STUDY ON DEFECT OF ALUMINIUM FILLED EPOXY MOLD INSERT IN INJECTION MOLDING

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To my beloved mother, father, wife and children.

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ABSTRAK

Kajian ini dilakukan untuk mengkaji penggunaan bahan komposit yang digunakan bagi menghasilkan alat kemasukan di dalam proses penyuntikan acuan. Campuran *Epoxy* dan Aluminum digunakan sebagai bahan utama dalam pembuatan alat kemasukan tersebut melalui proses penuangan. Seperti alatan – alatan lain yang dihasilkan melalui proses penuangan, proses pemesinan diperlukan memandangkan proses penuangan hanya dapat menghasilkan alatan yang menghampiri bentuk sebenar tanpa mengambil kira ukuran yang tepat. Oleh yang sedemikian, mesin CNC digunakan dalam proses pemesinan untuk mendapatkan bentuk dan ukuran yang dikehendaki. Perisian analisa aliran plastik digunakan untuk mendapatkan bacaan mesin penyuntikan acuan yang optimum dalam proses penghasilan barangan plastik daripada bahan *Polypropylene* (PP). Telahpun dibuktikan bahawa akan berlaku perubahan fizikal pada alat kemasukan kerana sifat bahan komposit tersebut dikatakan cenderung untuk mengalami kegagalan selepas proses suntikan diulang beberapa kali. Simulasi perisian analisa unsur terhingga keatas perubahan anjakan alat kemasukan dijalankan dan didapati ia berpunca daripada peningkatan suhu yang dialami oleh keseluruhan sistem acuan. Selepas 300 suntikan berjaya dilaksanakan, alatan kemasukan dikeluarkan dari acuan untuk pemeriksaan. Hasil pemeriksaan mendapati berlaku perubahan anjakan dari segi ukuran pada alat kemasukan. Keputusan perisian analisa unsur terhingga dibandingkan bersama dengan keputusan hasil pemeriksaan fizikal dan ukuran daripada proses ujikaji penyuntikan plastik. Selepas perbandingan dijalankan, didapati alat kemasukan mengalami perubahan fizikal dan ukuran.

ABSTRACT

The purpose of this project is to study the used of composite material as an insert in injection molding process. Epoxy with aluminium filled was used and casted to fabricate the cavity insert of the mold. As with most cast products, machining is necessary due to the fact that cast parts can only be made to near net shape. For that reason, CNC machine was used to machine the casted material into desired shape and dimensions. Plastic flow analysis software has been used to obtain optimum injection machine parameters for production of polypropylene (PP) part. It was evident that slight changes had happen to the insert as the composite material itself tends to fail after a number of injection shots. Finite element analysis (FEA) software was used to simulate the insert displacement or deformation due to the effect of molding temperature experienced by the insert. After 300 successful injections were obtained, the insert was inspected and measured physically. It was found that the insert experienced a slight change uniformly and dimensionally after comparing the data against results of the FEA software.

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LIST OF SYMBOLS & ABBREVIATIONS

%	percent
°C	Degree celsius
mm	Millimetre
MPa	Mega Pascal
N	Newton
wt	Weight
K	Degree Kelvin
Ni	Nickel
Cu	Copper
Fe	Iron
Mo	Molybdenum
Al	Aluminium
Ti	Titanium
Mn	Manganese
Si	Silicon
C	Carbon
N	Nitrogen
FCC	Face-centered cubic
ANSI	American National Standards Institute
CBN	Cubic boron nitride
CNC	Computer Numerical Control
CMM	Coordinate measuring machine
FEM	Finite Element Methodology
FEA	Finite Element Analysis
RT	Rapid Tooling
RE	Reverse Engineering

CHAPTER 1

INTRODUCTION

1.1 Background

The requirements for faster product development cycles, lower product cost and environmental sustainability are ever increasing in today's globally competitive market. Tooling is a very important phase in the product manufacturing cycle. To overcome the shortcomings of long lead time and high cost associated with conventional tooling processes, new tooling methods with shorter lead time and lower cost are strongly under demand. In the modern consumer market, the success in launching and marketing a new product is highly dependent upon the time to market [1]. Much work has been carried out with a variety of available Rapid Prototyping (RP) and Rapid Tooling (RT) techniques [2–6] for producing direct and indirect tooling used for mould production. In this paper, an indirect rapid soft tooling approach, namely, aluminium filled epoxy resin tooling for mould production which is based on RP fabricated master patterns, is evaluated.

The high cost of raw material stock used in current RP systems makes them economically unsuitable even for smallbatch production during the product evaluation and manufacturing stages [7]. Futhermore, many RP methods currently in use are unable to produce functional parts with good material properties, and are generally cost prohibitive for making more than a handful of models. Even though the technology is improving and there is increasing use of RP for direct rapid manufacturing (RM), it is often not possible to fabricate many parts that require high accuracy and good material properties. Therefore, it is highly desirable to have complimentary tooling, made to produce more components in representative materials, but still utilizing the speed and flexibility of rapid prototyping.

In today manufacturing world, many products have insufficient quantity requirements to justify steel tooling. Also in the new product development cycle, there is often need of some intermediate tooling to produce a small quantity of prototypes or working samples for marketing, functional test, or production process design and evaluation purposes. In these cases, making cost-effective tooling quickly for small batch production can become very important. In this aspect, RT is good enough to replace a more conventional method, saving time and money in the process. The demand for faster and less expensive tooling solutions has resulted in an impressive number of RT methods being developed worldwide. RP and RT technologies have been identified and proved to have a great impact on product development cycle lead time and cost [8]. Based on previous study, plastic tools can be up to 50% cheaper then conventional tooling and usually take 70% less time to manufacture. Since they are made of plastic, they are light in weight and easy to handle and need no special storage. Building plastic materials are usually epoxies or polyurethane which both set at room temperature. Oven treatment is necessary only when heat resistant tools are to be made. Plastic tools are easy to patch and not brittle. They bond to practically any material when inner support structures for additional tool stiffness is required. They are durable and won't rust and won't warp. They provide quick, easy and inexpensive modification for repair of valuable tools. For example, tooling for injection molding applications has been a promising area for deploying one of the RP method which is the Streolithography (SL) technique. SL molds allow complex geometry to be built with ease and with considerable reduction in cost and tool development time. SL molds can be built in hours instead of days or months as for conventional steel molds [9].

1.2 Problem Statement

During the last few years, significant research and developments are achieved by different research groups which have worked on rapid tooling issues. Weissman has demonstrated that a rapid prototype model can be used as a master to get a shell of metal and with a supporting material such as epoxy resin, it can be used for injection moulding, metal forming, and electrical discharge machining (EDM) electrode [12]. The injection of fibre reinforced thermoplastic polymers is in a process of great expansion. Moulds manufactured with metallic filled polymers exhibit limited durability, due to the extensive wear to which they are submitted during the filling injection stage of abrasive thermoplastic polymers, making their use in this application not very attractive. They are used for low to high volume runs, however these are also heat sinks, which greatly retard production cycles, and cannot be controlled to run at a consistent temperature.

Epoxy tools often will begin to crack and break apart when repeatedly brought to high temperatures and cooled to room temperature. High temperatures affect the mechanical properties of the composite, due to resin softening and reduction of the particle and fibre/matrix adhesion [11]. During ejection, stresses are applied at the surface of the mold due to the plastic part shrinkage on the core coupled with inherent interlocking between molds and the part. The molds usually chip at the surface leading to an immediate fracture, or cracks can initiate and failure may occur after limited further cycling. Other type of failure has been observed when the mold has had time to reach a steady state. after more than twenty cycles. This failure type usually involves some chipping. This process has been compared to a fatigue type of failure and can occur during either injection or ejection, depending on the length to which the crack has grown [9]. Depending on the geometry and the process conditions, the molds end up failing by one of these modes.

The low thermal conductivity of the epoxy resins, about 5% of the thermal conductivity of the metals, have a substantial influence in the heat transfer process.

One of the current possibilities to overcome the lower thermal properties of the materials is the incorporation of cooling channels within the mold. Hybrid injection molds with non-metallic components in the molding zone are being considered as the single possibility to realize short runs or single parts. Hot spots, occurring in low cooling areas, can be minimized leading to the desirable homogeneous temperature field throughout the part.

Despite the cost and time advantages, RT molds generally have poor thermal and mechanical properties, hence are liable to fail during the molding process. Previous work on RT molds has shown that their life is highly dependent on the stress applied to the mold during the injection molding cycle. During injection, the polymer flow creates a bending stress on small features, and can either permanently deform the mold or break it. There are several more problems that limit the effectiveness of rapid tooling. These problems include but are not limited to the following characteristic such as the surface roughness inherent to the layered process, the surface roughness and part inaccuracy owing to the approximation of the CAD model, the part inaccuracy owing to shrinkage, the poor injection mold properties owing to the low thermal conductivity of the material, and the short mold life owing to limited material strength and partially cured parts [9].

1.3 Project Objectives

The main objective of this research is to study the effect of the molding temperature on the RT mold insert by mean of Finite Element Analysis (FEA) and the actual experimental work. The effect on the insert was analysed in terms of the displacement defects on the insert itself. In order to achieve this goal, the following specific objectives were set for this research :

i. To determine the optimum parameters for injection molding machine for Polypropylene (PP) material by using plastic flow analysis method.
ii. To design and fabricate aluminium-epoxy cavity insert for production of PP material.
iii. To study the displacement of aluminium-epoxy composite insert due to molding temperature by using finite element method (FEM).
iv. To validate and verify the simulation results with experimental work.

1.4 Scope of the study

The scope of study for this project covers the followings :

i. Aluminium-epoxy composite material was used to fabricated the cavity insert.
ii. Plastic flow analysis simulation, MoldFlow software was used to predict molding temperature of the Polypropylene (PP) part.
iii. Injection Molding machine with capacity of 100 tones was used to conduct the experiments.
iv. CNC Lathe and CNC Milling was employed for insert fabrication.
v. Coordinate Measuring Machine (CMM) was used for inspection.
vi. Portable Reverse Engineering (RE) scanner was used to scan the insert.
vii. Finite element software, HyperMesh ver. 10 was used for linear static analysis to predict the insert deflection of the insert.

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