Sigma J Eng & Nat Sci 36 (4), 2018, 1175-1180

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

Research Article

INVESTIGATION OF WEAR BEHAVIORS OF PROSTHETIC MATERIALS ON BALL-DISC EXPERIMENT

Harun AKKUŞ*[1], Tahsin KAMIŞ[2], Hayrettin DÜZCÜKOĞLU[3]

[1]*Amasya University, Technical Sciences Vocational School, AMASYA;* ORCID: 0000-0002-9033-309X
[2]*Selçuk University, Technology Faculty, KONYA;* ORCID: 0000-0003-2894-1809
[3]*Selçuk University, Technology Faculty, KONYA;* ORCID: 0000-0002-7016-6888

Received: 11.09.2018 Accepted: 02.11.2018

ABSTRACT

In this study; The abrasion performances of uncoated Ti-6Al-4V and uncoated AISI 316 L stainless steel material were investigated in a ball-disc test apparatus. The experiments were carried out with 100Cr6 balls 10 mm in diameter in dry and sodium hyaluronate media to give a 500 m path under the influence of 7,5 N and 10 N forces at shear rates of 1-1,5-2 m/s. The wear quantities of the test specimens were examined for the ball and disc. As a result, it is observed that Ti-6Al-4V material is more resistant to abrasion than stainless steel material. The erosions in the medium added with sodium hyaluronate are very small compared to the dry medium and the erosion is reduced by 30-35% compared to the dry medium.
Keywords: Ti-6Al-4V, AISI 316 L, wear, sodium hyaluronate, ball-disc test.

1. INTRODUCTION

AISI 316 L stainless steel material is preferred as prosthetic material because it is inexpensive and easy to supply. Titanium alloys, especially Ti-6Al-4V, have advantages such as excellent corrosion resistance, low density, high strength / weight ratio, low modulus of elasticity [1-3]. Because of these properties, titanium alloys are used in many medical fields, especially due to the insensibility of aerospace industry and marine applications, sports vehicles and body fluids.

Especially if it is thought to be used in hard tissue implants, it seems to be a necessity to improve the surface properties of these implants which are exposed to abrasion, body fluids, and constant skin and repeated loads. It is thought that a normal adult person would make an average of one million steps each year. Joints that provide movement while walking, running, jumping, climbing, and so on are constantly exposed to variable loads. Therefore, the fatigue of these organs exposed to repeated loads is inevitable. In addition, joints are made up of co-workers. There is a synovial fluid that acts as a lubricant between the joints. Although there is synovial fluid occasionally, the part that comes into contact with time comes to wear. In addition, body fluids create a constantly corrosive environment. Therefore, fatigue, wear and corrosion of a biomaterials placed in the body occurs at the same time. These damage mechanisms can cause the implant placed in the human body to loosen up, wear, break down under sudden load, and

* Corresponding Author: e-mail: harun.akkus@amasya.edu.tr, tel: (358) 260 00 67 / 6316

inflammation in areas that come into contact with the body. This is the most common mechanism of wear. The duration and density of the prosthesis are the other important parameters affecting wear. It has been observed that different movements such as running and walking, as well as the fact that the ground on which these movements are made are flat and sloping, and that the increase in walking speed and the degeneration of the ground significantly increase the wear rate [4-5]. In a statistical study, it was stated that the hip prostheses placed in the body had to be replaced for a period of up to fifteen years, after which they were damaged due to wear and fatigue damage. The necessity of replacing the implant every 15 years, and the operation, both psychologically affect the patient and cause economic problems. The main purpose of the research is to increase the use time of the implant to 50 years. This information can be summarized in the light, why biomaterials require surface modification [6-9]: Biomimetic surface directly interacts with living tissues in the body. The implanta response of the tie is dependent on the surface pro perties. It is very rare for a biomaterial to have both good mass properties and suitable surface characteristics for clinical applications. Low blood and tissue compliance not only causes cellular damage, but also causes damage to the implant. In such cases, the hardness, abrasion and corrosion resistance are high, and it is thought that a biocompatible material can solve these problems.

Long-term use is a goal for biomaterials. Although metallic implants commonly used in orthopedic applications have superior mass properties such as strength and elasticity, they also have relatively weak surface properties. Therefore, a harmony between mass and surface properties is required.

Wear and corrosion are a major problem not only for implant materials, but also for engineering materials used in other areas. It is impossible to remove this problem altogether. The goal is to slow down the speed of this damage mechanism. Therefore, surface engineering plays an important role in industrial applications, especially in reducing the industrial cost of wear [10].

In this study, the abrasion performances of 316 L stainless steel and Ti-6Al-4V material were subjected to abrasion with 100Cr6 balls at 10 mm in diameter in dry and sodium hyaluronate media with different shear rates at 500 m under different shear rates under the influence of different forces on the ball- Ball and disc.

2. MATERIAL AND METHOD

The abrasion amounts of the test specimens were investigated by subjecting the test specimens to wear with 100Cr6 balls 10 mm in diameter in dry and sodium hyaluronate media to make 500 m under the influence of 7,5 N and 10 N forces at 1 m/s, 1,5 m/s and 2 m/s shear rates.

The reason why 316 L stainless steel material is used as an implant is the high resistance against intergranular and even stressed corrosion cracks. This material has been used as an experimental material in order to examine the possibilities of improving the strength properties due to not being able to harden with normal heat treatment applications. Titanium alloys to be used as biomaterials, particularly as hard tissue prostheses, are desired to have high resistance-low modulus of elasticity, high fatigue resistance and easy operation. Mechanical properties of titanium alloys; The composition of the alloy is directly dependent on the distribution of phases and the thermo-mechanical process. [11-12].

Hardness measurements were made on the Mht-2 brand micro hardness meter. The microhardness measurements were measured as HV by applying a load of 100 gr with a diamond tip for 15 seconds. The 316 L dissector hardness was measured as 320 HV1 and the Ti-6Al-4V dissembly hardness as 350 HV1. The 100Cr6 balls used as abrasive elements in the test were also measured in Rockvel C and the hardness of the measured ball was measured as 64-66 HRc.

Test specimens and abrasive ball After cleaning with ethanol, they are dried for 15 minutes in the drying oven shown in Fig. 1 and weighed beforehand with a weight measuring scale with 10-4 gr precision. Scaled specimens were exposed to abrasion under conditions with dry and sodium hyaluronate fluid on the ball-disk test apparatus. After the test, the samples were cleaned with ethanol and weighed to determin e the mass losses. The abrasion tests were carried out at room temperature and under normal atmospheric conditions in a dry and rubbing environment with sodium hyaluronate liquid. The 100Cr6 balls used for the test were brought into contact with the disc so as to make a separate trace for each experiment. After the studies in the dry environment, 0.5 liter sodium hyaluronate liquid was added with the aid of the tank included in the system and the same experiments were carried out in the liquid medium. All experiments were repeated three times and averaged.

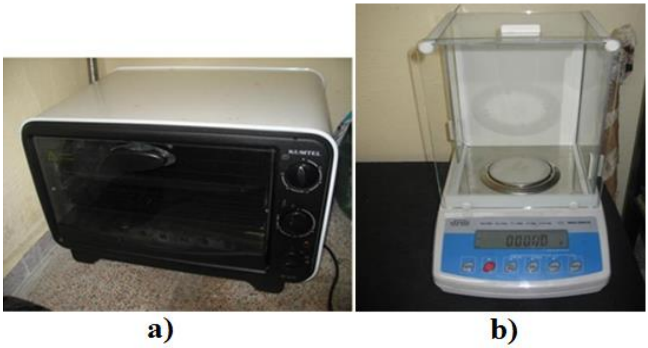

Figure 1. a) Drying oven, b) 10-4 gr Precision weighing device

Experimental studies were carried out on the ball-disk experiment device in Selcuk University Faculty of Technology Department of Mechanical Engineering. The ball-disk tester is operated with 2.2 kW and 1400 rpm motor and the disk is rotated. The device consists of a 2.2 kW AC motor, a 2.2 kW speed regulator, a disk mounted on the specimen, a support arm, a pence mechanism, a table, a slide mechanism, weight balancing devices, variable weights. A versatile, general-purpose, Squirrel data logger with 8 analog inputs is used for friction coefficient and temperature measurement. Using the Squirrel View interface program, 10 values were read and recorded at the moment. Figure 2 shows the general view of the ball-disk test apparatus.

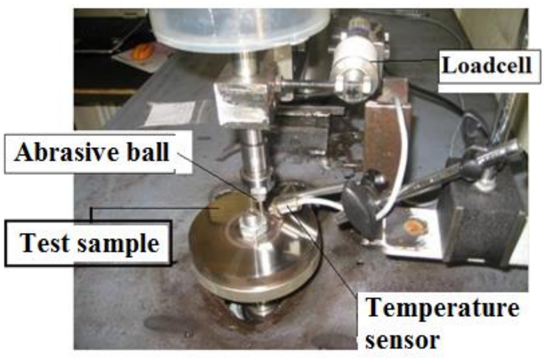

Figure 2. Ball-disk test apparatus

After the work in the dry environment is over, 0.5 liter of sodium hyaluronate liquid is added to the system by adding the tank shown in Figure 3. Thus experiments in the liquid medium were also carried out.

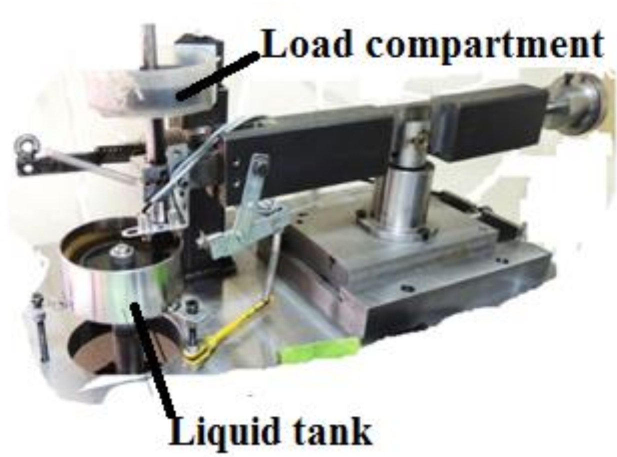

Figure 3. Ball-disk test apparatus; Working with sodium hyaluronate fluid

3. EXPERIMENTAL RESULTS

As a result of different test durations, wear rates and applied forces, wear amounts in both abrasive ball and discs were obtained in Table 1 and Table 2 according to the shear rate and applied abrasive force for each test sample in grams.

In Table 1, as the effect of force is increased, the amount of abrasion in the ball increases at all sliding speeds and for all discs. The reason for this is related to the increase of the load and the increase of the contact surface of the two materials. Again, in the same Table, the effect of the film formed by the liquid shows that the amount of wear is reduced in all tests. It appears that the liquid provides an advantage of between 25% and 35% in terms of wear amount of the ball.

Table 1. Mass loss according to shear rate and applied force for ball

	1 m/sn				**1,5 m/sn**				**2 m/sn**			
	7,5 N		**10 N**		**7,5 N**		**10 N**		**7,5 N**		**10 N**	
Test Samples	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid
	(g)		**(g)**		**(g)**		**(g)**		**(g)**		**(g)**	
316 L	0,0020	0,0015	0,0016	0,0012	0,0014	0,0010	0,0018	0,0012	0,0008	0,0006	0,0010	0,0007
Ti-6Al-4V	0,0025	0,0018	0,0019	0,0015	0,0017	0,0012	0,0020	0,0015	0,0010	0,0007	0,0012	0,0009

Table 2 shows wear amounts in discs exposed to wear with the 100Cr6 bearing ball. When the amount of wear on the discs is examined for liquid media, it can be seen in Table 2 that the wear amounts are between 20% and 50% lower than dry atmosphere.

Table 2. Sliding speed for disk and mass loss according to applied force

	1 m/sn				**1,5 m/sn**				**2 m/sn**			
	7,5 N		**10 N**		**7,5 N**		**10 N**		**7,5 N**		**10 N**	
Test Samples	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid
	(g)		**(g)**		**(g)**		**(g)**		**(g)**		**(g)**	
316 L	0,0096	0,0075	0,0105	0,0080	0,0101	0,0088	0,0110	0,0090	0,0106	0,0090	0,0115	0,0095
Ti-6Al-4V	0,0046	0,0038	0,0052	0,0040	0,0035	0,0030	0,0045	0,0035	0,0037	0,0028	0,0042	0,0036

Using the wear loss values in Table 1 and Table 2, and using Equation 1, the abrasion force-wear ratio changes were found for both discs and balls at three different shear rates.

$$K=k/H = V/FN.L \quad (1)$$

and the wear rate values calculated by substituting the equation in the equation. Here;

V: Volume wear (m3),
L: Slip path length (m),
FN: Normal force (N),
K: Shear wear coefficient,
H: The stiffness of the test material (HV) [12].

Using the wear rate values in Table 3 and Table 4, for each of the disks and balls, Slip velocity, abrasion force and wear rate were investigated. Table 3 gives the wear rates of discs subjected to wear with 100Cr6 bearing ball. It appears that the addition of liquid to the ball disk test set reduces the wear rate.

Table 3. Sliding speed for disks and wear rates according to applied force [Wear rate x 10^{-6} ($mm^3N^{-1}m^{-1}$)]

	1 m/sn				**1,5 m/sn**				**2 m/sn**			
Test Samples	7,5 N		10 N		7,5 N		10 N		7,5 N		10 N	
	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid
316 L	33	25	36	29	35	28	38	30	38	32	40	30
Ti-6Al-4V	23	17	27	22	20	15	21	17	20	15	22	16

In Table 4, as the force effect is increased, the rate of abrasion at all sliding velocities and discs is increasing. The reason for this is related to the increase of the load and the increase of the contact surface of the two materials.

Table 4. Slip speed for abrasive and abrasion rates according to applied force [Wear rate x 10^{-6} ($mm^3N^{-1}m^{-1}$)]

	1 m/sn				**1,5 m/sn**				**2 m/sn**			
Test Samples	7,5 N		10 N		7,5 N		10 N		7,5 N		10 N	
	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid	Dry	Liquid
316 L	4	3	7	5	4	3	5	3	2	1	3	1
Ti-6Al-4V	5	4	8	6	5	3	6	4	3	2	3	2

4. RESULTS

In this study, wear performance of AISI 316 L stainless steel and Ti-6Al-4V material were investigated using two different test environments. In the first test environment, test specimens were subjected to abrasion at different shear rates and forces under dry friction conditions, at room temperature. In the second test medium sodium hyaluronate fluid injected media, test samples were exposed to different shear rates and forces. The friction coefficients at all load cases and sliding speeds were lower than the dry medium in sodium hyaluronate added condition, which also reduced the wear rates. The erosions in the medium added with sodium hyaluronate are very small compared to the dry medium and the erosion is reduced by 30-35% compared to the dry medium.

In subsequent studies, the sodium hyaluronate fluid can be used as an abrasion-inhibiting lubricant. The lubrication properties of sodium hyaluronate liquid on other materials should be investigated. Wear performances can be examined by applying surface coatings to the test materials.

REFERENCES

[1] Bischoff, U., Freeman, M., Smith, D., Tuke, M., Gregson, P.,1994. Wear induced by motion between bone and titanium or cobalt-chrome alloys. Bone & Joint Journal, 76 (5), 713-716.

[2] Hirakawa, K., Bauer, T.W., Stulberg, B.N., Wilde, A.H., Secic, M., 1996. Characterization and comparison of wear debris from failed total hip implants of different types. J Bone Joint Surgam, 78 (8), 1235-1243.

[3] Gümüşderelioğlu, M., 2002. Biomaterials. Bilim ve Teknik Magazine, July special issue.

[4] Bowsher, J., Shelton, J., 2001. A hip simulator study of the influence of patient activity level on the wear of crosslinked polyethylene under smooth and roughened femoral conditions. Wear, 250 (1), 167-179.

[5] Li, C., Bell, T., 2004. Sliding wear properties of active screen plasma nitrided 316 austenitic stainless steel. Wear, 256 (11), 1144-1152.

[6] Rodriguez, R., 2004. The Sprint Database of Ion Implantation Centers. European Community Programme for Innovation and Technology Transfer.

[7] Kirkpatrick, C., Wagner, M., Kohler, H., Bittinger, F., Otto, M., Klein, C., 1997. The cell and molecular biological approach to biomaterial research: a perspective. Journal of materials science: Materials in medicine, 8 (3), 131-141.

[8] Zhao, Q., Zhai, G.-J., Ng, D., Zhang, X.Z., Chen, Z.Q., 1999. Surface modification of Al2O3 bioceramic by NH+ 2 ion implantation. Biomaterials, 20 (6), 595-599.

[9] Zhecheva, A., Sha, W., Malinov, S., Long, A., 2005. Enhancing the microstructure and properties of titanium alloys through nitriding and other surface engineering methods. Surface and Coatings Technology, 200 (7), 2192-2207.

[10] Waddell, D.D., Bricker, D.C., 2007. Total knee replacement delayed with Hylan GF20 use in patients with grade IV osteoarthritis. Journal of managed care pharmacy, 13 (2), 113-121.

[11] Ninomi, M., 1998. Mechanical properties of biomedical titanium alloys. Materials Science and Engineering: A, 243 (1), 231-236.

[12] Jackson, M. J., Ahmed, W., 2007. Surface engineered surgical tools and medical devices. Springer Science & Business Media.