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Investigation on the Mechanical Properties of Egg Shell Powder Reinforced Polymeric Composites

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***Abstract*— Any material consisting of two or more constituents with different properties and distinct boundaries between the components can be referred to as a composite material. Normally a composite consists of two phases one is reinforcing phase and other is matrix phase. Reinforcing materials are used to carry the loads and matrix is used to bind and transmit the load to fibers. Polymer based composites are most commonly used in the present days because of their superior mechanical properties as compared with other composites.**

In the present work polyamide/ nylon black egg shell composites are prepared by using injection moulding process. The test specimens were prepared according to ASTM standards. In which polyamide and nylon black is used as matrix materials, the egg shell particles are used as reinforced material to produce the composites. The mechanical properties such as tensile strength, impact strength, and flexural strengths have been evaluated for both the composites and comparison is made between them.

Key words —polyamide, nylon black, egg shell powder, tensile strength, impact strength and flexural strength.

I. INTRODUCTION

Materials are the basic elements of all natural and man-made structures. Figuratively speaking, this materializes the structural conception. Technological progress is associated with continuous improvement of existing material properties as well as the expansion of structural material classes and types.

In composites, materials are combined to make better use of their virtues with minimizing their deficiencies. This process of optimization can provide a relief to a designer from the constraints associated with the selection and manufacture of conventional materials. Most of designers are looking for materials having lighter weight and good mechanical properties. The composites satisfy these requirements with cheaper cost.

The majority of natural materials that have emerged as a result of a prolonged evolution process can be treated as composite materials. Wood is a natural composite material consisting of one species of polymer cellulose fibers with good strength and stiffness in a resinous matrix of another polymer.

In order to provide more environmentally-responsible products, manufacturers are exploring alternative approaches to reduce the amount of polymer used to produce various polymer-based products. One such approach involves substituting a portion of the polymer content with a plant-based or "bio-based" filler such as wood flour, starch, or distilled grain. However, plant-based fillers absorb water and swell in a moist or humid environment and degrade at the high temperatures used during processing. This leads to poor product performance and undesirable characteristics.

Normally egg shells are considered to be waste products at restaurants, food industries, houses etc. This will create pollution to the environment but it has high compressive strength. So Eggshell powder can be considered as an alternative to the standard plant-based materials. By using the eggshells pollution can be reduced. Eggshell is a cheapest material and this is a waste product for the regular use.

The eggshells have high compressive strength, polyamide has good impact strength and nylon black has good tensile strength. Generally, this composite have good application in automotives. Various parts of automotives require compressive, impact, tensile strengths based on the requirement of the component these materials are mixed in different proportions.

II. EGG SHELL POWDER PREPARATION

The egg shells were washed, dried and ground to a powder using the blender. A sieve was used to obtain an average particle size of 100 µm. The powder was treated with a solution of Sodium Hypo chloride (NaOCl), to remove the dust particles [4].

The powder was mixed with the solution and stirred for 30 minutes then kept at room temperature until two layers are formed. The upper layer was decanted and the deproteinised layer of precipitate was washed 10 to 12 times with distilled water. The powder was then stirred in a mixture of 6% of isophthalic acid in ethanol for an hour. The washed precipitate was dried in the oven at 140°C until a constant weight was observed. The cleaned eggshells and eggshell powder was represented in figure 1.

Fig. 1. Showing (a) dried eggshells (b) powdered eggshells

The most commonly used thermoplastic materials are polystyrene (low cost, lacking the strength and longevity of other materials), ABS or acrylonitrile butadiene styrene (a ter-polymer or mixture of compounds used for everything from Lego parts to electronics housings), polyamide (chemically resistant, heat resistant, tough and flexible – used for combs), polypropylene (tough and flexible – used for containers), polyethylene, and polyvinyl chloride or PVC (more common in extrusions as used for pipes, window frames, or as the insulation on wiring where it is rendered flexible by the inclusion of a high proportion of plasticizer).

Injection molding can also be used to manufacture parts from aluminum or brass (die casting). The melting points of these metals are much higher than those of plastics; this makes for substantially shorter mold lifetimes despite the use of specialized steels. Nonetheless, the costs compare quite favorably to sand casting, particularly for smaller parts.

III. INJECTION MOULDING

Injection moulding process involves injection of raw material into mould cavity under pressure. This process consists of four steps clamping, injection, cooling and ejection. The pellets of thermoplastics are first compressed in the reciprocating screw and then pushed into a heating chamber.

The softened material in the flowing state is then forced with pressure through a nozzle into cold mould having cavity of the desired shape. Plastic objects of intricate shapes can be formed in these cavity moulds. The objects can be removed by opening the moulds.

An important part of the injection moulding process is that the mould should be securely clamped during the injection moulding process. High pressure, fast action clamping should be provided either hydraulically or by the toggle mechanisms. After the injection of raw material into cavity it is solidified to acquire the required shape. Finally the shapes are ejected from the mould. Shown in figure 2.

Injection moulding is a faster process and suits best for large quantity productions. In general more quantity of plastic parts are made by injection moulding. Complex shapes of various sizes can be prepared by this process. Good dimensional accuracy can be obtained with this process.

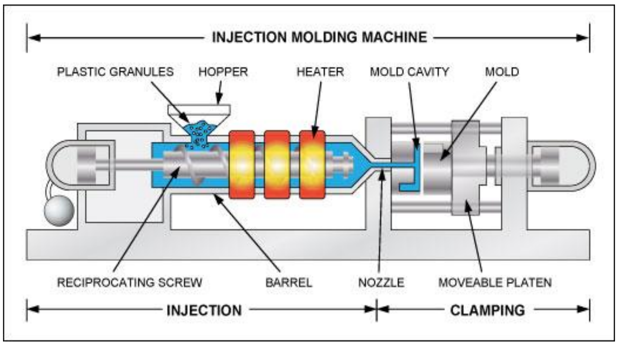


Fig. 2. Injection Moulding

IV. PREPARATION OF TEST SPECIMENS

A. Tensile testing (ASTM D 638-03)

The ductility of a sample is determined by conducting a tensile strength test on a Universal Testing Machine (UTM). During the stretching process, the machine measures the load (F), or the force applied to the sample, and the displacement of the sample (s); along with the original cross sectional area of the sample (Ao) and the original length (Lo), an engineering Stress-Strain Curve can be generated.

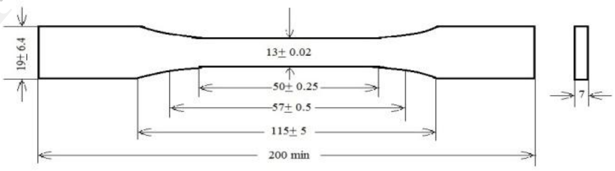


Fig. 3. Tensile test specimen

Fig. 4. Tensile test specimen after failure

B. Flexural strength test (ASTM D 790-03)

The flexural strength of a material is defined as its ability to resist bending forces applied perpendicular to its longitudinal axis.

The test is done on an UTM, which operates at a constant rate of crosshead motion over the entire range and error in load measuring system should not exceed 1% of the maximum load expected. The strain rate is 0.01in/in/min. The method followed is a three-point loading system utilizing central loading on a simple supported beam. A bar of rectangular cross-section rests on two supports and is loaded by means of a loading nose midway between the supports.

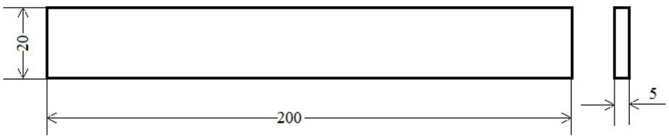


Fig. 5. Flexural test specimen

Fig. 6. Flexural test specimen after failure

C. *Charpy Impact Testing (ASTM D 256-04)*

Impact tests are used in studying the toughness of material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. A typical Charpy impact specimen is shown in the following figure.

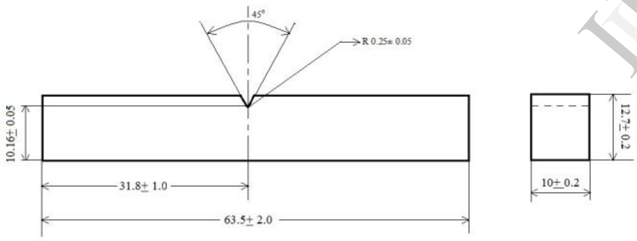


Fig. 7. Impact test specimen

Fig. 8. Impact test specimen before failure

V. RESULTS AND DISCUSSIONS

The characterization of the composites reveals that the filler content is having significant effect on the mechanical properties of composites. The mechanical properties of the polyamide/nylon black composites with different percentages of egg shell content under this investigation are presented. It is observed that the mechanical properties of these composite increases with increase in filler content. The tensile, flexural, impact strengths of nylon black are more as compared with polyamide.

The following notations are used in this experiment,

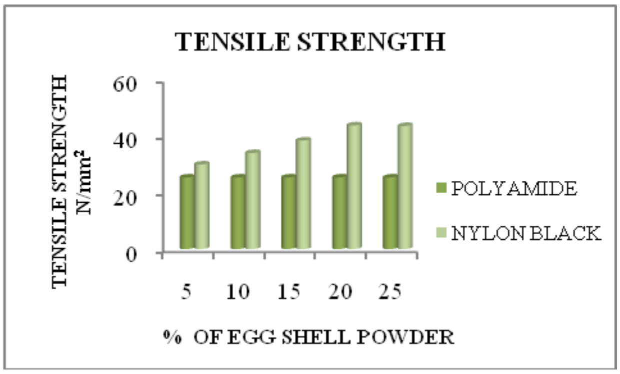
PA- POLYAMIDE
NB- NYLON BLACK
ESP- EGGSHELL POWDER

PA^1- 95% OF PA +5% OF ESP
PA^2- 90% OF PA +10% OF ESP
PA^3- 85% OF PA+15% OF ESP
PA^4- 80%OF PA+ 20%OF ESP
PA^5- 75% OF PA +25% OF ESP
NB^1- 95% OF NB + 5% OF ESP
NB^2- 90% OF NB + 10% OF ESP
NB^3- 85% OF NB + 15% OF ESP
NB^4- 80% OF NB + 20% OF ESP
NB^5- 75% OF NB + 25% OF ESP

A. *Tensile Strength*

By observing the graph1, the tensile strength of NB+ESP composite material gradually increases with increase of ESP percentage. The tensile strength of PA+ESP composite material is almost all equal in all percentages of ESP. In the present work NB^5 gives the maximum tensile strength. The tensile strength of NB^5 is 58.16% higher than PA^5.

This improvement is because of surface modification which improves the matrix bond property between the matrix and fibers. This could be due to the better dispersion of fibers and interaction between the matrix and fibers. Therefore this indicates that the chemical treatment of the fibers significantly increased the adhesion characteristics and further mechanical properties [1].

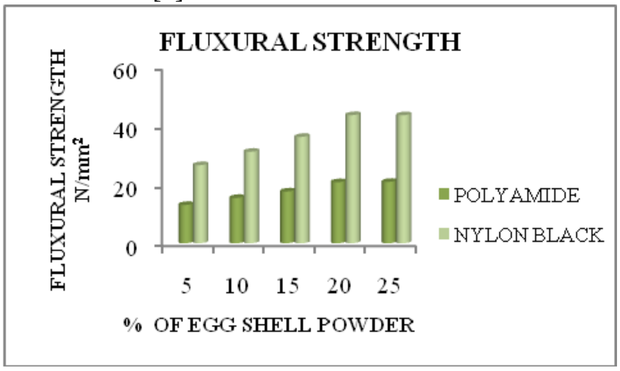


Graph1. Comparision of tensile strength for polyamide and nylon black

B. *Fluxural Strength*

The fluxural strength of NB+ESP, PA+ESP composite materials gradually increases with increase of ESP percentage. The graph 2 shows the variation of flexural strength with percentage of ESP. In the present work NB^5 gives the maximum flexural strength. This is further compared with PA5. The fluxural strength of NB5 47.91% higher than PA5.

With the results it is concluded that the introduction of the fiber increases the flexural strength. Due to the chemical treatment of reinforced surface the bonding strength between the fiber and matrix material is improved. It is also observed that the composites could transfer the stresses effectively from the matrix to the fibers. The treatment of the fibers modified the surface energy and the tension of the fibers and this further improves the molecular chain reactions [1].

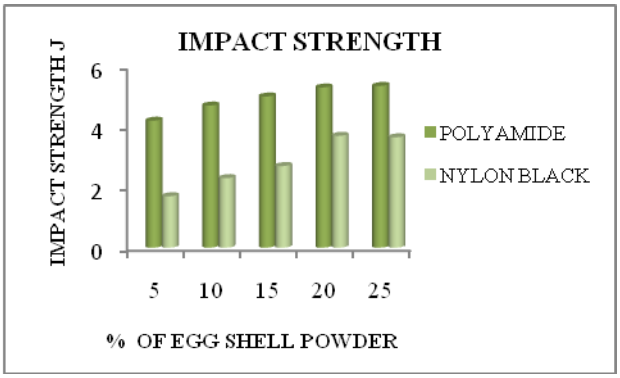


Graph2: Comparision of fluxural strength for poly amide and nylon black

C. *Impact Strength*

The impact strength of PA+ESP, NB+ESP composite materials gradually increases with increase of ESP percentage. The impact strength variation is illustrated in graph 3. In the present work PA5 gives the maximum impact strength. The impact strength of PA5 68.22% higher than NB5.

Further, chemical modification methods were adopted to improve the fiber –matrix interfacial bonding and to enhance the mechanical properties. This surface treatment improved the compatibility of the fiber and matrix and the effective stress transfer between the reinforced material and matrix. It is also clear that the strength and stiffness of the polymer composites is strongly depends on the quantity of the fiber [1].



Graph3: Comparision of impact strength for poly amide and nylon black

VI. CONCLUSION

The present investigations of mechanical behavior of polyamide/nylon black egg shell composites leads to the following conclusions:

1. Polyamide/nylon black eggshell composites have been successful fabricated by injection moulding.
2. It has been noticed that the mechanical properties of the composites such as tensile strength, flexural strength, and impact strength of the composites are also greatly influenced by the eggshell powder percentage.
3. Tensile strength, flexural strength, impact strength of the polyamide/nylon black egg shell composites increases with increasing of eggshell powder percentage.
4. The tensile, flexural, impact strengths of nylon black composites are more as compared with polyamide composites.

Finally the conclusion is these materials are preferred where the combination strengths are required to get good results with low cost.

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