

EVALUATION OF MECHANICAL PROPERTIES OF ALLUMINIUM FILLED
EPOXY COMPOUND FOR RAPID TOOLING APPLICATIONS

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In the name of God, most Gracious, most Compassionate

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ABSTRACT

In this study, the mechanical properties and microstructure inspection for aluminium filled epoxy including hardness, dimension accuracy, density, compressive test, fracture analysis were evaluated . An investigation measurement for the grain size on the three different temperature was carried out. Result shows that the grain size or G number microstructure for aluminium filled epoxy having a different size and distribution was corresponding with increase in temperature. In term of dimensional accuracy inspection, aluminium filled epoxy tends to have shrinkage experience with rate of 0.05% to 0.06% for round part while 0.15% for pin .The compressive strength shows a better trend during cooling in ambient temperature compared to cooling in an oven. In term of density, there was no significant effect to the hardness when tested with Vickers Hardness Tester , Barcol Impresser and Shore D Durometer . The parameter design mixing and curing for aluminium filled epoxy using Taguchi Method which based on larger is better is optimized .Four control factors are investigated in the study: pre curing time, degassing time, Interval time curing and maximum curing time. The response plot of the control factor shows factor A2 (pre curing at 50°C), B2 (degassing time at 45 minute) C3 (interval curing at 14 hour) D2 (maximum curing at (165°C) and factor A2 (pre cuing at 27°C), B3 (degassing time at 30 minute) C1 (interval curing at 14 hour) D2 (maximum curing at (165°C) were significant in contributing in mixing and curing to increase the hardness and density of aluminium filled epoxy.

ABSTRAK

Dalam kajian ini, sifat-sifat mekanikal dan pemeriksaan microstruktur untuk *aluminium filled epoxy* termasuk kekerasan, ketepatan dimensi, ketumpatan, ujian mampatan, analisis patah telah dinilai. Ukuran untuk saiz bijian pada tiga suhu yang berbeza telah dijalankan. Keputusan menunjukkan bahawa saiz butiran atau G number mikrostruktur *aluminium filled epoxy* mempunyai saiz yang berbeza selaras dengan peningkatan suhu. Dalam pengukuran ketepatan dimensi, *aluminium filled epoxy* cenderung untuk mengalami pengecutan dengan kadar 0.05% kepada 0.06% bagi sampel bulatan manakala 0.15% untuk pin. Kekuatan mampatan menunjukkan trend yang lebih baik semasa penyejukan suhu persekitaran berbanding penyejukan dalam oven. Dari segi ketumpatan, tidak ada kesan yang ketara kepada kekerasan apabila diuji dengan Vickers Hardness Tester, Barcol Impresser dan Shore D durometer. Reka bentuk parameter bagi penyediaan bahan untuk *Aluminium filled epoxy* dengan menggunakan Kaedah Taguchi yang berdasarkan yang lebih besar adalah lebih baik (*Larger the better*) Empat faktor kawalan disiasat dalam kajian ini: *Curing time*, *Degassing time* masa *Intervel time* dan *Maximum Curing Time*. Keputusan menunjukkan faktor A2 (*Curing time* 50 ° C), B2 (*Degassing time* 45 minit) C3 (*Intervel time* 14 jam) D2 (*Maximum Curing* 165 ° C) dan A2 (*Curing time* 27 ° C), B3 (*Degassing time* 30 minit) C1 (*Intervel time* 14 jam) D2 (*Maximum Curing* 165 ° C) adalah faktor penting bagi menyumbang kepada kekerasan dan ketumpatan semasa proses penyediaan bagi *aluminium filled epoxy*.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Increasing global competition, together with the rising number of product variants with shorter life cycles in today's way forcing manufacturing companies and industries to reduce their development time of the manufactured components. Currently, companies are experiencing increasing pressure to produce complex and diverse products in shorter product development cycles, aiming to achieve less overall cost with improved quality (Evans and Campbell, 2003). Besides product costs and quality, the set-up time of a new product is a key factor for the competitiveness of the manufacturing. Due to that, new manufacturing methods such as rapid tooling are becoming increasingly important to save the time, cost and lead time for fabricated tooling for injection moulding mould especially mold and cavity insert. Production of tooling is a slowest and most expensive exercises because of accuracy and quality needed depending on the manufacturing process involved. Rapid tooling processes are now being considered as an option specifically tooling to be developed economically. An idea in this research is to develop accurate process parameters for mixing and curing of aluminium filled epoxy compound for rapid tooling applications. It offers great potential and opportunity in product development especially to mold maker and rapid tooling application.

1.2 Problem Statement

Over the past years, rapid tooling (RT) has been largely seen as complementary technology, for quickly making tools for various kinds of prototype applications, within the tooling sector. Compare with conventional method, the traditional method of developing tool (punch and cavity) takes more time to be ready for production (Rahmati *et al.*, 2007). The use of epoxy resin in aircraft, guided weapons, ships and vehicle construction has increased markedly in the last decade and this dramatic growth rate shows every sign of continuing in shaping the future. Many efforts and attempts have been made to understand the behaviour of epoxy resin in product quality. Research by M.Vaezi *et al.*, (2010) reported that epoxy resin moulds had higher accuracy compared with conventional tooling for injection mould for manufacturing gas turbine blade. Epoxy resin in rapid tooling application can help to reduce both the cost and lead time required for part production by up to 25% and 50%. (Cheah *et al.*, 2002)

Like other materials, plastic, can be sensitive and tend to lose the structure integrity when damage. The damage can happen whether at time of manufacture or during in service. Its same goes to epoxy based material. When cured, epoxy resins are highly cross-linked, amorphous thermoset polymers and this structure results in many useful properties, such as high modulus, low creep and good performance at elevated temperature.

However, it also means that the unmodified epoxies are relatively brittle polymers with poor resistance. Cheah *et al.*, (2002) reported high pressures were imposed during moulding which caused significant amount of stress to be generated within the mould and causing crack in the epoxy resin mould. Figure 1.1 below shows a crack line observed on the cavity side mould half after series of 400 moulding cycle with PC material.

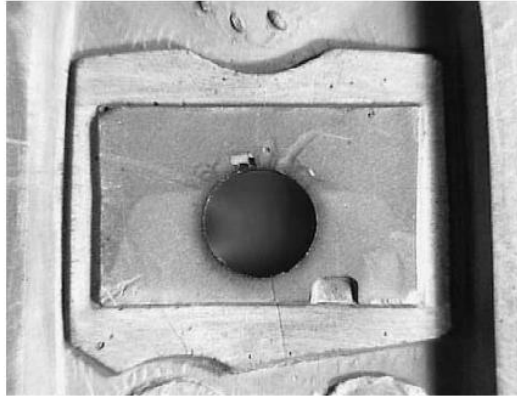


Figure 1.1 Crack appearing on the surface of mould half (Cheah *et al.*, 2002)

Depending on the specific needs for certain physical and mechanical properties, combinations of the right choices of epoxy resin and curing agents can usually be formulated to meet the market demands. The current challenges and issues found in epoxy resin are to combine strength, accuracy, surface finish and thermal characteristics. It is widely acknowledged that not all rapid tooling meet all above requirements. When tooling engineers considers RT to use in functional prototype production, varieties of issues arises. According to Nagahanumaiah *et al.*, (2003) issues in rapid tooling as follows:

- i. The accuracy, durability, surface finish and overall performance of tooling
- ii. Cost, lead time, process capability (geometric constraints)
- iii. The quantity of part produced
- iv. The quality of part produced

From previous researches that has been done, the data for curing and mixing is limited. No comprehensive data optimization in mixing and curing of aluminium filled epoxy. Thus, an initiative has been undertaken to conduct this research in order to determine the setting best parameter in mixing and curing for rapid tooling application. The mechanical and metallurgical properties of aluminium filled epoxy will be evaluated. It is expected that appropriate process parameters for mixing and curing of aluminium filled epoxy compound will offers significant benefits to mold maker and rapid tooling industries.

1.3 Research aim and objectives

The aim of the study is to establish and to evaluate the aluminium epoxy compound for rapid tooling application. In order to achieve the above goal, the specific objectives and scope were set for this research as follows:

1.4 Objectives of the study

- i. To determine the appropriate process parameters for mixing and curing aluminium filled epoxy compound for rapid tooling applications.
- ii. To evaluate the metallurgical and mechanical properties Aluminium filled epoxy compound.
- iii. To establish the optimum parameters for mixing and curing aluminium filled epoxy using Taguchi approach.

1.5 Research Scopes

- i. The resin used is aluminium filled with epoxy.
(Rencast © CW47 / Ren © HY 33)
- ii. Develop appropriate process parameters using Design of Experiment (DOE) approach.
- iii. To evaluate the metallurgical and mechanical properties of aluminium filled epoxy using Scanning electron microscope (SEM) and others mechanical testing equipment was used to plan the experiments and identify the significant parameters that affect the responses..

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