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RESEARCH ARTICLE

A COMPARATIVE STUDY OF ALUMINA AND SS 316L FRICTIONAL CONTACT AGAINST UHMWPE ON THE CHANGE IN THE SOFTER BEARING SURFACE MORPHOLOGIES

I. Nyoman Jujur, Nandang Suhendra, Muslim Efendi Harahap, Sudirman Habibie, Masmui, Sri Rahayu, Damisih, Aghni Ulma Saudi, Siti Amalina Azahra, Henny Purwati, Lukmana and Harun Setiawan
National Agency for Research and Innovation (BRIN) Republic of Indonesia (KST Prof. B.J. Habibie, Jl. Raya Puspiptek, Tangerang Selatan Banten, Indonesia 15314).

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Abstract

Alumina, with excellent physical, mechanical, and tribological properties, is considered an ideal material to be applied in various fields, including the health sector. This study investigates the effect of sliding Alumina composite and SS 316L on Ultra-High Molecular Weight (UHMWPE) surfaces. We conducted the wear testing on a tribometer device in dry conditions with a constant load of 10 N. Scanning electron microscope (SEM) and the laser probe embedded optical microscopy (Keyence) were used to characterise the morphology of samples before and after the test and to investigate the amount of material lost at the end of the experiment. The lost volume and wear rate on the UHMWPE surface due to sliding friction with Alumina is essential to measure the performance of Alumina as total hip-joint arthroplasty (THA) bearing component material against its counterfaces. Wear volume loss and wear rate on the UHMWPE due to sliding contact against 316L stainless steel (1.986 mg) was slightly higher than that caused by Alumina (1.948 mg). Furthermore, the surface interaction between UHMWPE and Alumina at the 30,000th cycle shows the surface profile of UHMWPE experiencing cracks, delamination and plastic deformation, and different groove patterns. From this result, Alumina could have a better effect than 316L Stainless Steel on THA longevity.

Introduction:-

The global competition demands an increase in the quality of ceramic-based industrial products, making the trigger for research related to ceramic technology continue. Meanwhile, each ceramic for specific applications requires unique technology in the manufacturing process. The development and application of alumina-based hybrid ceramic technology in the health sector, especially bone implants, such as total hip-joint arthroplasty (THA), is very advanced for the femoral head component.

Several studies that have supported the advancement of ceramic technology for these implants include Grabowi et al. [1] and other research groups [2, 3, 4, 5, 6]. Many research groups have conducted similar studies to this work and reported in published papers [7, 8, 9, 10]. The interaction in the form of contact and material friction between the cup and head on THA can be in the form of ceramic-on-ceramic (c-o-c); and metal-on-metal (m-o-m), metal-on-

Corresponding Author:- Nandang Suhendra
Address: National Agency for Research and Innovation (BRIN) Republic of Indonesia
KST Prof. B.J. Habibie, Jl. Raya Puspiptek, Tangerang Selatan, Banten, Indonesia 15314

polymer (m-o-p), and ceramic-on-polymer (c-o-p). UHMWPE is a polymer material commonly used in THA in pairs with metal and ceramic types. To study the behaviour of the developed ceramics against their opposing surfaces, it is easier to analyse when pairing them with a polymer material, namely UHMWPE.

For materials with high hardness, tribological research uses materials with a lower hardness to determine how far the tested material causes wear on the opposing surface [11, 12, 13]. Only a few studies have used ultra-high molecular weight polyethene (UHMWPE) as a benchmark material in comparing the performance of bearing surfaces [14, 15]. The present paper utilises the UHMWPE as a reference for investigating wear effects from Alumina and 316 Stainless Steel. Wang et al. reported that the wear of UHMWPE acetabular cups against metal femoral heads was significantly higher than that against ceramic heads [14]. The UHMWPE debris particles produced in hip wear simulation tests are classified as round debris, flake-like debris, and sticky debris, which are closely related to the primary mechanisms of abrasive wear, adhesive wear, and fatigue wear [14]. The main factor in the longevity of implanted prostheses is the tribological performance of artificial joint components. Surface roughness and coefficient of friction (COF) relationship under dry and lubricated environments is investigated. Results show that the friction coefficient keeps at the same value under the dry test. The reduction of surface roughness does not influence it [16]. Although a decrease followed the reduction in friction in the wear rate, the mechanisms for the observed behaviour were not explored.

This paper aims to study the tribological behaviour of Alumina-based composites by investigating the wear mechanism on the opposing surface resulting from friction with Alumina. This research investigated the friction coefficient, wear volume, wear rate, shape, and size of wear debris generated from the UHMWPE surface when friction with Alumina. The results are compared when friction contact with 316L Stainless Steel.

Materials and Methods:-

Materials:-

Alumina-based ceramic composites consisted of oxides of Al_2O_3, TiO_2, and MgO with a ratio per cent of the weight of 90:6:4, with a mole ratio, was: 88:0.8:1. The mixture of the three oxide compounds was then sintered at a sintering temperature of 1500^{o}C, with a holding time of 10 hours at the sintering temperature. Meanwhile, 316L and UHMWPE were obtained commercially on the market.

Methods:-

This test is intended to determine the tribological performance of alumina composite ceramic materials prepared in this study. For that purpose, SS 316L was chosen as a comparison material, where this material was once a THA component material with mechanical and tribological performance under CoCrMo alloy. UHMWPE was selected as a softer material than ceramics. The tribological impact of a given sliding distance can be identified from the softer material. The test results in dry conditions will differ from surface tribology conditions in wet environments. Dry test conditions are intended to obtain material performance comparison results more quickly. The results of this study are not intended to represent the function of material work in actual situations. This article reports on the early development of engineered ceramic materials that should prove their performance. Load and shear rates installed at 10 N and 120 rpm under dry conditions do not represent a tribological mechanism in THA. The testing was not designed to replicate in vivo. For this test, UHMWPE is not yet necessary to consider the sliding movement of the cross intended to inhibit the alignment of polymer chains.

The observations were made on the initial surface conditions of the investigated materials. Then, tribological testing was carried out on frictional contacts of Alumina on UHMWPE and 316L on UHMWPE. Observations were made on several effects on UHMWPE, such as friction coefficient, wear volume loss, wear rate, wear particle size and shape, and surface morphology. Figure 1 is a diagram that illustrates the research workflow in comparing the results of tribological tests pairing Alumina ceramic-on-UHMWPE and 316L-on-UHMWPE.

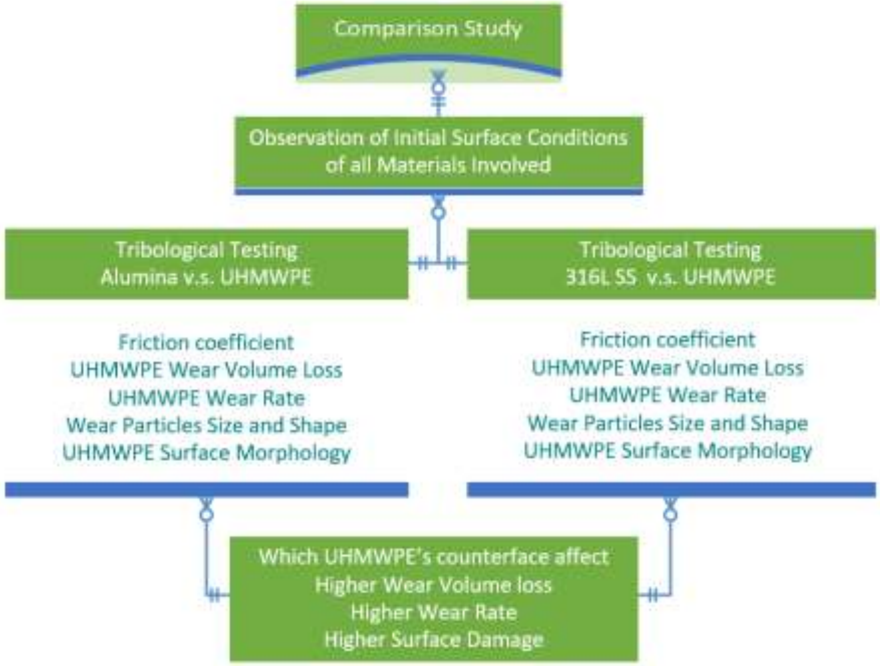
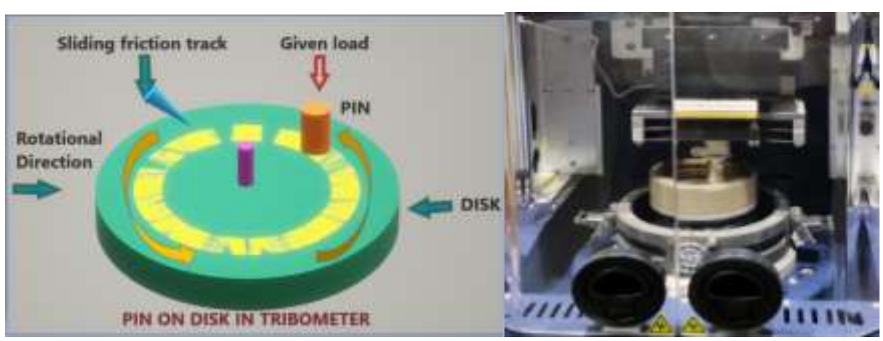


Figure 1:- Schematic diagram of the research method.

In this experiment, we prepared the test material by forming a composite of Alumina and 316L in pins and UHMWPE in disks. The installation of pins and disks in a test device called a tribometer (UMT Tribolab Bruker, as shown in Figure 2(b)) with a testing working principle is similar to a test device called a pin-on-disk. Alumina-on-UHMWPE, then 316L-on-UHMWPE. The pin-on-disk test results are: (1) a surface with frictional contact between the pin and the disc; (2) a particle that is a material that is detached from a softer surface, which in this case is a UHMWPE surface. Each pair of materials will be tested with three different sliding distance parameters represented by the number of cycles. The test results for other cycle numbers were expected to provide information on the trend of changes in wear volume from the smallest rotation number to the most considerable rotation determined in this research. The illustration of pins and disks is shown in Figure 2(a) below.



(a) (b)

Figure 2:- (a) Schematic illustration of pin-on-disk, and (b) the tribometer device.

Wear tests were conducted in a pin-on-disk tribometer. The cylindrical pins had a diameter of 6.29 mm and a length of 18.87 mm; meanwhile, the disc was 64.00 mm and 6.48 mm thick. On the disc, two holes were required on the test specimen; the centre hole was the shaft, which was located slightly to the edge and served as a grip when the disc rotated. In this experiment, all disks were made of polymer material, while the pins were made of ceramic and metal materials. After final polishing with 220, 600, and 1200 grit size diamond paste, the flat surfaces had a roughness of 0.1 pm RMS. In this experiment, all disks were made of polymer material, while the pins were made of ceramic and metal materials.

The weighing scale before and after the tribological test shows the weight loss due to the loss of many volumes during the wear process. The density and hardness of materials are summarised in the Table below (Table 1).

Table 1:- Physical and Mechanical Properties of Materials.

No.	Materials Type (density)	Materials Mass (g)	Volume (cm^3)	Hardness (HV)
1.	Alumina (3.95 gr/cm^3) [12]	2.16	0.58	1013.00
2.	316L SS (7.99 – 8.00 gr/cm^3) [17]	4.72	0.59	155.00
3.	UHMWPE (0.93 – 0.95 g/cm^3) [9]	19.81	20.85	67.00

The test sample was prepared with careful working steps, paying attention to the technical specifications of the polishing material, mechanical quantities, and other conditions to support the manufacture of tribology test samples. The details of the data used during the test sample work are shown in Table 2 below.

Table 2:- Preparation of Material Samples.

Sample	Operation	Grinding/ Polishing Agent	Grit Size	Applied Pressure (N/cm^2)	Time (minute)	Cooling Agent	Rotating Speed (rpm)
Ceramic	Polishing	Diamond	220, 600, 1200	12	10	water	150
316L SS	Polishing	Diamond	220, 600, 1200	12	10	water	150
UHMWPE	As Machining	Diamond	220, 600, 1200	10	10	water	100

The tribology testing was conducted with the following details: The UHMWPE was set up as a rotaTable disk, and the partner material was shaped and placed as a pin; the next step was to set a constant contact loading of 10 N, and a disk rotation rate of 120 rpm. The sliding distances are expressed by the number of cycles, which in this test are determined to be: 5,000, 15,000, and 30,000 cycles. The three different distances also apply to all material pairs tested, namely the 316L SS on UHMWPE and Alumina on UMMWPE pairings. These tribological tests were performed in a dry surface condition with no lubrication. All testing processes are carried out in an enclosed space, as shown in Figure 2(b), which is a picture of the tribometer's equipment. In this tribological test, the detected parameters are friction coefficient and contact force as a function of time. Another output is the volume lost due to the friction process followed by wear which is measured manually using a weighing scale. The reduced weight of UHMWPE disks that experienced more wear was converted into volume units, as the volume lost after experiencing friction for a specific rotation distance, namely 5000, 15,000, and 30,000 cycles. The wear rate is calculated based on the reduction in disk volume over each mileage specified above. Wear particles adhering to the pins and disk were collected. Particles taken from the surface of contacted surfaces using sticky tape were collected and stored in a closed container. Furthermore, the wear particles are sent to the micro-analysis laboratory to be characterised using an optical and scanning electron microscope (SEM).

Characterisation Techniques

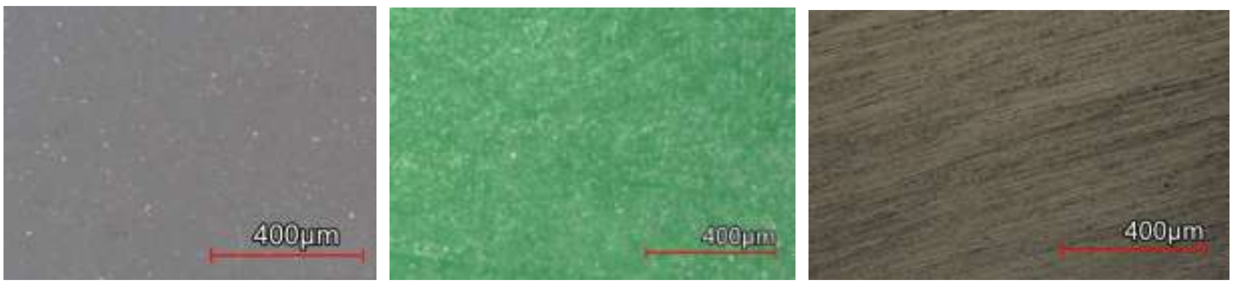
The surface Material characterisation was carried out before and after the material's tribological testing. Scanning electron microscope (SEM), JED-430 type JEOL, and optical microscopy with a laser probe (Keyence) were used to characterise the samples' morphology and investigate the amount of material lost at the end of the experiment. The main topic reported in this paper is describing the UHMWPE bearing surface in the initial conditions before and after tribological testing, in addition to investigating the amount of material lost at the end of the experiment. The Keyence was also used to determine the surface roughness of observed surfaces. Meanwhile, the Mountains 9.2 software was used to display surface morphology in 2D and 3D microscopy images.

Results and Discussion:-

The surface morphology of all samples has been obtained under Keyence VK-X Series and Scanning Electron Microscope EM imaging. The optical microscope is equipped with a laser probe, and the SEM gives us a higher magnification of the observed objects. Below is the initial surface before carrying out the core test of this research, namely tribological testing. The optical microscope used has reliable data reading capabilities. However, in this research work, the features that may be very useful in analysing the results of this tribological research have yet to be well known.

Surface Morphology

After having surface treatment and before commencing the tribological testing, we took surface images of all specimens under Keyence optical microscope with 120 x magnification, shown in Figure 3. The surface treatment of these three types of materials is the same. The mesh size and the diamond paste used during the polishing process are the same. Figure 3 shows that the morphological differences between the three types of material are visible—the Alumina, UHMWPE, and then the ~~SS~~316L Stainless Steel surfaces. Although the grain size is not seen very well in the three images, the surface structure observed in Figures 3(a) and 3(b) tends to be more uniform. Meanwhile, on the surface of 316L Stainless Steel, the smooth surface is limited by grooves with different structures. The relatively broad and elongated groove gives the impression of local plastic deformation, and scratches along the polish direction occur during polishing.



(a) (b) (c)

Figure 3:- Surface morphology initial condition of (a) Alumina; (b) UHMWPE; and (c) 316L Stainless Steel before Tribological Testing.

Loaded Contact

The load given for this tribological test has been set before the test starts at 10 N. The spectrum of the contact force shown in Figure 4 shows that the contact force that occurs during the test varies with a range of 4 N, between the lowest and highest values. The two surfaces' microstructure influences the contact force variation in contact with each other. The increased contact force was high at the beginning, as the force that arises is due to the retention of the asperity of the two surfaces. The stick and release of contacting asperities affect the contact force variation. It continues so that the recorded contacts' force curve varies, as shown in Figure 4. This contact force stabilised in the range of 10 N at the sixth hour.

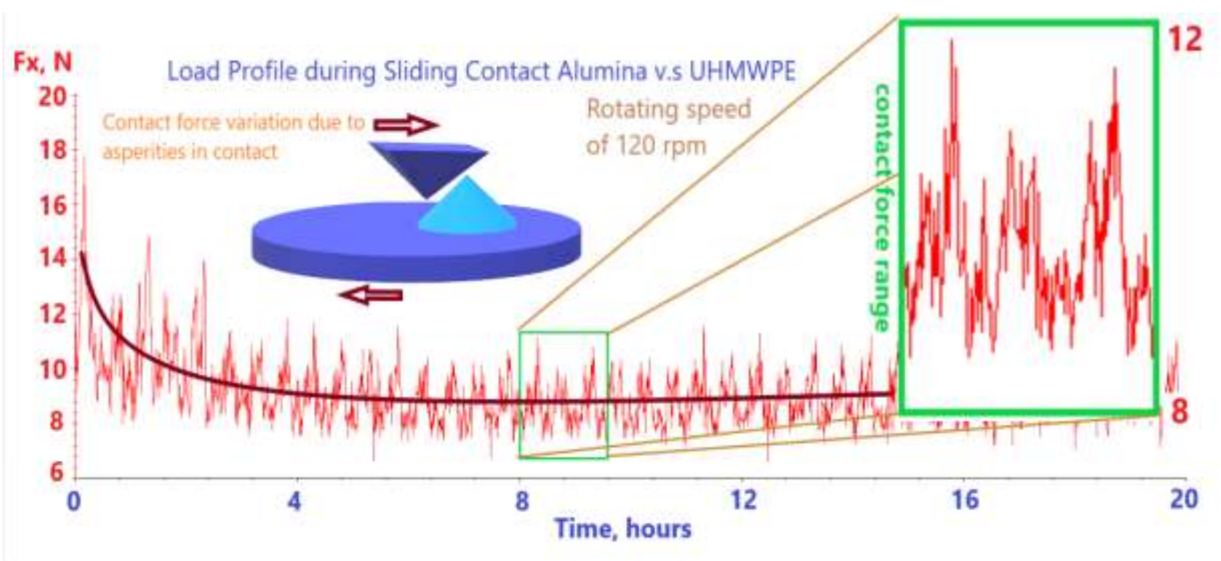


Figure 4:- Sliding contact force variation during tribology testing.

Furthermore, after the sixth minute had elapsed, the force seemed constant until the end of the test at the twentieth hour. The pressure reading is uncertain. The change in pressure is not caused by a decrease in the surface roughness of the softer material becoming smoother because the UHMWPE surface is subjected to abrasives that make the surface rough. The same happened in tribological experiments of the 316L Stainless Steel and UHMWPE pairs (the relationship between force vs shear contact travel time graph is usually similar to Figure 4). From a tribological point of view, the contact between Alumina and UHMWPE, or Stainless Steel 316L at low loads, such as the values we give in this 10N test, is limited to a small area of actual contact. The contact area is precisely distributed among several micro-contacts [18]. The loading pattern in the form of a zigzag is possible because the shear contact occurs in dry surface conditions, so the frictional force on the contact surface is highly dependent on the roughness profile of the contact surface. Creep on polymeric materials at the asperity level has the potential to change transducer readings periodically [18, 19]. The loading pattern in the form of a zigzag is possible because the shear contact occurs in dry surface conditions, so the frictional force on the contact surface is highly dependent on the roughness profile of the contact surface. Creep on polymeric materials at the asperity level has the potential to change transducer readings periodically [20]. Alamos et al. suggested that stress and contact area depend on normalised creep time, a function of material creep parameters, Young's modulus, and hardness. A similar study on the contact behaviour of a creeping sinusoidal surface concluded that surface geometry plays an essential factor in the growth of the contact area [20].

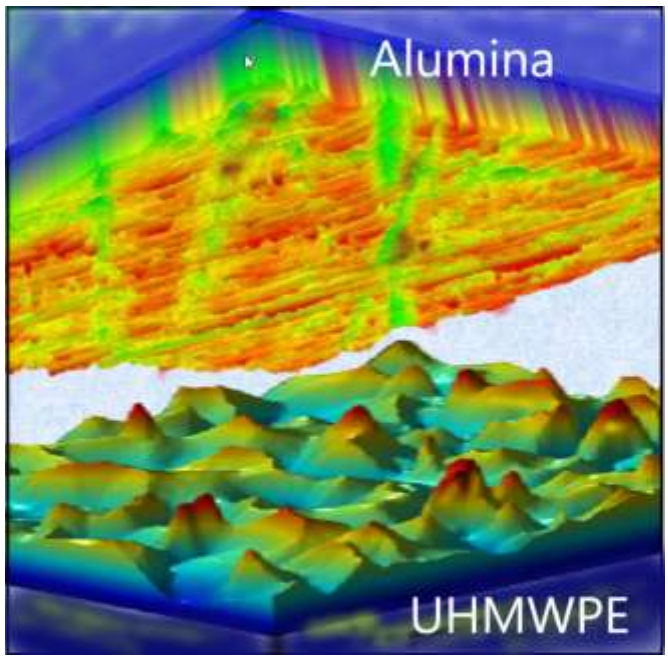


Figure 5:- Illustration of asperities that almost touch each other.

The mountains 9.2 software was used to illustrate a micron scale surface (Figure 5). As seen in Figure 5, the surface structure of asperity is very complex. Due to its complexity, developing the asperities model for particular research purposes requires simplifying the geometrical aspect [21]. Thus, studying an object's surface and how it interacts with other surfaces on a micro-scale must be accompanied by statistics.

Wear volume measurement

The results of measuring the weight of the pin and disk material after tribological testing are arranged in Table 3. There is a reduction in weight on UHMWPE at mileage ranging from 5000 to 30000 rounds. Meanwhile, the weight reduction in Alumina and 316L Stainless Steel materials was not detectable by the available weight meter. The UHMWPE weight reduction was due to surface material release due to the wear process. Especially for UHMWPE, whose weight reduction can be measured and then plotted on a graph where the Y-axis is the amount of UHMWPE volume lost, and the X-axis is the disk rotation distance on the pin-on-disk measurement system. Table 3 shows that at a distance of thirty thousand times, the weight reduction of UHMWPE paired with Alumina and 316L SS is higher than that of Alumina.

Table 3:- UHMWPE weight loss.

Materials	Sliding Distance (Cycle number)					
	5,000		15,000		30,000	
	Digitally Measured	Tribometer	Digitally Measured	Tribometer	Digitally Measured	Tribometer
Alumina on UHMWPE	0.102	0.095 mg	1.003	1.055 mg	1.901	1.948 mg
316L SS on UHMWPE	1.050	1.076 mg	1.088	1.093 mg	2.000	1.986 mg

As a mating material, Alumina causes less weight loss from its contact partner, UHMWPE, than 316L Stainless Steel. We need to address factors influencing the wear rate for mating material. Under light load, the wear will improve when mating material has higher surface hardness. The wear behaviour of materials depends on the hardness and surface roughness of mating materials [22, 23]. If the bearing is for a light load, using a more rigid material could improve the wear of mating surfaces.

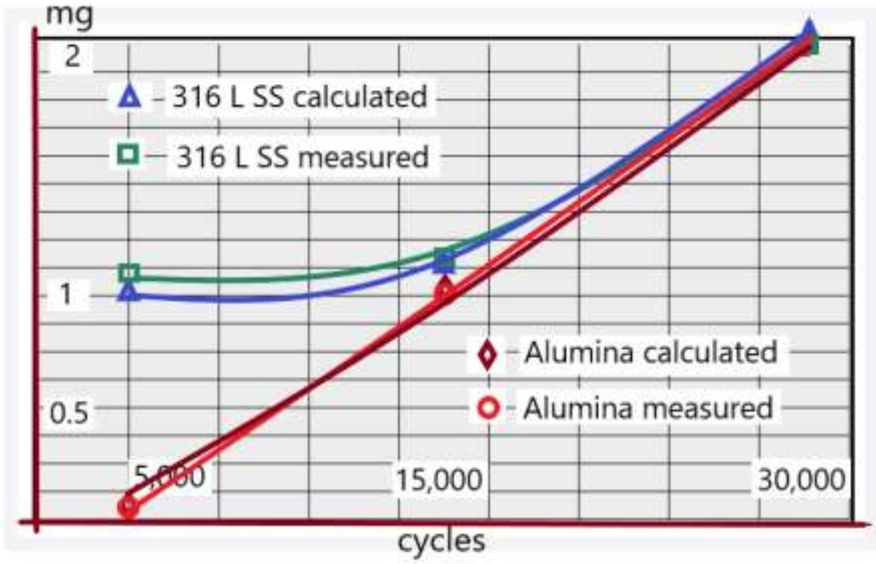


Figure 6:- Weight loss of UHMWPE for two different mating bearing surfaces.

UHMWPE volume loss measurement shows the difference in value between paired with Alumina and 316L Stainless Steel at the time of size at a distance of five thousand rounds. This gap occurs not only in the measurement results, but these differences are almost similar. This result is a phenomenon that occurs in the collection of tribological test data. Figure 6 shows the UHMWPE volume loss when they reach the number of cycles of five thousand times from the friction with 316L Stainless Steel as much as 1.0 mg, while the results from friction with Alumina are only in the range of 0.1 mg. Observing the surface profile of the 316L Stainless Steel before the test, which is homogeneous, wide bands could cause the loss of asperity on the UHMWPE surface at the beginning of the testing process. Simultaneously, the 316L Stainless Steel asperities also decrease. The graph shows wear rate decreases after passing the 5,000 cycles. After that, the wear rate slowly falls until, at the end of the test, the volume of UHMWPE loss is not much different from that experienced by UHMWPE when rubbing against Alumina (Figure 7).

The lost wear volume, along with the release of particles from the UHMWPE surface based on the results of measurements and calculations by this test instrument, is shown in Figure 7. The data plot of the relationship between wear volume and travel time is only a number from one of the parameters related to the material's behaviour at the interface of the two materials in contact. The wear rate's main influencing parameters are asperity flash temperature and friction coefficient. The asperity flash temperature could locally increase the contacting surface temperature during sliding friction. The asperity flash temperature arises due to friction [23]. This friction coefficient is directly proportional to the wear rate, mainly in softer materials, in this case, UHMWPE.

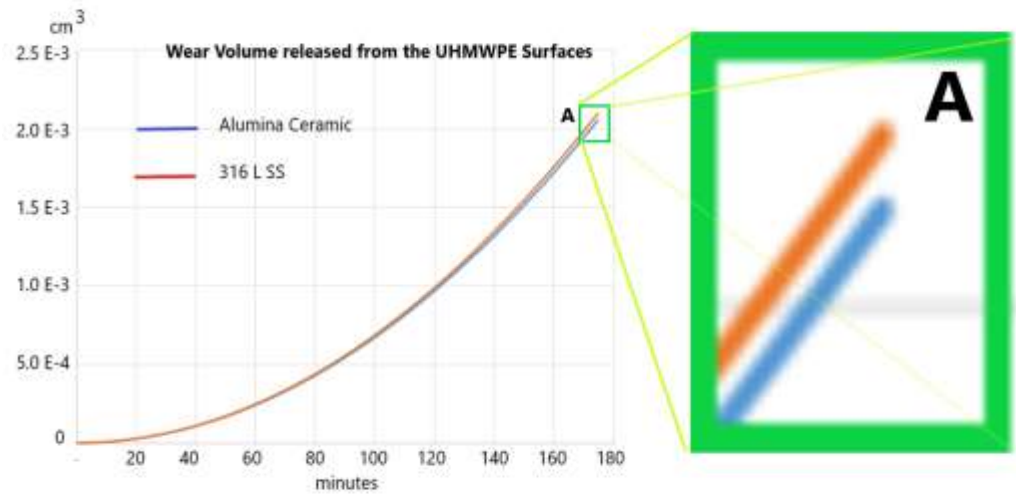
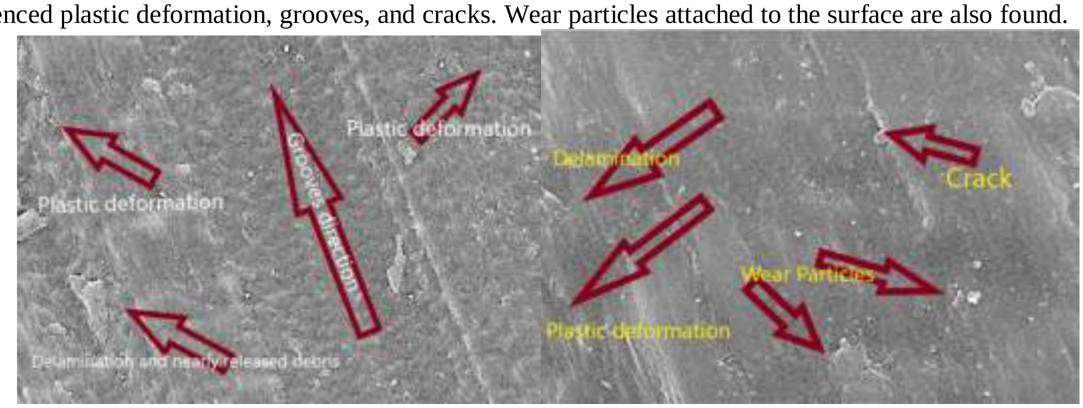


Figure 7:- Volume loss behaviour of UHMWPE as the increase of sliding distance (cycle number) represented by elapsed time (minutes**).**

Three dimensions (3D) surface topography measurement using existing facilities on the Keyence microscope in the form of a laser probe. A surface is represented as an area with a deviation of elevation. Surface profiler systems obtained from 2D images are indispensable in describing surface profiles in 3D.

UHMWPE's Surface Morphology

The UHMWPE surface was observed using an SEM. After having sliding contact with the Alumina, as shown in Figure 8(a), the UHMWPE surface areas have been experiencing plastic deformation; aside, grooves and delamination [18] in some parts of the surface. Figure 18(b) shows that the UHMWPE surface areas have also experienced plastic deformation, grooves, and cracks. Wear particles attached to the surface are also found.



(a) (b)

Figure 8:- Surface morphology of the UHMWPE surfaces after 30,000 cycles against (a) Alumina and (b) SS 316L.

This surface analysis is presented to convey a new method in surface roughness analysis using computational techniques. From the study's results using this analytical technique, the surface conditions of UHMWPE can be compared visually due to the interaction between Alumina and 316L ~~SS~~ Stainless Steel. The method used is suitable for viewing and not for proper roughness measurement. The quantitative assessment of surface roughness (called roughness parameters) can standardise the evaluation of the sampled material surfaces. The main roughness parameters are **root-mean-square height** (**Sq**) and **average height** (**Sa**). The degree of roughness computation is calculated from the average standard deviation of the measurements (valleys and peaks) in a surface profile.

The **Sa** and **Sq** parameters do not provide any local surface evaluation. Other height parameters are used for a local measurement, based on dividing the surface profile into smaller parts and considering information on peaks and valleys separately. This way, it is possible to analyse the roughness (surface height) evaluation in greater detail. The main feature involved in the computation of these parameters is that they are obtained from samples/patches of a surface, providing a level of local control because the maxima and minima of each part are considered. Finally, despite the local control provided in calculating the parameters based on the division of the profile into patches/samples, the multiresolution surface analysis yields the best results for roughness computation from geometry.

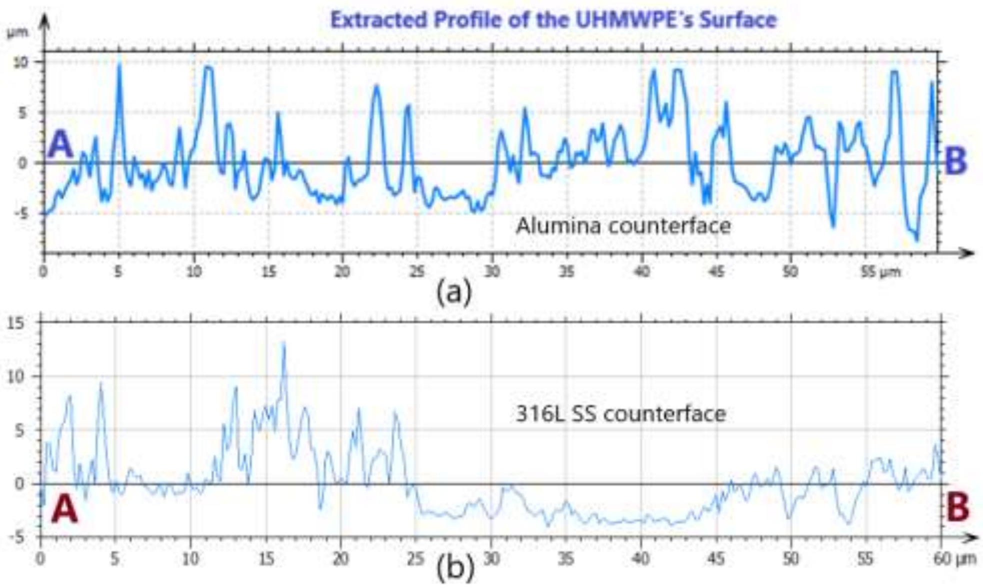


Figure 9:- Extracted surface profile of the UHMWPE surface at a sliding distance of 30,000 cycles from A to B points.

The 2D inner surface profile (as seen in Figure 9) is a slice of the UHMWPE surface that extends from point A to point B (Figure 10). Figure 9 shows the surface parameters in S_q, S_z, S_a, and S_{dr}, with values as listed in Table 4. This Figure shows two graphs of the extracted surface of UHMWPE interacting with the counterface (a) Alumina and (b) 316L Stainless Steel. The picture shows the surface profile with a maximum height of 22.06 and 20.18 microns, developed by Alumina and 316L Stainless Steel counterparts.

Additionally, the built-up interfacial area ratio of (a) 741.4 and 659.2 % for Alumina and 316L Stainless Steel bearing surfaces, respectively, indicates that the UHMWPE surface built by the Alumina counterface has a higher thickness than the thickness made by 316L SS. This ratio means that the surface erosion by Alumina is lower than by 316L SS. The scope of the analysed surface area is small compared to the sample's total area; the calculation using the fractal analysis method points out that particles that release the UHMWPE surface are mainly due to the 316L Stainless Steel counterface interaction.

Table 3:- Primary surface of the UHMWPE surface at a sliding distance of 30,000 cycles.

ISO 25178 – Primary surface				
Symbol	**Alumina**	**316L Stainless Steel**	**Unit**	**Parameters definition**
S_q	4.054	2.663	µm	Root-mean-square height
S_z	22.06	20.18	µm	Maximum height
S_a	3.100	1.990	µm	Arithmetic mean height
S_{dr}	741.4	659.2	%	The developed interfacial area ratio

The surface morphology of UHMWPE observed through SEM is shown in Figure 10. In this image, it can be seen that plastic deformation has occurred, which has shifted the material on the surface in such a way that compaction or accumulation occurs in one part. However, there are voids and even the formation of deep holes in other regions. It indicates that the UHMWPE surface has experienced plastic deformation, delamination, rupture, and material removal from the surface [24]. To understand the roughness patterns quantitatively and visually indicate texture variation behaviour and volume parameters along the surface, we used roughness analysis, the so-called multifractal analysis.

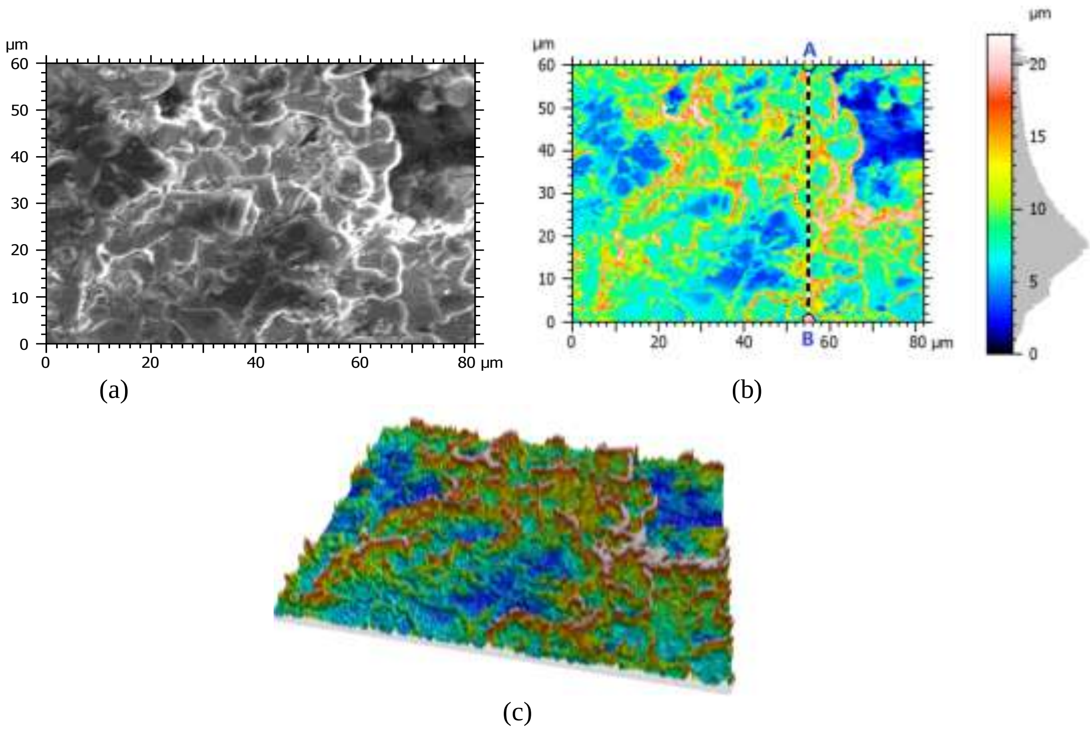


Figure 10:- (a) The UHMWPE (Alumina counterface) surface morphology at a sliding distance of 30,000 cycles, (b) Pseudo-color View, (c) in 3D image.

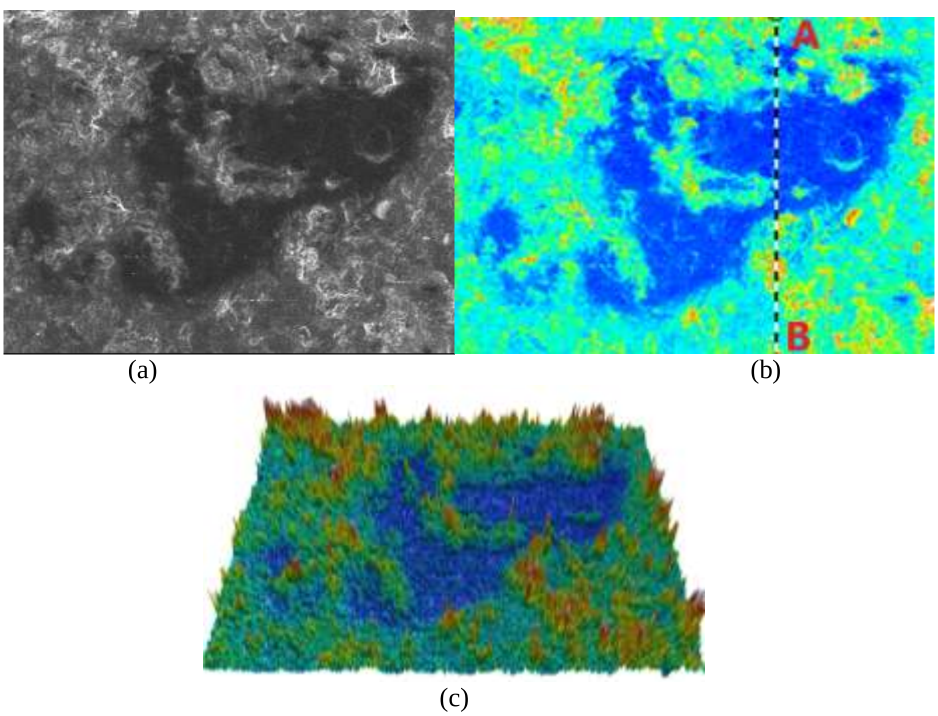


Figure 11:- (a) The UHMWPE (316L Stainless Steel counterface) surface morphology at a sliding distance of 30,000 cycles, (b) Pseudo-colour View, (c) in 3D image

The multifractal analysis in correlation with the SEM data provides greater insight into surface roughness quality control and performance of the Alumina, 316L Stainless Steel, and Polyethylene as implant materials. Multifractal analyses highlight the importance of choosing the size of the analysed area while maintaining the exact resolution [21].

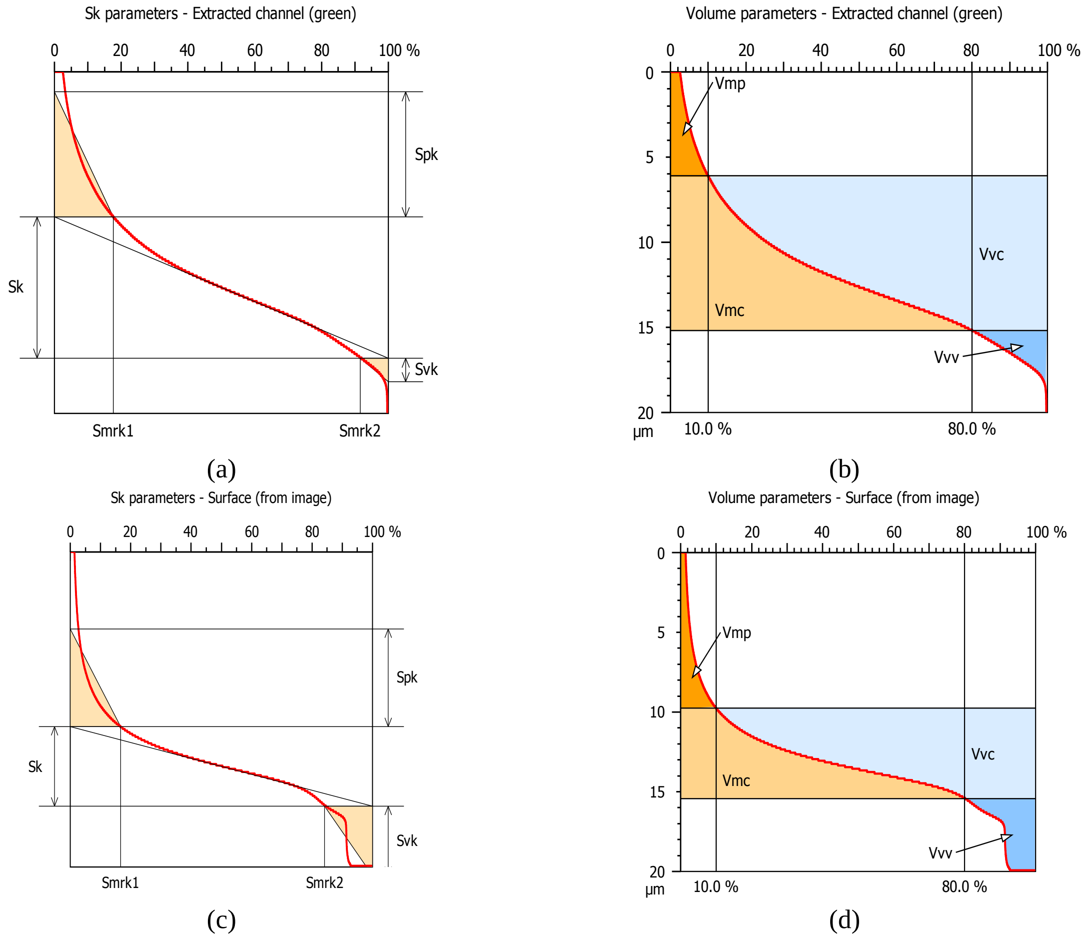


Figure 12:- S_k and volume parameters of UHMWPE, (a &b) against Alumina; (c & d) against 316L

The calculation is based on the Abbott curve and the comparative study of the volume of surface parameters [25], namely V_{mp}, V_{vc}, V_{mc} & V_{vv} parameters. Figure 12 shows two bearing ratio thresholds defined (using the vertical bars drawn with dotted lines). These thresholds are default set at 10% and 80% bearing ratios. The first threshold, p1 (default: 10%), defines the cut level c1 (and p2 represents c2, respectively).

Table 4:- S_k Parameters for Analysis of UHMWPE surface roughness.

Parameters – Extracted Channel				
Sk Parameters - ISO 25178				
Symbol	**Alumina**	**316L Stainless Steel**	**Unit**	**Parameters definition**
S_k	8.275	5.053	µm	Core Roughness Depth
S_{pk}	7.325	6.197	µm	Reduced Peak Height
S_{vk}	1.574	4.407	µm	Reduced Valley Depth
S_{mrk1}	17.62	16.67	%	Peak Material Portion
S_{mrk2}	91.58	84.14	%	Valley Material Portion

Table 5:- Volume Parameters – Extracted Channel for UHMWPE surface roughness analysis.

Parameters – Extracted Channel				
Volume Parameters - ISO 25178				
Symbol	**Alumina**	**316L Stainless Steel**	**Unit**	**Parameters definition**
V_{mp}	0.326	0.3467	$\mu m^3/\mu m^2$	Peak Material Volume

V_{mc}	3.265	2.149	$\mu m^3/\mu m^2$	Core Material Volume
V_{vc}	5.826	3.530	$\mu m^3/\mu m^2$	Core Void Volume
V_{vv}	0.279	0.474	$\mu m^3/\mu m^2$	Dale Void Volume/ Pit Void Volume

After a wear test of 30000 revolutions, as shown in Table 5, for Sk parameters, the roughness core depth of the UHMWPE from the surface effect of Alumina is 8,275 microns; Meanwhile, the impact of 316L produces a shallower core roughness, which is 5.053 microns. The difference between Peak height and Valley Depth left by Alumina is 6 microns greater than 316L by 2 microns. Likewise, in the Volume parameters, the grinding volume is due to friction with the Alumina surface, which is calculated from the difference between Core Material Volume and Peak Material Volume, which is relatively more significant than what happened in 316L (Table 6).

At the end of writing this scientific paper, we reiterate that after a series of testing activities, analysis of results, and discussion by presenting the multifractal analysis method, all of which are intended to provide confidence in comparing the effect of Alumina and 316L Stainless Steel on the wear rate which leads to wear volume-missing from the surface.

Conclusion:-

This article is a study to compare the tribological performance of Alumina composite ceramic and 316L Stainless Steel materials paired with UHMWPE. Partner material surface impact can be used as an indication of the tribological behaviour of the material. The results of tribological testing and analysis showed that the surface roughness of Alumina before the experiment was carried out had a uniform grain distribution with variations in size and shape around the observed area; meanwhile, on the surface of 316L Stainless Steel, different grain structures and after polishing with the same treatment as other materials, on the surface of this 316L Stainless Steel still visible streaks of straight scratches.

The effect of Alumina (1.948 mg) and 316L Stainless Steel (1986 mg) on UHMWPE's wear rate and wear volume is comparable with a slight difference. This effect is possible because the sliding distance is still relatively small. There is a strong relationship between surface roughness, material properties, friction coefficient, and wear rate.
Material surface morphology on a micro-scale significantly affects the behaviour of the contact force and the coefficient of friction and wear surface interaction between UHMWPE and Alumina at the 30,000th cycle shows the surface profile of UHMWPE experiencing cracks, delamination, plastic deformation, and different groove patterns.

Conflict of interest

There are no confilcts of interests to be mentioned

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