IMPACT TEST ANALYSIS OF NATURAL FIBRE REINFORCED POLYMER COMPOSITES FABRICATED WITH BAST FIBRES FOR INDUSTRIAL /HOUSEHOLD APPLICATIONS

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ABSTRACT: The Charpy impact test measures the amount of energy absorbed by a standard notched specimen while breaking under an impact load. The test consist of striking a suitable specimen with a hammer on a pendulum arm while the specimen is held securely at each end. Composites are judicious combination of two or more materials that produces aggregate properties that are different from those of its constituents. Composites are hybrid materials made of a polymer resin reinforced by fibres, combining the high mechanical and physical properties of the fibres and the appearance, bonding and physical properties of the polymers. This work studies the impact strength for given range of temperature (210° – 180°) force (5– 8KN and time (8-15mins) for six natural fibres reinforced with polypropylene matrix base. The bast fibres include viscose, Rayon, Lyocell, Linen, Jute and Hemp. The results show for Rayon a maximum impact strength of 32.3144KJ/m² at a force of 3KN, time of 10mins and a temperature of 200°. Viscose, a maximum impact strength of 30.7716KJ/M² at a temperature of 180°, time of 15mins and force of 5KN. Lyocell had a maximum impact strength of 29.3869KN/M² for an elapsed time of 10mins, impact force of 3KN and a temperature of 200°. Linen had a maximum strength of 35.8735KJ/m² at an elapsed time of 10mins, impact force of 3KN and a temperature of 200°. Jute had a maximum strength of 13.2075KJ/m² at an elapsed time of 8mins, impact force of 3KN and a temperature of 210°. Hemp had a strength of 12.7050KJ/m² at an elapsed time of 10mins, impact force of 3KN and a temperature of 200°.

KEYWORDS: Charpy impact test, hydrophilic fibre, hydrophobic polymer, fiber–matrix com mingling, Bio-sandwich composite, lignocellulosic fiber.

Date of Submission: 23-07-2023
Date of acceptance: 26-07-2023

I. INTRODUCTION

Natural fibres such as hemp, kenaf, flax and ramie can be used successfully in polymer composite components in order to realize reduced weight and cost. These fibre are renewable, recyclable, biodegradable, nonabrasive and nontoxic to industrial and household equipment and machinery Anders, 2006, and could be incinerated at the end of their life cycle for energy recovery as they possess a good amount of calorific content Ranganathan, 2015. They are also very safe during handling, processing and industrial/ house utilization. The distinctive properties of natural fibre reinforced polymer composites are improved tensile, flexural, creep rate.
greater ductility, greater resistance to cracking and hence improved impact strength Ikezue, 2016 as well as toughness and percent elongation. By changing the direction of the fibres in the resin matrix, the material properties can be tailored to the external load and industrial applications. In order to optimize the applications in construction multiple adjusted layers (Laminae) can be used to form a laminate Dong et al., 2020. By joining this, the poor capabilities and drawbacks of the individual components of the composite disappear. Natural fibers are generally lignocellosic in nature consisting of helically wound cellulose micro fibrils in a matrix of lignin and hemicelluloses. The mechanical and physical properties of a natural fibre reinforced composite depend on many parameters such as fibre strength, modulus, fibre length and orientation (Dhakal et al., 2018). In addition to the fibre matrix interfacial bond strength, a strong fibre matrix interface bond is critical for high mechanical and physical properties of the composites. A good interfacial bond is required for effective stress transfer from matrix to the fibre where by maximum utilization of the fibre length in the composite is achieved. Modification to the fibre during mercerization also improves resistance to moisture induced degradation of the interface and the composite properties (Arraiga, 2010). The use of natural fibres as industrial/household components improves environmental sustainability of the parts being constructed especially the automotive, aerospace and building / construction industry. The mechanical and physical properties of natural fibres depend mainly on the nature of the plant, locality in which it is grown, age of the plant, and the extraction method utilized Anders, 2003. The physical properties of natural fibres were mainly determined by their chemical and physical composition such as fibre structures, cellulose content, and angle of fibrils, cross-section and the degree of polymerization (Slapnik, 2022). Natural fibres could be classified as (1) animal fibres (sheep's wool, horse hairs, goat hair, bird feathers), (2) mineral fibres (metal, ceramic, asbestos), (3) plant or vegetables (seed fibre, cotton, kapok, leaf fibres (from plant leaves) sisal, agave, henequen, skin or bast fibres (from the bast or skin surrounding the stem) i.e. flax, Jute, banana, hemp, soybeans, fruit fibres (coconut) stalk fibre (from the stalks of plant) such as straws of wheat, rice, barley, bamboo and grass.

Natural fiber composites find widespread applications in the building and construction industry. (a) Panels for partitions and false ceiling window and door frames. (b) storage devices i.e. post boxes, grain silos, storage tanks, bio-glass contains (c) furniture i.e. chairs, tables, shower, bath units, swimming pools (d) electrical devices i.e. electrical appliances, cables, pipes (e) transportation sector i.e. facia panels, car bumpers, automobile interiors, rail interiors, aerospace application, marine or ship anchors.

The materials used in this work include the six material fibres i.e. Viscose, Jute, Rayon, Linen, Lyocell and Hemp. The climate chamber, laser cutter, the charpy impact test machine, polypropylene granules, desiccator, load cell/ sample striker gauge. The polypropylene resin was used to prepare composite sheets for each of the natural fibre as bio-sandwich laminates and subjected to varying degrees of temperature (180°C, 190°C, 200°C, 210°C) impact force (3KN, 4KN, 5KN) and elapsed time of 8mins, 10mins, 15mins) and cooled in a climate chamber at a temperature of 23°C and humidity of 53% for 24hours. A compression moulding procedure was used to prepare the composite laminates and cut into dimension 70mm x 70mm according to ISO test standards. The specimens were placed in the charpy impact tester and the amount of energy absorbed, were recorded. The mean and standard deviation for each specimen were also recorded.

II. MATERIAL AND METHODS

The materials used in this work include the six material fibres i.e. Viscose, Jute, Rayon, Linen, Lyocell and Hemp. The climate chamber, laser cutter, the charpy impact test machine, polypropylene granules, desiccator, load cell/ sample striker gauge. The polypropylene resin was used to prepare composite sheets for each of the natural fibre as bio-sandwich laminates and subjected to varying degrees of temperature (180°C, 190°C, 200°C, 210°C) impact force (3KN, 4KN, 5KN) and elapsed time of 8mins, 10mins, 15mins) and cooled in a climate chamber at a temperature of 23°C and humidity of 53% for 24hours. A compression moulding procedure was used to prepare the composite laminates and cut into dimension 70mm x 70mm according to ISO test standards. The specimens were placed in the charpy impact tester and the amount of energy absorbed, were recorded. The mean and standard deviation for each specimen were also recorded.
III. RESULTS AND DISCUSSION

A. RESULTS

Fig. 1: Temperature and force (pressure) interaction with impact strength

Fig. 2: Temperature and time interaction with impact strength
Fig. 3: Force (Pressure) and time interaction with impact strength

Fig. 4: Force (Pressure) and temperature interaction with impact strength
Fig.5: Time and Temperature interaction with impact strength

Fig.6: Time and force (Pressure) interaction with impact strength
Fig. 7: Temperature and Force (Pressure) interaction with impact strength

Fig. 8: Temperature and time interaction with impact strength
Fig.9: Force (Pressure) and time interaction with impact strength

Fig.10: Force (Pressure) and Temperature interaction with impact strength
Fig. 11: Time and Temperature interaction with impact strength

Fig. 12: Time and Force (Pressure) interaction with impact strength
Fig. 13: Temperature and Force (Pressure) interaction with impact strength

Fig. 14: Temperature and Time interaction with impact strength
Fig. 15: Force (Pressure) and Time interaction with impact strength

Fig. 16: Force (Pressure) and Temperature interaction with impact strength
Fig. 17: Time and Temperature interaction with impact strength

Fig. 18: Time and Force (Pressure) interaction with impact strength
B. DISCUSSION OF RESULTS

The experimental data set for each of the natural fibres reinforced polymer composite were statistically modeled to obtain the variation between impact strength and the primary variables ie force (pressure), time and temperature for the viscose fibre the empirical relationship is

\[
\text{Impact strength} = 108.4254 - 0.4441 \times \text{temp} - 14.1078 \times \text{force} + 4.1699 \times \text{time} \quad (1)
\]

The response surface methodology plots were shown in Fig 1.0 for the variation of temperature and force with impact strength. The force axis show significant decrease in strength as force increase while temperature axis show a slight decrease in impact strength. Fig 2.0 shows a variation between temperature and time as factors with impact strength. The time axis shows a significant increase in impact strength while the temperature axis show no significant change in impact strength. Fig 3.0 also shows a variation of force and time as factors with impact strength. The time axis show significant increase in impact strength as time increase while the temperature axis shows little decrease in impact strength as then temperature increase.

For the Rayon fibres the empirical relationship is given as:

\[
\text{impact strength} = 349.6015 - 1.3852 \times \text{Temp} - 24.5845 \times \text{force} + 4.6938 \times \text{time} \quad (2)
\]

The RSM plot is shown in Fig 4.0 for the variation of force (pressure) and temperature as factors with impact strength. The temperature axis shows significant decrease in impact strength as temperature increases while the force axis shows a significant decrease in impact strength as the force decreases. Fig 5.0 shows a variation of time and temperature as factors with impact strength. The temperature axis shows a significant decrease in impact strength as the temperature increases while time axis shows a significant increase in impact strength as the time increases. Time varies directly while temperature varies inversely with impact strength. Fig 6.0 shows a variation of the time and force (pressure) as factors with impact strength as time axis shows significant increase in impact strength as time increases while force axis shows significant decrease in impact strength as the force (pressure) increases. Time varies directly while force varies inversely with impact strength.

For the lyocell natural fibre the empirical relationship is given in equation 3 as follows:

\[
\text{Impact strength} = 342.6189 - 1.2964 \times \text{temp} - 20.2983 \times \text{force} + 0.1624 \times \text{time} \quad (3)
\]

The RSM plot is shown in Fig 7.0 for variation of temperature and force as factors with impact strength. The temperature axis shows a significant decrease in impact strength as temperature increases while the force axis shows significant decrease in impact strength as the force increases. Both of these vary inversely with impact strength Fig 8.0 shows a variation of temperature and time as factors with impact strength. The temperature axis shows significant decrease in impact strength as time increases (inverse variation) while time axis shows no significant change in impact strength. Fig 9.0 shows the variation of force and time as factors with impact strength. The force axis shows significant decrease in impact strength as time increases while time axis shows no significant change in impact strength.

For the linen natural fibre, the empirical model is given as

\[
\text{impact strength} = 442.7189 - 1.6344 \times \text{temp} - 38.1909 \times \text{force} + 3.293 \times \text{time}. \quad (4)
\]

The RSM plot is shown Fig 10.0 and shows a variation of force and temperature as factors with impact strength. The temperature axis shows a significant decrease in impact strength as temperature increases while the force axis shows a more significant decrease in impact strength as the force is increasing (inverse relationship) Fig 11.0 shows variation of time and temperature as factors with impact strength. The temperature axis shows significant decrease in impact strength as temperature increases (inverse relationship) while the time axis shows a significant increase in impact strength as time increases (direct variation) Fig 12.0 shows the variation of time and force as factors with impact strength. The time axis shows significant increase
in impact strength as time increase while the force axis shows a more significant decrease in impact strength as the force increases (inverse variation).

For the Jute natural fibre the derived empirical model is given as

\[
\text{impact strength} = 136.9369 - 0.4938 \times \text{temp} - 4.3409 \times \text{force} - 1.4319 \times \text{time}. \quad (5)
\]

The RSM plot is shown in Fig 13 as a variation of temperature and force as factors with impact strength. The temperature axis shows significant decrease in impact strength as temperature increase, thus varies inversely with impact strength. The force axis shows no significant change in impact strength. Fig 14.0 shows variation of temperature and time as factors with the impact strength. The temperature axis shows significant decrease in impact strength as the temperature increase while time axis shows little change in impact strength and varies inversely with strength. Fig 15.0 shows the variation of force and time as factors with impact strength. The force axis shows little decrease in impact strength as force increases (inverse variation with impact strength) while time axis shows little change in impact strength and thus varies inversely with impact strength.

For the Hemp natural fibre the empirical model is given as

\[
\text{impact strength} = -63.6162 + 0.2730 \times \text{temp} - 0.8893 \times \text{force} + 2.1476 \times \text{time} \quad (6)
\]

The RSM plot is given in fig 16.0 and shows variation of the force and temperature as factors with impact strength. The force (pressure) axis shows little decrease in impact strength as force increases (inverse variation with impact strength) while temperature axis shows relatively more significant change in impact strength and varies directly with impact strength. Fig 17.0 shows variation of time and temperature as factors with impact strength. The time axis shows significant increase in impact strength as time increases (direct variation) while temperature axis shows relatively no significant change in impact strength but varies directly with the impact strength. Fig 18.0 shows variation of time and force as factors with impact strength. The time axis shows significant increase in impact strength as time increases (direct variation) while the force (pressure) axis shows relatively no significant change in impact strength but varies inversely with impact strength.

**IV. CONCLUSION AND RECOMMENDATION**

The result of the impact test for each of the six natural fibres for the reinforcement of the polypropylene matrix shows that viscose fibre had a maximum impact strength of 30.7716KJ/m² at a temperature of 180°C, pressure (force) of 5KN and elapsed time of 15mins, Rayon fibre had a maximum strength of 32.3144KJ/m² at a temperature of 200°C force (pressure) of 3KN and an elapsed time of 10mins. Lyocell fibre had a maximum impact strength of 29.3889KJ/m² at a temperature of 200°C, Pressure (force) of 3KN at an elapsed time of 10mins. Linen fibre had a maximum strength of 35.8735 at a temperature of 200°C for an applied force of 3KN at an elapsed time of 10mins. Jute had a maximum impact strength of 13.2075KJ/m² at a temperature of 210°C for a force (pressure) at an elapsed time of 8mins. Hemp fibre had a maximum impact strength of 12.7050KJ/m² at a temperature of 200°C for a force (pressure) of 3KN at an elapsed time of 10mins. The scenario shows that the highest impact strength is obtained from linen fibre followed by Rayon and then Viscose, Lyocell, Hemp and Jute in that sequence. The impact strength characteristics for the three process variables ie time, temperature and pressure(force) could be determined for other natural fibres not studied in this work which include Ramie, Henequen, Sisal and Kapokor cotton.

The Optimal Process parameters occurred at a temperature of 200°C elapsed time 10mins and an impact force of 3KN, This is of course the best process of condition for the Composite Fabrications and testing.
REFERENCES


