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TRIBOLOGICAL WEAR INVESTIGATION OF UHMWPE AND PEEK FOR ARTIFICIAL HIP JOINT

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ABSTRACT

This study focus on the wear behaviour of artificial hip joint material Ultra high molecular weight polyethylene (UHMWPE) and compared with the Polyether ether ketone (PEEK) material. Pin on disc experiment is conducted with the un-lubricated condition with polymers as pin and metallic (SS316L) disc. Both the specimens was tested for 8km sliding distance Experiment results showed PEEK has lower wear rates compared to UHMWPE.

KEYWORDS :*UHMWPE, PEEK, Coefficient of friction, Specific wear rate, wear height.*

INTRODUCTION :

Artificial hip joint is the effective method for providing the patients suffering with the hip joint disease [8].Fig 1.1 shows the complete hip implant. The replacing of the hip joint consists of several parts such as the femoral head, shell, acetabular cup (bearing) and stem. Wear generation for metal on polymer artificial hip joints are the major issue. The most commonly used hip implant bearing material is Ultra high molecular weight polyethylene (UHMWPE) and it's been used as the bearing material since 1960 [7].

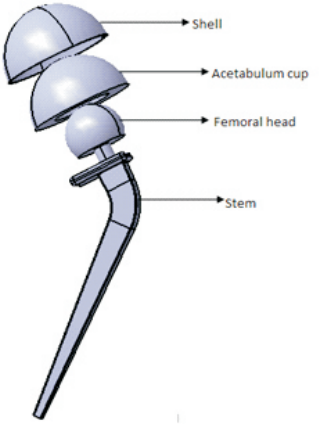

Fig 1.1

UHMWPE wear debris causes osteolysis and induces inflammation. Osteolysis tends to increase in the failure of the implant [1]. There is need for the replacement of the existing polyethylene material with alternative material to reduce the wear. In this paper in order to replace the UHMWPE as the bearing surface Polyether ether ketone (PEEK) has been investigated [2]. PEEK showed higher bio-compatibility and it has been used in the various biomedical application such as trauma, spinal fusion and total disc replacement from past two decades [5]. This work compares the wear behaviour of the UHMWPE and PEEK in a unidirectional pin on disc setup under unlubricated condition. The main aim is to study wear behaviour of the UHMWPE and PEEK compatibility as the bearing material.

2. MATERIALS AND SAMPLE PREPARATION

Stainless steel (SS) 316L, Co-Cr and titanium alloy were the primary metals used as the femoral stems[8]. In this paper wear test of UHMWPE and PEEK is conducted with polymers as pins and metal disc SS316L.

Table 1: The material properties used in this study.

	Material	Young's modulus Gpa	Poisons ratio	Density kg/m^3
1	UHMWPE	0.69	0.39	933
2	PEEK	4	0.3	1310
3	SS316L	205	0.3	7990

2.1 SAMPLE PREPARATION

Samples of UHMWPE are prepared from the block of 100x10mm thick and PEEK are prepared from 15 mm diameter rod. Both the Bio compatible grade material is supplied from royal hardware Bengaluru. Fig 2.1 shows the prepared specimen dimension.

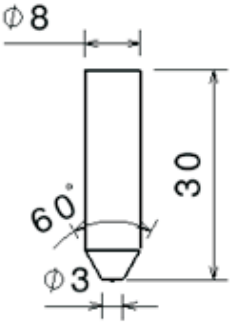

Fig 2.1

The pin used for the wear testing are made of cylindrical type with 30 mm length and 8 mm in diameter bevelled at an angle of 60o to make 3mm diameter. Bevelled face is the contact surface with the metallic disc. Due to geometry of the pin initial contact area and contact pressure changes over the time [3]. A similar reduction in the contact pressure is likely to happen in the implant [4].

Disc was prepared form the stainless steel 316L material. Disc are prepared to a dimension of 120 mm in diameter and 8 mm in thickness.

3. WEAR TEST

Pin on disc (POD) machine used is a unidirectional type with pin fixed to the Arm and disc to the disc holder. A load of 7kg is applied to the specimen then the contact pressure applied initially is 9.81 mpa. Both the specimens were slid against the metallic disc for a total run of 8km at 0.1 m/s sliding velocity Fig 3.1 shows the Pin on disc machine. Wear height in µm of both the specimen were measured for every 1000 meter run. Also Specific wear rate (K/H) of both the specimens were measured. Where K is the wear rate and H is the Hardness of the softer material. To determine the Specific wear rate wear volume is calculated. Obtained wear volume is then divided by the load applied and sliding distance.To check the effect of the frictional forceson sliding velocitypolymer specimens were tested for different sliding velocity of 0.1, 0.2 and 0.3 m/s.

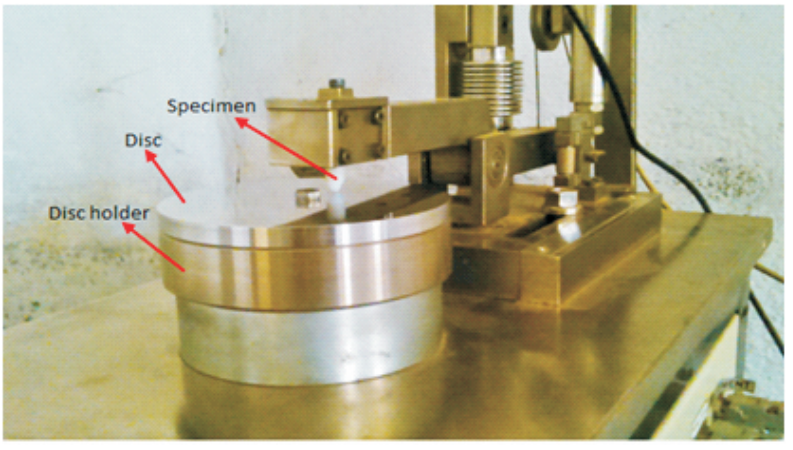

Fig 3.1 Pin on disc machine.

Table 2. The complete details of the machine setup

Sl/no	Particulars	Values
1	Sliding velocity	0.1 m/s or 47.77 rpm
2	Track diameter	40 mm
3	Contact pressure	9.81 mpa
4	Contact area	$7mm^2$

3.1 WEAR THEORY

According to Archard's wear equation volume of wear depends on the load applied, hardness of the softer material and sliding distance. See the equation 1

$$\frac{V}{L} = KA = K\frac{W}{H} \qquad (1)$$

Where V is the volume of wear in mm3, W is the load applied, H is the hardness of the softer material, A is the contact area and K is the wear rate. [9]

4. RESULTS

4.1 FRICTION MEASUREMENT

The frictional forces were continuously measured throughout the test of sliding distance of 8km. During the test coefficient of friction were lower and gradually it become higher and become constant. Coefficient of friction of 0.15 was measured for UHMWPE which was constant between 5 to 8 Km and similarly for PEEK coefficient of friction 0.37 was measured. Fig 4.1 shows the variation of the coefficient of friction for different sliding velocity.

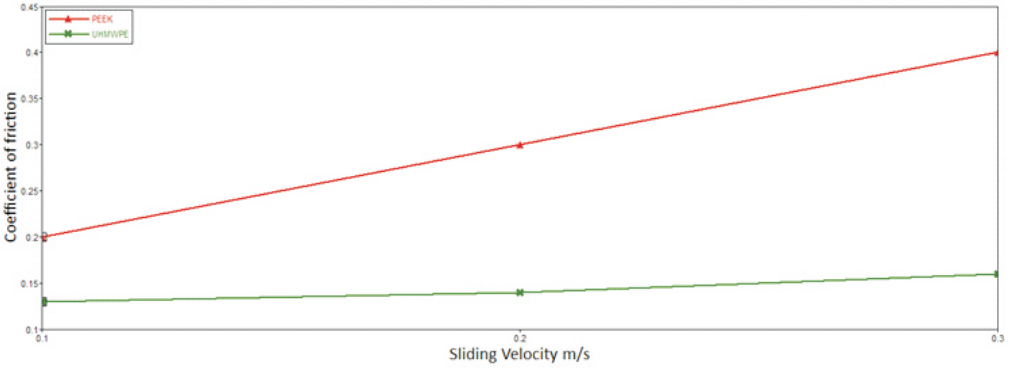

Fig 4.1variation of coefficient of friction vs sliding velocity

4.2 WEAR MEASUREMENT

Wear height of the both the specimen are compared in the Fig 4.2. Wear height of both the specimen was measured for every 1000 meter sliding distance.

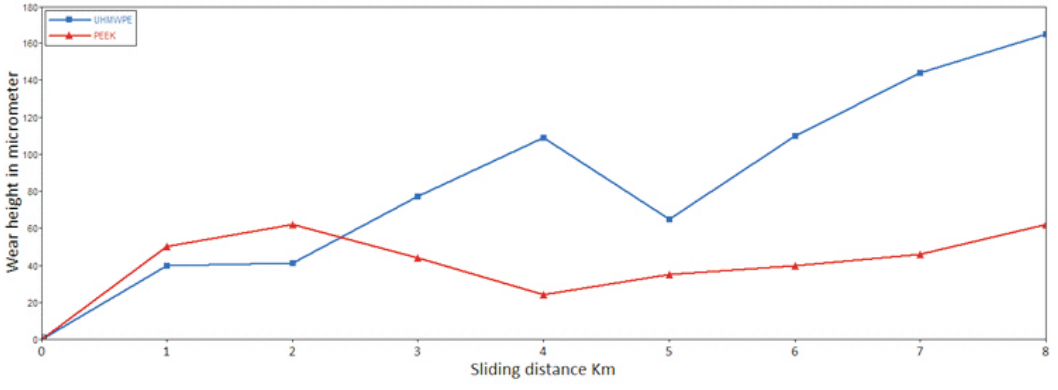

Fig 4.2 Wear height vs sliding distance

Wear volume of the each specimen were measured after sliding distance of 8km. Table 3 shows the wear volume and specific wear rate of the specimens. To measure the wear volume of the specimen initial and final weight of the specimen should be found out. Difference of the initial and final weight gives the weight loss in grams. And by dividing weight loss with the density of the material gives volumetric loss and specific Wear rate is measured using the equation (1).

Table 3 Wear volume and specific wear rate

Sl/no.	Material	Sliding distance (Km)	Load (N)	Wear Volume loss (mm^3)	K/H (mm^3/N-m)
1	UHMWPE	8	68.67	6.98924	1.27E-5
2	PEEK	8	68.67	2.21347	4.02E-6

5. DISCUSSION

A unidirectional pin on disc machine provides sliding motion and wear rates for the bio materials used in the hip prosthesis. This study investigate wear rate and variation of the coefficient of friction for different sliding velocity.

5.1 FRICTION RESULTS

Friction between the material is mainly depends on the surface roughness of the specimens. Variation of the coefficient of friction is mainly due to the varying surface roughness throughout test sliding distance. PEEK showed higher coefficient of friction is due to its higher abrasive nature.Higher abrasive nature of the PEEK creates scratches on the metallic disc. This may increase metal ion toxicity in the clinical trials hence it is not suitable for the bearing material in the hip joint. Whereas UHMWPE showed lower coefficient of friction and creates lower scratches on the disc. This is due to the self-lubricating property of the UHMWPE.

Fig 4.1 shows the increase in coefficient of friction for different sliding velocity. Effect of velocity on coefficient of friction is very little in certain condition [10]. But the experimental results shows effect of velocity on coefficient of friction is significant.

5.2 WEAR RESULTS

Fig 4.2 shows Wear height of the specimen. Initially PEEK showed higher wear compared to the UHMWPE this is due to the initial surface roughness and contact pressure [1]. In this work contact pressure initially was at 9.81 mpa. Due to the wear of the material and the geometry of the specimen contact pressure reduces [4]. But in the case of UHMWPE wear height was initially lower and gradually increase over the sliding distance.

Study of the UHMWPE and PEEK showed that PEEK has lower wear rate compared to UHMWPE. Even though PEEK showed higher coefficient of friction wear rate is lower because of the hardness of the material.

6. CONCULSION

In this study wear test were conducted using a pin on disc machine setup for unlubricated condition. Tribological Investigation showed that the behaviour of the frictional and wear behaviour of the polymer material used.

Study of the variation of the friction with different sliding velocity showed coefficient of friction increases with the increase in the velocity. PEEK showed higher coefficient of friction compared to UHMWPE material.

Wear height comparison showed the surface roughness and the contact pressure effects the wear behaviour of the polymers. Especially for PEEK wear height varied along the sliding distance. Upon

experimental results UHMWPE has lower wear rates than PEEK material.PEEK has showed higher wear resistant and produced lower wear debris.But higher abrasive nature PEEK made scratches on the metallic disc hence use of the PEEK as the bearing material for artificial hip implant is not suitable.

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REFRENCES.

[1]A.Escudeiro, M.A.Wimmer, T.Polcar, A.Cavaleiro 'Tribological behavior of uncoated and DLC-coated CoCr and Ti-alloys in contact withUHMWPE and PEEK counterbodies' Tribology International 89 (2015) 97–104

[2]Jean Geringera, Witold Tatkiewicza, G. Rouchouseb, 'Wear behavior of PAEK, poly(aryl-ether-ketone), under physiological conditions' Wear 271 (2011) 2793– 2803

[3]Mohammed Hoseini, Anneli Jedenmalm, Antal Boldizar 'Tribological investigation of coatings for artificial joints' Wear 264 (2008) 958–966

[4]Vesa Saikko 'A multidirectional motion pin-on-disk wear test methodfor prosthetic joint materials' 0021-9304/98/010058-07

[5]S. M. Kurtz, and J. N. Devine 'PEEK Biomaterials in Trauma, Orthopedic, and Spinal Implants' Biomaterials. 2007 November ; 28(32): 4845–4869

[6]Shirong Gea, Shibo Wang, Norm Gitis, Michael Vinogradov, Jun Xiao 'Wear behavior and wear debris distribution of UHMWPE against Si3N4 ball in bi-directional sliding' Wear 264 (2008) 571–578

[7]Uwe Holzwarth, Giulio Cotogna 'Total hip arthroplasty' JRC scientific policy and report 2012

[8]Feng liu "Effect of motion inputs on the wear prediction of artificial hip joints" Tribology International 63 (2013) 105–114, Elsevier 2012.

[9]J F Archard ' Wear theory and mechanism -Handbook'

[10]V A belly, A I Sviridenok, M I Petrokovets, V G Savkin "Friction and wear in polymer based material" pregamon press 1982