

SYNTHESIS AND CHARACTERIZATION OF MECHANICAL BEHAVIOUR OF UHMWPE REINFORCED WITH BIOMATERIAL COMPOSITES

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

By

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**DEPARTMENT OF MECHANICAL ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600119.**

APRIL - 2023



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **S.MARIA CLEMENT HARRISON (39150081)** and **M.MARIYA CLEMENT SAVIO (39150082)** who carried out the project entitled **"SYNTHESIS AND CHARACTERIZATION OF MECHANICAL BEHAVIOUR OF UHMWPE REINFORCED WITH BIOMATERIAL COMPOSITES"** under my supervision from December 2022 to April 2023.

Project Guide

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DECLARATION

We, **S.MARIA CLEMENT HARRISON**, and **M.MARIYA CLEMENT SAVIO** hereby declare that the ProjectReport entitled “**SYNTHESIS AND CHARACTERIZATION OF MECHANICAL BEHAVIOUR OF UHMWPE REINFORCED WITH BIO MATERIAL COMPOSITES**” done by us under the guidance of **Dr. V. SIVAPRAKASH M.E., Ph.D.**, at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering Degree in Mechanical Engineering.



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ABSTRACT

The prime objective of the work is focused on development of prosthesis with less cost and best quality for the hip replacement of human beings. Ultra-high molecular weight polyethylene (UHMWPE) is a thermoplastic material normally used as a bearing component for human joint replacements. However, formation of debris from UHMWPE after certain period of time may cause adverse effects which remain as an unresolved issue. The UHMWPE is extensively used to develop prosthesis due to its mechanical and biocompatible features.

The various research studies revealed the reinforcement of biomaterials with UHMWPE possesses superior biocompatibility and durability. Ultra-high-molecular-weight polyethylene (UHMWPE) is a type of thermoplastic polymer with a very high molecular weight, typically ranging from 3.5 to 7.5 million Daltons. Due to its unique combination of high strength, low friction coefficient, and high impact resistance, UHMWPE has found numerous applications in various fields, including biomedical implants, industrial components, and protective equipment. UHMWPE is also known for its excellent resistance to chemicals and abrasion, making it a popular material for wear-resistant applications.

In this abstract, we provide a brief overview of the properties and applications of UHMWPE, highlighting its importance as a high-performance polymer in various industries. Composite materials are constructed from two distinct materials with distinct physical and chemical properties. Composites are used in a variety of engineering fields because they have superior material properties to their constituent materials, such as higher strength and lower stiffness. Composites have become increasingly popular in biomedical engineering over the last few decades.

This paper presents a critical analysis of UHMWPE for the latest advancement polymeric implants by adding another biomaterial and a mineral. An effort has been made to highlight the exceptional features of modified UHMWPE by adding hydrous magnesium silicate and zirconium.

CONTENTS

CHAPTER NO.	PARTICULARS	PAGE NO.
	ABSTRACT	i
	LIST OF FIGURES	iv
	LIST OF TABLES	v
	LIST OF ABBREVIATIONS	vi
1	INTRODUCTION	1
	1.1 INTRODUCTION TO BIOMECHANICS	1
	1.2 PRINCIPLE OF HUMAN MOVEMENT	2
	1.3 HIP IMPLANT BASIC	4
	1.3.1 FEMUR	4
	1.3.2 ACETABULUM	5
	1.4 BIOMECHANICS OF THE HIP JOINT	5
	1.4.1 BODY SEGMENT COORDINATE FRAMES	6
	1.5 WALKING CYCLE OF HUMAN	7
	1.5.1 STAGES OF WALKING	7
	1.6 TYPES OF HIP REPLACEMENT	8
	1.6.1 TOTAL HIP REPLACEMENT	8
	1.6.2 HIP RESURFACING	9
	1.7 COMMON COMPLICATIONS OF HIP JOINT	11
	1.7.1 LOOSENING OF THE JOINT	11

CHAPTER NO.	PARTICULARS	PAGE NO.
	1.7.2 WEAR AND TEAR	11
2	LITERATURE SURVEY	12
3	AIM AND SCOPE	19
	3.1 AIM	19
	3.2 SCOPE OF THE PROJECT	20
4	MATERIALS AND METHODOLOGY	21
	4.1 MATERIALS	21
	4.1.1 ULTRA HIGH MOLECULAR WEIGHT POLYETHYLENE(UHMWPE)	21
	4.1.2 HYDROUS MAGNESIUM SILICATE(TALC)	22
	4.1.3 ZIRCONIUM	23
	4.2 METHODOLOGY	24
	4.2.1 SAMPLE EXTRACTION	24
	4.2.1.1 COMPRESSION MOULDING	24
	4.2.1.2 CUTTING PROCESS	27
5	RESULTS AND DISCUSSION	28
	5.1 MECHANICAL CHARACTERIZATION	28
	5.2 TENSILE TEST	28
	5.3 COMPRESSION TEST	31
6	CONCLUSION	35
	REFERENCE	36
	APPENDIX I	38

LIST OF FIGURES

FIG NO.	TITLE	PAGE NO..
1.1	CLASSIFICATION OF BIOMECHANICS	2
1.2	THE PELVIC CO-ORDINATE SYSTEM	3
1.3	ARTIFICIAL HIP IMPLANTATION	3
1.4	FEMUR	4
1.5	ACETABULUM	5
1.6	BODY SEGMENT COORDINATE FRAME OF THE HIP JOINT	6
1.7	HIP REPLACEMENT TYPES	8
1.8	TOTAL HIP REPLACEMENT	9
1.9	HIP RESURFACING	10
1.1	HEALTHY HIP	10
4.1	POWDER OF UHMWPE	22
4.2	POWDER OF TALC	23
4.3	POWDER OF ZIRCONIUM	24
4.4	COMPRESSION MOULDING SETUP CIT COIMBATORE	25
4.5	COMPOSITE MATERIALS	26
4.6	CUTTING MACHINE	27
5.1	UNIVERSAL TENSILE TESTING MACHINE	29
5.2	LINE GRAPH OF TENSILE TEST RESULTS	30
5.3	TENSILE TEST SPECIMEN	30
5.4	AFTER ELONGATION	31
5.5	UNIVERSAL COMPRESSION TESTING MACHINE	32
5.6	COMPRESSION TEST RESULT LINE GRAPH	33
5.7	BEFORE DEFORMATION	34
5.8	AFTER DEFORMATION	34

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
4.1	PROPERTIES OF UHMWPE-MATRIX	21
4.2	PROPERTIES OF HYDROUS MANGNESIUM SILICATE	22
4.3	PROPERTIES OF ZIRCONIUM	23
4.4	SAMPLE PERCENTAGE	25
5.1	TABLE OF TENSILE STRESS	29
5.2	TABLE OF COMPRESSION TEST	33

LIST OF ABBREVIATIONS

UHMWPE	Ultra-High Molecular Weight Polyethylene
ASTM	American Society for Testing and Materials
DIA	Diameter
UTM	Universal Testing Machine
TS	Tensile Strength
CS	Compressive Strength
Max	Maximum
Min	Minimum
YS	Yield Strength

CHAPTER 1

INTRODUCTION

1.1.INTRODUCTION TO BIOMECHANICS

Biomechanics is the study of the structure and function of biological systems such as humans, animals, plants, organs, and cells by means of the methods of mechanics. Biotechnics is closely related to engineering, because it often uses traditional engineering sciences to analyze biological systems. The word "biomechanics" (1899) and the related "biomechanical- were coined by Nikolai Bernstein from the Ancient Greek words bios "life" and "mechanics", to refer to the study of the mechanical principles of living organisms, particularly their movement and structure. Some simple applications of Newtonian mechanics and or materials sciences can supply correct approximations to the mechanics of many biological systems. Applied mechanics, most notably mechanical engineering disciplines such as continuum mechanics, mechanism analysis. Structural analysis, kinematics and dynamics play prominent roles in the study of biomechanics.

Usually, biological systems are more complex than man-built systems. Numerical methods are hence applied in almost every biomechanical study. Research is done in an iterative process of hypothesis and verification, including several steps of modelling, computer simulation and experimental measurements. Bio-tribology is a study of friction, wear and lubrication of biological systems especially human joints such as hips and knees. For example. femoral component and tibial component of knee implant rub against each other during daily activity such as walking or stair climbing.

If the performance of tibial component needs to be analyzed, the principles of bio-tribology are used to determine the wear performance of the implant and lubrication effects of synovial fluid. In addition, the theory of Contact mechanics also becomes very important for wear analysis. The main aspects of Contact mechanics and tribology are related with friction, wear and lubrication when the two surfaces come in contact during motion i.e., rub against each other, friction, wear and lubrication effects are very important to analyze in order to determine the performance of the material.

The study of biomechanics ranges from the inner workings of cell to the movement and development of limbs, to the mechanical properties of soft tissue and bones. Biomechanics is also applied to studying human musculoskeletal systems. Such research utilizes force platforms to study human ground reaction forces and infrared videography to capture the trajectories of markers attached to the human body to study human 3D motion. The sub fields of biomechanics are shown in Figure 1.1

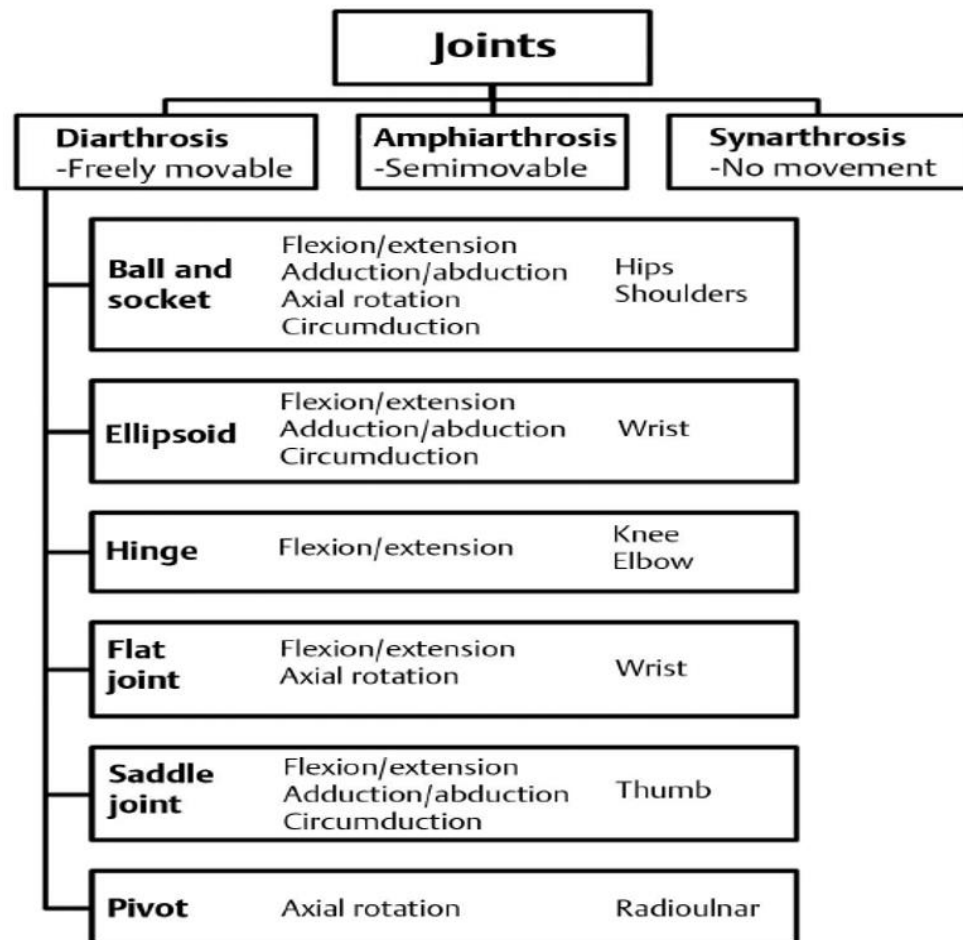


Figure 1.1 Classification of Biomechanics

1.2 PRINCIPLE OF HUMAN MOVEMENT

Biomechanics is a multidisciplinary specialty. In Orthopedics, it influences the prevention, diagnosis and treatment of most musculoskeletal injuries and diseases. Biomechanics utilizes and applies the principles of mechanics to biological problems to allow description of human movement. Therefore, understanding the biomechanics of the hip joint is very important. This requires relative findings and expressing them in an anatomical coordinate frame, consisting of three mutually

perpendicular cardinal planes figure. 1.2. The subject is considered to be in neutral posture when they are upright and erect on both legs with legs with arms to side. Biomechanical assessment of motion uses the principal of rigid body mechanics, which regards the distance between points on moving segment to be invariant. A common exception to use this rule is skin movement, which is considered non-rigid. A rigid-body has six degrees of freedom, with three translational and three rotational degrees of freedom which are used to describe the location and orientation of a body segment is shown in figure. 1.3

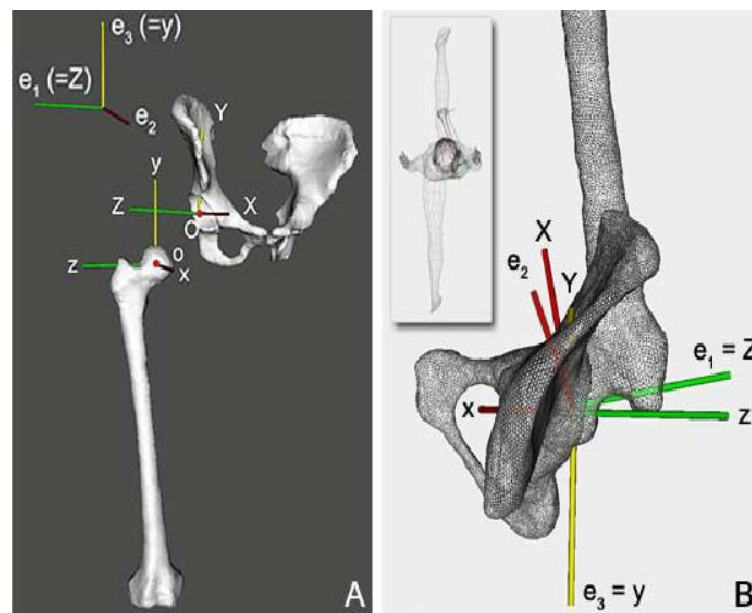


Figure.1.2 The pelvic co-ordinate system

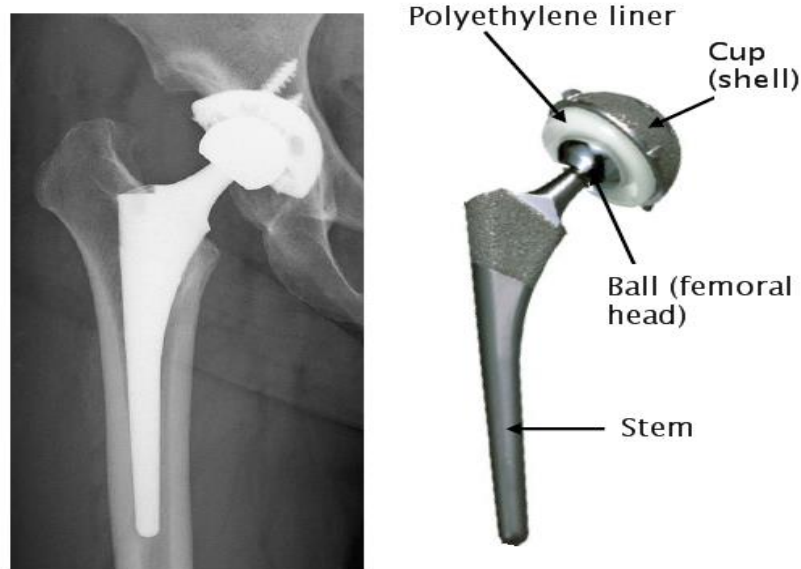


Figure1.3 Artificial Hip Implantation

1.3 HIP IMPLANT BASIC

In a total hip replacement surgery, the diseased or damaged hip with an implant consisting of a stem, ball, liner and socket. The stem, made up of metal, is inserted into femur (thigh bone) and anchors the implant in place. The ball is attached to the stem. The socket is anchored into the pelvis and the ball, which is attached to the top of the top of the stem, then rotates within the liner figure.1.4. The area where the moving parts of the implant connect is known as the bearing. The bearing gives the ball of the hip implant a smooth surface on which to glide and rotate. The term "bearing" actually refers not just to a single part of the implant, but also to the area at which the ball and socket.

1.3.1 Femur

The femur head is the highest part of thigh bone. It is supported by the neck of the femur figure.1.5. The head is globular and forms rather more than a hemisphere is directed upward, medial ward, and a little forward, the greater part of its convexity being above and in front. Its surface is smooth, coated with cartilage in the fresh state, except over an ovoid depression, the fovea capitis femoris, which is situated a little below and behind the center of the and gives attachment to the ligament of head of femur. If there is a fracture of the neck of the femur, the blood supply through the ligament becomes crucial.

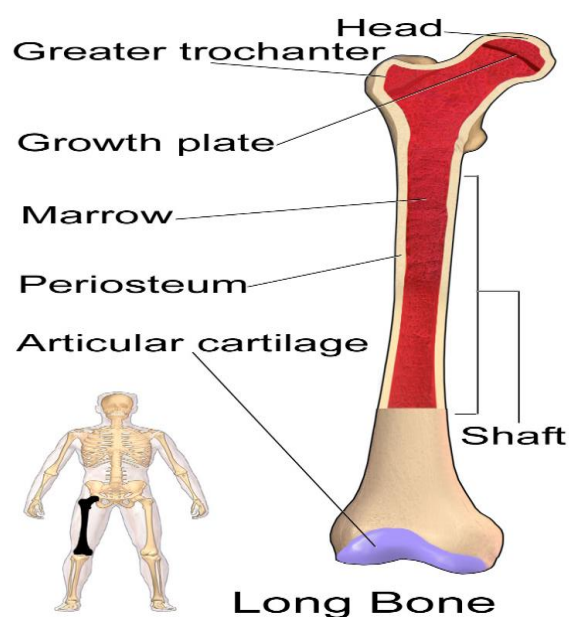


Figure1.4 Femur

1.3.2 Acetabulum

Acetabulum, a concave surface of the pelvis is shown in figure.1.6. The head of the femur meets with the pelvis at the acetabulum, forming the hip joint. At the lowest part of the acetabulum is the acetabular notch, which is continuous with a circular depression, the acetabular fossa, at the bottom of the cavity of the acetabulum. The rest of the acetabulum is formed by a curved, crescent-moon shaped surface, the lunate surface, where the joint is made with the head of the femur. The well-fitting surfaces of the femoral head and acetabulum, which face each other, are lined with a layer of slippery tissue called articular cartilage, which is lubricated by a thin film of synovial fluid.

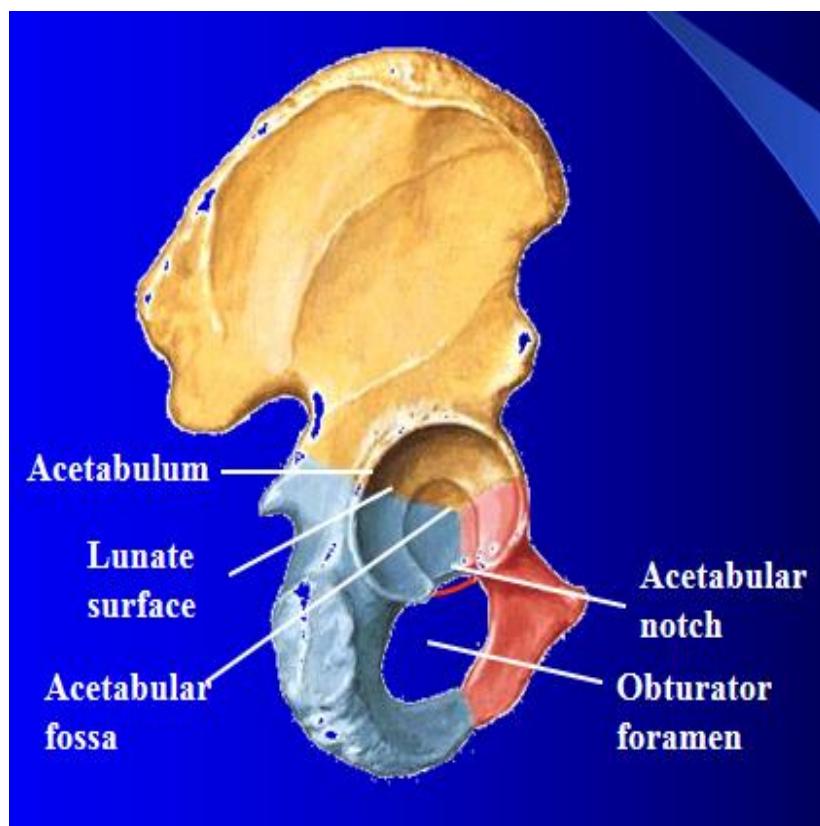


Figure 1.5 Acetabulum

1.4 BIOMECHANICS OF THE HIP JOINT

This section will outline how the motion of the hip joint is expressed. At first, the pelvic and femoral body segment coordinate forms will be introduced. This will be followed by how these body segments are aligned in a hip joint coordinate frame to express joint articulation.

1.4.1 Body Segment Coordinate Frames

To describe the motion of a bone, a cartesian coordinate frame is established. The rotation center is fixed over the entire range of motion of the hip joint. Consequently, as the origin of the hip joint coordinate frame is located at the center of the hip, there are no translational effects within the joint and only the rotational motions of flexion/tension, abduction/adduction and internal/external rotation are possible figure 1.7. Hip joint prosthetics are manufactured to be spherical therefore exhibit this perfect “ball and socket” behavior providing there is enough tension in the soft tissue structure and the femoral neck does not impinge against the rim of the pelvic acetabular cup.

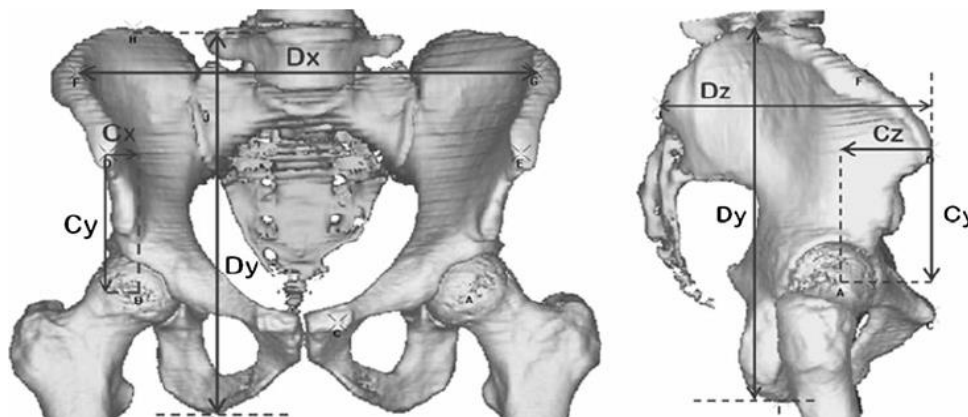


Figure 1.6 Body segment coordinate frame of the hip joint

The coronal plane defined, which contains the hip joint center and the medial and lateral femoral epicondyles. The anterior – posterior axis is constructed perpendicular to the coronal plane located at the hip joint center. The medial lateral axis is constructed orthogonal to the other two axis.

- X- Axis: Medial/Lateral (Inboard to Outboard)
- Y-Axis: Anterior/Posterior (Front to Rear)
- Z-Axis: Superior/Inferior (Head to Toe)
- First Rotation: Flexion/Extension (f) about the X-Axis
- Second Rotation: Abduction/Adduction (a) about the floating axis
- Third Rotation: Internal/External rotation (r) about the femoral Z-Axis

1.5 WALKING CYCLE OF HUMAN

The hip joint is one of the most important weight bearing and shock absorbing structure during both static (standing) and dynamic (walking, running, stumbling, climbing upstairs and climbing downstairs etc.,) postures. The main function of the hip is mobility and support the weight of the body. The hip joint has to support approximately three-four times of the body weight during static condition. The forces considered into account of the body weight; counter balanced by the force exerted by the gluteal muscles. The factor influencing the joint pressure are the body weight, the neck angle, the position of the fulcrum, the distance of the line is to support the body weight and the use of body stick.

1.5.1. Stages of Walking

The typical walk consists of a repeated gait cycle. The cycle itself contains two phases – a stance phase and a swing phase:

Stance phase: Accounts for 60% of the gait cycle. It can be divided into the heel strike, support, and toe-off phases.

Swing phase: Accounts for 40% of the cycle. It can be divided into the leg lift and swing phases.

We will now work through each individual stage in turn, discussing them in more detail.

Heel-Strike: In the heel-strike stage, the foot hits the ground heel first. Three muscles/muscle sets are involved, each acting at a different joint.

Gluteus maximus: acts on the hip to decelerate the forward motion of the lower limb.

Quadriceps femoris: keeps the leg extended at the knee and the thigh flexed at the hip.

Anterior compartment of the leg: maintains the ankle dorsiflexion, positioning the heel for the strike.

After the heel strike stage, the rest of the leading foot hits the ground, and

the muscles work to cope with the force passing through the leg. This is known as the support stage. Next, the heel hits the ground, and the whole cycle repeats.

1.6 TYPES OF HIP REPLACEMENT

Hip replacement is a surgical procedure in which the natural hip joint is replaced by an artificial implant. The earliest record attempts at hip replacement which were carried out in Germany use an ivory to replace the femoral head. Hip replacement surgery could be performed as a total hip replacement or hemi replacement.

The three types of major hip replacement are

- Total Hip Replacement
- Partial Hip Replacement
- Hip Resurfacing

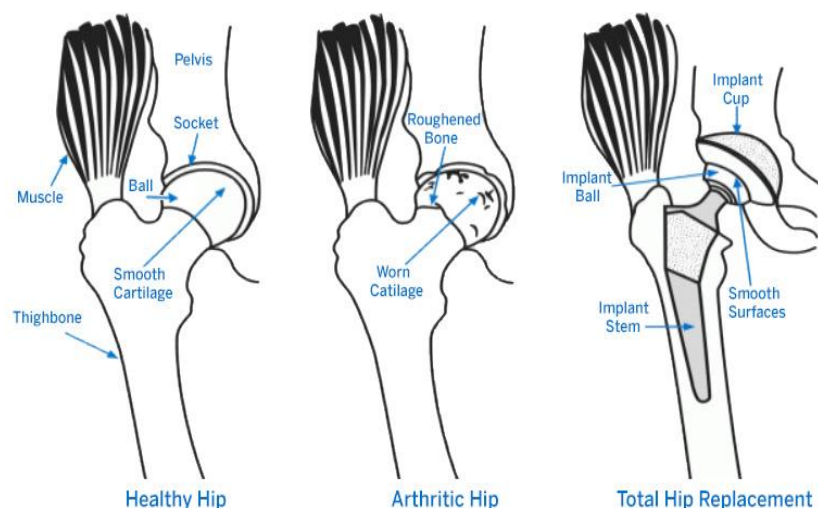


Figure 1.7 Hip Replacement types

1.6.1 TOTAL HIP REPLACEMENT

The most common type of hip replacement surgery is called a total hip replacement (also called total hip arthroplasty). In this surgery, worn-out or damaged sections of your hip are replaced with artificial implants. The socket is replaced with a durable plastic cup, which may or may not also include a titanium metal shell. Your femoral head will be removed and replaced with a ball made from ceramic or a metal alloy. The new ball is attached to a metal stem that is inserted into the top of your femur.



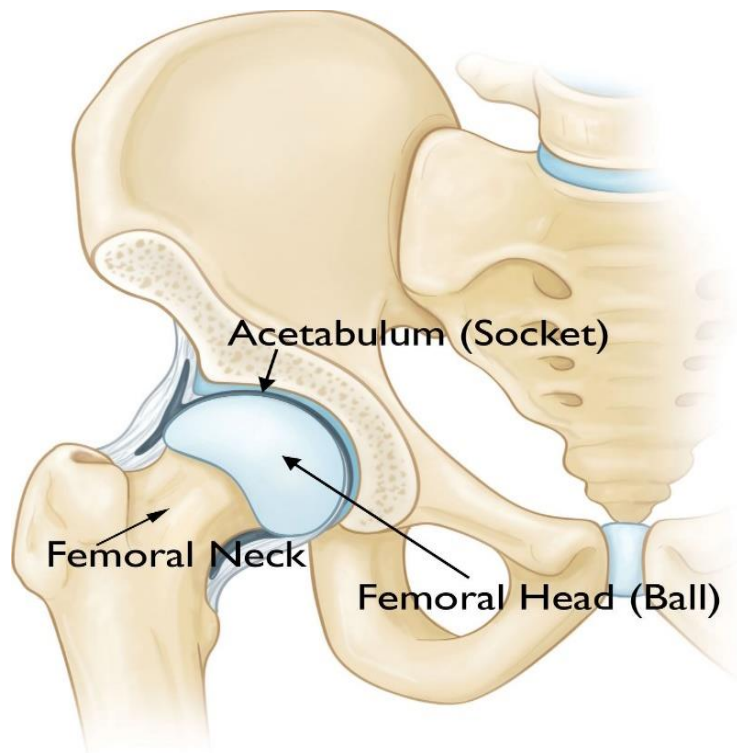
Figure1.8 Total Hip Replacement

1.6.2 HIP RESURFACING

Hip resurfacing has been developed as a surgical alternative to total hip replacement (THR). The procedure consists of placing a cap (usually made of cobalt-chrome metal), which is hollow and shaped like a mushroom, over the head of the femur while a matching metal cup (similar to what is used with a THR) is placed in the acetabulum (pelvis socket), replacing the articulating surfaces of the person's hip joint and removing very little bone compared to a THR. When the person moves the hip, the movement of the joint induces synovial fluid to flow between the hard metal bearing surfaces lubricating them when the components are placed in the correct position. The surgeon's level of experience with hip resurfacing is most important; therefore, the selection of the right surgeon is crucial for a successful outcome. Health-related quality of life measures are markedly improved and the person's satisfaction is favourable after hip resurfacing arthroplasty.



Figure 1.9 Hip Resurfacing



Front of a Healthy Hip

Figure 1.10 Healthy hip

1.7 COMMON COMPLICATIONS OF HIP JOINT

The common complication that are observed in implanted hip joint include wear and tear, loosening of the joint, dislocation and infection.

1.7.1 Loosening of the Joint

The most common problem that can arise as a result of a hip replacement is loosening of the joint. This can be caused by the shaft of the prosthesis become loose in the hollow of the thigh bone, or due to thinning of the bone around the implant. Loosening of the joint can occur at any time, but it normally occurs 10-15 years after the original surgery was performed.

1.7.2 Wear and Tear

One of the main complications of hip replacement surgery is wear and tear of the artificial sockets. Particles that have worn off the artificial joint surfaces can be absorbed by surrounding tissue, causing redness and swelling (inflammation) in and around the joint. Anti-inflammatory medication such as (inflammation) in and around the joint. Anti-inflammatory medication such as ibuprofen may stop the problem. Metal-on-metal implant wear sooner than expected and causing complication.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY

In this paper due to the benefit of adaptation to the defect margin and ease of handling, injectable biomaterials are receiving more and more attention for the healing of bone defects. RADA16 peptide hydrogel greatly promoted bone growth, according to our prior investigations. For the creation of a RADA16/CaSO₄/HA composite biomaterial, the porous calcium sulfate/nano-hydroxyapatite (CaSO₄/HA) cement biomaterial was filled with RADA16 peptide hydrogel to increase the mechanical force. These suggest that the controlled release of bFGF by bFGF- incorporated RADA16/CaSO₄/HA, which offers a unique injectable biomaterial design to precisely release growth factors for bone deficiencies, can further increase bone formation. [1]

This paper intends to show the implantation of biomaterials and bone grafting are the topics of this essay. The paper discusses selection difficulties for applications using biomaterials and bone grafting. There has been much discussion of the mechanical requirements for different types of biomedical implants in order for them to be compatible with host tissue. Additionally, advantages of polymer composite over metal and ceramic for implantation are also covered. The manufacture of several kinds of biomaterials is described, along with the difficulties encountered. Also covered in detail are the advantages and restrictions. 3D modelling biodegradable plastic Biomaterial Bone Implants technical characteristics Compression moulding with microwave assistance Sol-gel total replacement of the knee. [2]

This study shows that two separate materials with diverse physical and chemical properties are combined to form composite materials. Due to their superior material properties such as increased strength and decreased stiffness composite materials are used in a variety of engineering fields. Over the past few decades, the usage of composites in biomedical engineering has increased significantly. Various implants and grafting/substitute materials are needed to replace and/or heal damaged tissues and/or organs; ideally, these materials

should have certain mechanical properties that match the target host tissue. First, the structure and makeup of naturally occurring composite materials in the human body are discussed, along with cellular reactions to implanted composite materials. The next section highlights composite material characterization and manufacture procedures. The usage of composite materials in various applications for both hard and soft tissues is then explained. [3]

In this work the Intervertebral disc (IVD) herniation- related disability is lessened by discectomy procedures, however flaws in the annulus fibrosus (AF) caused by herniation are not repaired. Although cell treatment holds promise for IVD repair, cell delivery biomaterials that can correct biomechanical function and seal AF flaws work poorly biologically. Biomaterials for IVD cell delivery must balance the biomechanical and biological needs of the process. The National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) of the National Institutes of Health (NIH) funded this research with funds R01 AR057397 (JCI), R01 AR080096 (JCI), and F31 AR077385 (CJP). The Flow Cytometry CoRE, qPCR CoRE, and Microscopy CoRE at the Icahn School of Medicine at Mount Sinai were gratefully acknowledged for their assistance with sample processing and equipment training. The authors also acknowledge the Morphological Research Unit and Experimental Biomechanics at the Orthopedic Research Laboratories.[4]

Bio ceramics made of strontium carbonate (SrC) are suggested as viable biomaterials for effectively treating bone deformities. However, the development of SrC bio ceramics is hindered by their intrinsic poor mechanical strength. In this study, strontium-containing phosphate glass was used to create SrC-based composite bio ceramics (SrC-SrP) (SrP). The SrC-SrP bio ceramics sustained the release of sodium, phosphorus, and strontium ions and helped apatite precipitate on their surface. The SrC-SrP bio ceramics with specific quantities of SrP increased proliferation, alkaline phosphatase activity, and osteogenesis-related gene expressions of mouse bone mesenchymal stem cells in comparison to the well-known -tricalcium phosphate bio ceramics.[5]

Here, a novel composite biomaterial called Mg-3Zn-0.2Ca composite with 0.6wt%MgO was processed using the equal channel angular process (ECAP)

with the route BC at 300°C in order to implant the components in the human body. After ECAP, the granules' microstructure greatly homogenized. The findings show that the composites' compressive strain at fracture (CSF) rose from 14.1% to 34.18% without substantially reducing strength. Given the rise in ECAP pass rates. In this study, the impacts of grain orientation second phase distribution, microstructure homogenization, and grain refinement on mechanical performance during ECAP were examined. [6]

This study is held with a focus on dangerous heavy metals, refractory organics, and pathogenic microbes trace environmental contaminants have grown to be a significant issue. Because of the synergistic impact, integrating biosorption and photocatalysis to create biomaterial/TiO₂ composite photocatalysts is a potential technique to remove these trace contaminants. The importance of using these composite photocatalysts for the targeted eradication of trace pollutants is also covered. Before realistic applications, as outlined in the final part, can be realized, a number of issues need to be resolved. [7]

In order to prevent the hydrothermal ageing of yttria-stabilized zirconia and increase its suitability for biomedical applications, this work investigates the incorporation of two-dimensional nanostructures based on graphene as moisture barriers. Few layer graphene and exfoliated graphene nanoplatelets were incorporated into two independent sets of very dense zirconia composites with substantially varied lateral dimensions. Due to the fine dispersion of the exfoliated graphene nanosheets throughout the matrix, which effectively seemed to limit grain growth and slow the propagation of the transformation front to the ceramic bulk, the composite incorporating this material in particular displayed outstanding resistance to ageing. [8]

One of the most common and plentiful natural biopolymers in the world is cellulose. Nanocellulose is a term used to describe cellulose-based substances that are produced by bacteria or tunicates, or that are isolated from trees, annual plants, agricultural waste, and algae. Nanocellulose, one of many other environmentally friendly nanomaterials, is attracting more interest for use in environmental remediation technologies because of its alluring qualities, such as outstanding mechanical capabilities. Nano cellulose is a versatile material that

can be used in a wide range of products, including those for the automotive aerospace electronics, medical, textiles, food, optics, packaging, gels, composites, pharmaceuticals dental products bone replacement tissue engineering, construction, coatings, paints, papermaking, and cosmetics.[9]

The challenge of creating soft biomaterials with several functions that can meet all the demands of intricate tissue regeneration processes is tough. Recent research efforts are increasingly focused on biomimetic design principles that can be converted into soft biomaterials via sophisticated manufacturing technologies in order to address the existing problems. In the context of soft tissue engineering and drug delivery applications, this paper discusses soft network composite systems with a focus on the design, biomaterial, and fabrication elements.[10]

The implantation of biomaterials and bone grafting are the topics of this essay. The paper discusses selection difficulties for applications using biomaterials and bone grafting. There has been much discussion of the mechanical requirements for different types of biomedical implants in order for them to be compatible with host tissue. Additionally, advantages of polymer composite over metal and ceramic for implantation are also covered. The manufacture of several kinds of biomaterials is described, along with the difficulties encountered. Also covered in detail are the advantages and restrictions. The implantation process typically involves a surgical procedure where the damaged or diseased bone is removed and replaced with the biomaterial implant. The implant is placed in the affected area, and the surrounding tissue and bone are allowed to grow and fuse with the implant. Biomaterials used for bone implantation can be made from a variety of materials, including metals, ceramics, polymers, and composites. Some commonly used biomaterials for bone implantation include titanium, hydroxyapatite, and polyethylene. The success of a bone implantation procedure depends on several factors, including the patient's overall health, the type and quality of the biomaterial used, and the surgical technique employed. Proper implant placement and post-operative care are also critical to the success of the procedure.[11]

The Earth's internal circulation of hydrogen has an impact on the planet's

long-term evolution. The majority of this hydrogen is kept in thermodynamically stable crystal structures in the deep Earth that are made of dense minerals that can withstand extreme pressures and temperatures. To comprehend the cause of their steadiness in such harsh circumstances. Deuterated high-quality crystals with the chemical formula $\text{Mg}_{2.28}\text{Si}_{1.32}\text{D}^{2.15}\text{O}_6$ were produced under the required high-pressure and high-temperature conditions. The nuclear density distribution measured by neutron diffraction suggested that the O—D dipoles were oriented towards nearby O^{2-} ions to create strong interlayer hydrogen bonds. Under such extreme high-pressure and high-temperature circumstances, this bonding is essential for stabilizing hydrogen within the mineral structure. In this structure, Mg^{2+} , D^+ , and Si^{4+} are thought to exchange actions, allowing the hydrogen capacity to be flexible.[12]

Due to their capacity to transport water to deep mantle regions in subduction slab conditions, dense hydrous magnesium silicates (DHMS) are thought to be important phases in planetary water cycles. Knowledge of the water content and stability of iron-bearing DHMS is necessary to comprehend water cycles in iron-enriched planetary systems, such as Mars. Two initial compositions were used to create iron-containing DHMS. In a hydrous Martian mantle, these hydrous phases could hold a significant amount of water at core-mantle boundary conditions (1500 °C and 23 GPa), according to the high-temperature stability of iron-bearing DHMS with a bulk composition similar to Mars.[13]

The only hydrous magnesium silicate in which all of the Si atoms are octahedrally coordinated is phase D ($\text{MgSi}_2\text{O}_6\text{H}_2$). Brillouin spectroscopy has been used to measure the phase D single-crystal elastic constants in ambient circumstances. Based on a trigonal unit cell, the elastic constants C11, C33, C44, C12, C13, and C14 are 284.43.0, 339.49.1, 120.71.9, 89.44.2, 126.63.1, and 4.71.4 GPa, respectively. Using the Voigt-Reuss-Hill (VRH) technique, the aggregate adiabatic bulk modulus is 175.314.8 GPa. Even if the data were gathered from various independent crystals, data for a particular crystallographic plane are still lacking. The lack of data points on the same plane, interference from the cover glass and/or glue, or termination due to laser damage are the causes of this. But the information from one specific crystallographic plane

produced good outcomes.[14]

High-pressure deformation tests and computational methods were used to explore the flexibility of the dense hydrous magnesium silicate (DHMS) phase A, a crucial hydrous mineral inside cold subduction zones. At 11 GPa, 400, and 580 °C, the deformation experiments were conducted, and in-situ measurements of stress, strain, and lattice preferred orientations were made (LPO). According to viscoelastic self-consistent modelling (VPSC) of the measured LPO, glide on the (0 0 0 1) basal and prismatic planes is compatible with the deformation mechanisms at 580 °C. Dense hydrous magnesium silicate (DHMS) is a mineral commonly found in the Earth's mantle. DHMS is known for its high water content and its ability to store water under high pressure and temperature conditions. In terms of flexibility, DHMS has been shown to exhibit some degree of plastic deformation under high-pressure conditions. This means that it can be deformed or stretched under certain conditions without breaking. DHMS has also been shown to undergo a phase transition at high pressures, which can affect its mechanical properties. Overall, the flexibility of DHMS is an important factor to consider when studying its role in the Earth's mantle and the global water cycle.[15]

Bone implants using biomaterial composites are devices designed to replace or augment damaged or diseased bone tissue. Biomaterials are materials that are compatible with biological tissues and can integrate with the body's natural processes. They can be used to create a wide range of medical devices, including bone implants.[12]

Biomaterial composite implants are typically made by combining two or more materials, each with its unique properties. For example, a composite may consist of a metal framework coated with a layer of ceramic or polymer material. The metal provides strength and support, while the coating can help the implant bond with surrounding tissue and stimulate new bone growth.[11]

One of the key advantages of using biomaterial composite implants is that they can be customized to meet the needs of each patient. This means that the size, shape, and composition of the implant can be tailored to fit the specific

requirements of the individual, resulting in a better outcome. Another advantage of biomaterial composite implants is that they can be designed to degrade over time, leaving behind only natural bone tissue. This process is known as biodegradation and is particularly useful for young patients who are still growing.[9]

Biomaterial composite implants have been used successfully in a wide range of applications, including hip and knee replacements, dental implants, and spinal fusion surgery. Ongoing research is focused on developing new materials and techniques to improve the safety, effectiveness, and longevity of these devices.[14]

Ultra-high molecular weight polyethylene (UHMWPE) is a biocompatible synthetic polymer that has been used in orthopedic surgery for several decades. It has excellent wear resistance and mechanical properties, which make it ideal for use in joint replacements, such as hip and knee replacements. Zirconium is a biocompatible metal that has been used in orthopedic implants, such as hip and knee replacements, for many years. It has excellent corrosion resistance and biocompatibility, which make it a suitable material for use in implants.[15]

Talc is a mineral that is widely used in many industries, including the medical field. It has been used as a filler material in bone grafting for many years. Talc helps to increase the volume of the bone graft material and provides additional support to the bone during the healing process. The combination of UHMWPE, zirconium, and talc has been used in bone grafting procedures to provide a strong and biocompatible material for bone regeneration. The UHMWPE provides mechanical strength and wear resistance, while the zirconium provides biocompatibility and corrosion resistance. The talc helps to increase the volume of the bone graft material and provides additional support during the healing process.[10]

Overall, the combination of UHMWPE, zirconium, and talc has been shown to be an effective and safe material for use in bone grafting procedures. However, as with any medical procedure, there are risks and potential complications that should be discussed with a qualified healthcare professional.[8]

CHAPTER 3

AIM AND SCOPE

3.1 AIM

Ultra-high-molecular-weight polyethylene (UHMWPE) reinforced with zirconia and magnesium silicate is a composite material that combines the high strength and toughness of UHMWPE with the added mechanical and thermal properties of zirconia and magnesium silicate. Zirconia is a ceramic material that is known for its high strength and toughness, as well as its resistance to wear and corrosion. When incorporated into UHMWPE, it can enhance the material's strength and wear resistance. Magnesium silicate, also known as talc, is a mineral that has a number of properties that make it useful as a reinforcement material in composites. It is lightweight, chemically inert, and has good thermal and electrical insulation properties. When combined with UHMWPE, it can improve the material's stiffness and thermal stability.

The resulting composite material can be used in a variety of applications, including medical implants, automotive parts, and industrial machinery components. Its enhanced strength, toughness, and wear resistance make it a popular choice for applications that require high-performance materials. Compression molding is a manufacturing process where a thermoplastic material is heated and then compressed into a specific shape using a mold. UHMWPE, or ultra-high molecular weight polyethylene, is a thermoplastic material known for its high strength, low coefficient of friction, and resistance to wear and abrasion. Zirconia and magnesium silicate are ceramic materials that can be added to UHMWPE to improve its mechanical properties.

To perform compression molding of UHMWPE with zirconia and magnesium silicate, the following steps can be taken:

1. Prepare the UHMWPE, zirconia, and magnesium silicate materials in the desired proportions.
2. Heat the UHMWPE material to a temperature above its melting point, typically between 130-140°C.
3. Add the zirconia and magnesium silicate materials to the molten UHMWPE

material and mix thoroughly.

4. Pour the mixture into a preheated compression mold.

5. Apply pressure to the mold to compress the mixture into the desired shape.

6. Cool the mold and remove the compressed UHMWPE material.

7. Post-process the compressed UHMWPE material, if necessary, such as machining or finishing.

It is important to note that the exact process parameters will depend on the specific materials used and the desired properties of the final product. Proper testing and optimization may be necessary to achieve the desired results.

3.2 SCOPE OF THE PROJECT

- To fabricate a novel composite material using Ultra High Molecular Weight polyethylene and zirconium with hydrous magnesium silicate by compression molding process.
- To evaluate the tensile strength, compression strength and flexural strength of the fabricated composite material.
- To measure the surface roughness and shore d hardness of the fabricated composite material.
- Analyse and perform a characteristic study on the properties of the biomaterial composites

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 MATERIALS

4.1.1 ULTRA HIGH MOLECULAR WEIGHT POLYETHYLENE (UHMWPE)

- Ultra-High-Molecular-Weight polyethylene is a subset of the thermoplastic polyethylene.
- It is odorless, tasteless and nontoxic material.
- It is 15 times more resistant to abrasion than carbon steel.
- It is highly resistant to corrosive chemicals except oxidizing acids
- It has clinical history as a biomaterial for use in hip, knee and for spine implants.

PROPERTIES	VALUE
Density (g/cm ³)	0.932
Melting point(°C)	180-200
Tensile Strength (MPa)	24.1
Modulus of Elasticity (GPa)	0.689
Elongation at Yield (%)	< 20
Elongation at break (%)	> 200

Table 4.1 Properties of UHMWPE-Matrix



Figure 4.1 Powder of UHMWPE

4.1.2 Hydrous Magnesium Silicate (TALC)

- Talc or talcum is a clay mineral, composed of hydrated magnesium silicate
- Talc is easily distinguishable by its extreme softness
- It is available in white, colorless, dark green, brown and grey
- Dense high purity talc is called steatite.

PROPERTIES	VALUE
Density (g/cm ³)	2.76
Melting point(°C)	1500
Specific gravity(g/cm ³)	2.5-2.8

Table 4.2: Properties of Hydrous Magnesium Silicate



Figure 4.2 Powder of TALC

4.1.3 ZIRCONIUM

- The name zirconium is taken from the name of the mineral zircon.
- It is a lustrous, grey-white, strong transition metal
- Zirconium is mainly used as a refractory and opacifier, although small amounts are used as an alloying agent for its strong resistance to corrosion
- In powder form, zirconium is highly flammable, but the solid form is much less prone to ignition.

PROPERTIES	VALUE
Density (g/cm ³)	5.68
Melting point(°C)	1850
Compressive Strength (MPa)	2600
Flexural strength (MPa)	900

Table 4.3: Properties of Zirconium



Figure 4.3 Powder of Zirconium

4.2 METHODOLOGY

4.2.1 SAMPLE EXTRACTION

4.2.1.1 COMPRESSION MOULDING

Compression molding is a process of molding in which a feeding material is placed into an open, heated mold cavity. The mold is then closed with a top plug and compressed with large hydraulic presses in order to have the material contact all areas of the mold. The charge cures in the heated mold. Compression molding is a high-volume, high-pressure method suitable for molding complex, strength fiberglass reinforcements. Advanced composite thermoplastics can also be compression molded with unidirectional tapes, woven fabrics, randomly oriented fiber mat or chopped strand. The advantage of compression molding is its ability to mold large, fairly intricate parts. Also, it is one of the lowest cost molding methods compared with other methods such as transfer molding and injection molding; moreover, it wastes relatively little material, giving it an advantage when working with expensive compounds. Compression molding was first developed to manufacture composite parts for metal replacement applications, compression molding is typically used to make larger flat or moderately curved parts. This method of molding is greatly used in manufacturing automotive parts such as hoods, fenders, scoops, spoilers, as well as smaller more intricate parts.

Dies are used to shape metal and other metal forms. A typical application is the making of automobile body parts. We use two dies of measurement 150 x 150 x 4 mm (Die 1) and 100 x 100 x 13 mm (Die 2). Die 1 is used to make tensile test specimen and flexural test specimen. Die 2 is used to make compression test specimen and roughness test specimen.

Sample NO	UHMWPE (%)	TALC (%)	ZIRCONIUM (%)
1	88	2	10
2	88	6	6
3	88	10	2
4	100	0	0

Table 4.4: Sample Percentage



Fig 4.4 Compression Moulding Setup CIT Coimbatore

The materials obtained from the compression molding machine undergo cutting process using ASTM standard. There are three ASTM standards for different mechanical tests we use in this project.

Sequence of Operation

1. Prepare the UHMWPE, zirconia, and magnesium silicate materials in the desired proportions.
2. Heat the UHMWPE material to a temperature above its melting point, typically between 130-140°C.
3. Add the zirconia and magnesium silicate materials to the molten UHMWPE material and mix thoroughly.
4. Pour the mixture into a preheated compression mold.
5. Apply pressure to the mold to compress the mixture into the desired shape.
6. Cool the mold and remove the compressed UHMWPE material.
7. Post-process the compressed UHMWPE material, if necessary, such as machining or finishing.

It is important to note that the exact process parameters will depend on the specific materials used and the desired properties of the final product. Proper testing and optimization may be necessary to achieve the desired results.

The materials obtained from compression molding machine is given below:



Figure 4.5 Composites Materials

4.2.1.2 CUTTING PROCESS

The cutting process for bio-material composites can vary depending on the specific materials being used and the desired outcome of the cutting process. However, there are some general guidelines and techniques that are commonly used.

One common technique for cutting bio-material composites is mechanical cutting using a saw blade or rotary cutting tool. This method is suitable for materials that are relatively thin and have a relatively uniform composition, such as plywood or particleboard made from wood chips and resin.

The materials obtained from the compression molding machine undergo cutting process using ASTM standard. There are three ASTM standards for different mechanical tests we use in this project.



Figure 4.6 Cutting machine

CHAPTER 5

RESULTS AND DISCUSSION

5.1 MECHANICAL CHARACTERIZATION

Composite materials were subjected to various mechanical tests to measure strength elastic constants, and other material properties, the results of such test were used for two primary purposes. Engineering design (for example, failure theories based on strength, or deflections based on elastic constants and component geometry). Quality control either by the material producer to verify the process or by the end user to confirm the material specifications.

Universal Testing Machine: A Universal Testing machine (UTM) is an instrument used for measurement of loads and associated test specimen deflections such as those encountered in tensile, compression or flexural modes, it is used to test the tensile, compressive flexural hardness of materials. A load cells and extensometers measure the key parameters of force and deformation as the sample was tested.

5.2 TENSILE TEST

Tensile Testing is a form of tension testing materials science test whereby controlled tension is applied to a sample until it fully fails. Tensile refers to a type of external physical force applied to a material in a pulling direction away from its surface. Tensile strength is an important mechanical property. Tensile strength is a measurement of the force required to pull something such as rope, wire, or a structural beam to the point where it breaks. The tensile strength of a material is the maximum amount of tensile stress that it can takes before failure.

The tensile test is generally conducted for ductile materials only. Prepare test specimens according to a standard, such as ASTM E8/E8M, which specifies the dimensions and geometry of tensile test specimen. Install the test specimen in a tensile testing machine, which will apply a gradually increasing load to the specimen until it fails. Record the load and the corresponding elongation of the specimen at regular intervals, typically using an extensometer attached to the specimen. Calculate the tensile strength, yield strength, and other mechanical

properties of the material based on the results.

Samples	Time (seconds)	Extension (mm)	Tensile Stress(MPa)
Sample 1	924.9	29.95	30.02
Sample 2	918.4	29.95	27.43
Sample 3	914.7	29.95	22.6
Sample 4	911.6	29.95	26.75

Table 5.1: Table of Tensile Stress



Figure 5.1 Universal Tensile Testing Machine

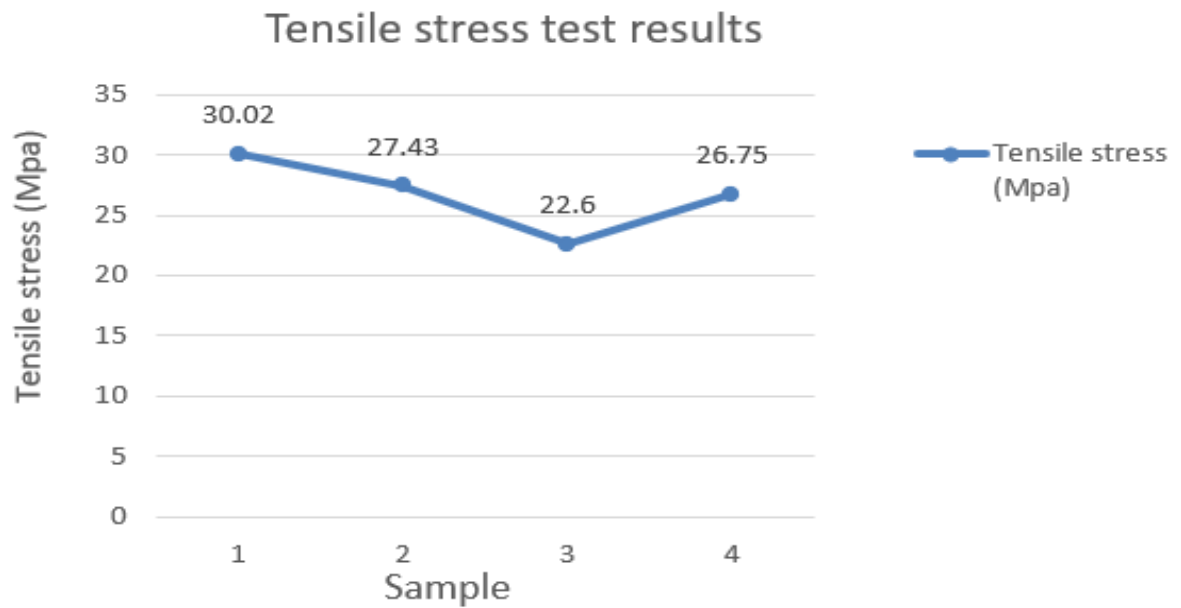


Figure 5.2 Line graph of Tensile test result



Figure 5.3 Tensile Test Specimen

The length of the specimen is 105 mm and thickness is 4 mm. Once the tensile force is applied, the specimen begins to elongate and starts yielding. After reaching the ultimate load, elongation (Figure 5.4) occurs and the material is extended. The tensile strength (TS) of a specimen is conventionally reported as the maximum force measured during a tensile test divided by the original cross-sectional area of the specimen.

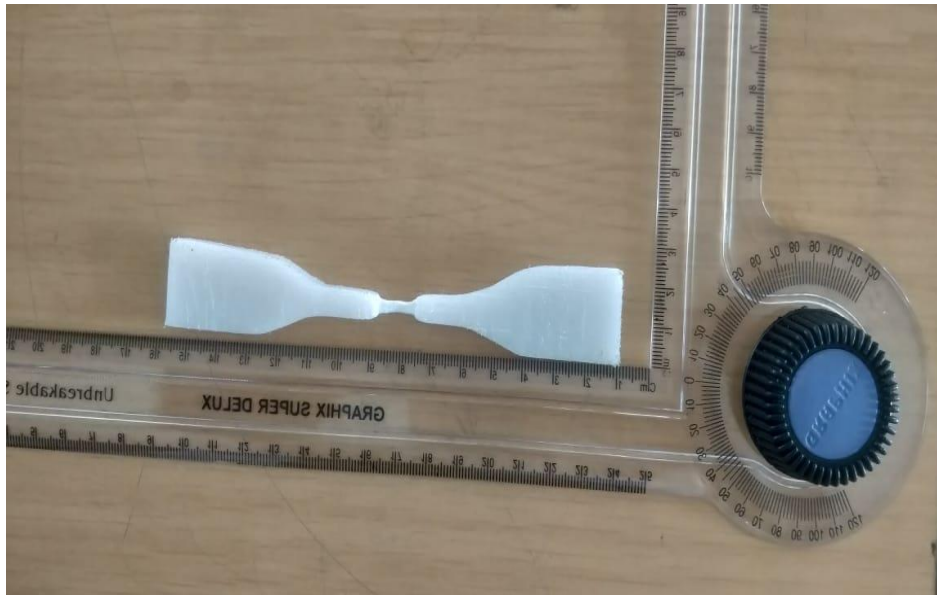


Figure 5.4 After Elongation

ASTM D638-14 is performed by applying a tensile force to a sample specimen and measuring various properties of the specimen under stress. It is conducted on a universal testing machine (also called a tensile testing machine) at tensile rates ranging from 1 to 500 mm/min until the specimen fails (elongates). The Tensile Test is carried out on the specimen at VIT and the results are tabulated, (Table 5.1)

As mentioned in the above test, the brittleness of composite material decreases with increase in weight percentage for particulate composite. Generally brittle material will not permit any deformation. The tensile test involves straining of the test piece by applying a tensile load over the fabricated specimen ultimately leading to fracture, with a view to determine one or more mechanical properties of the specimen. Hence from the tensile test, the tensile strength of the specimen decreases gradually all because of brittleness of material and wettability. Due to this, elongation is also decreased. Three samples were only calculated. From the results obtained, Sample 1 showed the maximum tensile strength of all other ratios.

5.3 COMPRESSION TEST

Compression testing is used to determine how a product or material reacts when it is compressed, squashed, crushed or flattened by measuring fundamental parameters that determine the specimen behavior under a compressive load. We can determine the strength of component, characterize the compressive properties

of materials, assess the performance of products. The stress strain graph of brittle material will always be steep curve. This indicates that the deformation of the brittle material will always be less even at high loads.

The specimen for compression test was fabricated as per ASTM standard, ASTM D695. This test determines compressive property of the composite materials. This test was carried out in Universal Testing Machine. The specimen was placed between the upper and lower plates and compressive loads were applied on the plates. ASTM D695 is a test method used to determine the compressive property of un-reinforced and reinforced plastics. It is used alongside its tensile test standard equivalent, ASTM D638.

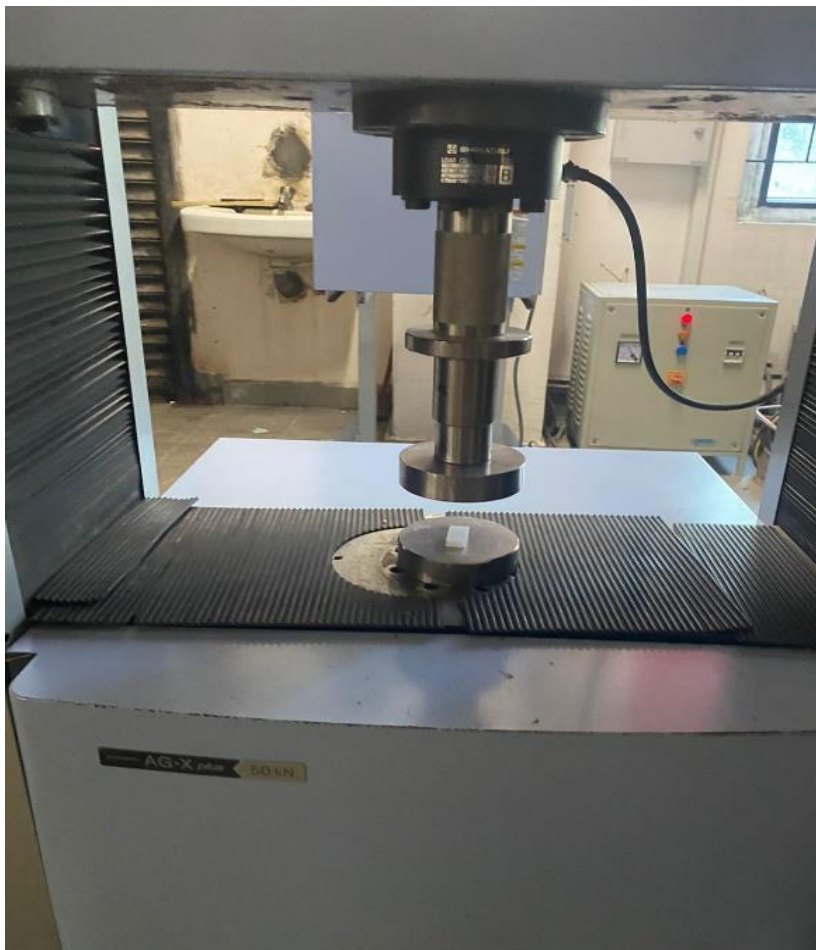


Figure 5.5 Universal Compression Testing Machine

Samples	Compressive Stress (MPa)
Sample 1	12.37
Sample 2	9.852
Sample 3	8.153
Sample 4	7.59

Table 5.2: Table of compression test

Basically, this test is used to find out the compressive strength of the material, breaking point and ultimate strength of the material under testing. Generally, sample 4 has lower strength than other composites and sample 1 has higher strength. The specimen is of ASTM standards. Samples are experimented under compression loading using the Universal Testing Machine and results for each composite were noted and a graph is drawn below.

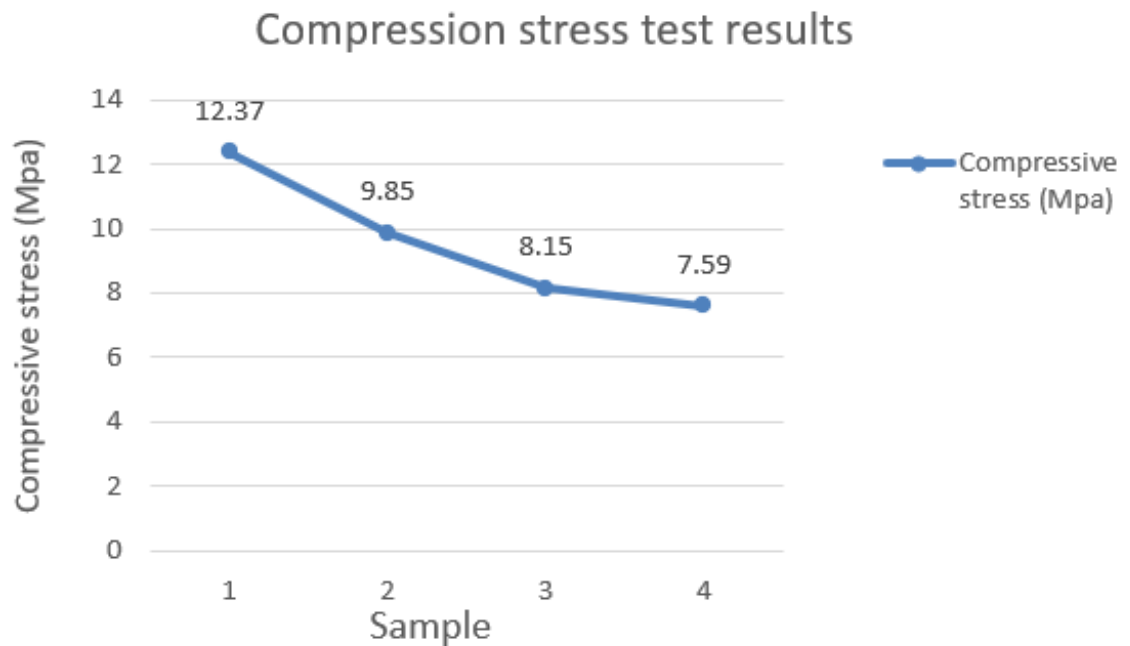


Figure 5.6 Compression test result line graph



Figure 5.7 Before Deformation



Figure 5.8 After Deformation

CHAPTER 6

CONCLUSION

6. CONCLUSION

In this project Ultra High Molecular Weight Polyethylene (UHMWPE) was used as matrix and Hydrous Magnesium silicate (Talc) and Zirconium is used as reinforcements. In present work various mechanical characteristics of Ultra-High Molecular Weight Polyethylene (UHMWPE) and it's reinforced Hydrous Magnesium silicate (Talc) and Zirconium Composites have been studied under controlled precise studies. The tests conducted on the particulates and thus the specimen itself revealed some important results on the pros and cons of the selection of various parameters like percentage of reinforcement, discrete values of proportions, matrix material, etc. Four samples with different weight percentages of Ultra-High Molecular Weight Polyethylene (UHMWPE) matrices are prepared and fabricated via compression molding technique. The samples were tested for tensile, compressive, flexural strength Shore D Hardness and Roughness test. The test results thus reveal the tensile strength (30.02 MPa), compressive strength (12.37 MPa) of sample 1. Ultra-High Molecular Weight Polyethylene Composites were found to be superior enough compared to pure Ultra-High Molecular Weight Polyethylene (UHMWPE).

Ultra-High Molecular Weight Polyethylene (UHMWPE) reinforced with 2% of Hydrous Magnesium silicate (Talc) and 10% of has higher strength compared to pure UHMWPE and other composites The composite material can be used as an alternative to metal plates.

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