. The data that had been collected then tabulated in the Statistical Package for the Social Sciences (SPSS) and

Minitab software. SPSS and Minitab software are data management and analysis to analyze based on mathematical functions. The data taken from Optical Video Measuring System were compared with the data from simulation software to get the best design of honeycomb rib structures and suitable parameters will be chosen.

1.6.1 PROJECT LIMITATION

In this project, the limitations are:

i. To reduce the usage of plastic material as honeycomb ribs consume more material compared to normal ribs.

   Honeycomb ribs consume more material compared to normal ribs as the hexagonal shape of honeycomb ribs is tabulated on surface of plastic part's combine together. A normal rib not consumes material as there is a gap between each rib.

ii. The suitable machining method to fabricate the core and cavity insert.

   The suitable method to machining the core and cavity inserts need to be defined as the researcher might facing the problems of tool breakage as the tool used is small. Moreover, time limitation need to consider during machining the core and cavity insert as it will take much time on machining the honeycomb.

iii. Part stuck during ejection process.
   The project may face the product stuck during ejection process at injection moulding. It will consume much more time to rework the inserts such as polishing process especially at the honeycomb ribs. Ejector pin also needs to add more on the core insert to eject the product uniformly without affecting the warpage.

1.7 PROJECT REPORT ORGANISATION

This report is divided into five chapters. Chapter one is the introduction about the project. This chapter includes the brief project, problem statement, project objectives, project impact, scope of the study and limitation that may occur in this project.

Chapter two discussed about literature review. This chapter provided with introduction of the project design strategies. Here, the general design guidelines for ribs have been discussed. Then it also includes the brief introduction about past research and also selected method that may be used in this project such as types of machine and software.

Chapter three discussed about methodology of the project. Firstly the design of project study and frame work is studied. Then it moves to machining process that consists of machining mould base, electrode and the mould insert. Furthermore, the analysis of Autodesk Moldflow Insight software also had been tabulated in table to make graphs and then compared them to get the best result as expected in the project objectives.

Chapter four is focusing on preliminary results and discussion. The design evaluation in MoldFlow analysis software is applied on thin wall part differs on honeycomb ribs and normal ribs. Then followed by measuring the warping using Optical Video Measuring System equipment for data comparison. The results that had been analyzed are shown in this chapter.

Chapter five is about the conclusion and recommendations are made based on the results that have gained in the research project. This chapter also mentioned about the alternative way and recommendation for future research in order to get the best results.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed about the plastic product warping as well as honeycomb rib structure and its guidelines. This chapter give a brief explanation about the functions of rib design in designing plastic part product to overcome warping. This chapter also provides a review of past research efforts related to honeycomb ribs study and also the important criteria that need to be considered when designing ribs to overcoming part warping. From the related journal and article, the idea in designing a honeycomb rib structure on overcoming part warping can be more structured and as an aid in completing this project.

2.2 WARPAGE ON THIN WALLED PLASTIC INJECTION MOULDED PART

Plastic Injection Moulding is considered the most prominent process for mass producing plastic parts. More than one third of all plastic products are made by injection moulding, and over half of the world's polymer processing equipment is used for the injection moulding process (B. Sidda Reddy et al., 2009). One of the most important quality problems of plastic injection moulding part is warpage. Warpage can be defined as a distortion of the shape of the final injection moulded item caused by differential shrinkage. For example, if one area or direction of the article undergoes a different degree of shrinkage than another area or direction, the part will warp. It also caused by the concentrated stress at the junction of high and low shrinkage area that may cause a part subjected to warping.

Theoretical research paid attention to shrinking and stress distribution influence to the warpage deformation. During forming procedure, due to orientation and shrinking non-uniform of the molten plastic materials, the stress distribution becomes non-uniform, leading to the warpage formation when taken out from the mold. In some reported work, warpage was considered coming from the residual stress caused by non-uniform shrinking of the final product. Especially, the MOLDFLOW Company had done an overall research on such issue, and developed the coherent FEA software of MOLDFLOW (X.M Cheng et al., 2009).

Moreover, the shrinkage can be also the reason of warpage. To minimize warpage it is important to assure the uniformity of the temperature across the part. It will also result in preventing sink marks and different shrinkage in the parts (E. Bociaga et al., 2010). Thin-wall plastic parts usually refer to a wall thickness of 0.5~ 2.0 mm of plastic parts. Thin-wall plastic parts not only can reach lightweight, compact, multi-functional fashion design but also can greatly reduce product cost. But, in the moulding process, the thickness of thin-walled plastic parts often appears uneven also warping thus not fully meet the requirements (J.Z Chu et al., 2011).

2.3 MOULDING CONSIDERATION AND DESIGN GUIDELINES

Uniform wall thickness in plastic part design is needed to prevent part especially thin walled part from warping as non-uniform wall thickness can cause serious warpage and dimensional control problems. If greater strength or stiffness is required, it is more economical to use ribs than increase wall thickness. In parts requiring good surface appearance, ribs should be avoided as sink marks on the opposite surface will surely appear. If ribbing is necessary on such a part, the sink mark is often hidden by some design detail on the surface of the part where the sink mark appears, such as an opposing rib. Even when uniform wall thickness is intended, attention to detail must be exercised to avoid inadvertent heavy sections, which can not only cause sink marks, but also voids and non-uniform shrinkage. To minimize the volume as well as simplify the arrangement for the optimum strength without altering the shape of a product is definitely to be the critical issue of designing a rib (Tian-Syung Lan et al., 2008).

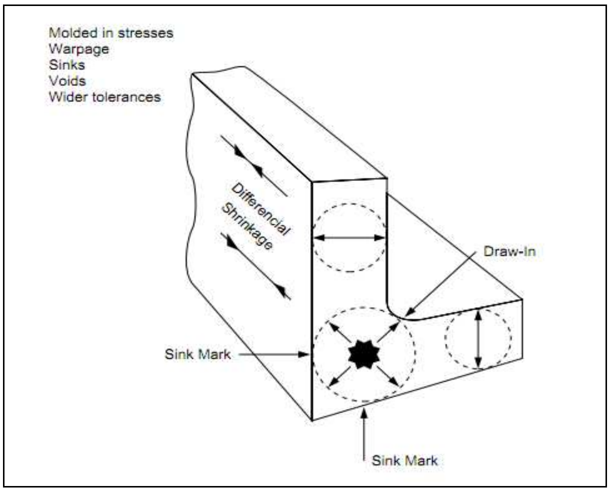

Figure 2.1: Effect of non-uniform wall thickness on moulded part.

Source: (Dupont, 2000)

Figure 2.1 shows a simple structural angle with a sharp outside corner and a properly filleted inside corner could present problems due to increased wall thickness at the corner. Sink mark will occur as a result from unbalance and non uniform wall thickness on moulded parts.

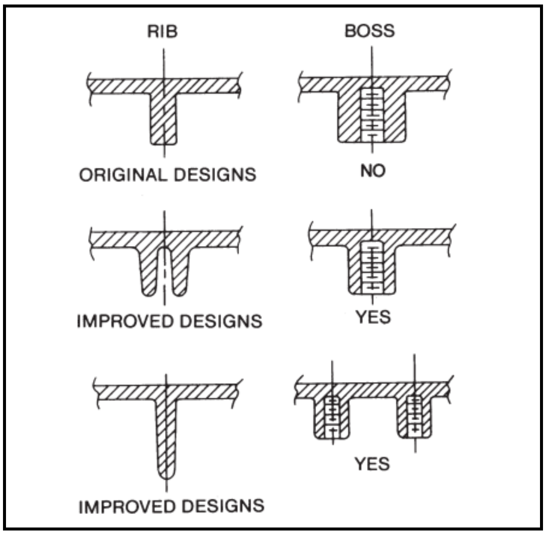

Figure 2.2: Design consideration for maintaining uniform wall

Source: (Dupont, 2000)

Figure 2.2 shows the design consideration for maintaining uniform wall and avoid the effects of non-uniform wall thickness from occur. External fillet also can be used to achieve uniform wall thickness as in figure 2.3. Thus, the defects like sink mark will be prevented from occur.

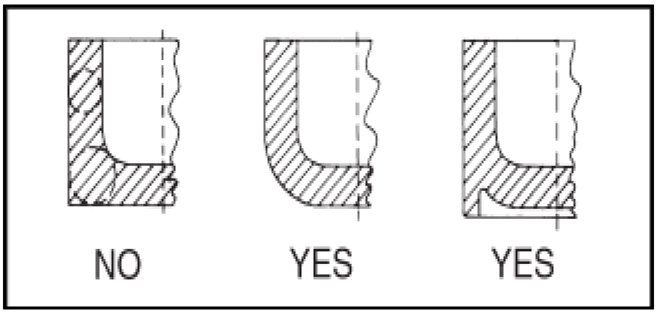

Figure 2.3: Example of External Fillet

Source: (Dupont, 2000)

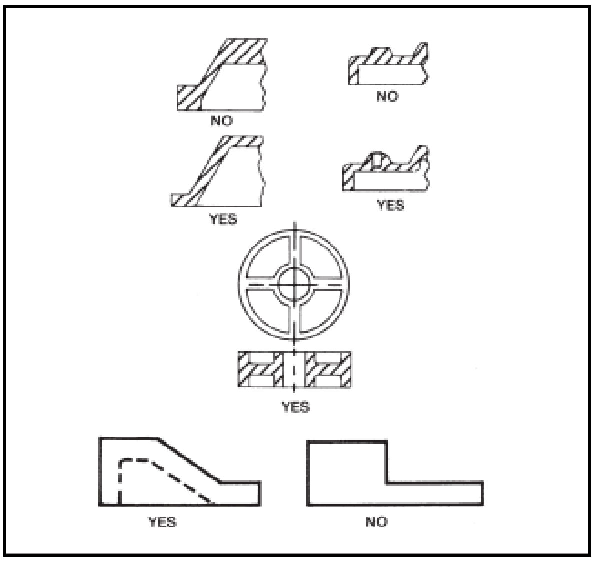

Figure 2.4: Method for Designing Uniform Wall Thickness

Source: (Dupont, 2000)

Figure 2.4 above shows how coring improves the design. Where different wall thicknesses cannot be avoided, the designer should effect a gradual transition from one thickness to another as abrupt changes tend to increase the stress. Further, if possible, the mould should be gated at the heavier section to insure proper packing.

Reinforcing ribs are an effective way to improve the rigidity and strength of moulded parts. Proper use can save material and weight, shorten moulding cycles and eliminate heavy cross section areas which could cause moulding problems. Where sink marks opposite ribs are objectionable, they can be hidden by use of a textured surface or some other suitable interruption in the area of the sink. Ribs should be used only when the designer believes the added structure is essential to the structural performance of the part (Dupont, 2000).

2.4 COMPUTER SIMULATION SOFTWARE FOR PREDICTION OF WARPING

To reduce the cost and time at the design stage, it is important to simulate warpage of the injection moulded part. By using computer simulation program, the researcher can check and analyse the part warping more easier before fabricating the part. Computer simulation programs are very good tools for prediction of quality problems with injection moulded parts. It is possible to predict polymer flow inside the cavity as well as other physical properties distribution of melt across the entire cavity like pressure, shear stress, shear rate, temperature as well as weld lines and air traps.

With the emergence of Computer Aided Engineering (CAE) and Design of Experiment (DOE) technology, it can realize the optimization of process facilitate. In this research, MoldFlow software used to analyze the parameters of injection moulding. Optimization of process parameters under the guidance of the orthogonal test can reduce the warpage of plastic part effectively. Adopting Taguchi DOE technical design experiments to analyze the process parameters on the impact of warpage (J.Z Chu et al., 2011).

2.4.1 AUTODESK MOLDFLOW INSIGHT SIMULATION SOFTWARE.

Autodesk MoldFlow Plastic Insight (MPI) simulation analysis software is specialised for plastic injection simulation software. It provides tools that help manufacturers validate and optimize the design of plastic parts and injection moulds, and study the plastic injection moulding process. Moreover, this software help to reduce the need for costly physical prototypes, avoid potential manufacturing defects, and get innovative products to market faster. This software also provides plastic injection moulding simulation tools for use on digital prototypes.

Autodesk Moldflow Plastic Insight (MPI) helps to simulate the filling and packing phases of the injection moulding process so that the user can better predict the flow behaviour of melted plastics and achieve higher-quality manufacturing. This software also currently used by some of the top manufacturers in the automotive, consumer electronics, medical, and packaging industries. The warpage values were found by analyses which were done by a computer aided engineering software MoldFlow Plastic Insight (MPI).

2.5 HONEYCOMB RIBS DESIGN

Honeycomb is two-dimensional, prismatic cellular materials with a regular and periodic microstructure ((Xiu hui Hou et al, 2010). Honeycomb structures are widely used in structural applications because of their high strength per density. Meanwhile, conventional honeycomb structures can be fabricated to have a negative Poisson’s ratio. A finite element method (FEM) technique developed for the study of spatially periodic materials is applied to the analysis of the linear elastic responses of regular and re-entrant honeycomb structure (Lee et al., 1996). The re-entrant honeycomb structure has a negative Poisson’s ratio in the cell plane with a value that depends upon the re-entrant angle of the cell rib (refer to figure 2.6).

Because of their light weight and high resistance to bending forces, metal honeycomb structures are used for aircraft and aerospace component, in buildings and transportation equipment. More recent developments include making honeycomb structures using reinforced plastics, such as aramid-epoxy (Serope Kalpakjian et al., 2006). Honeycomb structures use a minimal amount of material to create surface materials that are strong and light. Honeycombs appear in nature-most famously in the cellular buildings of honey bees. Similar structures are used extensively in the design of product, from corrugated cardboard and plastic to airplane wings (X.M Cheng et al., 2009). Figure 2.5 below shows conventional honeycomb structure are tabulated with regular hexagonal cells, dashed rectangle, and repeating unit.

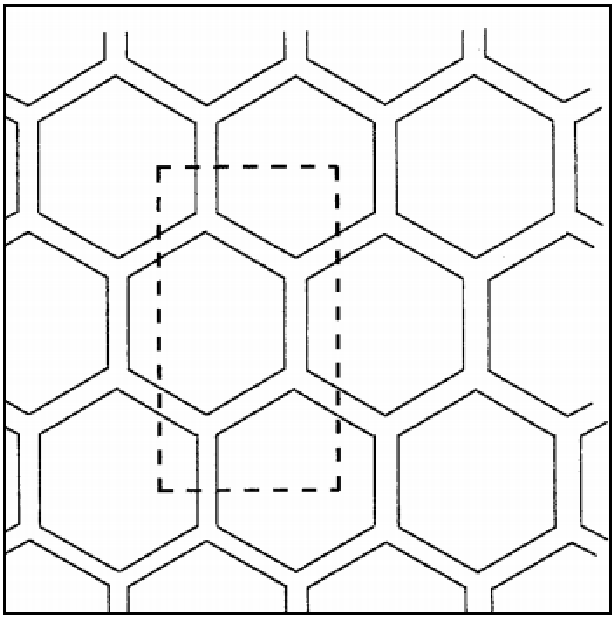

Figure 2.5: A conventional honeycomb structure

Source: (JinHee Lee et al., 1996).

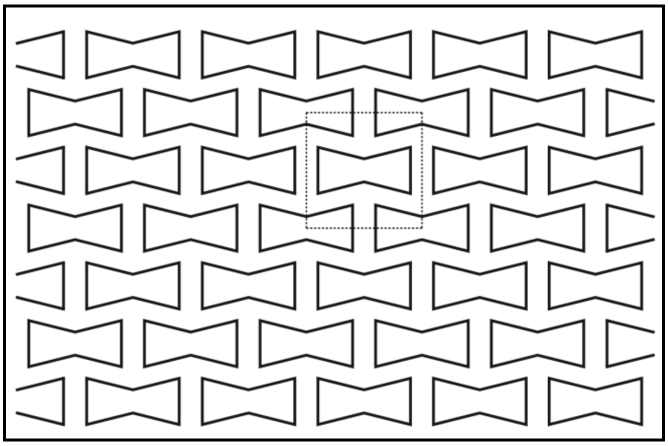

Figure 2.6: The re-entrant honeycomb structure

Source: (JinHee Lee et al., 1996).

Lee et al. (1996) applied FEM analysis to regular and re-entrant honeycomb structure (refer to figure 2.5 and 2.6) composed of classical materials. In this paper, they consider the plane strain and plane stress conditions of the micro polar elasticity theory to derive a 3-node linear triangular finite element formulation of the honeycomb structure for analysis. They also assume that the honeycomb structure material is micro polar elastic. Figure 2.7 shows the representative element of a re-entrant honeycomb structure, according to their previous study (Yang D.U et al., 2001). Moreover, they adopt appropriate geometric parameters of the honeycomb structure that could cause the best results of negative Poisson's ratio. In comparison with the micro polar material constants, they consider the vertical cell rib length a to be 10mm and the oblique cell rib length b to be 20mm ða=b ¼ 0:5Þ: Consider the cell rib width, w as 1mm and the cell rib depth t as 1mm and the re-entrant angle u is 14.478 in this paper (Fuang Yuan Huang et al., 2002).