UNIVERSITI PUTRA MALAYSIA

DESIGN, ANALYSIS AND FABRICATION OF GLASS FIBER-REINFORCED PA 6,6 COMPOSITE AUTOMOTIVE CLUTCH PEDALS

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By

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To Dad and Mom

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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A study of injection number and location is important since it often affects product quality such as weld line and shrinkage as well as process quality such as molding efficiency. This study is also critical because unlike any other processing parameters such as filling speed, pressure and temperature that could be modified instantly, gate location is permanent and any modification equals to increase in cost and time.

The main objective of this research is to simulate and analyze the effects of increasing number of gates for a clutch pedal using short glass fiber reinforced PA 6,6. The research compares the effects of a single gated and a double gated mould. A prototype of the composite clutch pedal model is then fabricated and compared with the simulation works.

In order to achieve the above-mentioned objectives, two numerical softwares will be used in this study. Moldflow Plastic Insight (MPI) software is used to investigate the effects of mold design on fill time, pressure, temperature, weld line, air traps and fiber

orientation and distribution while LUSAS software is used to analyze stress distribution for pedal profiles and rib patterns.

The studies show that there are many advantages and disadvantages associated with the design of single and double gated mold. Firstly, a mold designed with a single gate is advantageous in terms of flow balance, fill time and weld line since it provides a more balanced flow, shorter fill time and shorter length of weld line compared to a double gated mold. However, a double gated mold precedes a single gated mold in terms of injection pressure, part shrinkage and trapped air. The study revealed that a double gated mold reduces the required injection pressure as well as pressure variation, hence a lower volumetric shrinkage. Such design also produces less amount of trapped air. Finally, the comparison study of simulation and actual model showed great consistency in terms of fill time, air traps and weld line formations.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

REKAAN, ANALISIS DAN FABRIKASI KOMPOSIT PA 6,6 BERTETULANG GENTIAN KACA BAGI INJAK CEKAM AUTOMOTIF

Oleh

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Pengerusi: **Profesor Madya Mohd. Sapuan Salit, PhD., P.Eng.**

Fakulti: **Kejuruteraan**

Penyelidikan mengenai bilangan dan lokasi suntikan adalah penting kerana ia mempengaruhi kualiti produk seperti garisan penemuan, pengecutan dan juga kualiti proses seperti kecekapan pengacuan. . Kajian ini juga adalah mustahak kerana berbeza dengan elemen-elemen pemprosesan lain seperti kelajuan suntikan, tekanan dan suhu yang boleh diubah dengan mudah, lokasi suntikan adalah tetap dan sebarang perubahan yang dilakukan akan mengakibatkan peningkatan dari segi kos dan masa.

Objektif utama penyelidikan ini adalah untuk menjalankan simulasi dan mengkaji kesan-kesan akibat peningkatan jumlah suntikan acuan bertetulang bagi injak cekam automotif menggunakan komposit PA 6,6 bertetulang gentian kaca. Kajian ini membandingkan kesan-kesan rekaan acuan berdasarkan satu suntikan dan dua suntikan. Contoh-sulung komposit gentian kaca ini turut dihasilkan untuk tujuan perbandingan dengan hasil penyelakuan yang dijalankan.

Bagi mencapai objektif-objektif yang disebutkan diatas, dua kaedah perisian berangka utama telah digunakan. Perisian Moldflow Plastic Insight (MPI) digunakan untuk mengkaji kesan-kesan rekaan acuan keatas masa pengisian, tekanan, suhu, garisan penemuan, kandungan udara yang terperangkap dan penghalaan serta pengagihan gentian kaca manakala perisisan LUSAS digunakan untuk mengkaji sebaran tegasan bagi susuk cekam dan rangka rusuk.

Hasil daripada kajian ini menunjukkan jumlah suntikan bagi acuan iaitu satu atau dua mempunyai kelemahan dan kelebihan yang tersendiri. Pertama, keputusan penyelakuan menunjukkan acuan dengan satu suntikan mempunyai kelebihan daripada segi keseimbangan pengaliran bahan, masa pengisian dan garisan penemuan kerana ia menghasilkan pengaliran bahan yang seimbang, pengisian masa yang singkat dan garis penemuan yang pendek. Namun, rekaan acuan dengan dua suntikan mendahului rekaan satu suntikan daripada segi tekanan suntikan, pengecutan produk dan jumlah udara yang terperangkap. Rekaan ini mengurangkan tekanan suntikan yang diperlukan dan variasi tekanan; oleh itu, pengecutan isi produk dapat dikurangkan. Ia juga mengurangkan jumlah udara yang terperangkap. Akhir sekali, kajian perbandingan diantara penyelakuan dan contoh-sulung menunjukkan keputusan yang konsisten dari segi masa pengisian, udara yang terperangkap dan garisan penemuan.

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LIST OF ABBREVIATIONS

S_gFRIMT	Short glass fiber reinforced injection molded thermoplastic
MPI	Moldflow Plastic Insight
LUSAS	Finite element analysis software
PA (6,6)	Polyamide 6,6
SGFRP	Short Glass Fiber Reinforced Polyamide
f_p	Distribution of fiber orientation
EDM	Electric Discharge Machining (EDM) Machine
CNC	Computer Numerical Control
NC	Numerical Control

CHAPTER 1

INTRODUCTION

1.1 Overview

The last twenty years have seen an escalating interest in fiber reinforced polymeric based composite. This is due to its high strength to weight ratio, dimensional stability and resistance to heat, cold, moisture and corrosion. Polymeric based composite offers potential for lower conversion costs from intermediate material forms into final end-use parts by process automation and indefinite storage life that facilitates the logistics of the manufacturing procedure (Sapuan and Sharuddin, 2003).

For various reasons, many composites are reinforced by short fiber instead of continuous fiber. Matthew and Rawlings (1994) explained that continuous fibers are more expensive than other forms of reinforcement. Furthermore the manufacturing processes for continuous fiber reinforced composites tend to be slow and inflexible. For instance, processing techniques such as hand lay up, filament winding and autoclave are suitable for short runs or one off requirements of high performance high-priced products.

Finally, such interest is also caused by the advent of computer simulation packed with a multitude of analysis programs. Engineers no longer do the task of product analysis and product design separately; instead the task has been integrated

and can be done simultaneously by a sole engineer. Furthermore these user- friendly analysis programs permit a designer to evaluate not only the form and function of a design but also the manufacturability of that design at the early stage in the design cycle (Reifschneider, 2000). This concurrent design approach is essential for polymeric based composite since processing affects fiber orientation distribution, which in turn greatly affects the mechanical properties of the composite.

This product design approach has replaced much of the prototyping of the past. This is preferable since it reduced the rework involved in product design, time and cost of production. The use of such analysis programs by product designers is one of the latest developments in the time compression trend within manufacturing (Reifschneider, 2000).

1.2 Problem Statement

In previous years, many injection-molded molds have been designed by mold makers based on their intuition and experience alone. It is also a common practice that molds are made on iterative basis in which product prototypes are produced repetitively in order to identify mold problems. Hence the correlation between product design and mold design are mostly overlooked or ignored. Such tendency creates problems in which parts become overly designed and an increase in manufacturing time. This product development scenario is not acceptable since future global demands require shorter transformation time from on paper design into market.

Due to this scenario, it is hoped that this simulation study will shed some light on the relation between product design and mold design, product quality and ease of manufacturability especially for composite products. A study of injection numbers and locations is important since it easily affects product quality such as weld line and air trap formation; fill time and fiber orientation distribution. This study is also important since unlike other processing parameters such as filling speed, pressure and temperature that could be modified instantly, the gate location is permanent and any modification equals to increase in cost and time. Furthermore, works pertaining to relationship between design of injection mold and product process and product quality is still scarce especially for glass fiber reinforced composite automotive clutch pedal.

Finally, such study is also aligned with the current worldwide needs to reduce human dependency on steel due to depleting ore resources and unstable market price. Thus more steel products have been designed from polymer composite. Such approach also benefits the automotive industry since it improves fuel economy by reducing the weight of automotive parts. This is achievable with the use of strong, lightweight polymer composites.

1.3 Objectives of the Research

The main objective of the research is to simulate and analyze the effects of increasing number of gates for a clutch pedal mold using short glass fiber reinforced polyamide 6,6 (PA 6,6). This study involves the use of two finite element analysis softwares, LUSAS and Moldflow Plastic Insight (MPI). MPI software is used

extensively to investigate the effects of mold design on fill time, pressure, temperature, weld line, air traps and fiber orientation and distribution while LUSAS software is used to a lesser extent to analyze stress distribution for pedal profiles and rib patterns.

The clutch pedal is then fabricated using injection molding. The resultant model is then compared with the simulation results.

Thus the overall objectives of this research can be simply summarized as follows:

1. To design a short glass fiber reinforced polyamide 6, 6 clutch pedal for injection molding. The design process also involves comparison study between "V" and "X" rib based on:
   - Stress
   - Weight
   - Fill time
   - Pressure
   - Air Trap
   - Weld line
   - Average fiber orientation
   - Cost
   - Ease of manufacturing
2. To study the effects of gating number on:
   - fill time
   - pressure distribution

- temperature
- weld line
- air traps
- fiber orientation distribution

3. To compare simulated results and actual product

1.4 Scope and Structure of Work

The first chapter presents the background for this research which includes a brief introduction to short glass fiber reinforced injection molded thermoplastic (S_gFRIMT), objectives and significance of this study. The structure of the study is given in Figure 1.1. The study undertaken involves the use of LUSAS and MPI Software for analysis.

Chapter 2 discusses briefly literatures related to mechanical property, design, manufacturing and mold considerations for polymeric based composites in accordance with their importance and relevance.

Chapter 3 outlines the overall simulation plan and procedures. This chapter also includes a description of the software tools used to carry out the simulation analysis.

Chapter 4 describes the preliminary design results from MPI and LUSAS simulations namely on clutch pedal profiles ("I" and "T" sections) and rib designs