

Synthesis and Properties Evaluation of Biopolymer Composites

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ABSTRACT: The objective of this paper is to fabricate a polyethylene biomaterial with good wear properties by reinforcing aluminium oxide in to Ultra high molecular weight polyethylene (UHMWPE). Ultra high molecular weight polyethylene is broadly used for articulating surfaces in total hip and knee replacements. In this work, UHMWPE based polymer composites were synthesized by reinforcing bio inert aluminium oxide (Al_2O_3) using compressed injection moulding. Properties like Hardness and Wear of the polymer composites and pure aluminium oxide were investigated by durometer of shore D scale and tribometer respectively. The addition of aluminium oxide in the polymer composite provides better hardness and better wear properties comparing to the pure ultra high molecular weight polyethylene.

KEYWORDS: Ultra high molecular weight polyethylene, aluminium oxide, shore D scale, Wear rate.

I. INTRODUCTION

Development of bio materials for joints and joint surfaces were made by reinforcing materials with polymers for better properties. Here initially ultra high molecular weight polyethylene was used for replacement of joints. Here they are integrated with other components for better properties. UHMWPE is used as an insert for one of the load-bearing, articulating surfaces in orthopedic implants such as the acetabular cup in the hip prosthesis. The use of UHMWPE can be justified as it has excellent biocompatibility and a lower wear rate and coefficient of friction than that of other polymers. However, its strength is low as compared to human bone and it cannot be used in other non-load bearing joint or as a possible bone substitute material. Important medical advancement for UHMWPE in the past decade has been the increase in the use of fibers for sutures. Alumina is one of the most effective and widely used material in the family of engineering ceramics. This material with good performance, technical grade made are readily available. High purity alumina is a bio inert material and widely used as load bearing articulating component designed for its excellent wear and corrosion resistance, and excellent biocompatibility. Al_2O_3 possesses high elastic modulus and compressive strength, and its bio inert behaviour does not impair the cyto compatibility. Al_2O_3 addition not only improved the mechanical properties but also retained good biocompatibility.

II. EXPERIMENTAL

MATERIALS AND PROCESSING

The UHMWPE powder with a density of 0.93 g/cm^3 was taken and weight measured. The particle size was ranging about 100-500 micrometer. Similarly aluminium oxide (Al_2O_3) was taken that which are also being the same size of powder particles for ensuring fine blending mixture. UHMWPE was taken and mixed with various proportions and four types of samples were made using injection moulding.

The blending is the process of mixing the powders for fine mixture production. The Results of the experimentation depends on the proper blending of the powders. Here the powders are mixed in the ratio of the 100:0, 95:05, 90:10, and 85:15 ratio of UHMWPE and aluminium oxide respectively. They were taken in a bowl and stirred by manual method for around 2 hours.

The preheating process involves in heating the mixture around 100 C in a Heater. The process of preheating enables the process of moulding to be effective and it takes place after the blending process. The preheating process takes place about 1 hour. After this next process is Moulding.

The preheated powder mixture was poured into the die cavity of the moulding cavity. After pouring it is closed and pressed. Then the desired polymer composite material was formed as per the die shape, after the moulding process it was taken out and allowed to cool. Pins of 6 mm diameter were made.

III. PROPERTIES EVALUATION

Hardness

The shore D scale Durometer was used to find the hardness. The ASTM test method designation is ASTM D2240 was used to find the hardness.

Shore D scale specifications:

Hardened steel rod indenter diameter	= 1.4 mm
Conical point angle	= 30°
Radius tip	= 0.1 mm

Wear Rate

The cylindrical pins of length 45mm and diameter 6 mm. The opposite surfaces of the pins were ground parallel to each other and finally lapped to a surface finish. The disc surface was polished. The disc was fitted to the rotating disc in the plexiglass chamber in a pin-on-disc type unidirectional wear and friction monitor. The polymer pin was fitted to the holder. Load was Provided by hanging weights at the end of the lever arm. And connected to the holder. A variable speed electric motor was used to rotate the counter face disc in counter-clockwise direction. The test conditions are listed in Table . Wear of the polyethylene pin was estimated by the mass decreased in the pin.

The pin on disc tribometer consists of a stationary pin under an applied load in contact with a rotating disc. The physical and mechanical properties of the disc are listed in Table After performing the wear test in the tribometer the following results had obtained which shows the addition of aluminium oxide in the ultra-high molecular weight polyethylene leads to decrease in wear.

The wear factor calculated by the following equation

$$W = \frac{M}{PS}$$

Where W is the wear rate in gram/(newton.meter),

M is the mass wear in grams,

P is the load on the pin in Newton,

S is the distance slid in meters.

For measuring the wear rate, a Pin on disc Tribometer experimental setup was used. The sample was taken as the pin and tests were performed was both the pure ultra high molecular weight polyethylene sample and composite sample one after another for same operating condition.

Disc material properties

The disc was fitted to the pin on disc rotor which is monitored by the friction monitor, and tachometer for checking the speed. The disc material properties were listed below.

Material EN 24
Hardness: 60 HRC
RA : 0.25 μ m

The pin which was about to slid on the disc is made of polymer materials. The diameter of the sample was about 6 mm. Length of the pin was about 45 mm.

Sample	Track Diameter (mm)	Sliding velocity (m/s)	Speed (rpm)	Time (seconds)	Track Distance (metre)
U100A00	25	1.5	1146	666.67	1000
U95A05	25	1.5	1146	666.67	1000
U90A10	45	1.5	636.942	666.67	1000
U85A15	45	1.5	636.942	666.67	1000

Table 1: Pin on disc tribometer operating parameters

IV. RESULTS AND DISCUSSION

The addition of Al₂O₃ in the pure ultra high molecular weight polyethylene leads to increase in density of the composite gradually due to the density difference of aluminium oxide and UHMWPE. Since aluminium oxide possess high density than ultra high molecular weight polyethylene around 2.76 g/cc which leads to increase in the density of the composite.

The density of the base materials were

UHMWPE= 0.93 gram/cc, Density of the Al₂O₃ = 3.69 gram/cc

Density of the U100A00 = 0.930 gram/cc

Density of the U95A05 = 0.970 gram/cc

Density of the U90A10 = 1.008 gram/cc

Density of the U85A15 = 1.047 gram/cc

Hardness

The materials were being polymer, the shore D scale durometer was used to measure the Hardness of the polymer.

Shore hardness for U100A00 = 65 shore D

Shore hardness for U95A05 = 68 shore D

Shore hardness for U90A10 = 70 shore D

Shore hardness for U85A15 = 72 shore D

The addition of aluminium oxide shows a gradual increase in the hardness of the material due to reinforcement of aluminium oxide.

From the shore hardness test it can be seen that the addition of aluminium oxide is beneficial for the improvement of hardness property.

Wear rate.

Coefficient of friction mentioned in the table was average value of testing time. The actual coefficient of friction for the overall testing time was shown as a graph below. The average coefficient if friction for UHMWPE was 0.278. The average coefficient if friction for polymer composite was 0.098

Sample	Initial mass (grams)	Final mass (grams)	Coefficient of friction	Frictional force (N)	Wear rate g/Nm
U100A00	0.9830	0.9812	0.278	1.3635	3.6×10^{-7}
U95A05	0.9920	0.9905	0.265	1.299	2.9×10^{-7}
U90A10	0.9975	0.9962	0.198	0.9711	2.6×10^{-7}
U85A15	1.0101	1.0090	0.1223	0.5998	2.2×10^{-7}

Table 2 : wear rate of samples

. Thus the addition of Al₂O₃ in the ultra high molecular weight polyethylene leads to wear reduction and the material gets to come more material life.

V. CONCLUSION

From the result of the experiments for the pure ultra high molecular weight polyethylene and the polymer composites of various composition samples, the following conclusions were made after comparing the properties of the samples. The addition of the Al₂O₃ in the ultra high molecular weight polyethylene leads to increase in the Density of the polymer composite

Also the addition of the Al₂O₃ in the ultra high molecular weight polyethylene makes the composite more wear resistant and reduces wear due to the increase in hardness. In overall aluminium oxide in the Ultra high molecular weight polyethylene leads to better properties of the polymer composites. Further the properties can be made better by altering the reinforcement material amount and by also reinforcing the better strength elements like carbon and graphenes. Also further reinforcements like Hydroxy apatite, etc may also leads to the better properties

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Figure 1: Location of Spar and Ribs from root of wing
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