Faculty of Manufacturing Engineering

OPTIMIZATION OF INJECTION MOULDING PARAMETERS FOR RECYCLED HIGH DENSITY POLYETHYLENE

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OPTIMIZATION OF INJECTION MOULDING PARAMETERS FOR RECYCLED HIGH DENSITY POLYETHYLENE

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "Optimization of Injection Moulding Parameters for Recycled High Density Polyethylene" 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	:	....
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 Science in Manufacturing Engineering.

Signature	:	....
Supervisor Name	:	....
Date	:	....

DEDICATION

I would like to dedicate my thesis to my mother who always taught me to stay strong and believe in Allah s.w.t and my father for being my first teacher in my life.

ABSTRACT

Most plastics dispose very slowly in landfills, and these will not only occupy valuable space but will also generate toxic emissions and greenhouse gases such as carbon dioxide. It can remain in the environment for a long period of time, thereby causing problems to the environment and to the health of the society. The practical solution is to recycle and reuse the plastics that have already been used. Nearly all the plastic products that can be seen in our daily life, such as mobile phone housings, automobile bumpers, lunch boxes or bottles are produced by injection moulding. However, incorrect parameter settings in injection moulding will cause bad performance on the specimens such as lack of mechanical strength. Therefore, finding the optimized parameters is highly desirable. This research investigated the usability of recycled HDPE as a substitute for pure HDPE by determines their tensile and flexural strength. The parameters evaluated were melting temperature, injection pressure, holding pressure, holding time, cooling time and injection time. Design Expert 7.0.0 software was used for the screening process by Factorial method and melting temperature, injection pressure and holding time were found as significant parameters. These three parameters then were analysed and optimized by RSM analysis and four process models (tensile of p-HDPE, flexural of p-HDPE, tensile of r-HDPE and flexural of r-HDPE) are successfully developed and validated. The ANOVA suggested that melting temperature is the most significant parameter affecting the tensile and flexural strength of both materials and it was followed by injection pressure and holding time. The optimal result of tensile strength of p-HDPE (27.405 MPa), flexural strength of p-HDPE (21.744 MPa), tensile strength of r-HDPE (15.86 MPa) and flexural strength of r-HDPE (14.353) was obtained at the melting temperature of 240 ºC, injection pressure of 95 MPa and holding time of 30 s. This study also found that the comparison of tensile and flexural strength between p-HDPE and r-HDPE is 42.13% and 33.99% respectively. The specimens of r-HDPE were crushed and injected again by injection machine to produce the specimens. The specimens were tested and compared by the performance of r-HDPE where the reduction of tensile and flexural strength is 10.33% and 20.32% respectively. Some applications such toys, laboratory tubing and plastic pipe have been compared to these three materials based on their strength properties. The result shows the tensile and flexural strength of all materials in the range of the applications strength, and it automatically indicates that r-HDPE can be utilised as a substitutes of p-HDPE in some applications.

ABSTRAK

Kebanyakan plastik melupus sangat perlahan di tapak pelupusan, dan ia bukan sahaja akan menduduki ruang yang berharga malah akan menghasilkan toksik dan gas rumah hijau seperti karbon dioksida. Plastik boleh kekal di alam sekitar dalam tempoh masa yang panjang, sekaligus menyebabkan pencemaran dan kesihatan masyarakat terjejas. Penyelesaian praktikal adalah dengan mengitar dan mengguna semula plastik yang telah digunakan. Hampir semua produk plastik yang dapat dilihat dalam kehidupan seharian, seperti sarung telefon bimbit, bumper kereta, bekal makanan atau botol dihasilkan oleh pengacuan suntikan. Walau bagaimanapun, tetapan parameter yang tidak betul dalam pengacuan suntikan akan menyebabkan prestasi buruk pada spesimen seperti kekurangan kekuatan mekanikal. Oleh itu, mencari parameter yang optimum adalah sangat wajar. Kajian ini menyiasat kebolehgunaan bahan r-HDPE sebagai pengganti untuk p-HDPE dengan menentukan kekuatan tegangan dan lenturan. Parameter yang dinilai adalah suhu lebur, tekanan suntikan, tekanan memegang, tempoh memegang, tempoh penyejukan dan tempoh suntikan. Design Expert 7.0.0 telah digunakan untuk proses saringan dengan kaedah Factorial dan suhu lebur, tekanan suntikan dan tempoh memegang didapati sebagai parameter yang ketara. Ketiga-tiga parameter kemudian dianalisis dan dioptimumkan oleh RSM dan empat model proses (tegangan p-HDPE, lenturan p-HDPE, tegangan r-HDPE dan lenturan r-HDPE) berjaya diperoleh dan disahkan. ANOVA mencadangkan bahawa suhu lebur adalah parameter yang paling penting mempengaruhi kekuatan tegangan dan lenturan pada kedua-dua bahan diikuti oleh tekanan suntikan dan tempoh memegang. Hasil optimum kekuatan tegangan p-HDPE (27.405 MPa), kekuatan lenturan p-HDPE (21.744 MPa), kekuatan tegangan r-HDPE (15.86 MPa), kekuatan lenturan r-HDPE (14.353 MPa) telah diperolehi di suhu lebur 240 ºC, tekanan suntikan 95 MPa dan tempoh memegang 30 s. Kajian juga mendapati bahawa perbandingan antara kekuatan tegangan dan lenturan antara p-HDPE dan r-HDPE adalah 42.13 % dan 33.99 %. Spesimen r-HDPE kemudian dihancur dan disuntik semula oleh mesin suntikan untuk menhasilkan spesimen. Spesimen diuji dan dibandingkan dengan prestasi r-HDPE dimana pengurangan kekuatan tegangan dan lenturan adalah 10.33 % dan 20.32 %. Sesetengah aplikasi seperti alat permainan kanak-kanak, tiub makmal dan paip plastik telah dibandingkan dengan ketiga-tiga bahan berdasarkan sifat kekuatan mereka. Hasilnya menunjukkan kekuatan tegangan dan lenturan semua bahan berada di dalam julat kekuatan semua aplikasi tersebut, dan sekaligus menunjukkan bahawa r-HDPE boleh digunakan sebagai pengganti kepada p-HDPE.

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LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
ANOVA	-	Analysis of variance approach
ASTM	-	American Society for Testing and Materials
BBD	-	Box-Behnken Design
BPA	-	Bisphenol A
BS	-	British Standards
BS EN ISO	-	British, European and International Standards
CAD	-	Computer-aided design
CAE	-	Computer-aided engineering
CCD	-	Central Composite Design
DDT	-	Dichlorodiphenyltrichloroethane
DNA	-	Deoxyribonucleic acid
DOE	-	Design of Experiment
FEA	-	Finite element analysis
ICI	-	Imperial Chemical Industries
ISO	-	International Organization for Standardization
L/D	-	Ratio of length to diameter
LDPE	-	Low Density Polyethylene
MDPE	-	Medium Density Polyethylene

MSW	-	Municipal Solid Waste
NP	-	Nonylphenol
p-HDPE	-	pure High Density Polyethylene
PAHs	-	Polycyclic Aromatic Hydrocarbons
PBDEs	-	Polybrominated Diphenyl Ethers
PC	-	Polycarbonate
PCBs	-	Polychlorinated Biphenyls
PE	-	Polyethylene
PET	-	Polyethylene Terephthalate
phr	-	Parts per hundred rubber
PL	-	Polyesters
PLA	-	Polylactic Acid
PP	-	Polypropylene
PS	-	Polystyrene
PU	-	Polyurethanes
PVC	-	Polyvinyl Chloride
r-HDPE	-	recycled High Density Polyethylene
RSM	-	Response Surface Methodology
SAN	-	Styrene acrylonitrile
SEM	-	Scanning Electron Microscope
SI	-	International System of Units
UV	-	Ultraviolet

LIST OF SYMBOLS

$^{\circ}C$	-	Degree Celsius
%	-	Percentage
ε	-	Strain
ε_f	-	Strain at failure
σ	-	Stress
σ_f	-	Stress at failure
b	-	Width of tested beam
D	-	Midspan deflection
d	-	Depth of tested beam
E	-	Modulus
g	-	Gram
g/cm^2	-	Gram per centimetre square
g/cm^3	-	Gram per centimetre cube
H	-	Height
Kg	-	Kilogram
kJ/m^2	-	Kilojoule per square meter
KPa	-	Kilo Pascal
L	-	Length
L	-	Support span

m	-	Meter
m/s	-	Meter per second
mm	-	Millimeter
mm/s	-	Millimeter per second
MPa	-	Mega Pascal
N	-	Newton
P	-	Load at a given point on the load-deflection curve
r	-	Strain
W	-	Width

LIST OF PUBLICATIONS

Journal

Zuraimi, R., Sulaiman, M.A., Joseph, S.A.E., Mohamad, E. and Che Haron, C.H., 2015. Tool Life Performance of Coated Carbide Tool on Titanium Alloy Extra Low Insterstitials. *Jurnal Teknologi Science & Engineering*, 77 (1), pp. 85-93.