UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

EFFECT OF STAMPING PARAMETERS ON THE SPRING-BACK BEHAVIOUR OF OIL PALM FIBRE COMPOSITE

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DECLARATION

I declare that this thesis entitle "Effect of Stamping Parameters on the Spring-back Behaviour of Oil Palm Fibre Composite" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Muhammad „Ammar Bin Che Mahzan

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering.

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Date	:	....

DEDICATION

To my beloved mother and father

ABSTRACT

Composite materials have been vastly known worldwide for its uses in various sectors such as aerospace, infrastructures and automotive industries. Natural fibres are gaining recognition as a substitute to synthetic fibres due to their recyclability and abundance. In Malaysia, research on palm fibre composite had mainly focused on tensile and flexural properties but not on its stamp forming behaviour. Oil palm fibre reinforced polypropylene composite panel has the potential to be stamp formed in order to build complex geometries. In stamp forming the most sensitive feature is elastic recovery during unloading. This phenomenon will affect the net dimension of the final product. This research studies the effects of tool radius, feed rate, temperature and weight ratio of fibre to polypropylene on the spring-back of oil palm fibre composite and to formulate an empirical equation to predict the spring-back angle. The composite material are mixed together with different fibre composition of 10wt%, 20wt%, 30wt%, 40wt% and pure polypropylene using an internal mixer and hot pressing. The samples are cut into rectangular shape samples with a dimension of 180mm x 20mm x 2mm for V-bend testing and are 160mm x 20mm x 2mm accooding to ASTM D3039 for tensile testing. A V-bending die is used to characterise the spring-back angle of the oil palm fibre composite. The results are computed using a statistical software (Minitab). Statistical analysis conducted shows all the studied parameters gave significant effect towards spring-back. Based on the analysed result, an empirical model was formulated to predict the spring-back angle. A stereo microscope was used as a visual aid to show the surface on the deformed area. It can be concluded that the higher the temperature, feed rate and fibre composition (up to 30wt %) the smaller the spring-back but the smaller the tool radius, the smaller the spring-back angle.

ABSTRAK

Bahan-bahan komposit diketahui mempunyai banyak kegunaan dalam pelbagai sektor seperti aeroangkasa, infrastruktur dan industri automotif. Kini gentian semulajadi semakin diiktiraf sebagai pengganti gentian sintetik. Perubahan ini berlaku kerana gentian semulajadi banyak diperolehi selain mempunyai daya kitaran semula yang tinggi. Di Malaysia kajian berkaitan komposit gentian sawit lebih terarah pada sifat tegangan bukan terhadap perilaku lenturan. Panel gentian kelapa sawit yang diperkukuhkan komposit polipropilena mempunyai potensi untuk lenturkan bagi membentuk geometri-geometri kompleks. Ciri sensitif utama lenturan ialah pemulihan elastik semasa memunggah. Fenomena ini memberi kesan terhadap dimensi net produk akhir. Penyelidikan ini mengkaji kesan jejari alat, kadar kelajuan, suhu dan perbandingan berat gentian dengan polipropilena ke atas keanjalan patah balik komposit gentian kelapa sawit selain untuk merumus persamaan bagi meramal sudut keanjalan patah balik. Bahan-bahan komposit dicampur dalam pelbagai peratusan komposisi iaitu 10wt%, 20wt%, 30wt% dan 40wt% bersama polipropilena tulen menggunakan mesin mixer dalaman dan penekan mesin panas. Sampel dipotong dalam bentuk segi empat tepat dengan dimensi 180mm x 20mm x 2mm bagi ujian lentur V. Ujian tegangan menggunakan sampel dimensi 160mm x 20mm x 2mm mengikut ASTM D3039. Dai lenturan V digunakan bagi mencirikan sudut keanjalan patah balik komposit gentian kelapa sawit. Data kajian dianalisis menggunakan perisian statistik Minitab. Analisis menunjukkan bahawa semua parameter yang dikaji mempunyai kesan signifikan terhadap keanjalan patah balik. Berpandukan hasil analisis, suatu model empirikal telah dirumus bagi tujuan meramal sudut keanjalan patah balik. Mikroskop stereo digunakan sebagai alat bantu visual untuk mempamer kawasan permukaan yang dilenturkan. Kesimpulannya semakin tinggi suhu, kadar kelajuan dan komposisi gentian (sehingga 30wt%) semakin rendah keanjalan patah balik. Manakala, semakin kecil tool radius, semakin kecil sudut keanjalan patah balik.

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LIST OF ABBREVIATIONS

EFB	-	Empty fruit bunch
OPEFB	-	Oil palm empty fruit bunch
OPF	-	Oil palm fibre
OPFC	-	Oil palm fibre composite
PP	-	Polypropylene
MAPP	-	Maleic Anhydride Polypropylene

LIST OF SYMBOLS

α-value	-	Alpha value
T_s	-	Softening temperature
T_r	-	Room temperature
α_r	-	Radial expansion coefficient
α_l	-	Linear expansion coefficient
$\Delta\theta$	-	Deviation angle

LIST OF PUBLICATION

A. Journal

1) M.A.C. Mahzan, S. DharMalingam, Sivaraos, M. Z. Selamat, M. R. Said., 2014. A Study on the Mechanical and Forming Performance of Oil Palm Fibre Reinforced Polypropylene Composite. *American-Eurasian Journal of Sustainable Agriculture*, 8(4), pp. 141-147.

2) S. DharMalingam, M.A.C. Mahzan , M. R. Said, A. Rivai, M.N.A. Nordin, M. Z. Selamat, Sivaraos, "V-Bend Die Forming Performance of Oil Palm Fibre Composite", Accepted in the Applied Mechanics and Materials 2014.

3) S. DharMalingam, M.H.R. Hashim, M.R. Said, A. Rivai, M.A Daud, Sivaraos, M.A.C Mahzan, "Effect of Reprocessing Palm Fibre Composite on the Mechanical Properties", Accepted in the Applied Mechanics and Materials 2014.

CHAPTER 1

INTRODUCTION

1.1 Background research

Materials used in the automotive and aerospace industries have mainly been dominated by monolithic metals and plastics. Composite based materials have recently gained recognition due to its excellent mechanical and chemical properties. Some advantages that composite materials possess are, that it has higher specific strength, stiffness and fatigue characteristic that allows the materials to be more versatile in design.

Composite are materials comprises of reinforcement and a matrix. The reinforcement provides strength and rigidity to help support the structural load. While the matrix is the weaker material that maintains the position and orientation of the reinforcement. The qualities that one does not possess may be found in another. This in turn will create a material that cannot be found in a single material alone.

Fibres can be classified into two groups which are natural fibres and synthetic fibre. Natural fibres include those made from animal, mineral sources and plant. Animal fibres generally consist of animal hair, silk fibres, and avian fibres. For synthetic fibres, it consists of asbestos, ceramic fibres, and metal fibres. While examples of the plant fibres are seed fibres, leaf and skin fibres. However, many of the early work on composites focused almost entirely on inorganic materials. Natural fibres are currently being studied intensively by researchers to replace synthetic fibres. This is because natural fibres are lower in cost, greenability, low density, recyclable, biodegradable and usually produced in an abundant amount at a time. These fibres are also renewable materials and have relatively high strength and stiffness (Joseph et al., 2006). Automotive giants such as Daimler Chrysler use flax–sisal fibre mat embedded in an epoxy matrix for the door panels of Mercedes Benz E-class models (John & Thomas, 2008). Coconut fibres bonded with natural rubber latex are being used in seats of the Mercedes Benz A-class models. Besides the automotive industry, lignocellulosic fibre composites have also been applied in buildings and construction industries for panels, ceilings, and partition boards (Hariharan & Khalil, 2005)

Malaysia is one of the world"s largest producers and exporters of oil palm. The oil palm plantation has gradually dominated the Malaysian agricultural crop with a total plantation area exceeding 4 million hectares (Basri, 2005). To fully utilise Malaysia"s natural resources, oil palm empty fruit bunch (OPEFB) fibres were chosen as the natural fibre for this research. The fresh oil palm fruit bunch contains about 21% palm oil, 6-7% palm kernel, 14-15% fibre, 6-7% shell, and 23% empty fruit bunch (Yusoff et al., 2009). OPEFB fibre is extracted from empty fruit bunch (EFB) and during the manufacturing process of oil palm fibre; EFB is shredded, separated, refined and dried. The OPEFB fibre is clean, biodegradable and compatible compared to other fibre from wood species (Kwei et al., 2007).

It is estimated that over 3.6 tonnes per hectare of oil palm waste product were produced annually (Yusoff et al., 2009). These wastes are usually burnt down to produce bunch ash that is used as fertilisers. These actions will result in environmental problems for the country such as air pollution and global warming. However recently, only a small part of oil palm waste is used as fertilisers. Thus a huge amount of EFB is left to decompose. By using EFB as a natural resource, not only can we fully utilise the natural fibre but in addition we can also reduce the environmental problems that comes with it. In the long run it can also enhance the nation‟s economy and resource. Many researchs had found that the incorporation of EFB into polymers plays an important role in cost reduction and reinforcement (Rozman et al., 2001; Kalam et al., 2005; Ratnam et al., 2007). The mechanical properties of EFB/polypropylene composites have been investigated and it was found that EFB increased the tensile modulus but decreased the tensile strength of the composites (Rozman et al., 2001).

Polymers can be classified into two types which are thermosetting polymers and thermosplastic polymers. Thermosetting polymers, also known as a thermoset materials are generally stronger than thermoplastic materials due to this three-dimensional network of bonds (cross-linking), and are also better suited to high-temperature applications up to the decomposition temperature. However, they are more brittle. Since their shape is permanent, they tend not to be recyclable as a source for newly made plastic. Examples of thermoset materials are polyesters, polyurethane, vulcanized rubber and melamine resin (Dante et al., 2009). Meanwhile, thermoplastic or thermosoftening plastic, is a plastic material, typically a polymer, that becomes pliable or moldable above a specific temperature and solidifies upon cooling (Baeurle et al., 2006). Most thermoplastics have a high molecular weight. The polymer chains associate through intermolecular forces, which weaken rapidly with increased temperature, yielding a viscous liquid. Thus, thermoplastics may be reshaped by heating and are typically used to produce parts. Examples of thermoplastic polymers are acrylic, nylon, polyethylene, teflon and polypropylene.

Two main processing methods for thermoplastic composite materials are injection moulding and thermoforming or hot stamp forming. Both injection moulding and thermoforming have quite similar attributes regarding processing. However, the surface finish for thermoforming is greater than injection moulding or can be graded as class „A" finish (Anonymous, 2012). The issues of swirls, sink marks, weld lines, gate marks, etc. are not present with thermoforming. On cars, plastic bumpers and plastic lower side panels are typically thermoformed.

Stamp forming is being used to produce mass production of products such as in the automotive industries. In stamp forming, the most sensitive feature is elastic recovery during unloading called spring-back. This phenomenon will affect bend angle and bend curvature. One of the stamp forming tests is the V-bend. V-bending is a single curvature deformation process often utilised to characterise the spring-back or deviation angle of a material. This will reduce the knowledge gap on the material"s forming behaviour of the material.

For this research, Polypropylene (PP) and Maleic Anhydride Polypropylene (MAPP) were used acting as the matrix and as the coupling agent for the composite. Polypropylene is a semi-crystalline polymer that is used extensively due to its unique properties which are inexpensive and easy to fabricate. MAPP act as an effective functional molecule for the reactive compatibility between PP and OPEFB. MAPP can improve the bonding between PP and OPEFB fibres. The variables that were investigated for this project are fibre content, temperature, feed rate and tool radius. The materials will undergo two mechanical testing which are tensile test and V-bending. Based on the data gathered, an analytical model will be produced in predicting the spring-back effect of the composite material.

1.2 Problem statement

Many of the early work on composites focused almost entirely on inorganic materials. However, in the early 1980s the interest in composites made from natural fibres has been growing. This interest has largely stemmed from problems with recyclability, costs and the environmental effects of synthetic fibres, and the abundance of natural fibres (Bhattacharya et al., 2003). Renewable materials produce only low levels of carbon emissions and therefore help to combat climate change.

In Malaysia, researches on palm fibre composite had mainly focused on tensile and flexural properties. Stamp forming behaviour of thermoplastic based oil palm fibre composite (OPFC) is yet to be well understood, thus there is great need to study this behaviour in order to improve the material characteristics in the production processes.

1.3 Objective

In tackling the problem discussed, the objectives have been determined as listed:

- To determine the effects of forming rate, tool radius, temperature and fibre to matrix on the spring-back of palm fibre composite.
- To develop an empirical model in predicting the spring-back angle.

1.4 Scope

In order to achieve the objectives of the research, the scopes are listed:

a) V-bending test will be utilised to characterise the spring-back angle of palm fibre composite.

b) This research will only focus on the forming rate, tool radius, temperature and fibre to matrix on the spring-back angle of palm fibre composite.

c) Tensile test will be utilised to measure the tensile strength of each composites with different fibre composition.

d) A differential scanning calorimetry (DSC) test will be used to determine the melting temperature of polypropylene.

e) A stereo microscope will be utilised to analyse the effect on the deformed area of the samples after V-bending.

1.5 Significant of study

The main aim of this research was to identify whether oil palm composite is suitable to be stamp formed to produce automotive parts such as cup holders, dashboards and speaker grilles.

The effects of tool radius, feed rate, temperature and fibre composition on the oil palm fibre composite spring-back angle after stamping will be examine. The empirical equation will help in determining and predicting the effect of the parameters towards the spring-back angle. This can be a reference for industries to determine the necessary parameters that is required to produce a component made from oil palm fibre composite.