Nigerian Research Journal of Engineering and Environmental Sciences 3(1) 2018 pp. 163-169

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

RJEES

Original Research Article

EFFECT OF BARREL TEMPERATURE ON THE MECHANICAL PROPERTIES OF INJECTION MOULDED POLYPROPYLENE-GRASS COMPOSITE

***Olodu, D.D. and Osarenmwinda, J.O.**

Department of Production Engineering, Faculty Engineering, University of Benin, PMB 1154, Benin City, Nigeria.
*dickson.olodu@eng.uniben.edu; joosarenmwinda@uniben.edu

ARTICLE INFORMATION

Article history:
Received 18 January, 2018
Revised 01 May, 2018
Accepted 02 May, 2018
Available online 30 June, 2018

Keywords:
Barrel temperature
Composite
Mechanical properties
Injection moulding
Polypropylene-grass composite

ABSTRACT

This study investigated the effect of barrel temperature on the mechanical properties of injection moulded polypropylene-grass composite. The polypropylene and grass were mixed together to form a homogenous mixture with various percentage composition by volume. A two-screw plunger injection moulding machine with maximum clamping force of 70 tons and shot capacity of 3oz was used to produce the composite at various barrel temperature ranging from 210°C to 310°C. The produced composites were evaluated for their mechanical properties which included tensile strength, proof stress, percentage elongation and flexural strength. The maximum tensile strength for the produced PP-Grass composites was determined as 35.11N/mm^2 at a barrel temperature of 290°C, while the proof stress was 36N/mm^2 at a barrel temperature of 260°C, percentage elongation was 125% at a barrel temperature of 290°C and flexural strength was 42×10^{2}N/mm^2 at a barrel temperature of 310°C. The results obtained shows that barrel temperature of the injection moulding machine contribute significantly to the mechanical properties of the produced composites.

1. INTRODUCTION

The utilization of process control and process monitoring are rarely fully implemented for the production of injection moulded products (Zhou and Mallick, 2005). This may be due to a poor scientific understanding of the moulding process based on the complexities of the process containing multiple variables affecting the final part. A qualitative analysis of the influence of barrel temperature on the mechanical properties of a moulded part will be helpful in gaining better insight into the presently used processing methods (Osarenmwinda and Olodu, 2015).

In the work of Mosle *et al.* (2009) on sawdust-PET composite using the hot press compression moulding, the tensile strength was 38.32N/mm^2 at melt temperature of 210^{o}C, the proof stress was 34.22N/mm^2 at melt temperature of 210^{o}C, the percentage elongation was 182% at melt temperature of 210^{o}C and the flexural strength was 40.22×10^{2}N/mm^2 at melt temperature of 170^{o}C. Zhou and Mallick (2005); Njoku and Obikwelu (2008); examined the effect of reinforcement combination on the mechanical strength of glass reinforced plastic using compression moulding. A Proof stress of 29.52N/mm^2 at a barrel temperature of 232^{o}C was obtained. Shubbar (2013) investigated the effect of temperature on the properties of high density polyethylene crates, and short term mechanical properties was observed from tensile testing. The results indicated that environmental conditions influenced the moulded part quality to varying degrees and that the environmental conditions should be controlled for applications with tight tolerances. Ranjusha et al (2012) investigated the flexural strength of polypropylene/ High Density Polypropylene/clay/Glass Fiber Composites. They obtained a value of 32.25×10^{2}N/mm^2 at barrel temperature of 190^{o}C for flexural strength. They concluded that the value obtained was probably high due to the presence of clay and glass fibre in the Polypropylene material. Su et al (2010) studied the effect of barrel (melt) temperature on the morphology, thermal behavior and the resultant mechanical properties of the injection moulded bars. They found that the mechanical properties, especially the tensile ductility and the impact strength, were greatly affected by the processing temperature. The samples obtained at low temperatures had the highest elongation at break and impact strength, while those moulded at high temperature had the poorest toughness. Osarenmwinda and Olodu (2015) also investigated the effect of barrel temperature on mechanical properties of injection moulded PP (polypropylene) plastics. From their result, a tensile strength of 21.67N/mm^2 was obtained for PP at a barrel temperature of 270^{o}C. A proof stress of 20.63N/mm^2 was obtained for PP at a barrel temperature of 250^{o}C. Percentage elongation of 172% was obtained for PP at a barrel temperature of 270^{o}C. A flexural strength of 29.03×10^{2}N/mm^2 was obtained for PP at a barrel temperature of 280^{o}C. These studies have shown that barrel temperature is the key to successful moulding because one basic requirement of an automatic injection moulding process is that the moulded parts must be produced automatically without the need for secondary finishing operations.

This study seeks to produce a new composite using injection moulding machine that will overcome the effect of barrel temperature in polymeric industries**.** The focus of this research work was therefore to study the effect of barrel temperature on the mechanical properties injection moulded polypropylene-grass composite.

2. MATERIALS AND METHODS

2.1. Equipment and Tools

A two stage-screw plunger injection machine with a toggle clamp attached to the injection end was used. The mould was made of Silicon – killed forging quality steel AISI type H140 treated to 252 –302 Brine 11. The mould was obtained from Adig Plastic Company, Lagos State, Nigeria. Monsanto tensometer, Type 'W' Serial No. 8991 was used for tensile testing experiment.

2.2. Materials

The grass used for this study was giunea gra**ss** (*Panicum maximum*), and was obtained from Benin City, Edo State, Nigeria**.** The Plastic material used for this study was Polypropylene (PP) and was obtained in powder form from Adig Plastic Company Limited in Lagos State, Nigeria.

2.3. Preparation of Grass

The harvested grass was washed and soaked with dilute sodium hydroxide (NaOH) of concentration 0.10mol/dm^3 for 6 hours to ensure effective bonding between the grass and the plastic (Polypropylene) material. The grasses were first air dried in the sun and later transferred to an oven and dried at 105^{o}C. It was continuously monitored until moisture content of about 4$\pm$ 0.2% was obtained (Adeyemi and Adeyemi, 2016). The grass was ground to granules using crushing machine. The ground grass was screened to a particle size of 300µm diameters using vibrating sieve machine.

2.4. Production of Composites

Polypropylene (PP) was mixed with ground grass in the proportion shown in Table 1 (Chunping *et al.,* 2007; Osarenmwinda and Nwachukwu, 2010; Osarenmwinda and Olodu, 2015; Olodu, 2017). The Polypropylene-grass mix was blended in a cylindrical container until a homogenous mixture was obtained. The homogenous mixture of the composite was fed into the hopper of the injection moulding machine and was produced at various barrel temperature ranging from 210ºC to 310ºC.

Table 1: Composition of the Produced HDPE-Grass Composite (Chunping et al., 2007; Osarenmwinda and Nwachukwu, 2010; Osarenmwinda and Olodu, 2015; Olodu, 2017)

SN	Percentage by volume of Plastic (HDPE)	Percentage by volume of Grass
1	80	20
2	70	30
3	60	40
4	50	50
5	40	60
6	30	70
7	20	80

2.5. Evaluation of Composite Mechanical Strength

The produced composites were evaluated for mechanical strength (tensile strength, proof stress, percentage elongation and flexural strength) using Equations 1 to 4.

$$\text{Tensile strength} = \frac{\text{Maximum Load}}{\text{Original Cross - Sectional Area}} \quad (1)$$

The original cross-sectional area of the specimen is 18.9mm^2.

$$\text{Proof stress} = \frac{\text{Force at yield}}{\text{Cross - Sectional Area}} \quad (2)$$

The Cross-sectional area of specimen =18.9 mm^2

$$\text{Hence, proof stress} = \frac{\text{Force at yield}}{18.9} \text{N}/mm^2$$

$$\text{Percentage (\%) Elongation} = \frac{\text{Extension}}{\text{Gauge Length}} \text{ x } 100\% \quad (3)$$

Flexural Strength:

$$(\text{EI}) = \frac{\text{P}L^3}{48\text{y}} \quad (4)$$

Where y is the deflection in mm, P= Load, L= Length of test specimen

3. RESULTS AND DISCUSSION

3.1. Shot and Clamping Force

The required shot, clamping force and the required amount of material per shot was determined to be 9.588cm^3/shot, 12 tons and 8.64 grams/shot respectively (Mosle et al, 2009; Osarenmwinda and Olodu, 2015; Olodu, 2017).

3.2. Effect of Barrel Temperature on Composites Properties

Figures 1 to 4 shows the effects of barrel temperature on tensile strength, proof stress, percentage elongation and flexural strength of the composites respectively.

3.2.1. Effect of barrel temperature on tensile strength

The tensile strength increased as the barrel temperature increased in each composition until a maximum tensile strength of 35.11N/mm^2 was attained for PP-grass composite at a barrel temperature of 290^{o}C after which the tensile strength began to decrease to a value of 34.75N/mm^2 at a barrel temperature of 300^{o}C (Figure 1). This is due to chain scissioning (molecular breakdown), reduction in molecular weight and melt viscosity; hence decrease in crystallization and orientation occurring with processing temperatures above 290^{o}C for PP-grass composite. Moreover, it was observed that a mix ratio of 60% by volume polypropylene and 40% volume of grasss produced the maximum tensile strength for the composite (Figure 1). The value obtained in this research was slightly higher from the results obtained by Osarenmwinda and Olodu (2015) with a tensile strength of 21.67N/mm^2 obtained at barrel temperature of 270^{O}C for polypropylene (PP). It may have been slightly higher due to addition of grass to polypropylene in the produced composite. In the work of Mosle et al (2009) on sawdust-PET composite using the hot press compression moulding, the tensile strength was 38.32N/mm^2 at melt temperature of 210^{o}C and was found to compare favourably with the value obtained in this study.

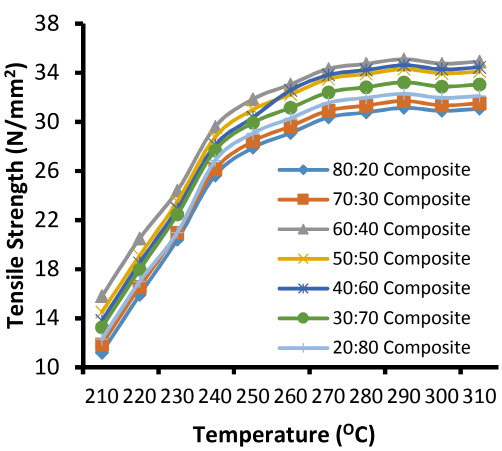

Figure 1: Effect of barrel temperature on tensile strength for PP-Grass composites

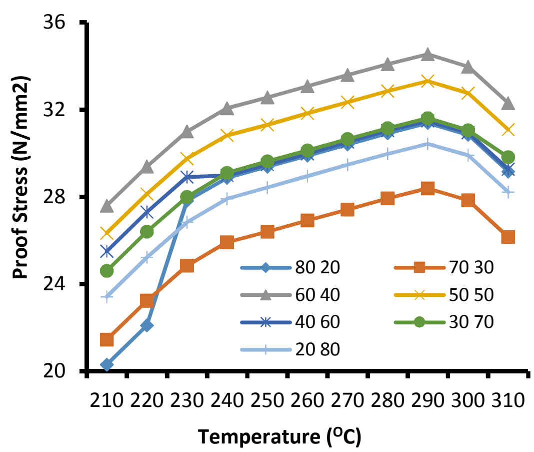

Figure 2: Effect of barrel temperature on proof stress for PP-Grass composites

3.2.2. Effect of barrel temperature on proof stress

The maximum proof stress for PP-grass composite was 36.00N/mm^2 at a barrel temperature of 260^{o}C before decreasing (Figure 2). Moreover, it was observed that a mix ratio of 50% by volume polypropylene and 50%

volume of grasss produced the maximum proof stress for the composite (Figure 2). The value of the proof stress in this study was found to compare favourably with value of 29.52N/mm^2 at a barrel temperature of 232^{o}C obtained by Zhou and Mallick (2005) and 25N/mm^2 by Sahin and Yayla (2005) for Talc-filled polypropylene random copolymer respectively. The proof stress for all the polypropylene-grass composite material experienced a steady decrease after attaininig its maximum value as the barrel temperature increased. This may be due to the fact that increase in the barrel temperature increases crystallinity and lowers viscosity, shear stress and orientation. This also permits greater relaxation ultimately leading to decrease in the proof stress of the moulded polypropylene-grass product. The value obtained in this study was slightly higher than the results obtained by Osarenmwinda and Olodu (2015) with a proof stress of 20.63N/mm^2 obtained at barrel temperature of 250^{o}C for PP. It may have been slightly higher due to addition of grass to plastic in the produced composite. In the work of Mosle et al (2009) on sawdust-PET composite using the hot press compression moulding, the proof stress was 34.22N/mm^2 at melt temperature of 210^{o}C and was found to compare favourably with the value obtained in this study.

3.2.3. Effect of barrel temperature on percentage elongation

It was observed that the percentage elongation increased as the barrel temperature increased until a maximum percentage elongation of 125% was attained for PP-grass composite at barrel temperature of 290^{o}C after which the percentage elongation began to decrease (Figure 3). The sudden decrease in percentage elongation is due to molecular breakdown as thermal degradation began to set in above 290^{o}C. Moreover, it was observed that a mix ratio of 60% by volume of polypropylene and 40% volume of grasss produced the maximum percentage elongation for the composite (Figure 3). This value was found to compare favourably with value of 165% at a barrel temperature of 260^{o}C obtained by Shubbar (2013) for High Density Polyethylene Crates. The value obtained in this study was lower than the results obtained by Osarenmwinda and Olodu (2015) with a percentage elongation of 172% obtained at barrel temperature of 270^{o}C for PP. It may have been slightly lower due to addition of grass to plastic in the produced composite. In the work of Mosle et al (2009) on sawdust-PET composite using the hot press compression moulding, the percentage elongation obtained was 182% at melt temperature of 210^{o}C and was found to compare favourably with this study.

3.2.4. Effect of barrel temperature on flexural strength

The maximum flexural strength for PP-grass composite was 42×10^{2}N/mm^2 at barrel temperature of 310^{o}C (Figure 4). Moreover, it was observed that a mix ratio of 70% by volume polypropylene and 30% volume of grasss produced the maximum flexural strength for the composite (Figure 4). This is slightly lower than the value of 43.25×10^{2}N/mm^2 obtained by Ranjusha et al (2012) at barrel temperature of 190^{o}C for polypropylene/ High Density Polypropylene/clay/Glass Fiber Composites probably due to the presence of clay and glass fibre in the Polypropylene material. This value was found to compare favourably with a value of 42.80×10^{2}N/mm^2 at a barrel temperature of 140^{o}C obtained by Shubbar (2013) for High Density Polyethylene Crates. The value obtained in this study was higher than the results obtained by Osarenmwinda and Olodu (2015) with a flexural strength of 29.03×10^{2}N/mm^2 obtained at barrel temperature of 280^{o}C for PP. It may have been slightly higher due to addition of grass to polypropylene in the produced composite. In the work of Mosle et al (2009) on sawdust-PET composite using the hot press compression moulding, the flexural strength was 40.22×10^{2}N/mm^2 at melt temperature of 170^{o}C and was found to compare favourably with the value obtained in this study.

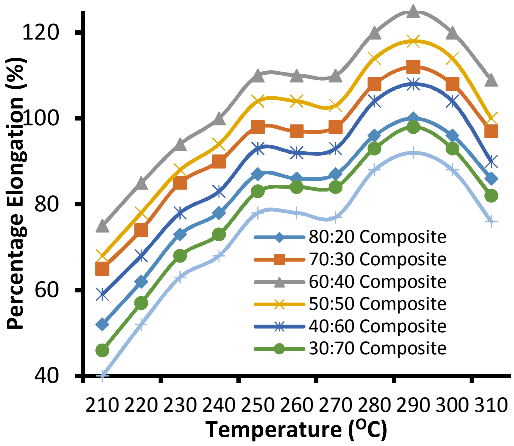

Figure 3: Effect of barrel temperature on percentage elongation for PP-Grass composites

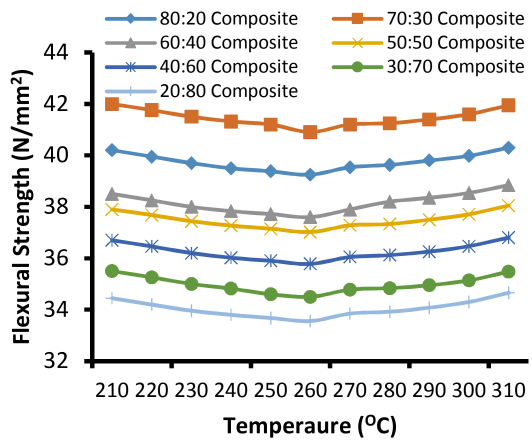

Figure 4: Effect of barrel temperature on flexural strength for PP-Grass composites

4. CONCLUSION

The results obtained shows that maximum tensile strength, proof stress, percentage elongation and flexural strength for PP-Grass composite were 35.11N/mm^2, 36.00N/mm^2, 125% and 42×10^{2}N/mm^2 at barrel temperature of 290^{o}C, 260^{o}C, 290^{o}C and 210^{o}C respectively. It is hopeful that the development of this new material (PP-grass composite) will lead to economic growth of the country and will find application both for industrial and domestic use. The developed material and the study of the effect of barrel temperature on the mechanical properties of injection moulded polypropylene-grass composite will also be useful to researcher, industrialist and small-scale manufacturer to ease the production of polypropylene-grass composite.

5. ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and contributions of Adig Plastic Company and the staff of Department of Production Engineering, University of Benin, Benin City toward the success of this research.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Adeyemi, S.O. and M.B Adeyemi, (2016). Temperature Effect on Extrusion Moulded Plastic. *International Journal of Materials and Product Technology,* 5(6), pp. 300-311

Chunping, D., Changing Y. and Cheng Z, (2007). Theoretical Modeling of Bonding Characteristics and Performance of Wood Composites. *Journal of wood and fiber science*, 39, pp. 48-55.

Mosle, H. G., Bruller, O.S. and Dick, H. (2009). Influence of the Geometry and Processing Parameters on the Mechanical Properties of Injection Moulded Plastic. *38th Annual Technical Conference New York Hilton, Published by SPE.*

Njoku, R.E. and Obikwelu, D.O. (2008). Swelling Characteristics and Tensile Properties of Natural Fibre Reinforced Plastic in Solvents. *Nigeria Journal of Technology, 27(2),* pp. 58-63.

Olodu D.D. (2017). Modelling and Development of Injection Moulded Plastic-Grass Composites. *PhD Thesis, Department of Production Engineering, Faculty of Engineering, University of Benin, Nigeria*

Osarenmwinda J.O, Nwachukwu J.C. (2010). Development of Composite Material from Agricultural Waste. *International Journal of Engineering Research in Africa*, 3, pp. *42-48.*

Osaremwinda, J. O. and Olodu, D.D, (2015). Effects of Barrel Temperature on the Mechanical Properties of injection Moulded Product. *Nigeria Journal of Technology*, *34(2)*, pp 292-296.

Ranjusha J.P, Anjana R. and George K.E. (2012). Effects of Moulding Temperature on the Properties of Polypropylene/High density Polypropylene /Clay/Glass Fibre Composites. *International Journal of Engineering and Applications, 2(5), pp922-926.*

Sahin, S. and Yayla, P. (2005). Effects of processing parameters on the mechanical properties of polypropylene random copolymer. Polymer testing, 24(8), pp. 1012-1021.

Shubbar, S.D. (2013). Injection Temperature Effects on the Properties of High Density Polyethylene Crates. *Journal of Engineering, 19(6),* pp. 754-763

Zhou, Y. and Mallick, P.K. (2005). Effects of Melt temperature and Hold Pressure on the Tensile and Fatigue Properties of an injection Molded Tac-Filled Polypropylene. *Polymer Engineering Science*, *45*, pp. 755-763.