Tribological and Mechanical Behaviour of the Polymer Matrix Composite Reinforced with Ceramics Used as Implant Material

K R Dinesh, Gururaj Hatti, Vishwanath V.H, V.S. Konnur, V.S. Kanal

Abstract*: Recently, leading to its various attractive properties, Polymer matrix composites are suitable material in medical applications. This includes a light weight to high strength, a simple and complex shape easy to process. This paper describes the effect of Alumina, $CaCO_3$, and TiO_2 reinforcements with bio polymer UHMWPE matrix. The samples were fabricated by injection molding machines with different particle reinforcement percentages. On prepared samples, various experiments have been carried out, viz tensile, bending, impact, hardness, and wear. Samples were developed according to the ASTM standard. Polymer matrix composites of 65% LDPE + 5% TiO2 + 15% Al2O3 + 15% CaCO3 is suitable biomaterial candidate. Thus, it can be used in an orthopedic approach applied on hard or soft tissues.

Keywords: LDPE, aluminum oxide (Al2O3), titanium di oxide (TiO2), calcium carbonate, implant material.

I. INTRODUCTION

Composites comprising of a blend of at least two phases materials. It has numerous applications, composites are mainly subbing metals, especially for engg., materials where the primary favorable position is mass decrease with better properties. In medical applications, such as implants, sutures, drug release, and in agricultural applications like mulch and agrochemical products, biodegradable polymers can also be used. biologically degraded polymers contain enzymatic-sensitive, enzymatic hydrolysis and oxidation functional groups.

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Examples of such products are polyesters, polyvinyl alcohol, and polyvinyl alcohol. Biodegradable polymers must be designed to certain lifetime by combining polymers with certain reinforcement materials. Researchers use alumina (Al2O3) with titanium oxides (TiO2) to improve the wear characteristics when added with low density polyethylene. Alumina is thermally stable to 20000C and a rigid substrate with 1900HV hardness. Because of the outstanding biocompatibility, the tissue around the implantation, in particular hard tissue substations, cardiac and cardiovascular applications, Titanium with its composites are of specific attention for medical field [2]-[4]. The most abundant material of a earth is calcium carbonate (CaCO3), which is an important building block in the environment (e.g., in limestone, snake skin, pearl, sea body shells, egg shell); PLA bone replacement and calcium carbonate have even greater apatite hydroxycarbonate capability (HCA) than pure polymer or hydroxyapatite / polymer composite bone substitutes, in the synthetic body fluid (SBF). The high level of calcium carbonate was attributed to the rapid deposition of HCA on the surface, which has the ability to actively improve the HCA super saturation due to the fast dissolution of the calcium carbonate vaterite used. HCA has a very similar structure and chemical composition to the apatite of a biological bone since it is considered a modern biomaterial. In cell attachment, spreading and differentiation, HCA shows effective compatibility [5]-[6].

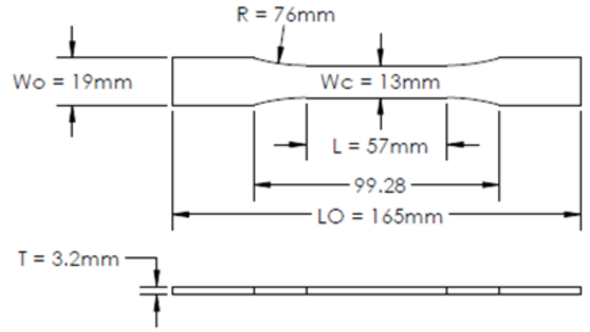
II. MATERIALS AND METHODS

The polyethylene is available in three kinds. In which UHMWPE has weak properties such as ductility and durability rupture. Their two other polyethylene, low density & high-density polyethylene, have a strong cross-relationship effect this marks in stronger mechanical properties and molecular structures [1]. similar properties are possessed by both LDPE and HDPE. In this study, (LDPE) is used as a material for matrix material. LDPE has weak mechanical strengths which can be improved to the polymer matrix with inclusion of metal or / and ceramics. Therefore, the reinforcements (alumina, calcium carbonate and titanium oxide) materials which are in a powder form with 325 mesh sizes are considered in the current study. Various compositions used to develop the samples for the perfect results. As per literature survey the percentage of reinforcements (alumina, calcium carbonate and titanium oxide) in each composition is decided [7]-[8]. The matrix and reinforcement vol. % of composites is given in Table I.

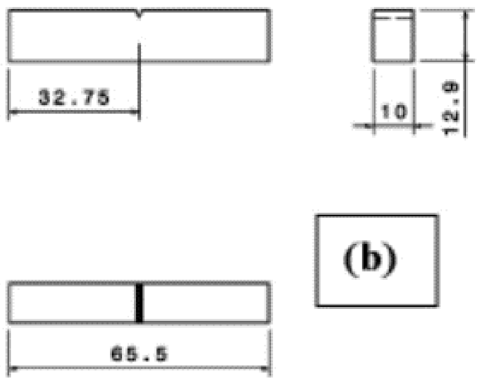
Table I Vol. % of hybrid composite with designation

Sr. No.	LDPE (%)	TiO_2 (%)	Al_2O_3 (%)	$CaCO_3$ (%)	Designation
1	100	0	0	0	C1
2	85	5	5	5	C2
3	75	5	10	10	C3
4	65	5	15	15	C4

According to ASTM standard, all the test samples are fabricated. Wear test is carried as per ASTM Tensile investigation specifications as per ASTM D638, D790 ASTM designed for the flexural test and D256 ASTM aimed at the investigation impact value. 1 (a, b, c) Figures shows specimen's sizes as per standards for considered mechanical properties test.



(a)



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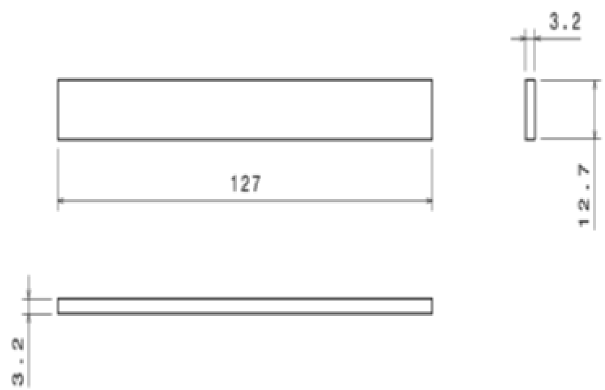


(c)

Fig. 1 (a), (b) and (c) Tensile, impact and bending strength test specimen dimensions (mm)

The procedure for preparation of samples is carried out as per [9] for considered matrix and reinforcements.

Mechanical properties tests were performed in the Department of Polymer science and technology, SJCE, Mysore, Karnataka, India. UTM make had LOAD limit 999kg and speed 50 mm min^{-1}. Flexural testing is conducted with test speed of 13.5 mm min^{-1}. Impact and D shore hardness tests are conducted. Wear test is conducted at SDMCET, Dharwad, Karnataka. Figure 2 shows fabricated specimens

Tensile Specimen

Bending specimen

Impact specimen

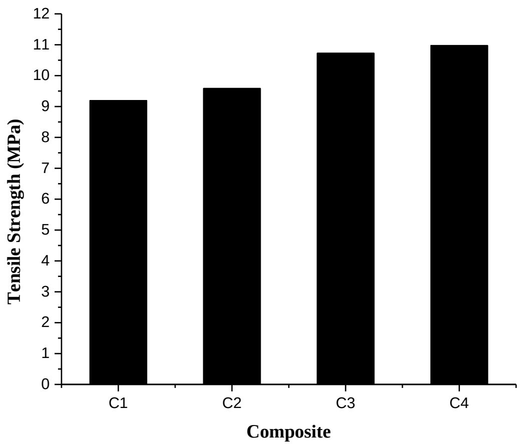
Fig. 2 Samples prepared as per ASTM standard

III. RESULTS AND DISCUSSIONS

Mechanical behaviour of the polymer composites (LDPE, Al2O3, CaCO3 & TiO2) is illustrated. Testing was performed in compliance to ASTM specifications and the samples are made using injection moldings.

A. Tensile Strength

Graph 1 indicates that the values of tensile behaviour of the composite's samples, were its value increases with increase in the vol. % of A12O3 and CaCO3 and were titanium oxide (Titanium Dioxide) is kept constant in all composites. Reinforcements particulate content in the composite material is very hard and tough and there is an efficient stress transfer between reinforcements and the matrix. As a result, composite materials increase the load carrying capacity. The highest tensile strength is obtained in composite C4.



Graph 1 ***Tensile Strength of Composites***

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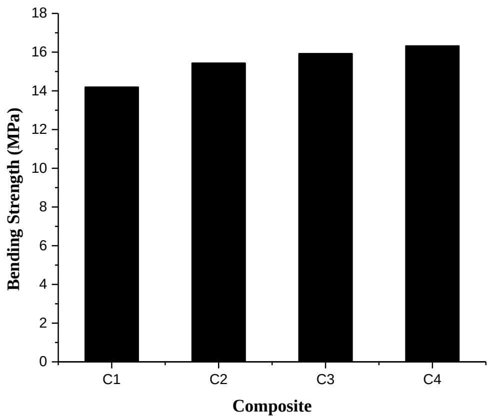
B. Flexural strength

Graph 2 indicates that the flexural or bending value increases with increases with rise in the vol. % of A12O3 and CaCO3 and were titanium oxide (Titanium Dioxide) is kept constant in all composites. Due to the inclusion of tough and rigid reinforcements in the compositions.

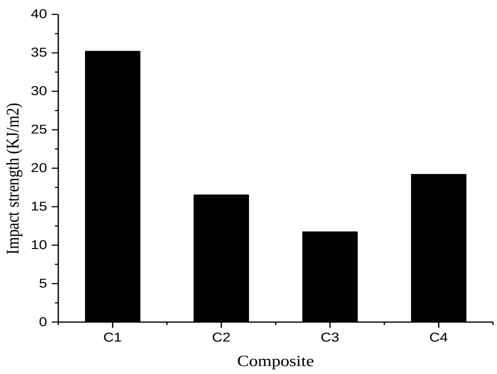
Particulate aluminum and calcium carbonate resist the composite material's deformation, which increases bending Strength. Also, it is seen that there is no breakage of samples during the test is observed.



Graph 2 Flexural strength of Composites

C. Impact Strength

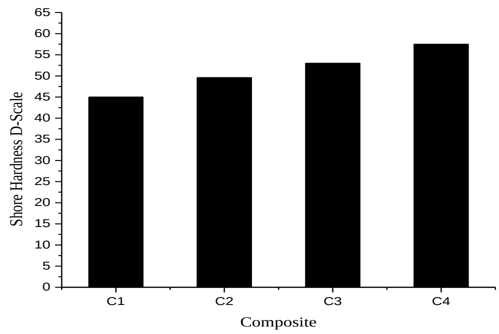
Graph 3 shows the composites impact strength. When the reinforcements vol. % increase in composites, impact strength drops. As the reinforcements are hard and rigid, they improve the workable and bending strength and decrease the material's ductility. The agglomeration of particles in the matrix can contribute to a greater decrease in impact strength. Agglomeration leads to a decreased bond strength in the matrix between particles and there is decline in the impact value of the composites.



Graph 3 Impact strength of Composites

D. Hardness (Shore hardness D-Scale)

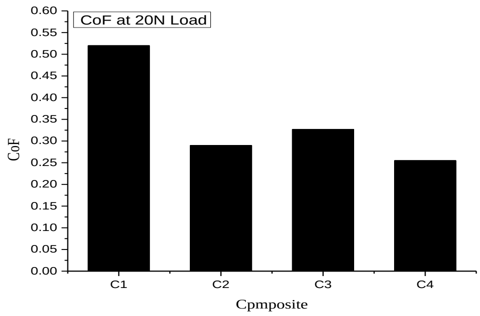
The composites hardness values with various concentrations of reinforcements are shown in graph 4. Hardness has been tested in 3 dissimilar places on each sample and usual values are taken into account. Graph 4 shows Increase in composite hardness. This is due to the reinforcements exist in the matrix of composite and also due to stronger and stiffer nature of reinforcement materials increases resistance to deformation of the composites.



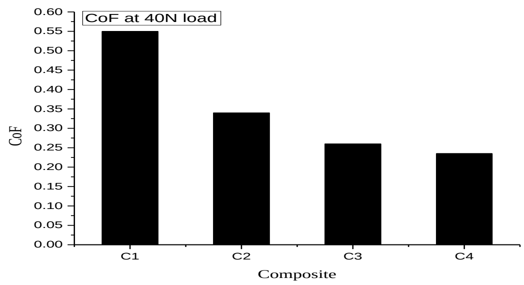
Graph 4 Hardness value of the composites

E. Wear

The wear and friction monitor commonly known as a pin-on-disk machine has been used to measure the wear properties of composite materials. The samples prepared as per ASTM standard G99. A series of measurements were performed with track diameter of 75 mm under loads of 20N and 40N over 15 mins duration with sliding speed of 400rpm. Graph 5 (a) and (b) shows the Coefficient of friction (CoF) for 20N and 40N and graph 6 (a) and (b) shows the Wear in microns for 20N and 40N. The CoF and wear are shown in graph 5 and 6, which indicates that as the percentage of reinforcements in the composites increases both CoF and wear decreases and their will increase in the confrontation of the composition to wear. The inclusion of tougher, harder reinforcements elements rises the resistance of the amalgamated material to peeling or scraping of it. The minimum values for the friction coefficient and wear can be caused by the presence of reinforcements that improves rolling traction rather than sliding.

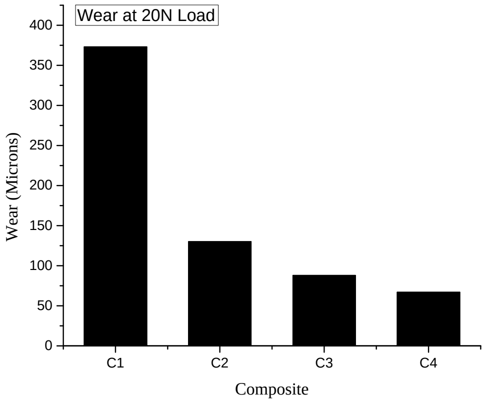


(a)

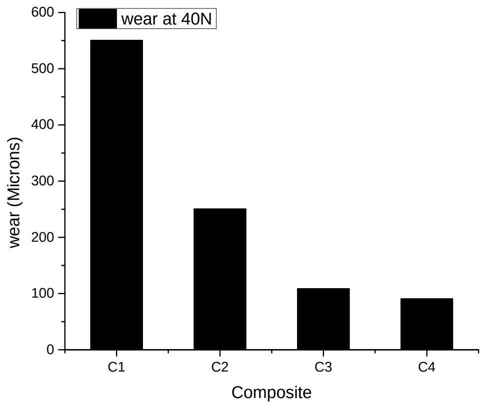


(b)

Graph 5 (a) and (b) CoF of composites for 20N and 40N



(a)



(b)

Graph 6 (a) and (b) wear of composites for 20N and 40N

IV. CONCLUSION

In this analysis a polymer bio-composite, such as implant material for bone replacement, had been attempted to produce orthopedic application. In light of the consequences of this research, the associated outcomes can be drawn.

1. Composites tensile strength is increased with increased vol. % of reinforcements in the composites. The maximum value is obtained in the composite C4.
2. The composite's bending strength and hardness values raised with increased percentage of reinforcements in the composites. The maximum value is obtained in the composite C4.
3. Impact strength of the consider compositions, as increase in the reinforcements of the composites, impact values decreases. Maximum value is obtained in C1 composite and minimum value in C4 composite.
4. Both Wear and CoF of the composites decreases with the increase in the reinforcements in the polymer matrix.

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