International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

Vol.3, Special Issue 1 Aug - 2017

Evaluation of Mechanical Properties of Ultra High Molecular Weight Polyethylene Reinforced with TiO_2 Particles

Shanawaz Patil[1] , Sharan Teja Reddy K[2] C Naveen Krishna[3] Syed Sameer[4]

[1,2,3,4]Assistant Professor, School Mechanical Engineering, REVA University, Bengaluru, India,

Abstract

Bones and joints in human body made of a natural composite material are fractured due to excessive loads and impact stress. The various types of bone fractures which occur in human body depend upon crack size orientation, morphology and its location. In general, the mean load on the hip joint is expected up to three to five times of the body weight during jumping, jogging etc. These loads are fluctuating depending on the activities such as standing, sitting, jogging, climbing the staircase etc. The material of prosthesis and the durability of alternate bone material is of critical importance, because it largely determines how load is transferred through the stem. In the geometry and design of the material, the young's modulus of a material is critical design variable.

The polymeric bio-composites reasons, why they are becoming most common composites, include their low cost, high strength and simple in manufacturing principles by molding process. But they suffer from poor mechanical properties like higher wear rate, lower hardness and Young's modulus.

An attempt has been made to develop hybrid bio polymer matrix composites using high density poly ethylene as the matrix material with Titanium Oxide (TiO_2) particles as the reinforcement material with varying percentage using extruder injection moulding machine. The different testing namely, tensile, hardness, flexural strength, density, corrosion and wear test were conducted on the standard samples prepared. It is found as appreciable improvements in the mechanical and tri-biological properties of the hybrid polymer matrix composite, which can be used for variety of applications in the human body bone replacement. In this case, their application in orthopedic as implantable material in the bone surgery has been considered and studied. These composite materials have found wide use in orthopedic applications, particularly in bone fixation plates, hip joint replacement, bone cement and bone graft.

Keywords: *High Density Polyethylene, Titanium Oxide (TiO_2) particles, Orthopedic Applications.*

1. INTRODUCTION

The recent trend advances in the development of composite materials have, in recent years, enabled major improvements in the design of modern orthopaedics and prosthetic devices[1] Composites are engineered materials made from two or more constituents, each offering different physical or chemical properties, which can be combined to produce a material with characteristics different from the individual material. Properties and architectures of biological materials can thus be reflected more accurately by means of tailoring [2]. Fiber reinforced polymer composites are, at present, the most widely used multiphase materials in orthopaedics. In addition, most of today's upper- and lower-limb prostheses are now made from composites with underlying polymer matrix. These types of materials are favorable due to their exceptional strength to weight characteristics as well as their superior biocompatibility [3].

Bone, which is a natural composite material, consists mainly of collagen fibers and an inorganic bone mineral matrix in the form of small crystal called apatite. Collagen is the main fibrous protein, the composite of mineral component in the body. Cartiligen is a collagen based tissue which contains large protein saccharin molecules that form a gel in which collagen fibrous are bonded [4] . Articular cartillery forms the baring surfaces of the moveable joints of the body which behaves linear visco-elastic. It has also very low coefficient of friction largely attributed to the presence of senovial fluid that can be squeezed upon compressive loading.

A biomaterial is a material that relates or interacts with human tissue and body fluids to treat, improve, or replace anatomical elements of the human body. Biomaterial devices used in orthopedics are commonly called implants; these are manufactured for a great number of orthopedic applications. .Biological materials such as human bone allografts (transplants of tissue between genetically different individuals) are considered to be biomaterials because they are used in many cases in orthopedic surgery. Biocompatibility is the primary characteristic that a medical device should have in any orthopedic application; that is, it must not adversely affect the local and systemic host environment of interaction (bone, soft tissues-ionic composition of plasma, as well as intra- and extracellular fluids)

Ultra-High-Molecular-Weight Polyethylene is a subset of thermoplastic polyethylene. Commonly called as High-Density Polyethylene (HDPE). The longer chain of molecules serves to transfer the load more effectively to the polymer-backbone by strengthening intermolecular interactions. HDPE is the non-toxic, tasteless, odorless, 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 [3]. The use of High Density Polyethylene as matrix material, Titanium Oxide and TiO_2 as reinforcement and it is inferred that appreciable improvements in the mechanical and tribological properties of the hybrid polymer matrix composite, which can be used for variety of applications in the human body bone replacement. In this case, their application in orthopaedic as implantable material in the bone surgery has been considered and studied. These composite materials have found wide use in orthopaedic applications, particularly in bone fixation plates, hip joint replacement, bone cement and bone graft [5].

Polymers are filled with inorganic nano-particles are very important sort of nano-composites based on the use of a polymer matrix. They usually combine the advantages of polymer matrix such as low weight, easy formability with the unique characteristics of the inorganic nano-particles. This kind of incorporation of the materials makes the nano-composites to gain a series of properties such as optical, mechanical, electrical and magnetic. However, there are some disadvantages of nano-particles like agglomeration followed by insufficient dispersion in the polymer matrix [6].

In this present paper, the Ultra High Molecular weight Polyethylene used as polymer matrix material and varying percentage of Titanium oxide (TiO_2) particles were used as reinforcing agent. The mechanical properties and Corrosion behavior of Biopolymer composite were investigated.

2. EXPERIMENTAL STUDY

2.1 Preparation of Biopolymer Composites:

This paper highlights the fabrication of biopolymer composite materials and study of mechanical properties which are required to replace fractured bones dental by synthesis of biopolymer matrix composite. The biopolymer matrix composite which suits to the human body host tissues and biocompatible. The polymer matrix composite consist of matrix resin and reinforcing materials particulates or fibrous. Polymer matrix materials can be processes easily, low cost and offer high strength. Biopolymer composite were prepared by using the twin screw extruder and injection molding machine. In the present study, twin screw machine was used extensively for mixing, compounding the high density polyethylene and Titanium oxide. Twin-screw extruders have a proven record in continuous compounding with feeding of different additives (solid, liquid or gas) along the extruder barrel. The combination of a twin-screw extruder unit with additional sensors offers the ability to measure material properties of the melt during processing. Twin-screw extruders can be quickly and easily configured for a wide variety of applications and conditions.

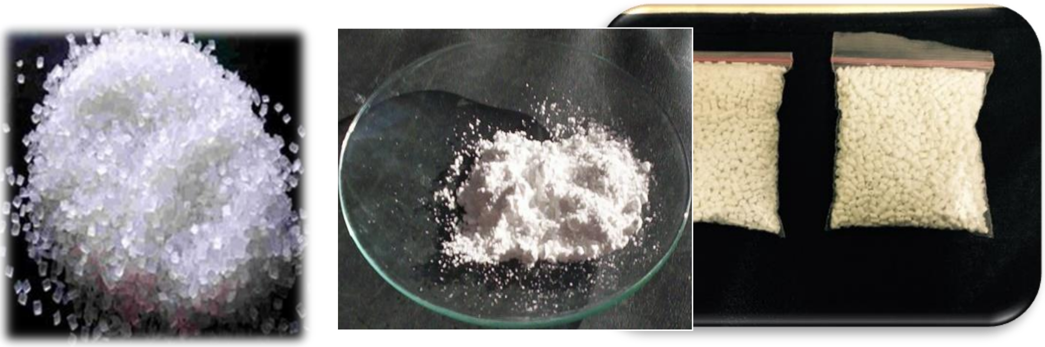
Twin screw extruder consists of 30 mm co rotating intermeshing twin screw with segmented barrel and segmented screw. The process involved in twin screw extruder was the high density polyethylene were dehumidified. After the completion

International Journal of
Advances in Scientific Research and Engineering (ijasre)
E-ISSN : 2454-8006
Vol. 3. Special Issue 1, August-2017

of dehumidification, HDPE and TiO_2mixed with the help of high speed mixer. The granules of HDPE and TiO_2 were fed into hopper of extruder for plasticizing (melting-extruder) of about melting temperature 135^o C and passed through the water bath to cool. Dry air is passed to dry the compound before the palletizing. Finally the compound is then taken for the specimen preparation as per ASTM standards by 75 tonnage injection molding machine. Injection molding machine is used to fabricate polymeric parts by injecting material into a mold. The compound of HDPE is fed into a heated barrel, mixed with the help of screw and melted between the processing temperature 175 ^{o} C to 190^o C. Forced into a mold cavity , where it cools and hardens to the configuration (designed) of the mold cavity.

Figure 1.1: 75 Tonnage Injection Molding Machine Figure1.2: Twin Screw Extruder Molding Machine

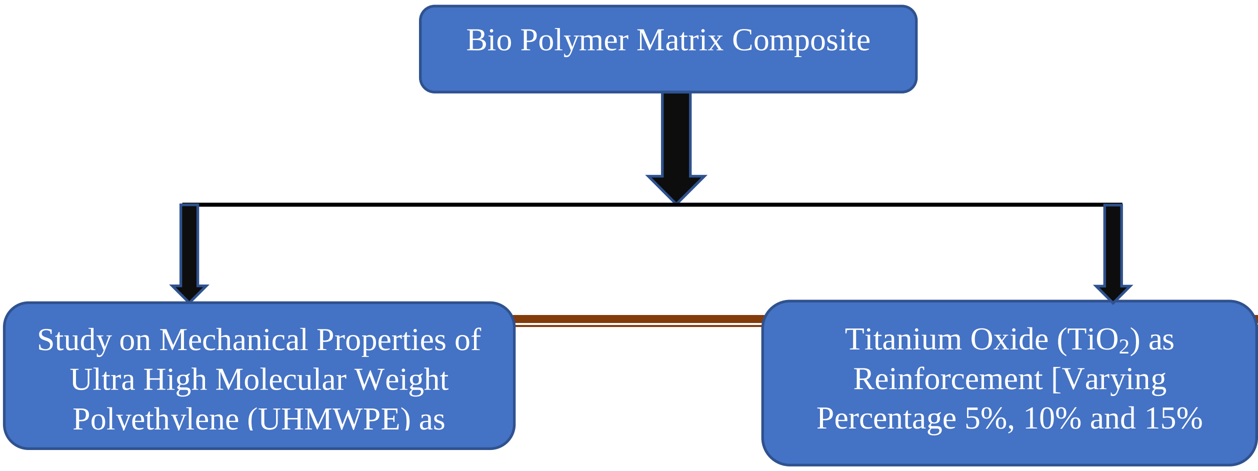
Using rule of mixture of composites with HDPE as matrix materialand 5%, 10% & 15% by weightof TiO2as reinforcing material, hybrid biopolymer composites were fabricated using injection molding



HDPE TiO_2Small grids of HDPE + TiO_2 material

Figure1.3:Bio-Polymer composite materials

2.2 Flow Chart:



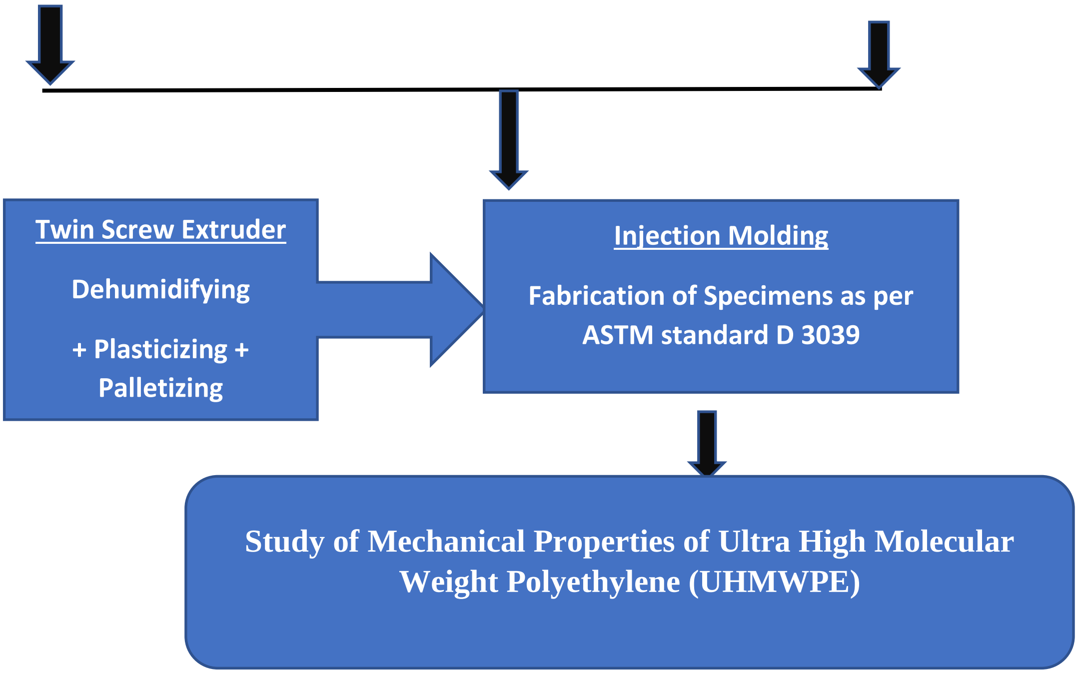


Figure1.4: flow chart Bio-Polymer Matrix materials

Application of Ultra High Molecular Weight Polyethylene polymer matrix composite material in different parts of human body are;

1. Dental Bridges
2. Bone Replacement Material
3. Finger Joint
4. Total Hip Replacement
5. Bone Cement
6. Total Knee Replacement

List of samples prepared with different composition of HDPE and TiO_2 are shown in Table 1 below.

Table 1.1: List of samples

SPECIMENS	HDPE	TiO_2
S1	100%	0%
S2	95%	5%
S3	90%	10%
S4	85%	15%

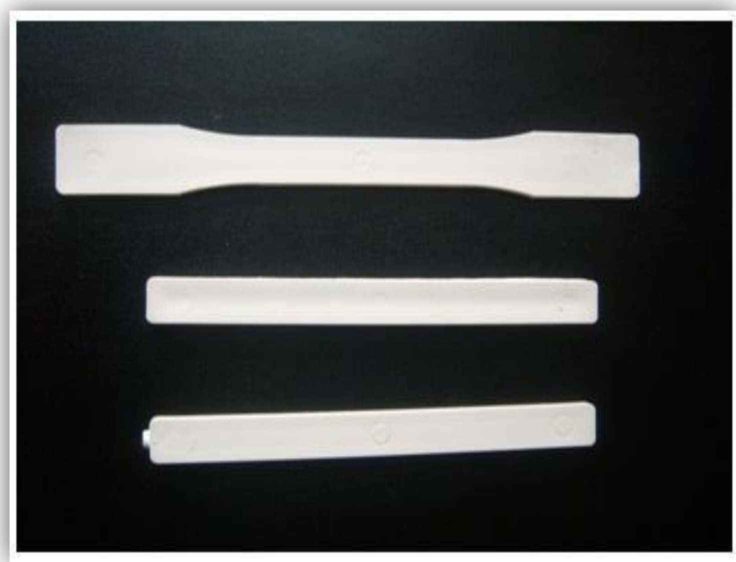


Figure 1.5: Specimens of HDPE and TiO2 as varying reinforcement

2. RESULTS AND DISCUSSION

The results of tensile tests are reported in Table 1.2. It is observed that the addition of Titanium oxide (TiO_2) as reinforcement, increased in Young's Modulus and tensile strength of composite material increases with increasing percentage of reinforcement contents namely 5%, 10%, 15% of TiO_2. This results in the increasing of the load carrying capacity of composite material. The maximum tensile strength were found to be 19 MPa for HDPE and 15% of TiO_2.

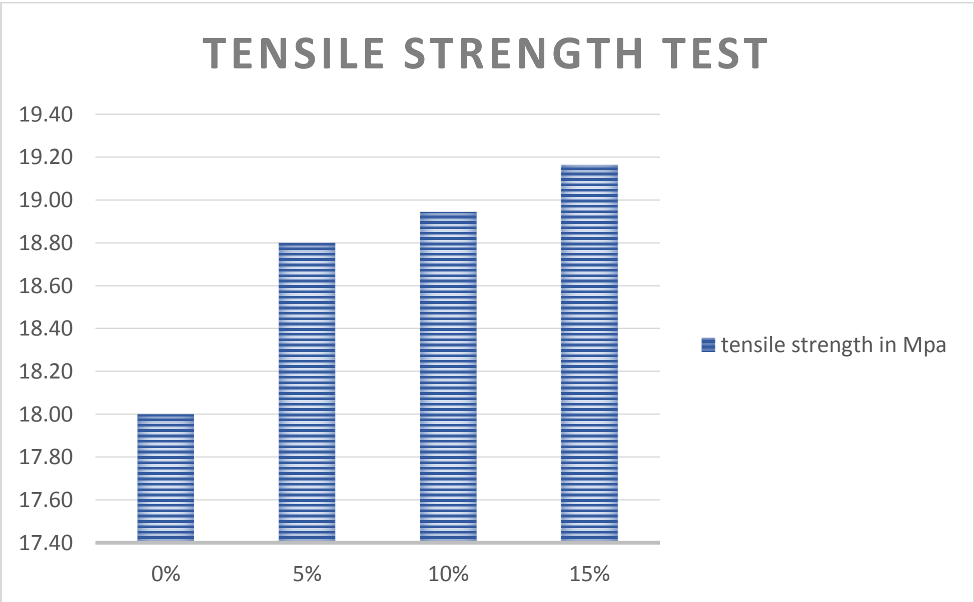


Figure 1.6: Results of Tensile Strength for varying percentage of TiO_2

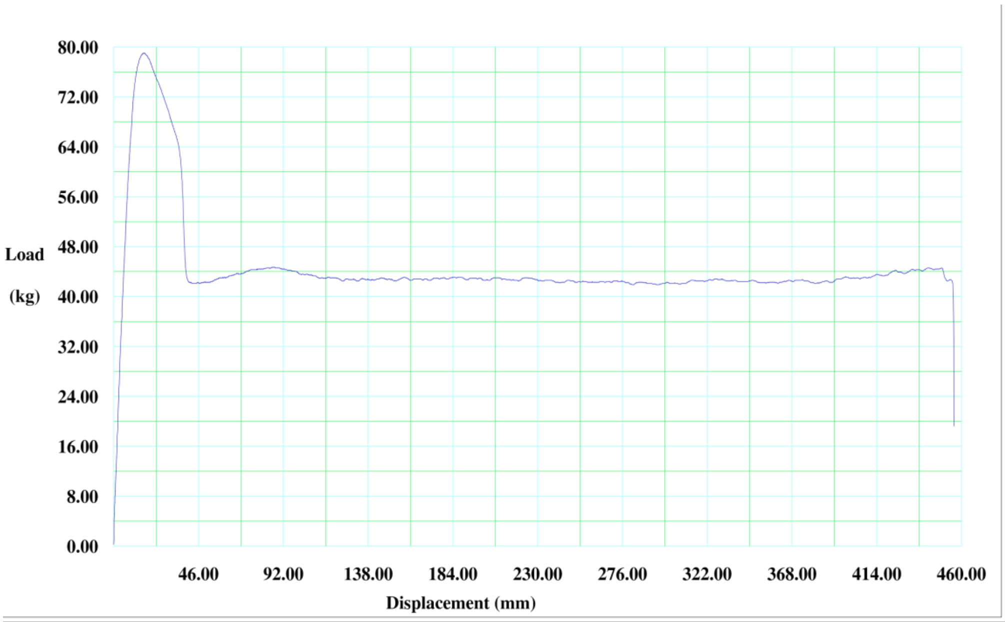


Figure 1.7: Load Vs Displacement curve for HDPE and 15% TiO_2

1. Flexural Test:

From the results of flexural test, it is conferred that variation in the flexural strength of composite specimen with varying percentage of reinforcement material TiO_2 structural strength of opposite material increases with increase in the reinforcement material (TiO_2).

The maximum flexural strength were found to be 12.5 MPa for 15% of TiO_2

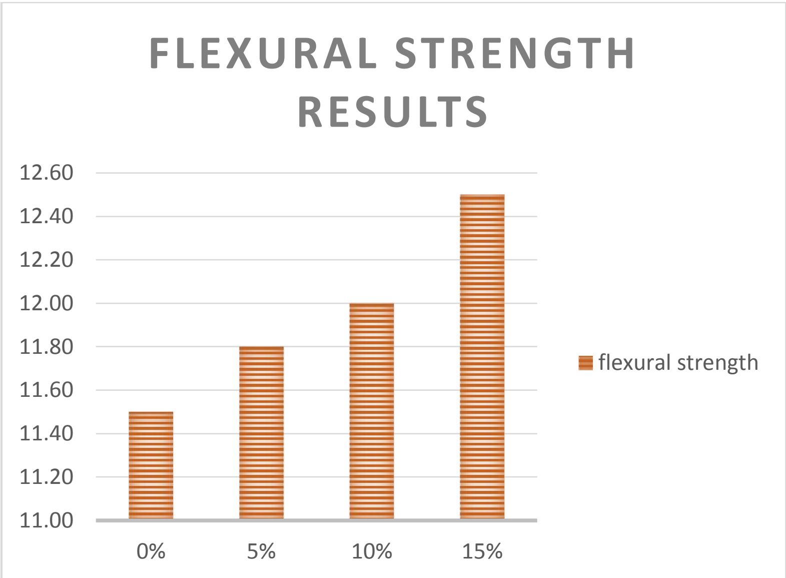


Figure1. 8: Variation in Flexural Strength for varying percentage reinforcement

Material – HDPE + 15% TiO_2

1. The flexural stress at peak load : 185.355kg/cm^2.
2. Percentage deflection at peak load : 23.8%.
3. Ultimate modulus : 852.69MPa

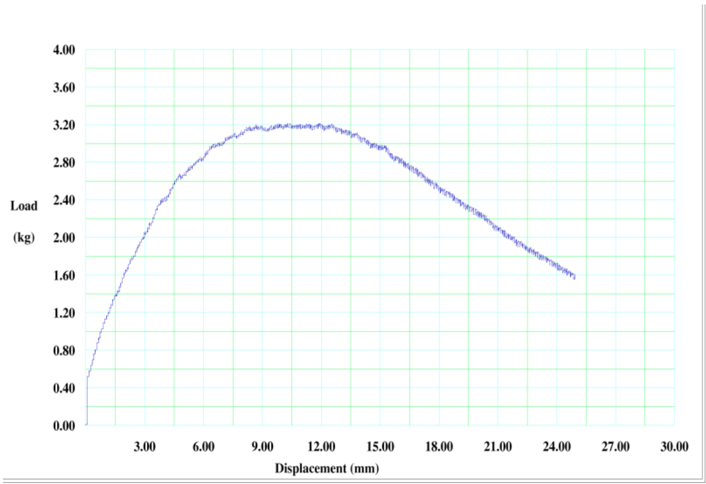


Figure 1. 9: Load versus Displacement for 20% of TiO_2

2. Shore D Hardness Result
   Hardness test were carried out on Shore D equipment and from the tests it is inferred that, Hardness of the bio polymer composite increases with increase in percentage of TiO_2. The maximum shore D number were found to be 55.33.

1. The hardness number for this specimen HDPE + 0% of TiO_2 is 40.
2. The hardness number for this specimen HDPE + 5% of TiO_2 is 46.33
3. The hardness number for this specimen HDPE + 10% of TiO_2 is 49.66.
4. The hardness number for this specimen HDPE + 15% of TiO_2 is 55.33.

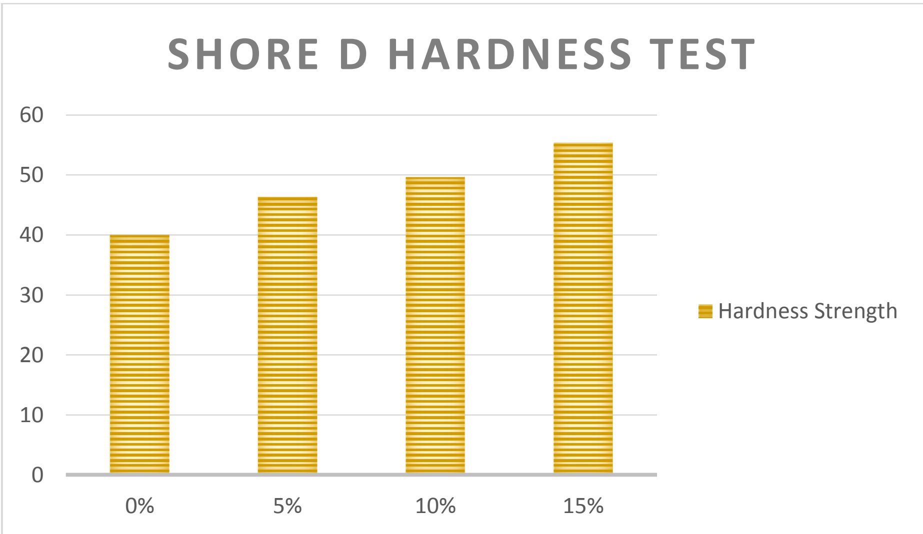


Figure1. 10: Variation in Hardness for varying percentage reinforcement (TiO_2)

3. **Corrosion Test:** The salts spray test were carried on biopolymer composite. Sodium chloride solution is exposed on to the specimens for about 24 Hrs and no corrosion was observed.

Table 1.2: Salt-Spray Conditions

Salt- Spray Conditions	
Test Solution	Sodium chloride (AR Grade) Solution in distilled

Method of Cleaning after test	Running Water
Volume of Solution Collected/Hr/80Cm^2 Area	1.1 ml
Concentration of Test Solution	5% Nacl
Test Temperature	35.1
pH of Test Solution	7.16
Exposure Period	24 hrs

DATE	TIME	OBSERVATION	TOTAL HOURS	TEST METHOD
18.05.2017	10.00 am	------	-----	ASTM B 117 - 2011
19.05.2017	10.00 am	No corrosion was observed	24hrs	

Initial Weight : 4.9167 gm.
Final Weight : 4.9174 gm.
Difference In Weight : 0.0009 gm.

Remarks : No weight and Red corrosion was observed.

4. CONCLUSION

This polymer matrix composite (HDPE+15% TiO2) have variety of applications in the human body and they can be applied on hard and soft tissues of implantable materials.

Composite materials are extensively used in orthopaedic applications particularly in bone fixation plates, hip joint replacement, bone cement and bone graft. The investigations of all possible factors which may affect the life time, together with response of human body, body parts, tissues and muscles changing itself with increasing age, may be performed by special procedures with sophisticated approach.

Maximum tensile strength of 19.18 MPa, Maximum hardness of 55 shore D number and Maximum Bending strength of 12MPa was achieved with HDPE + 15% TiO2 reinforcement.

It is observed that, the tensile strength, hardness and bending strength and of this bio polymer composite increases with the increase in percentage of reinforcement.

REFERENCES

[1] M.S. Scholz et al, The use of composite materials in modern orthopaedic medicine and prosthetic devices: A review

[2] Fu T, Zhao J-L, Xu K-W. The designable elastic modulus of 3-D fabric reinforced biocomposites. Mater Lett 2007; 61 (2):330–3.

[3] Evans SL, Gregson PJ. Composite technology in load-bearing orthopaedic implants. Biomaterials 1998; 19 (15):1329–42.

[4]Ramakrishna S et al. Biomedical applications of polymer-composite materials: a review. Compos Sci Technol 2001; 61(9):1189–224.

[5] Mohammed Haneef, Shanawaz Patil et al, Hybrid Polymer Matrix Composites for Biomedical Applications, vol 2, issue 2, March-April 2013 pp-970-979

[6] Adams D, et al, Carbonfiber-reinforced carbon as a potential implant material, j Biomedical Materials Research 1978; 12:35-42.
[7]Marks LJ, Michael JW. Artificial limbs. BMJ 2001; 323(7315):732–5.
[8] Jenkins GM, de Carvalho FX. Biomedical applications of carbon fibre reinforced carbon in implanted prostheses. Carbon 1977; 15(1):33–7.
[9] Soo Whon Lee, Carlos Morillo, Joaquin Lira-Olivares, Seung Ho Kim, Tohru Sekino, Koichi Niihara, Bernard J. Hockey, paper entitled "Tribological and microstructural analysis of Al2O3/TiO2 Nan composites to use in the femoral head of hip replacement", WEAR journal, Science direct, wear 255 (2003), PP (1040-1044), ELSEVIER.
[10] C.X. Dong, S.J. Zhu, Mineo Mizuno and Masami Hashimoto, paper entitled "Fatigue behavior of HDPE composite reinforced with silane modified TiO2", Journal Material Science Technology (JMST), Science direct, 2011 27(7), pp (659-667), ELSEVIER.
[11] S. Mazurkiewicz et al, paper entitled "The Methods of evaluating mechanical properties of polymer matrix composites", Archives of foundry engineering journal ISSN (1897-3310), Volume 10, Special Issue 3/2010, pp (209 – 212).
[12] K. Van de velde and P. Kiekens paper entitled "Biopolymers: overview of several properties and consequences on their applications", POLYMER TESTING Journal 21 (2002), pp (433-422), ELSEVIER.
[13] Santiago Visbal, Joaquin Lira-Olivares, Tohru Sekino, Koichi Niihara, Byung Kyu Moon, Soo Whon Lee, paper entitled "Mechanical properties of Al2O3 - TiO2- Sic Nan composites for femoral Head of Hip Joint Replacement", Material Science forum Journal, June (2005), Volumes (486-487), pp (197-200), Material Science forum.
[14] Mirigul Altan and Huseyin Yildirim, paper entitled "Mechanical and morphological properties of polypropylene and high density polyethylene matrix composites reinforced with surface modified nano sized TiO2 particles", World Academy of Science, Engineering and technology Journal, 70, 2010.
[15] W.Pompe, H. Worch, M. Epple, W. Friess, M. Gelinsky, P. Greil, U. Hempel, D. Scharnweber, K. Schulte, paper entitled "Functionally graded materials for biomedical applications" Materials Science and Engineering journal, A362, (2003), pp (40–60), ELSEVIER.
[16] R M Hall et al, paper entitled "The friction of explanted hip prosthesis", British Journal of Rheumatology, 1997, 36: pp (20-26).
[17] T.Kameyama et al, paper entitled "Hybrid bioceramics with metals and polymers for better Biomaterials" T KAMEYAMA.Vol no 22, no 3.1999 Indian academy of science.
[18] C. M. Manjunatha, S. Sprenger, A. C. Taylor,A. J. Kinloch, paper entitled "The Tensile Fatigue Behavior of a GFRP Composite with Rubber Particle Modified Epoxy Matrix", Journal of Reinforced Plastics and Composites 2010, 29: pp 2170.
[19] Subhadip Bodhak, Shekar Nath and Bikramjit Basu, paper entitled "Friction and Wear Properties of Novel HDPE-Hap-Al2O3 Biocomposites against Alumina counter face", Laboratory for Advanced Ceramics, Department of Materials and Metallurgical Engineering. Indian Institute of Technology IIT-Kanpur, 208016, India.
[20] E.J.Giordani et al, paper entitled "Effect of precipitates on the corrosion-fatigue crack initiation of ISO58329 stainless steel biomaterial", International journal of Fatigue 26 (2004), pp (1129-1136), ELSEVIER.
[21] Ravikumar et al, paper entitled "Compliance calibration for fatigue crack propagation testing of ultra high molecular weight polyethylene", Journal of Biomaterials 27 (2006) pp (4693-4697), ELSEVIER.

[22] XiSHi WanG et al, paper entitled "The hip stress level analysis for human routine activities", Journal of Biomedical engineering-Applications, basis and communications, June (2005), 17: pp (153-158).

[23] Santavirta S, Bohler M, Harris WH, Konttinen YT, Lappalainen R, Muratoglu O. Rieker C, Sazler M, paper entitled "Alternative Materials to improve total hip replacement tribology", Department of Mechanical Engineering, University of Leeds, UK.

[24] Shekar Nath and Bikramjit Basu, Paper entitled "Development of designed Biocomposites for Orthopedic Applications" Department of Materials and Metallurgical Engineering. Indian Institute of Technology IIT-Kanpur, India.

[25] Amogh Tathe, Mangesh Ghodke, Anna Pratima Nikalje Paper entitled "Brief review on biomaterials and their applications", International Journal of Pharmacy and Pharmaceutical Sciences ISSN-(0975-1491) Volume 2, Suppl 4 (2010), pp (19-23).

[26] Black J, Hasting GW. Handbook of biomaterials Properties. London, UK: Chapman Hall, 1998.

[27] A text book of "Manufacturing Engineering and Technology" Serope kalpakjian and Steven R. Schmid, Pearson Education, ISBN 81-7808-157-1, 2001.Ozaki, Y. Adachi, Y. Iwahori, and N. Ishii, Application of fuzzy theory to writer recognition of Chinese characters, International Journal of Modeling and Simulation, 18(2), 1998, 112-116.