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Study on the behavior of the polymer materials with biomaterials

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Abstract —A biomaterial is essentially a material that is used and adapted for a medical application. This paper constitutes the wear study of SS304, PEEK and PEEK30%GF used as Bio-Material. One of the primary reasons that biomaterials are used is to physically replace hard or soft tissues that have become damaged or destroyed through some pathological process. It has been observed that one of the most important properties governing the suitability of the material to be a bio implant is 'WEAR RESISTANCE'. There is no specific standard for testing or measuring a materials wear resistance. The study was conducted by using a pinon-disk apparatus and is issued under the standard ASTM G-99. For the PIN-ON-DISK wear test conducted in this research, the specimens were a pin with a rounded tip, which is positioned perpendicular to a flat circular disk.

Key Words:Bio-material, SS304, PEEK, PEEK30%GF, Wear resistance

I. INTRODUCTION

Biomaterial can be described as a combination of substances originating from natural, inorganic or organic materials that is biocompatible in exactly or partially contact with the body for healing time. They involve complete or part of a living organism or biomedical device which performs, augments or replacements any natural function. Biomaterials can be derived either from nature or synthesized in the laboratory using a variety of chemical approaches utilizing metallic components, polymers, ceramics or composite materials. Biomaterial devices [1] used in orthopedics are commonly called implants; these are manufactured for a great number of orthopedic applications.

The main fundamental requirements that orthopedic devices must fulfill in order to function adequately are summarized in this section.

- Biocompatibility.
- Appropriate Design and Manufacturability of Implants,
- Mechanical and Biological Stabilities.
- Corrosion Resistance.
- Resistance to Implant Wear and Aseptic loosening
- Properties of biomaterials.

Biocompatibility is, by definition, a measurement of how compatible a device is with a biological system. The purpose of performing biocompatibility testing is to determine the fitness of a device for human use, and to see whether use of the device can have any potential harmful physiological effects.When trying to understand the evolution of biomaterials research and their clinical availability during the last 60 years, Hench &Polak in 2002 classified three different generations: Bio-inert materials (first generation),

Bioactive and biodegradable materials (second generation), Materials designed to stimulate specific cellular responses at the molecular level (third generation). The first really successful substitutive joint prosthesis was the total hip prosthesis developed by Charnley in the very late 1960[3]. The Co–Cr–Mo alloy was introduced in hip prostheses by Mckee& Watson-Farra in 1966. Punt in 2008 used Co–Cr alloys (Vitallium) in combination with polyethylene (PE) in the fabrication of artificial disc prostheses [4]. Another conventional metallic material appeared when the shape memory effect was discovered [5] in NiTi alloys by Buehler & Wang in 1967.

The goals of the present study are:

- To study the bio mechanical behavior.
- To report wear analysis.
- To study wear properties of biomaterials.
- To compare results with SS316L material.
- To study thesuitable bio compatible material.

BONE

The human skeleton is made of individual or fused bones (such as in the skull, pelvis and sacrum), supported and supplemented by a structure of ligaments, tendons, muscles and cartilage. Bones all have an arterial blood supply, venous drainage and nerves. The non-articular surfaces of bones are covered with a tough fibrous layer. The skeleton is not unchanging; it changes composition over a lifespan. Early in gestation, a foetus has no hard skeleton;

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bones form gradually during nine months in the womb. At birth, all bones will have formed, but a new born baby has more bones than an adult. On average, an adult human has 206 bones, but the number can vary slightly from individual to individual), but a baby is born with approximately 300 bones. The difference comes from a number of small bones that fuse together during growth, such as the sacrum and coccyx of the vertebral column. An infant is born with pockets of cartilage between particular bones to allow further growth. The sacrum (the bone at the base of the spine) consists of five bones which are separated at birth but fuse together into a solid structure in later years. Growing is usually completed between ages 13 and 18, at which point the bones have no pockets of cartilage left to allow more growth Bone does not have same strength if loaded in different direction a property known as anisotropicity. Bone is less strong and less stiff when stressed from side to side.

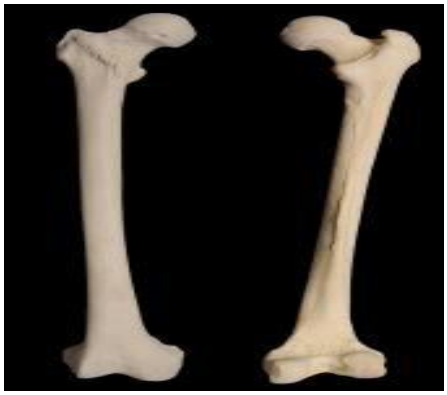

Figure 1.1 Femur bone

SELECTION OF BIOMATERIAL

It is important for orthopedic surgeons to understand the nature of biomaterials, their structural configurations, and their properties, as well as the effects of their interaction with soft and hard tissues, blood, and intra- and extra cellular fluids of the human body.

DIFFERENT TYPES OF BIO-MATERIAL USED IN ORTHOPEDICS ARE*:*

Metals: The metallic implants most widely used in orthopedic surgery are:

- Low carbon grade austenitic stainless steels: SS304.
- Titanium and titanium-base alloys: Commercially Pure Titanium (CPTi), Ti-6Al-4V,
- Other titanium-base alloys. Cobalt alloys: Co-Cr-Mo, and other cobalt-base alloy.

Nonmetals: Three main subgroups make up this category: polymers, ceramics (alumina), and composites. Polymers areorganic materials that form large chains made up of many repeating units. Polymers are extensively used in joint replacement components. Currently the polymers most widely used in joint replacements are: Ultrahigh molecular weight polyethylene (UHMWPE). Acrylic bone cements. Thermoplastic polyether ether ketone (PEEK).

REQUIREMENTS OF BIOMATERIALS

The following are the requirements of a Biomaterial:

- It must be inert or specifically interactive.
- It must be Biocompatible.
- Mechanically and chemically stable.
- Biodegradable.
- Processable (for manufacturability): It must be machinable, moldable, and extrudable.
- Nonthrombogenic (if blood contracting).
- Sterilizable.
- Non-carcinogenic, non-pyrogenic, non-toxic, non-allergenic, blood compatible, non-inflammatory.
- Physical Characteristics Requirements: Strength, Toughness, Elasticity, Corrosion-resistance, Wear resistance, Long term stability.

PROPERTIES OF SELECTED MATERIALS

The materials used were SS304, Polyether etherketone (PEEK), Polyetheretherketone 30 % glass fiber (PEEK-30%GF).

Materials / properties	Density (g/cm3)	Tensile Strength ultimate (MPa)	Modulus of elasticity (Gpa) Tension
SS304	7.85	510-620	190
PEEK	1.32	90-100	3.6
PEEK 30% GF	1.52	190	12

Table 1: Properties of selected materials

WAYS IN WHICH MATERIALS CAN FAIL

Corrosion

Gradual degradation of material by electrochemical attack, when placed in the electrolytic environment of the body. Corrosion can be minimized by:

- Choosing a corrosion resistant material

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- Treating the surface with a passivating layer prior to use
- Not using combinations of metals in close proximity.
- Careful operating technique to reduce surface scratching.
- Using non modular implants.

Fatigue

Progressive failure of a material due to the application of cyclical stresses below the ultimate stress of the material is causing crack propagation. Stress concentrator or stress riser e.g. a scratch, a hole, a corner or a change in cross section or where fretting is occurring. At these places stress is greater than the average stress in the material.

Wear Corrosion

The removal of material from solid surfaces by mechanical action. Effects of wear - Most predominant in joint prostheses. Joint wears out but prior to this, the particles produced by wear (metal or polyethylene or cement particles) are phagocytosed by osteoclasts causing osteolysis and therefore loosening of components.

II. METHODOLOGY

A number of wear tests have been developed by committees in an attempt to standardize wear testing for specific applications. Wear test is done by PIN-ON-DISK method and is issued under the standard ASTM G- 99. For the PIN-ON-DISK wear test conducted in this research, the specimens were a pin with a rounded tip, which is positioned perpendicular to a flat circular disk.

PIN-ON-DISC METHOD

This test method covers a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus and is issued under the standard ASTM G 99. For the pin-on disk wear test conducted in this research, the specimens were a pin with a rounded tip, which is positioned perpendicular to a flat circular disk (the test sample). A ball, rigidly held, is often used as the pin. The test machine causes either the disk specimen or the pin to revolve about the disk center. The sliding path is a circle on the sample surface. The pin is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. The wear test which is the test done for the this materials which tells the exact details of the material co-efficient of friction, wear factor which is very much essential for the wear rate of the material which can be implemented for the ss316l material which is been used for the further process. This test is very much important for the material which can be used for the further process on the testing and the implants used in the polymer materials and also as the biomaterial which is further classified for the future materials.

DESCRIPTION	DETAILS
Normal load(N)	5 to 100
Frictional force (N)	0.1 to 200
Wear (mm)	+2 or -2
Wear track diameter(mm)	10 to 100
Sliding speed (m/sec)	0.5 to 10
Pin size(mm)	3,4,5,6,8,10 & 12

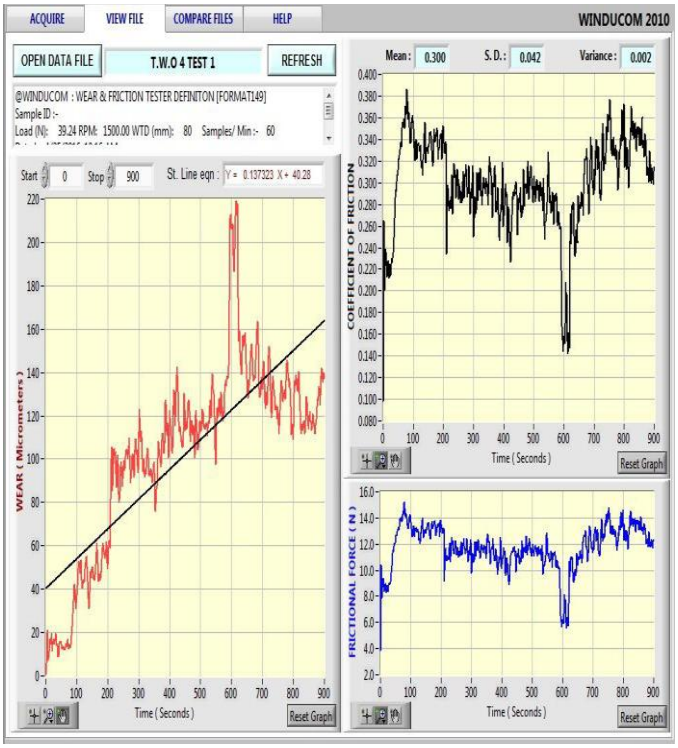
Table 2: Test rig specifications

III. RESULTS AND DISCUSSIONS

TEST RESULTS FOR PEEK

TEST RESULTS FOR PEEK 30% GLASS FILLED

The above results shows the peek 30% which can be the best wear rate which is obtained in the wear factor for the different methods of using the technology for the different material testing and handling for the initial and final weight which can be used in the wear loss for the different wear factor can be used for the different materials



Graph 1: Wear, Coefficient of friction, Frictional force of PEEK

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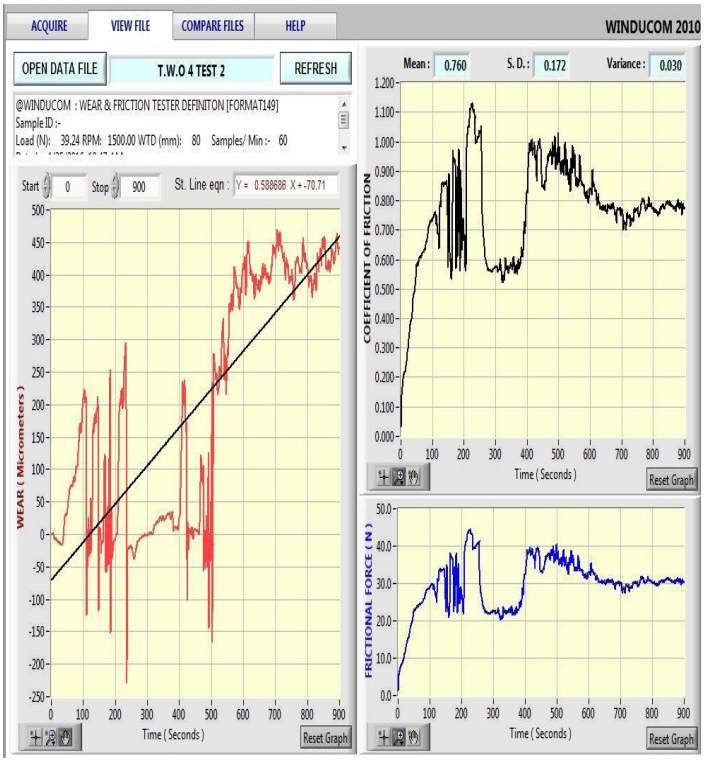
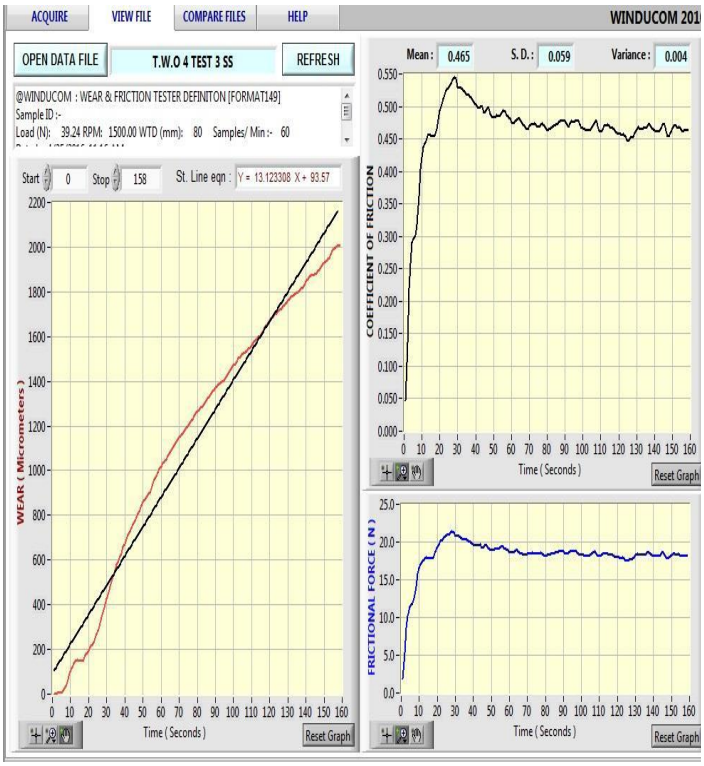


Graph 2: Wear, Coefficient of friction, Frictional force of PEEK 30% GLASSFILLED

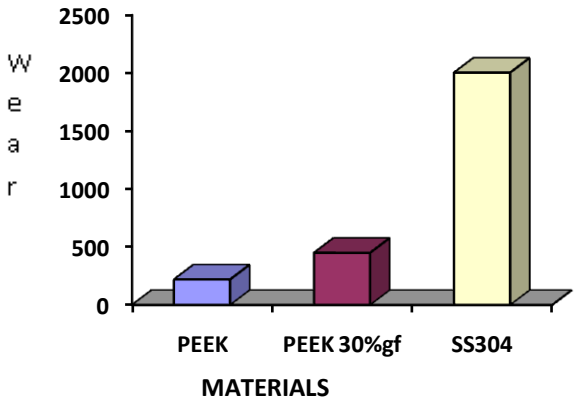
TEST RESULTS FOR SS304



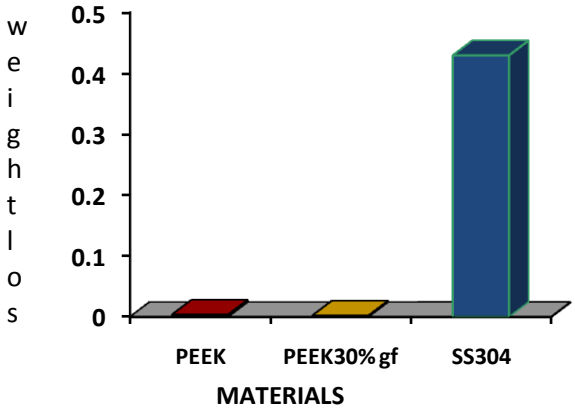
Graph 3: Wear, Coefficient of friction, Frictional force of SS304

MATERIALS	WEAR(microns)	Frictional force (N)	Coefficient of friction
PEEK	220	12	0.300
PEEK 30%GF	450	30.4	0.760
SS304	2005	18.6	0.465

Table 3: Tabulated results with pin disc apparatus



Graph 4: Wear rate for materials



Graph 5: Weight loss of the materials

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IV. CONCLUSIONS

- PEEK 30% Glass Fiber has better wear property SS304, PEEK (general) which can be used has alternative materials for human Orthopedic Implants.
- PEEK 30% Glass Fiber has the best wear property than SS304, PEEK (general).
- Among all the materials polymers can be the best replacement materials because it's of good mechanical properties.
- The highest percentage of the polymers with the properties involves for better biocompatibility of the future reference to the materials with ceramics and metals.

V. SCOPE FOR FUTURE STUDY

- Polymer materials can be used as biomaterial for all the implants done in the biomedical applications
- In the future work polymer materials can complete replace metals
- Biomaterials as the wide range applications which can be used for the polymer materials, with the lot of advantages the research can be developed and it can be implanted for the better study in involving the material to the bio implants.
- The intersection of biomedical science and materials engineering is an exciting one, and largely falls in the province of biomaterials and tissue engineering. Many of the advances being made at the interface of these two disciplines are central to new medical and health-based technologies and are changing the way we live and treat illness.
- As general medicine improves across the globe the average lifespan of the human increases, but with an average life expectancy of over 80 years in many developed countries the problem of age related illness or reliance on social care is a growing concern. [12] The process of ageing can be a happy one but for many the idea of growing old and the negative effects involved are a cause of stress.

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