The Investigation on Mechanical Properties of HDPE Reinforced Carbon Fiber Powder Composites for Orthopedic Implants

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Abstract - Metallic implants have been used widely in a lot of orthopaedic applications. Titanium, Ceramics, medical grade titanium and other metal alloys are been used a lot in orthopaedic implants. The disadvantages of metal implants however are corrosion and the release of ions, so there is need for finding new orthopaedic materials like composites, which have a closer density to the natural bone too. This work is part of the manufacturing and processing of carbon fibre powder/HDPE composite and the assessment of its mechanical properties. Mechanical properties are estimated by ASTM standard methods. Results are represented according to evaluation of composite performance mechanically and show the best choice of composite parts in order to improve future use of orthopaedic applications.

Key Words: ***HDPE Polymer, Injection moulding process, Orthopaedic implants, Mechanical Properties.***

1.INTRODUCTION

In recent years, the interest in composite materials is increasing due to its advantages as compared to monolithic metal alloys. Composites are either naturally occurring or engineered materials that are made from two or more constituents. In other words, composites are materials that consist of strong load carrying reinforcing material embedded in a weaker matrix material. Basically, composites have two constituents. The principal constituent of composites having a continuous phase and that forms the major part of the composite is called matrix. Matrix is usually less hard and is more ductile. Matrix can be either organic or inorganic. The secondary constituent has a discontinuous phase and is embedded in the matrix, this is known as reinforcement. The constituents of composites retain their individual physical and chemical properties, however when combined, they produce a combination of properties that individual constituents would be incapable of producing alone. In the past decade, composite materials have been used as an alternative in several light weight and high strength uses because of their high strength-to-weight ratio and high tensile strength. With the continuous growth and development in technology, the need for different materials with highly specific properties is increasing day to day and these demands cannot be achieved by use of existing metal alloys, ceramics and polymers. This is where composites come into picture as various metals, ceramic and polymers can be mixed together to get the specifically desired properties.

Synthetic fibre reinforced polymer in bio industrial has initiate to overcome problem sort by medical practitioners. Orthopaedic surgeon is using metallic plates, bone plates for human bone fracture. Usage of metals in bone fixation such as stainless steel and titanium alloy causes problems like metal incompatibility, corrosion and reduce in bone mass enhance bone porosity.

NEED OF COMPOSITE AS A BIOMATERIAL

Bones as a hard tissue are solid and hardened and obviously have high elastic modulus. Human bones are normally and fundamentally composite material made of collagen fibre and Nano crystal of hydroxyapatite which are sediment in collagen fibre.

The elastic modulus of collagen fibre is low and hydroxyapatite have high elastic modulus which contains 70% weight of the dry bone and match the stiffness of the bone. With this reality, composite material has good biocompatibility

2. OBJECTIVES AND SCOPE

OBJECTIVES OF THE PRESENT WORK

1. Fabrication of unsaturated HDPE resin reinforced with Carbon fibre powder with and without filler additions.

2. To evaluate the Mechanical characteristics of the prepared composite materials.

a) Mechanical characteristic like tensile strength, compression, flexural strength.

b) To study effects of incorporation of with and without filler addition

2.1. SCOPE OF THE PRESENT WORK

Literature on hand reveals that no single group of researchers has completely characterized the mechanical characteristic of Hybrid synthetic fibre reinforced HDPE polymer by adding fillers material.

The current work is an attempt to make use of the natural recycled resources to develop bio composite material for biomedical applications such as bone Plates, bone screws material for both internal, external fixations. The synthetic carbon fibre power is used as reinforcement in HDPE resin matrix and silicon carbide is used as fillers. Hence silicon carbide is used as a stabilizer to a predictable synthetic matrix, the polymer get in touch with the earth or water is assault through the microbes.

2.2. METHODOLOGY

In this experiment selection of material is done initially which is HDPE as matrix, carbon fibre powder as reinforcement and silicon carbide powder as filler. These materials are mixed in different proportion and composite material is made using injection moulding method. Tensile and flexural tests of composite materials are done in Tensometer.

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2.3. SELECTION OF MATERIALS

Selection of matrix phase

HDPE has been selected as matrix as it is a polyethylene thermoplastic made from petroleum with a high strength-to-density ratio. The density of HDPE can range from 0.93 to 0.97 g/cm^3 or 970 kg/m^3. Although the density of HDPE is only marginally higher than that of low-density polyethylene.It is also harder and opaquer and can withstand somewhat higher temperatures (120^{0}C/248 F for short periods). HDPE is the non-toxic, tasteless, odourless, extremely low moisture absorption and has a very low co-efficient of friction and hence wear resistance. HDPE is among the most widely used polyolefin because of its high strength, very low cost, excellent process ability and also high chemical resistance.

Fig 1: HDPE

Selection of Carbon fiber Powder

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties and to provide strength to the finished part. The most commonly used reinforcement materials are carbon fiber powder. This is due to the fact that many of the desired performance characteristics require the use of carbon/graphite fibbers. Fibers are about 5–10 micrometers in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion.

Fig 2: Carbon fiber powder

Selection of silicon carbide filler

Fillers are particles added to material (plastics, composite material, and concrete) to lower the consumption of more expensive binder material or to better some properties of the mixture material.. Silicon carbide is an excellent abrasive. It has high strength low thermal expansion, high thermal conductivity, high hardness, high elastic modulus, excellent thermal shock resistance, superior chemical inertness.

Fig 3: silicon carbide powder

3.NEW DATA COLLECTED

The polymer composites samples are prepared with following compositions:

Table 1: Constituents and their concentration in the prepared composites

Sl. No	Composition	Composites	Reinforcement (%)	Matrix (%)	Filler (%)
					SiC
1	1	Carbon fibre powder/HDPE	0	100	0
2	2	Carbon fibre powder/HDPE	20	80	0
3	3	Carbon fibre powder/HDPE	20	78	2
4	4	Carbon fibre powder/HDPE	20	76	4
5	5	Carbon fibre powder/HDPE	20	74	6

3.1. SPECIMEN PREPARATION

Injection moulding is the most commonly used manufacturing process for the fabrication of plastic parts. A wide variety of products are manufactured using injection moulding, which vary greatly in their size, complexity, and application. Injection mouldings machines have many components and are available in different configurations, including a horizontal configuration and a vertical configuration. Samples of different compositions have been prepared by vertical injection moulding machine.

The injection unit is responsible for both heating and injecting the material into the mould. The first part of this unit is the hopper, a large container into which the raw plastic is poured. The hopper has an open bottom, which allows the material to feed into the barrel. The barrel contains the mechanism for heating and injecting the material into the mould.

This mechanism is usually a ram injector or a reciprocating screw. A ram injector forces the material forward through a heated section with a ram or plunger that is usually hydraulically powered. In this way composite materials are prepared in a mild steel die using vertical injection molding. These specimens are then cut by water jet machining later using ASTM standard for tensile and flexural test. The size of die used is 120mm*120mm*3mm.

Fig 4: Injection molding machine

Fig 5: Final product is prepared

Fig 6: Specimen for testing according to ASTM STD

4.EXPERIMENT AND RESULT

TENSILE TEST(ACCORDING TO ASTM-E8)

The results of ultimate strength as a function of filler content of neat HDPE and their composites are shown in figure 7 .For all the composites tested, it is observed that the strength increases linearly with increase in filler content.

At 6 % SiC filler content with 20% carbon fibre powder reinforced 74% HDPE has the ultimate stress of 21.5 MPa, ultimate strength of 15.9 MPa for Pure HDPE polymer.

Ultimate tensile stress

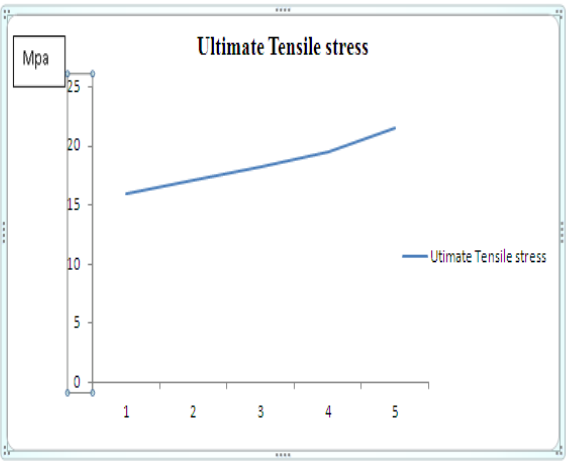

Fig 7: Ultimate tensile stress

COMPRESSION TEST (ACCORDING TO ASTM D-695)

The results of ultimate compressive stress as a function of filler content of neat HDPE and their composites are shown in figure 8. For all the composites tested, it is observed that the strength increases linearly with increase in filler content.

At 6 % SiC filler content with 20% carbon fibre powder reinforced 74% HDPE has the ultimate compressive stress of 10.8 MPa and ultimate strength of 7.1 MPa for Pure HDPE polymer.

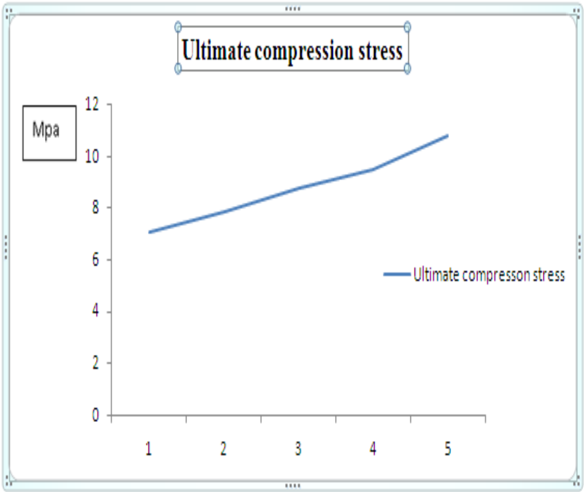

Fig 8: Ultimate compressive stress

BENDING TEST (ACCORDING TO ASTM D-790)

The results of the ultimate strength as a function of filler content of neat HDPE and their composites are shown in figure 9. For all the composites tested, it is observed that the strength increases linearly with increase in filler content.

At 6 % SiC filler content with 20% carbon fibre powder reinforced 74% HDPE has the ultimate bending stress of 48.98 MPa and the lowest valve of ultimate strength of 25.11 MPa for Pure HDPE polymer.

This is attributed to the fact that SiC-Carbon fiber powder reinforced HDPE composite, HDPE reinforced carbon filler powder with filler addition content shows better results compared to the pure HDPE.

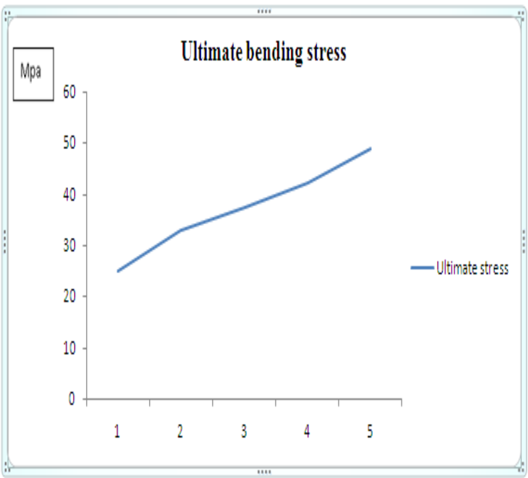

Fig 9: Ultimate bending stress

5.CONCLUSION

The current work has been undertaken, with an objective to explore the potential of the treated carbon fibre powder reinforced HDPE polymer composites and to learn the mechanical characteristic of the composites and therefore mechanical properties are follows:

Tensile Test: At 6 % SiC filler content with 20% carbon fibre powder reinforced 84% HDPE has the ultimate tensile stress of 21.5 MPa and the lowest value of ultimate strength of 15.9 MPa for Pure HDPE polymer.

Compression Test: At 6 % SiC filler content with 20% carbon fibre powder reinforced 84% HDPE has the ultimate compressive stress of 10.8 MPa and the lowest value of ultimate strength of 7.1 MPa for Pure HDPE polymer.

Bending Test: At 6 % SiC filler content with 20% carbon fibre powder reinforced 74% HDPE has the ultimate bending stress of 48.98 MPa and the lowest value of ultimate strength of 25.11 MPa for Pure HDPE polymer.

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