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AN INVESTIGATION ON MECHANICAL PROPERTIES OF HYBRID POLYMER COMPOSITES

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Abstract: Metallic implants have long been used in a variety of orthopaedic procedures. In orthopaedic implants, titanium, ceramics, medical grade titanium, and other metal alloys are commonly used. Metal implants, on the other hand, have the disadvantages of corrosion and ion release, necessitating the development of materials such as polymer composites. This work is related to the production and processing of carbon fibre powder/HDPE composites with Al_2O_3 and SiC filler addition, as well as the investigation of their mechanical properties. ASTM standard methods are used to estimate mechanical properties. The best choice of composite parts for future use in orthopaedic implants is shown in the results, which are based on mechanical evaluation of composite performance.

***Index Terms* - HDPE Polymer, Injection moulding process, Orthopaedic implants, Mechanical Properties**

1.0 INTRODUCTION

Composites are made up of two or more physically and/or chemically distinct components. The matrix, the reinforcement, and the interface between the matrix and the reinforcement comprise a composite. A matrix is a continuous phase of composites that maintains the orientation of the reinforcements. As reinforcement, a stronger substance is distributed throughout the matrix. Matrix and reinforcements are chemically or mechanically bonded. The types of matrix and reinforcements used in composites are used to classify them. Based on the matrix, composites are classified as polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs). This is sample paper format only please use this format and follow this structure as per your requirement.[1]

In order to achieve maximum tensile, compressive, minimum friction, load bearing efficiency, and uncompromised biocompatibility properties, the hybrid hip prosthesis is made up of a combination of metal, polymer, and ceramic materials. Metal on polyethylene, ceramic on polyethylene, ceramic on metal prostheses, and so on are all types of hybrid hip prostheses. THR bio implants, for example, use a UHMWPE liner in a Ti alloy acetabular socket, a CoCr femoral head, and a Ti6Al4V alloy femoral stem. In general, such hip implantations are preferred for patients who are less active and in their 70s [2].

Recently, an appealing grouping such as ceramic on polyethylene has been introduced to reduce metal ion release and debris particle formation. Furthermore, oxide ceramic (alumina, zirconia, or ZTA) has excellent wear resistance. Ceramics can also withstand high compressive stress while having a low fracture toughness [3]. The main concern in such a combined joint is that wear debris from polyethylene (PE) causes periprosthetic osteolysis and aseptic loosening, which leads to implant failure [4]. Hydrophobic polytetrafluoroethylene (PTFE) and ultra-high molecular weight polyethylene (UHMWPE) have a low coefficient of friction and chemical stability. However, the polymers that deliver the high wear debris cause tissue reaction and granuloma formation in the long run. This occurrence occurred as a result of low compressive strength and stiffness, which resulted in debris formation under bearing action[2].In light of the foregoing, research is currently underway on UHMWPE reinforced with carbon fibre, graphene oxide, PMMA, hydroxyapatite, Al2O3, ZrO2, and SiC to simulate the best properties in vivo[5].

1.1 OBJECTIVES OF THE PRESENT WORK

1. Fabrication of HDPE polymer resin reinforced with Carbon fiber powder with and without filler additions.
2. To evaluate the Mechanical characteristics of the prepared composite materials.

a) Mechanical characteristics like tensile strength, compression, flexural strength, Impact strength.
b) To study effects of incorporation of with and without filler addition.

1.2 Scope of the Present Work

Writing close by uncovers that no single gathering of scientists has altogether portrayed the mechanical attribute of Hybrid manufactured carbon fiber powder supported HDPE polymer by adding fillers material.

The current work endeavors to utilize the common reused assets to create bio-composite material for biomedical applications like bone plates, bone screws material for both inner and outside obsessions. The engineered carbon fiber power is utilized as support in the HDPE, Al_2O_3 and silicon carbide is utilized as fillers. Henceforth silicon carbide and Al_2O_3 is utilized as a stabilizer to an anticipated engineered grid, the polymer connects with the earth, or water is attack through the organisms.

1.3 METHODOLOGY

In this experiment, the material selection is made initially:

- HDPE as the matrix.
- Carbon fiber powder as reinforcement
- Silicon carbide and aluminum oxide powder as filler addition.

These materials are mixed in different proportions, and composite material is made using the injection molding method. Tensile, flexural and compression tests of composite materials are done in universal testing machine. HDPE was chosen as a matrix because it is a petroleum-based polyethylene thermoplastic with a high strength-to-density ratio.

2. SELECTION OF MATERIALS

2.1 Selection of Matrix Phase

HDPE can have a density of 0.93 to 0.97 g/cm3 (970 kg/m3). HDPE, on the other hand, has a density that is only slightly higher than that of low-density polyethylene. It's also more complex and opaquer, and it can withstand slightly higher temperatures (120^0 C/248F for short periods of time). HDPE is non-toxic, tasteless, odorless, has low moisture absorption, and has a low friction coefficient, making it resistant to wear. Because of its high strength, low cost, excellent processability, and chemical resistance, HDPE is one of the most widely used polyolefins.

Fig 1: HDPE polymer

2.2 Carbon Fiber Powder Selection

Reinforcement in a composite material improves the mechanical properties and gives the finished part more strength. Carbon fibre powder is the most commonly used reinforcement material. This is because carbon/graphite fibres are required for many of the desired performance characteristics. Fibers have a diameter of 5–10 micrometres and are mostly made up of carbon atoms. Carbon fibres have a number of advantages, including a high strength-to-weight ratio.

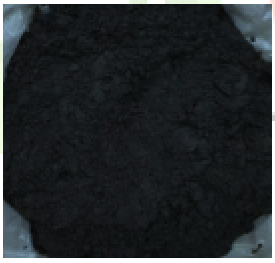


FIG 2: CARBON FIBER POWDER

2.3 Selection of silicon carbide filler

Fillers are particles added to materials (plastics, composites, and concrete) to reduce the use of more expensive binder materials or improve the properties of some mixture materials. Silicon carbide is a great abrasive material. It has excellent chemical inertness, high strength, low thermal expansion, high thermal conductivity, high hardness, high elastic modulus, and excellent thermal shock resistance.

Fig 3: silicon carbide powder

2.3 Selection of silicon carbide filler

Aluminium is the most abundant metallic element in the earth's crust, and it can be found in rocks like felspar and mica. Aluminium oxide has the chemical formula Al2O3 and is an amphoteric oxide of aluminium. In the mining, ceramic, and materials science communities, it's also known as alumina or aloxite. Al_2O_3 is a hard material that resists hydration and acid attack. With a hexagonal close packed, HCP array of anions.

Fig 4: Aluminium oxide

2.4 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	Al_2O_3
1	H1	Carbon fibre powder/HDPE	0	100	0	0
2	H2	Carbon fibre powder/HDPE	20	80	0	0
3	H3	Carbon fibre powder/HDPE	20	76	2	2
4	H4	Carbon fibre powder/HDPE	20	72	4	4
5	H5	Carbon fibre powder/HDPE	20	68	6	6

3 SPECIMEN PREPARATION

The material used in this study is Carbon fiber powder reinforced HDPE polymer with fillers Al2O3 and SiC addition, HDPE (with a trade name of, obtained from ACE workshop, bangalore, India), Carbon fiber powder (with a trade name of Arrow Technical Textiles Private Limited, obtained from Mumbai, India) and fillers Al2O3 and SiC (with a trade name of Vasa Scientific, obtained from Bangalore, India) were compounded by an extruder.

Compounding of HDPE Polymer and carbon fiber powder composite consists of an extruder and seven auxiliary equipment's. These are respectively; extruder, feeders, extrusion control unit, feeder control unit, heat exchanger, cooling bath, pelletizer, storage silo and bagging unit as shown in Figure 3.1. The extruder used for compounding (900 rpm). In the micro injection moulding process, an injection itself indicates that it has to be an orifice wherein a liquid or resin is pressurized to get the shape. Injection moulding machine is used to make the specimens from the pellets.

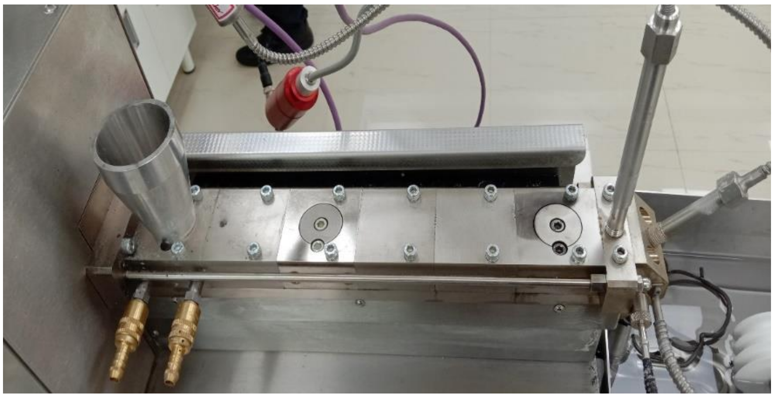


Fig 5: Twin screw extruder

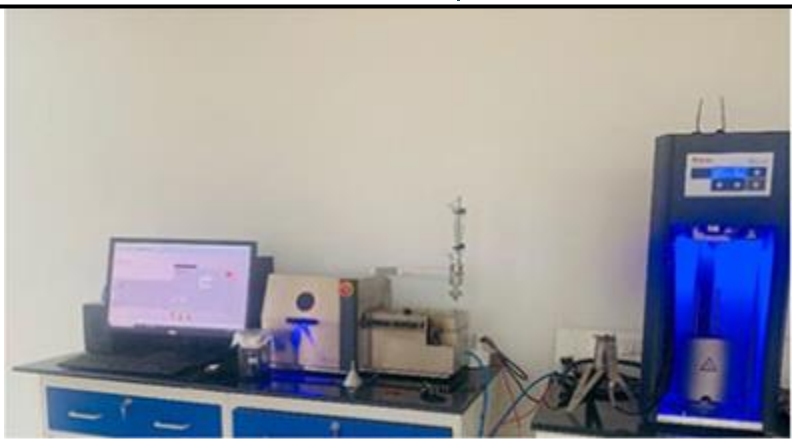


Fig 6: Micro injection moulding machine

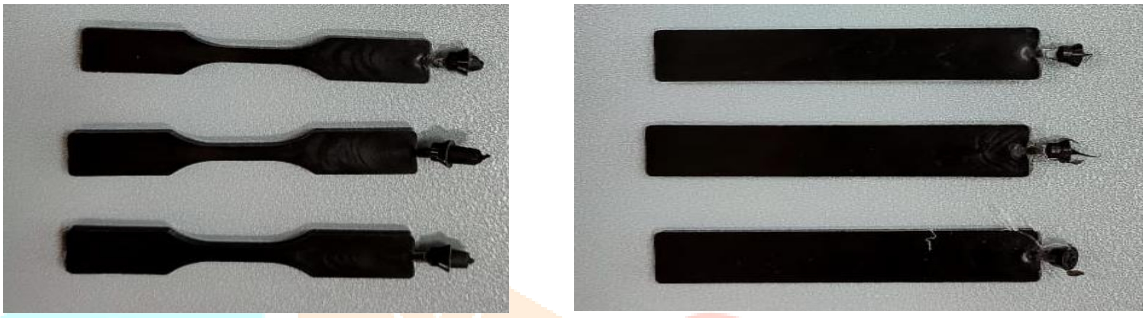


Fig 7: Tensile and impact sample prepared by micro injection moulding machine according to ASTM standard

4 RESULTS AND DISCUSSION

4.1 Tensile Test

TABLE 2 Experimental Results of Tensile Properties

SL No	Specimen Composition	Matrix phase (HDPE)	Reinforcement Carbon fiber powder	Filler's addition		Tensile stress (MPa)	Tensile modulus (MPa)
				Al_2O_3	SiC		
1	H1	100	0	0	0	15.9	250
2	H2	80	20	0	0	17	275
3	H3	76	20	2	2	19.5	415
4	H4	72	20	4	4	22.5	510
5	H5	68	20	6	6	23.8	550

Figure 8 shows the tensile stress and Elastic modulus of the hybrid composites under quasi-static tensile load while the summary of the tensile test data is presented in Table 2.

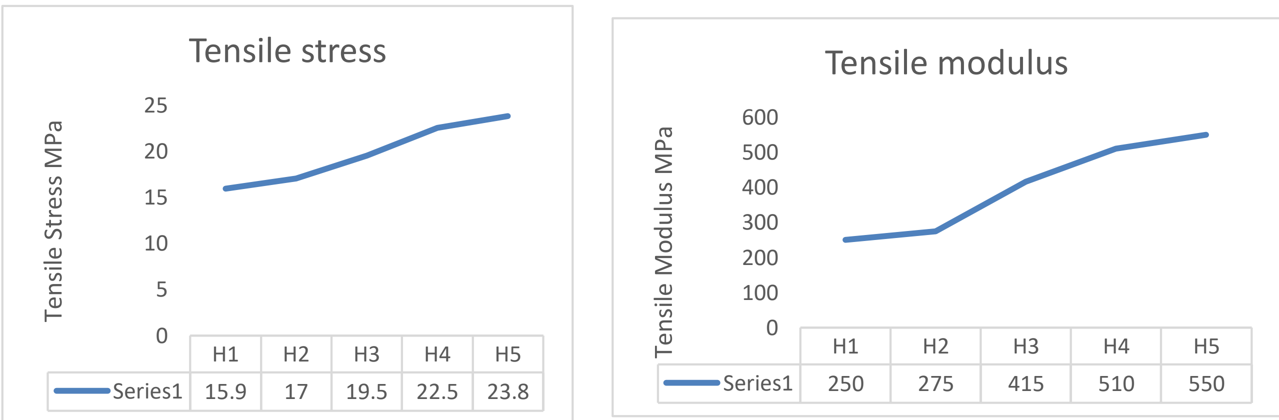


Fig 8: Tensile stress and Tensile Modulus

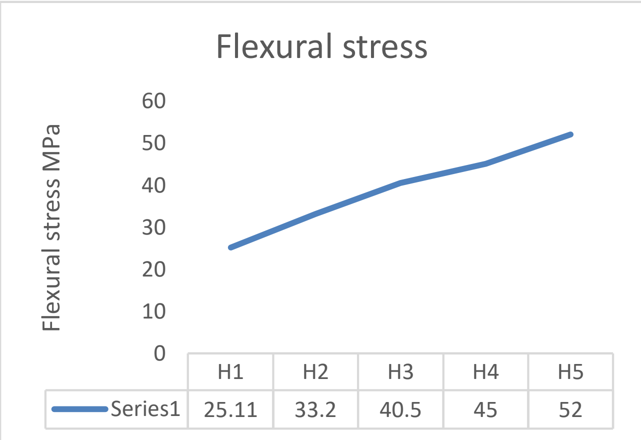
The Hybrid polymer composite specimen with carbon fibre powder as 20% reinforcements and fillers containing both 6% Al_2O_3 and SiC had the highest tensile strength values. This is due to more efficient load transfer across the fiber/matrix interphase, which results in the composites having a lower tendency to fracture under tensile loading. The addition of fillers to carbon fibre powder reinforced HDPE increases the tensile strength even more.

4.2 Flexural Test

TABLE 3 Experimental Results of Flexural Properties

SL No	Specimen Composition	Matrix phase (HDPE)	Reinforcement Carbon fiber powder	Filler's addition		Flexural stress (MPa)	Flexural modulus (MPa)
				Al_2O_3	SiC		
1	H1	100	0	0	0	25.11	902
2	H2	80	20	0	0	33.2	975
3	H3	76	20	2	2	40.5	1150
4	H4	72	20	6	6	45	1390
5	H5	68	20	4	4	52	1435

Figure 9 shows the flexural stress and flexural modulus of the hybrid composites under quasi-static tensile load while the summary of the flexural test data is presented in Table 3.



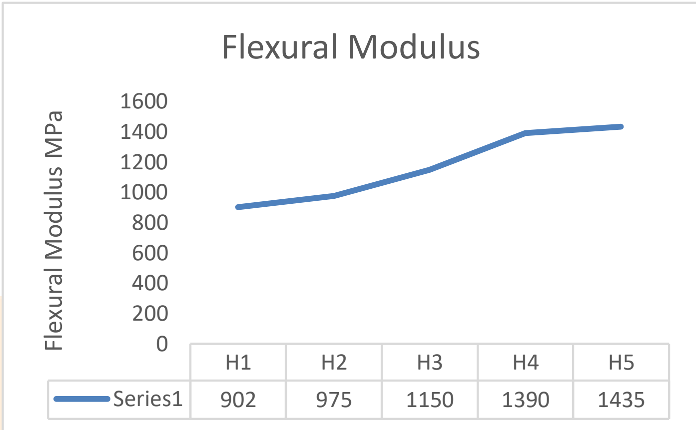


Fig 9: Flexural stress and Flexural Modulus

Compressive and tensile stresses are combined in the flexural stresses induced. Flexural strength and modulus clearly increase with fibre loading, peaking at 20% fibre loading for hybrid composites, and then increasing due to the effect of entanglement of the fibres at higher loading, as well as the effective wetting of the fibres by the Polymer. It has been observed that as the fibre content of hybrid polymer composites increases from 0 % to 20% , the flexural strength and modulus of hybrid polymer composites both increase linearly.

4.3 Compression Test

TABLE 4 Experimental Results of Compression Properties

SL No	Specimen Composition	Matrix phase (HDPE)	Reinforcement Carbon fiber powder	Filler's addition		Compressive stress (MPa)	Compressive modulus (MPa)
				Al_2O_3	SiC		
1	H1	100	0	0	0	7.1	105
2	H2	80	20	0	0	7.9	132
3	H3	76	20	2	2	9.9	207
4	H4	72	20	6	6	11.2	242
5	H5	68	20	4	4	13.2	335

Figure 10 shows the compressive stress and compressive modulus of the hybrid composites under quasi-static tensile load while the summary of the compression test data is presented in Table 4.

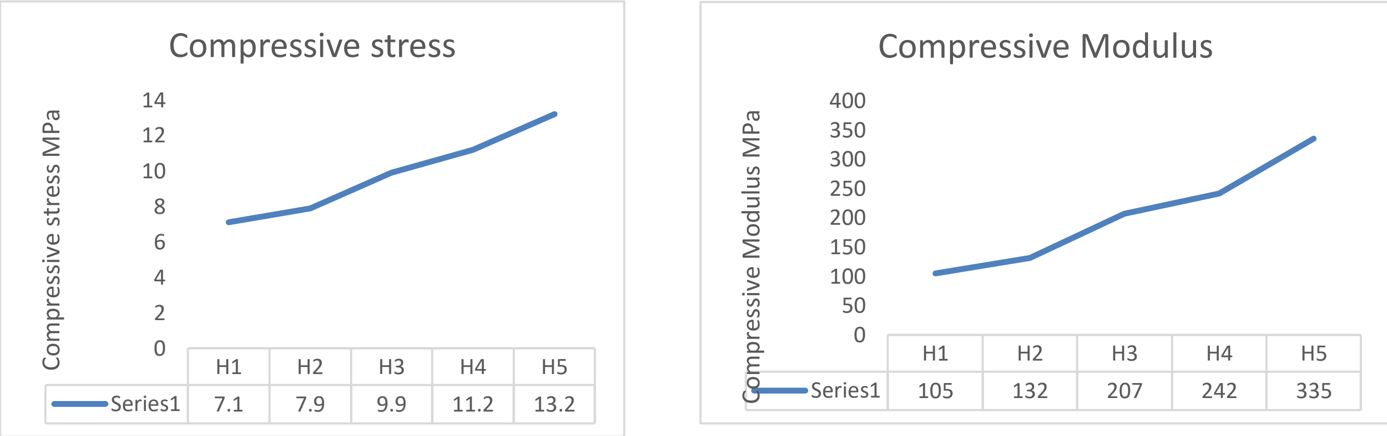


Fig 10: Compressive stress and Compressive Modulus

The composite specimens' compressive strengths were assessed using a uni axial compression test, and the results for the hybrid polymer composites are presented in Tables 4. The compressive strength of carbon fibre powder reinforced HDPE composites is improved when different weights (percentages) of carbon fibre powder, Al_2O_3, and SiC are added, and this improvement is a function of the carbon fibre powder, Al_2O_3, and SiC content. While the compressive strength of neat HDPE polymer is 7.1 MPa, when 20% vol percent carbon fibre powder is added, it increases by about 90 percent to 13.2 MPa, with both having 6 % vol percent Al_2O_3 and SiC fillers.

4.4 Impact Test

TABLE 5 Experimental Results of Impact Properties

SL No	Specimen Composition	Matrix phase (HDPE)	Reinforcement Carbon fiber powder	Fillers addition		Impact energy (J/m)
				Al_2O_3	SiC	
1	H1	100	0	0	0	8.5
2	H2	80	20	0	0	11.2
3	H3	76	20	2	2	13.5
4	H4	72	20	6	6	16.4
5	H5	68	20	4	4	20.7

Figure 11 shows the impact energy of the hybrid composites under Izod impact test while the summary of the impact test data is presented in Table 5.

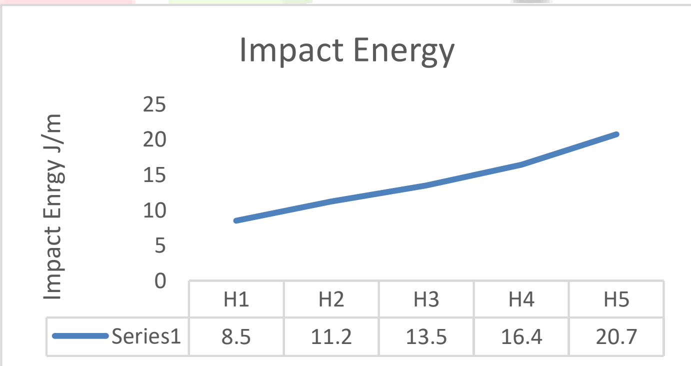


Fig 11: Impact Energy

Carbon fibre powder as 20 percent reinforcements and fillers additions containing both 6 percent Al_2O_3 and SiC also contribute to the higher impact strength of hybrid polymer composites. Hybrid polymer composites provide a 150 percent increase in impact strength. This could be due to the presence of organic groups on the Al_2O_3 and SiC surfaces, which improved the filler-matrix compatibility. In the case of good phase adhesion, the time when the matrix actually separates from the particles is determined by particle size due to a subsequent debonding sequence (void formation) that would result in specimen failure. When the adhesion between the matrix and the filler is good, small particles are preferred. Because the SiC has a lower surface energy, the particles agglomerate to form small particles at higher filler concentrations. As a result, impact strength in HDPE polymer composites with 6% Al_2O_3 and SiC is found to be increased.

5 CONCLUSIONS

The current research was carried out to determine the potential of treated carbon fibre powder reinforced HDPE polymer composites and to learn about their mechanical properties.

Firtsly, adding fibre and filler content to a composite increased the tensile strength value for a 20% composition and filler addition of both 6% Al_2O_3 and SiC. After that, it increased again for 20 percent composition with both 6 percent Al_2O_3 and SiC additions, which is the maximum tensile strength value.

Although, at first, carbon fibre powder has a significant reinforcing effect in the HDPE composite used. However, as the amount of fibre added to composites increased. This means that up to 20% of the fibres in the composites are well distributed, and there is better interfacial bonding between the fibre and the matrix.

The flexural properties of the material improve after adding 6% Al_2O_3 and SiC. The good dispersion of micro particles at higher filler concentrations can be attributed to this. The flexural strength of carbon fibre powder reinforced HDPE composites varies depending on how much carbon fibre powder, Al_2O_3, and SiC are added. The flexural strength of the composites increased as the fibre content in all composites increased, with 20 percent composite providing the highest value. Composites' flexural modulus shows how the flexural modulus of reinforced carbon fibre powder reinforced HDPE composites varies depending on how much carbon fibre powder, Al_2O_3, and SiC are added.The flexural modulus of the composites increased as the fibre content increased for composites with 20% fibre content.

The compressive strength of carbon fibre powder reinforced HDPE composites is improved when different weights (percentages) of carbon fibre powder, Al_2O_3, and SiC are added, and this improvement is a function of the carbon fibre powder, Al_2O_3, and SiC content. While the compressive strength of neat HDPE polymer is 7.1 MPa, when 20 % vol percent carbon fibre powder is added, it increases by about 90 percent, with both having 6 % vol percent $Al_2O_3$and SiC fillers. The measured compressive strength values of the hybrid composites filled with carbon fibre powder, Al_2O_3, and SiC filler in various proportions, showing a gradual increase in compressive strength values with increasing filler content.

The effect of fibre loading on unnotched Izod impact strength of carbon fibre fiber/HDPE composites. This demonstrates that the impact strength increases until the carbon fibre powder content reaches 20%. This contributes to the fact that the fibre's resistance to cracking, which is caused primarily by the debonding and pull-out processes, increases as carbon fibre powder content rises.

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