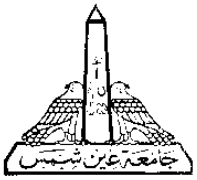

Ain Shams University

Faculty of Engineering

Design and Production Engineering

Effect of Injection Moulding on Fibre Morphology in Polymer Composites

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Mechanical Engineering

(Design and Production Engineering)

by

Menna Tullah Mohamed Adel Saleh El Sayed

Bachelor of Science in Mechanical Engineering

(Manufacturing Engineering Program)

Faculty of Engineering, Ain Shams University, 2012

Supervised By

Prof. Samy J. Ebeid

Associate Prof. Iman M. A. Taha

Cairo – (2016)

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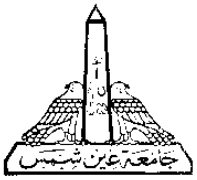
Supervising' Committee

Name and Affiliation	Signature
Prof.: Samy Jimmy Ebeid, ASU	…….
Assos. Prof.: Iman Mohamed Ahmed Taha, ASU	…….

Date:



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Examining Committee

Name and Affiliation	Signature
Prof.: Tarek Ahmed Fouad Khalifa	…….
Prof.: Mohamed Hazem Abdellatif	…….
Prof.: Samy Jimmy Ebeid	…….

Date:

Statement

This thesis is submitted as a partial fulfilment of Master of Science in Mechanical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Signature

Menna Tullah Mohamed Adel Saleh

Date: 14 August 2016

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Menna A. Saleh

Researcher Data

Name	: Menna Tullah Mohamed Adel Saleh El Sayed
Date of birth	: 01/05/1989
Place of birth	: Cairo, Egypt
Last academic degree	: Bachelor of Science
Field of specialization	: Manufacturing Engineering
University issued the degree	: Ain Shams University
Date of issued degree	: 2012
Current job	: Teaching Assistant

Thesis Summary

With increasing environmental concerns, natural fibres have moved to the focus of investigations in the field of polymer composites for various applications. Beside their relatively good specific properties and low cost, natural fibres are less hazardous in contrast to synthetic fibres. Further, thermoplastic matrices, especially high-density polyethylene (HDPE) has been used in combination with natural fibres, due to its relatively low processing temperatures. In this respect, injection moulding is the most commonly applied manufacturing process. However, prior to injection moulding, mixing of reinforcement fibre and matrix through twin screw extruders becomes an inevitable stage. The processing parameters during injection moulding, such as temperature, speed and pressure further play a vital role in determining the final properties of the composite material. Although several studies were concerned with the effect of injection processing parameters on the final mechanical properties, the correlations between morphology and mechanical properties for natural fibre composites are not well developed yet.

In this research, the correlation between both morphological and mechanical behaviours was investigated for different injection moulding parameters. The thesis is divided into three stages. At first stage, the selection for both materials and process parameters was carried out according to literature survey. Then sample preparation was conducted using both extrusion and injection moulding with different parameters. Finally, characterization of both morphological and mechanical properties was performed on composite material and correlation between them was studied.

HDPE was compounded with 10 wt.% flax fibres using twin screw extruder followed by sample preparation using injection moulding at different injection parameters which are; injection temperature (170, 180, 195, 210, 220) ^{o}C, injection speed (8, 50, 125) mm/s, and rotational screw speed (75, 185, 250) rpm.

In order to fully analyse the mechanical behaviour in terms of tensile and impact strength, the morphology of the composite, involving fibre orientation, fibre length, composite viscosity in addition to composite degree of crystallinity was investigated.

It can be observed that amongst the parameters under investigation, the injection temperature is the most predominant parameter affecting fibre and matrix morphology, and herewith the mechanical behaviour of the composites. Using higher injection temperatures associated with an increase in cooling rates did not allow the re-arrangement of polymer chains to form high crystalline structures and consequently led to a reduction in tensile strength. Further, the injection temperature had a significant effect on the weight average fibre length within the composite. Higher temperatures could be associated with longer reinforcement fibres due to the reduced viscosity of the matrix and the reduction in shear stresses causing fibre breakage during processing.

Whereas injection speed and screw rotational speed had minor effects on crystallinity, it can be clearly observed that their increase causes a scission of fibre length. As a result, the mechanical behaviour of composites processed at higher temperatures and speeds did not yield highest performance.

It is further to be noted, that an increase in injection temperature beyond 200 °C results in thermal degradation of the fibres, leading to a brownish discolouration of the samples, negatively affecting the mechanical properties. Based on the studied parameters, optimum processing conditions (yielding highest tensile strength of 22.4 MPa, and a 21% improvement with respect to the neat matrix) were observed at an injection temperature, speed, and screw speed of 180 °C, 8 mm/s, and 185 rpm, respectively.

Although a weak interfacial bond between fibre and matrix is associated with an increase in impact strength, the present study shows a reduction in toughness at higher injection temperatures and speeds, attributed to the excessive fibre degradation and the formation of voids under these conditions. Accordingly, highest impact strength was measured to be 7.91

kJ/m^2 for the composite prepared by applying 170 °C, 8 mm/s, and 75 rpm, respectively.

Keywords: Flax fibre, High Density Polyethylene (HDPE), Injection moulding, Crystallinity, Viscosity, Morphology, Mechanical properties.

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