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Effect of Processing Parameter of Compression Molding Process on the Mechanical Properties of Polymer Matrix Composite Using E-glass Fiber

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Abstract

This research investigates the effect of processing parameters of the compression molding process, such as temperature, pressure, and curing time, on the mechanical properties of polymer matrix composites (PMCs). The application of PMCs has been widely increased in automobiles, aerospace, chemical plants, and marine engineering due to their excellent properties, lightweight, high strength-to-weight ratio, corrosion resistance, etc. The main objective of this investigation is to use the Hand Lay-up method to prepare Sheet Molding Compound (SMC) using polymer composite material. The characterization of mechanical properties such as tensile strength, flexural strength, Izod impact strength, and hardness was conducted as per the ASTM standard. Polyester resin is used as matrix material, and E-glass chopped roving is used as reinforced material. The SMC is a combination of 30% E-glass fiber and 70% matrix material. In this research work, the effect of processing parameters on the mechanical properties of PMC was analyzed. The test results obtained show that there is a good impact of processing parameters on the mechanical properties of SMC.

Keywords

Polymer composite, Compression molding, E-glass fiber, Hand Lay-up method

Introduction

Composite materials are one of the best alternatives to metal in industries such as aerospace, automotive, marine, and chemical. It is the combination of base material matrix and reinforcement material. PMCs materials have attracted-many industries due to their excellent properties such as lightweight, high stiffness-to-weight ratio, high strength, heat resistance, corrosion resistance, and flame retardant [1]. In PMC, E-glass fiber-reinforced materials were commonly used in all engineering applications [2]. Rajaee et al. [1] carried out research work on the microstructure and mechanical properties of glass fiber-reinforced PMCs. A study was conducted on the chopped glass fiber bulk molding compound process. Then, the molding material was further processed by compression molding. The mechanical properties of tensile strength, flexural strength, and impact strength were studied. In this research work, the effect of the processing parameter of compression molding on the SMC was studied.

Experimental Methodology

Materials

Resin: Unsaturated polyester isophthalic resin was selected as the main constituent of the polymer matrix material. Reinforcing Element: The chopped roving of E-glass fiber length ½ (half an inch) with random orientation used. Filler:

Calcium carbonate is used as filler material in PMC. Mold release agent: Zinc stearates are used as mold release agents. Catalyst: Principal catalysts of organic peroxide were used, which initiates the copolymerization reactions.

Mixing of matrix material unsaturated polyester resin and filler materials

All the constituents of raw material of SMC (PMC) were mixed in a mechanical mixer. The complete mixture should be stirred for 20 min between 750 - 800 rpm. After the mixture is ready, ensure the viscosity of the paste is as per the requirement.

Fabrication of SMC (PMC) using the Hand Lay-up method

The hand lay-up process is used for the preparation of polymer composite SMC. In the laboratory, for experimentation purposes, we used a manual hand lay-up technique [3]. The reinforcement material chopped E-glass fiber rovings of the length of 1/2" (half an inch) used to prepare composite. First, apply the matrix material on the Teflon sheet and put the chopped glass fiber roving randomly on the hand lay-up bed specially made for this experimentation. After that, put again the upper layer of matrix material on randomly oriented glass fiber. Apply the pressure on the composite sheet uniformly to assure the wetting of the glass fiber.

Preparation of mechanical testing specimen using a compression molding technique

After the maturation of SMC (PMC), the next step is molding the compound by using any mechanical molding process. The compression molding process is primarily used with randomly oriented short fibers-reinforced thermosetting polymers. The compression molding machine is operated with the help of hydraulic pressure, a set of punch and die cavities, an ejection system, etc. Gombos et al. [4] investigated and studied the compression molding processing parameter. They prepared 4 x 230 x 230 mm composite panels in a compression molding machine. After molding, the component was allowed to cool at room temperature. The component testing was done by using a flexure test (three-point bending test).

Characterization of mechanical properties

The International standard and ASTM standard, which suggest the guidelines for the testing of polymer composite material of compression molded samples, were conducted.

Characterization of tensile test

The tensile test was conducted at a Universal Testing Machine of 100 KN capacity. The molded specimen samples were tested according to IS 8543 for the tensile test [5]. Three samples were tested.

Characterization of flexural test

The flexural test was conducted on the Universal Testing Machine, ASTM standard, which suggests the guidelines for the testing of polymer composite material of compression molded sample. The molded specimen samples are tested according to ASTM D 790-03 [6].

Characterization of Izod impact test

The Izod impact test was done on the Impact test machine of 25 J capacity. The polymer composite SMC material samples for the Izod impact test were molded by using a compression molding machine. The molded specimen samples were tested according to ASTM D 256-04 standard [7].

Results and Discussion

The results obtained from the experimentation and characterizations of polymer composite SMCs are presented in this section. The mechanical properties of a polymer composite material observed from experimentation are summarized in this section.

Tensile strength properties

The tensile strength test was carried out on the Universal Testing Machine. The values obtained from the test range from 76.525 N/mm^2 to 90.025 N/mm^2. It was observed from the analysis that the molding pressure may have been a major impacting factor on the material. At the same time, increasing the curing time of composite material provides sufficient strength to the material. Because of this, there was around an 8 to 10% increase in the values. The result analysis of the tensile strength test is shown in figure 1. The variation in the mechanical properties observed may be due to matrix material not being prepared well, so there may be less bonding between matrix and glass fiber, entrapment of air in the composite material, and insufficient wetting of glass fiber. This can be minimized by applying more pressure while preparing composite material to remove entrapped air from the composite material.

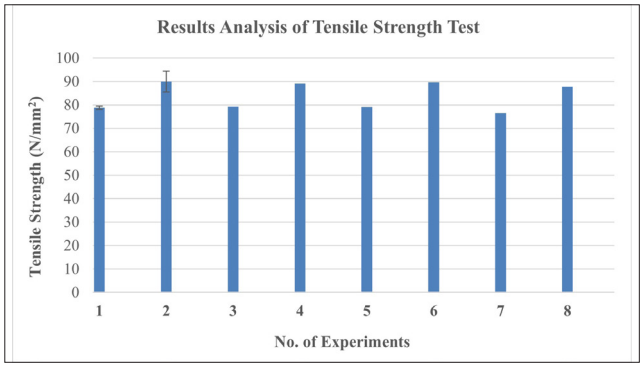


Figure 1: Tensile strength test results analysis.

Flexural strength properties

The flexural strength test was carried out on the Universal Testing Machine. The values obtained from the test range from 164.5 N/mm^2 to 174.3 N/mm^2. The flexural strength of the material increases from 7 to 10%. The increment in the value may be due to the combined effect of curing and molding pressure. The results analysis of the flexural strength presented in figure 2.

Izod impact strength

In the Izod impact strength test value for the test ranges from 111.7 to 114.475 KJ/m^2. It was observed from the analysis that there was not a specific trend in the values obtained.

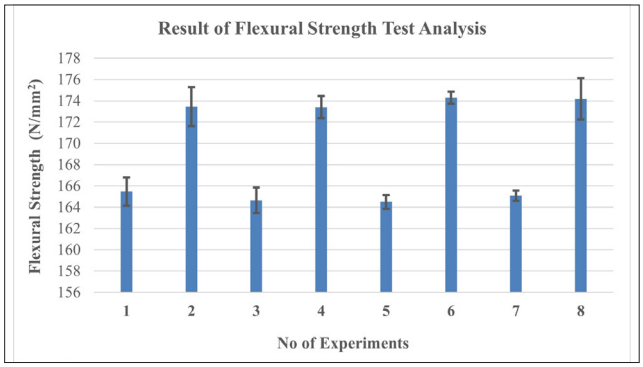


Figure 2: Flexural strength test results analysis.

We can say no specific increment or decrement in the values was obtained from the analysis. There was no specific effect observed due to processing parameters in the material during the Izod impact test. The result analysis in the graphical form is presented in figure 3.

Conclusions

This research work investigation based on results obtained from the experimental observation and testing results concludes the following important points.

- From the testing of tensile strength, there is an increase in the values of around 8 to 10% when the curing time and molding pressure increase. Because of this, there may be less chance of forming void content, as shown in figure 4, and higher tensile strength.

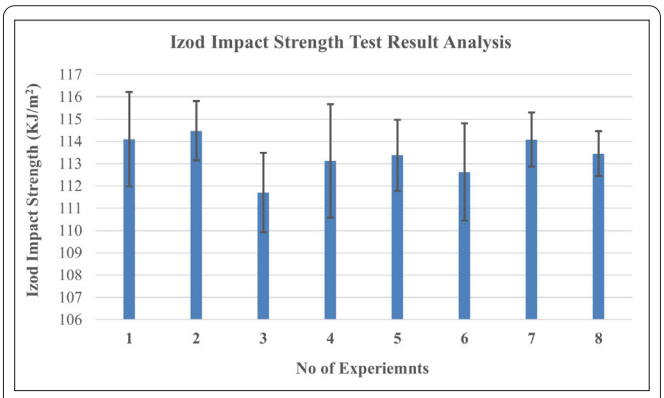


Figure 3: Izod impact test result analysis.

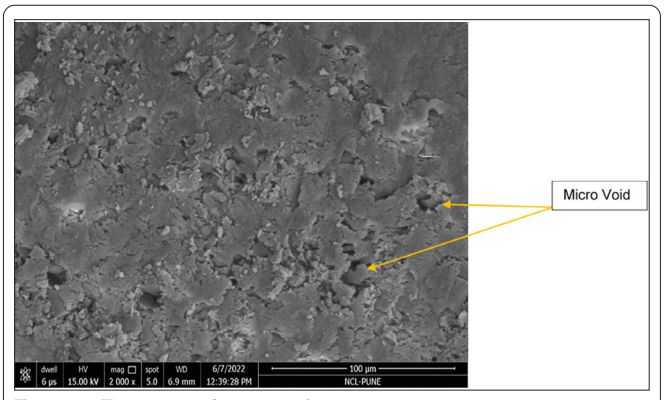


Figure 4: Formation of micro void.

- From the testing of flexural strength, it is evident that on average 7 to 8% increase in the value may be due to the combined effect of the processing parameter.
- In the Izod impact test results, there is no specific trend observed in the analysis of results.

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Conflict of Interest

None.

Credit Author Statement

Pankaj M. Dhongade: Conceptualization, Study design, Data acquisition, Data interpretation, Writing - original draft preparation, Writing - review and editing; V. G. Sargade: Data interpretation, Writing - review and editing, Data interpretation. All the authors read and approved the manuscript.

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