UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

STUDY ON PROCESSING PARAMETERS FOR POLYPROPYLENE REINFORCED WITH FIBER GLASS COMPOSITE PREPARED USING INJECTION MOLDING

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DECLARATION

I declare that this thesis entitled "Study on processing parameters for polypropylene reinforced with fiber glass composite prepared using injection molding" 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.

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Manufacturing System Engineering).

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DEDICATION

To my other half Nik Mohd Shahir Bin Nik Mohd Zainordin, my beloved parents Haji Rusli Bin Mat and Hajjah Wan Zunani Binti Wan Yusuf.

ABSTRACT

This report reveals the effect of processing parameters on mechanical properties for polypropylene reinforced with fiber glass composite prepared by injection molding process. The processing parameters involved on the experimental are melting temperature (MeT) (250°C – 280°C, injection pressure (IP) (22 MPa – 28 MPa) and cooling time (Ct) (60s – 90s). Box Behnken response surface method (RSM) was used to determine the most influential paremeters affected the experimental responses that are tensile strength, modulus strength and percentage of elongation. Further, investigation the optimum processing parameters value that give highest tensile strength, highest tensile modulus and shortest elongation were studied. There were 17 numbers of experimental run with three repetitions was conducted using the injection molding machine. The result collected was optimized using RSM meanwhile the analysis of variance (ANOVA was used to calculated the P-value and R-squared to find the most significant parameter affected the response. From the result analysis, it is found that the injection pressure is the most significant parameter that affacted tensile strength and percentage of elongation. Meanwhile, melting temperature shows the most significant parameter affected on the tensile modulus. The optimum parameters affected the tensile strength are 250°C for MeT, 22 MPa for IP and 77.97s for Ct. Further, optimum parameters affected the tensile modulus are 262.4°C for MeT, 27.0 MPa for IP and 60s for Ct. Finally, optimum parameters affected the percentage of elongation are 250°C for MeT, 28 MPa for IP and 90s for Ct. The multi optimization shows that the multiple optimized parameters values are 252.4°C for MeT, 27.8 MPa for IP and 60s for Ct which resulted the responses of tensile strength, modulus strength and percentage of elongation are 18.99 MPa, 2092.53 MPa and 12.31% respectively. Thus, RSM and ANOVA analysis can be used to optimized the injection moulding machine parameters that affected the mechanical properties of polypropylene reinforced with fiber glass composite.

ABSTRAK

Laporan ini mendedahkan kesan parameter pemprosesan pada sifat mekanik untuk polipropilena yang diperkuat dengan komposit kaca gentian yang disediakan oleh proses pengacuan suntikan. Parameter pemprosesan yang terlibat dalam kajian ialah suhu lebur (MeT) (250 ° C - 280 ° C, tekanan suntikan (Ip) (22 MPa - 28 MPa) dan masa penyejukan (Ct) (60s - 90s). Kaedah (RSM) digunakan untuk menentukan parameter yang paling berpengaruh terhadap keputusan eksperimen iaitu kekuatan tegangan, modulus tegangan dan peratusan pemanjangan. Kajian selanjutnya, berkenaan tentang penyiasatan nilai parameter pemprosesan optimum yang memberikan kekuatan tegangan tertinggi, modulus tegangan tertinggi dan peratusan pemanjangan terpendek. Terdapat 17 bilangan ujian eksperimen dengan tiga kali pengulangan dijalankan menggunakan mesin pengacuan suntikan. Keputusan yang diperoleh dioptimumkan menggunakan RSM manakala analisis varians (ANOVA digunakan untuk mengira nilai P dan R-kuadrat untuk mencari parameter paling penting yang mempengaruhi tindak balas kajian. Daripada analisis hasil, didapati tekanan suntikan adalah parameter paling ketara yang mempengaruhi kekuatan tegangan dan peratusan pemanjangan. Sementara itu, suhu lebur menunjukkan parameter yang paling ketara terhadap modulus tegangan. Parameter optimum yang mempengaruhi kekuatan tegangan ialah 250 ° C untuk MeT, 22 MPa untuk IP dan 77.97s untuk Ct. Selanjutnya, parameter optimum yang mempengaruhi modulus tegangan ialah 262.4 ° C untuk MeT, 27.0 MPa untuk IP dan 60s untuk Ct. Akhirnya, parameter optimum mempengaruhi peratusan pemanjangan adalah 250 ° C untuk MeT, 28 MPa untuk IP dan 90s untuk Ct. Pengoptimuman pelbagai menunjukkan bahawa nilai parameter yang dioptimumkan adalah 252.4 ° C untuk MeT, 27.8 MPa untuk IP dan 60s untuk Ct yang menghasilkan tindak balas kekuatan tegangan, modulus tegangan dan peratusan pemanjangan adalah masing-masing 18.99 MPa, 2092.53 MPa dan 12.31%. Oleh itu, analisis RSM dan ANOVA boleh digunakan untuk mengoptimumkan parameter mesin pengacuan suntikan yang mempengaruhi sifat mekanik polipropilena yang diperkuat dengan komposit kaca serat.

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LIST OF SYMBOLS

d	-	Diameter
w	-	Width
l	-	Length
x	-	Gauge length

LIST OF ABBEREVIATIONS

PP	-	Polypropylene
IM	-	Injection Molding
RSM	-	Response Surface Methodology
MeT	-	Melting temperature
IP	-	Injection Pressure
Ct	-	Cooling time
BB	-	Box- Behnken
DOE	-	Design of Experiment
ANOVA	-	Analysis of Variance

CHAPTER 1

INTRODUCTION

This chapter explains detail about the background and introduction of the research project. Next, proceed with problem statement, objectives and scopes of the research project.

1.0 Background

Polypropylene (PP) is one of the most commonly thermoplastic polymer used in a wide variety of applications worldwide. It is commonly used in a variety of applications such as packaging for consumer products, plastic parts for various industries including the automotive industry, special devices like living hinges, and textiles. In general, PP offers a good balance of properties and cost unachieved by most thermoplastics. It is lightweight yet stronger in such high flexural strength due to its semi-crystalline nature and has good impact strength. Furthermore, PP has a unique ability as it is easily molded into nearly any shape by all methods, including injection molding, blow molding, extrusion, blown, cast film, and thermoforming, providing one of the primary benefits of most plastics (American Chemistry Council, 2018)

Glass fiber or so call as fiberglass is the most commonly used fiber to reinforce thermoset and thermoplastic resins across a wide variety of applications and processes.

Fiberglass consists of numerous fine strands of silica polymers which may, depending on the type, include alkali oxides, aluminium, boron or other trace molecules. Glass reinforcements in which added or molded with other materials, help improve the surface aspect as it allow a uniform impregnation (with resins) and are not subject to cracking, breaking or splitting. It has a greater specific resistance in such higher tensile strength compared to steel. This characteristic is the primary reason for the use of glass strand in the production of high performance composites. Therefore by considering both material, PP reinforced with fiberglass to produce composite material that offer lightweight characteristics, flexibility, and high-end performance required nowadays in all manufacturing sectors.

Thus, this study investigates the most influential injection molding machine parameter such as melting temperature, injection time and cooling time towards mechanical properties such as tensile strength, tensile Young's modulus and the percentage elongation of composite PP with fiber glass using response surface method.

1.1 Problem Statement

In common practice, any manufacturer must attain the sustainable manufacturing practice (Madan Shankar, 2017). Sustainable manufacturing is defined as the creation of manufactured products through economically-sound processes that minimize negative environmental impacts. PP consumes the least amount of energy during production and produces the lowest carbon dioxide emissions when compared to other plastics due to its low density. While fiber glass also offers great properties as reinforced material, high mechanical strength and light weight. Therefore in order to minimize negative environmental impacts, PP will be reinforced with fiberglass using injection molding machine. Furthermore, glass fiber-reinforced polypropylene has improved dimensional stability, resistance to warpage, rigidity and strength.

Furthermore, many plastic injection molding companies having problem to setting injection molding optimum parameters during the production run especially for new mold and new plastic materials are introduced. Application of design of experiment (DOE) becomes more essential in optimization parameters. Therefore, trial and error practice in industry can be replaced by using systematical approach. One of DOE method is using response surface method (RSM). RSM is statistical method that uses quantitative data from appropriate experiments in order to determine and simultaneously solve multivariant equations. RSM is useful for the modeling and analysis of programs in which a response of interest is influenced by several variables and the objective is to optimize this response. Therefore by using RSM, the optimum factor of the machine parameter can be identified towards tensile strength, tensile Young's modulus and the elongation of composite PP with fiber glass.

1.2 Significant study

Ordinarily, polypropylene reinforced with fiber glass has improved dimensional stability, resistance to warpage, rigidity and strength. Since PP is easily molded into nearly any shape by all methods, hence the injection molding machine is chosen. Therefore this study will investigate the most influential machine parameter towards mechanical properties such as tensile strength, tensile Young's modulus and the elongation of the composite PP with fiber glass.

1.3 Objective of the study

The main objective of this study is to find the effect of the injection process parameters on mechanical properties such as tensile strength, tensile Young's modulus and the elongation of composite PP reinforced with fiber glass

The sub-objectives of this study are:

i. To investigate the most significant processing parameters towards mechanical properties of the composite PP reinforced with fiber glass using RSM method.

ii. To determine the interaction of process parameters on tensile strength, tensile modulus and percentage of elongation.

iii. To optimize machine parameter that related to the tensile strength, tensile Young's modulus and the elongation of the composite PP with fiber glass using single and multiple objective optimization.

1.4 Scope of the study

The scope of this research is to focus on studies of the influence machine parameter towards tensile strength, tensile Young's modulus and the elongation of composite PP reinforced with fiber glass. Whereby parameters evaluated to obtain tensile strength, tensile Young's modulus and the elongation of composite PP reinforced with fiber glass are melting temperature (MeT), injection pressure (IP) and cooling time (Ct). Value of melting temperature, injection pressure and cooling time is varied throughout the experiment.

1.5 Organization of report

Chapter 1 is introduction of chapter that explains about the background of the project, problem statement, objective that must be achieved and scopes of the project. Then, for Chapter 2 is literature review which relevant to the previous and present study of injection molding process especially related with composite PP and fiber glass. Meanwhile, in Chapter 3 explains the methodology of the experimental setup, composite and sample preparation, experimental parameters, machine and equipment used for injection molding process for the composite PP and fiber glass. Later, in Chapter 4 is a project result and discussion, it discusses about the analysis of data collection regarding to this project. Finally, in Chapter 5 is a conclusion and recommendation which it explains about the summary of the project that has been done and recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

This chapter explains the literature review of the materials used, properties of the composite material, injection molding machine, injection molding process control, design expert software, research surface methodology, and optimization of the experimental work.

2.1 Polypropylene (PP)

Polypropylene (PP) is one of the most commonly thermoplastic polymer used in a wide variety of applications worldwide. It is commonly used in a variety of applications such as packaging for consumer products, plastic parts for various industries including the automotive industry, special devices like living, and textiles. In general, PP offers a good balance of properties and cost unachieved by most thermoplastics. It is lightweight yet stronger in such high flexural strength due to its semi-crystalline nature and has good impact strength. Furthermore, PP has a unique ability as it is easily molded into nearly any shape by all methods, including injection molding, blow molding, extrusion, blown, cast film, and thermoforming, providing one of the primary benefits of most plastics.

In general polypropylene has demonstrated certain advantages in improved strength, stiffness and higher temperature capability over polyethylene. As indicated by Singh, (2015) polypropylene has been very successfully applied to the forming of fibers due to its good specific strength which is why it is the single largest use of polypropylene and hence revealed that polypropylene also happens to be one of the lightest plastics available with a density of 0.905 g/cm². Table 2.1 shows the general properties of PP.

Table 2.1: General properties of Polypropylene (Shubhra, 2011)

Property	Test method	Homopolymer		
Melt-flow index (MFI)	a	3.0	0.7	0.2
Tensile strength	b	500 (lb in^{-2}) 34 (MN/m^2)	4400 (lb in^{-2}) 30 (MN/m^2)	4200 (lb in^{-2}) 29 (MN/m^2)
Elongation at break (%)	b	350	115	175
Flexural modulus	-	190,000 (lb in^{-2}) 1310 (MN/m^2)	170,000 (lb in^{-2}) 1170 (MN/m^2)	160,000 (lb in^{-2}) 1100 (MN/m^2)
Brittleness temperature (°C)	I.CI./ASTM D746	+15	0	0
Vicat softening oint (°C)	BS 2782	145–150	148	148
Rockwell hardness	–	95	90	90
Impact strength (ft lb)	–	10	25	34

2.2 Fiber glass

Fiberglass is described to a group of products made from individual glass fibers then combined into a variety of forms. According to Singh, (2015) glass fibers can be divided into two major groups according to their geometry such continuous fibers used in yarns and textiles, and discontinuous (short) fibers used as batts, blankets, or boards for insulation and filtration. Fiberglass can be formed into yarn much like wool or cotton, and woven into fabric which is sometimes used for draperies.

Fiberglass can be classified into specific applications such as Type A (alkali), which is resist to any chemical, Type E (electrical), used as electrical insulation tape, textiles and reinforcement. Type S (structural glass) which is known for good mechanical properties. Type T (thermal) usually used for thermal insulation purpose.

The basic raw materials for fiberglass products are a variety of natural minerals and manufactured chemicals such as silica sand, limestone, and soda ash. Silica sand is used as the glass former, and soda ash and limestone help primarily to lower the melting temperature. Other ingredients are used to improve certain properties, such as borax for chemical resistance.

Glass fiber or so call as fiberglass is the most commonly used fiber to reinforce thermoset and thermoplastic resins across a wide variety of applications and processes. Fiberglass consists of numerous fine strands of silica polymers which may, depending on the type, include alkali oxides, aluminium, boron or other trace molecules. Glass reinforcements in which added or molded with other materials, help improve the surface aspect as it allow a uniform impregnation (with resins) and are not subject to cracking, breaking or splitting. It has a greater specific resistance in such higher tensile strength compared to steel. This characteristic is the primary reason for the use of glass strand in the production of high performance composites.

There are various number of advantages of fiberglass such as high mechanical strength whereby glass filament has a greater specific resistance (tensile strength/volumetric mass) than steel. Table 2.2 summarize the general mechanical properties of fiber glass.

Table 2.2: The general mechanical properties of fiber glass

	E-glass	**R-glass**	**HS2, HS4**	**T-glass**	**S-1**	**S-2**
Tensile Strength Gpa	1.9 - 2.5	3.1-3.4	3.1-4.0	4.0-4.2	3.8-4.1	4.3-4.6
Tensile Modulus Gpa	69 -80	86-89	82-90	84	85-87	88-91