Study on Wear Debris Characterization of Polycarbonate Urethane (PCU) as a Bearing of Artificial Hip Joint

by Wahyu Dwi Lestari

Submission date: 16-Mar-2022 07:38PM (UTC+0700)
Submission ID: 1785579277
File name: dy_on_Wear_Debris_Characterization_of_Polycarbonate_Urethane.pdf (646.96K)
Word count: 1919
Character count: 9297

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W D Lestari[1*], R Ismail[2], J Jamari[2], and A P Bayuseno[2]

[1]Department of Mechanical Engineering, Faculty of Engineering, University of Pembangunan Nasional "Veteran" Jawa Timur, 60294, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Diponegoro University, 50275, Indonesia

[*]wahyu.dwi.tm@upnjatim.ac.id

Abstract. As with all artificial joints, wear debris is of particular concern due to its effect on both implant life and the in vivo biological reactions that can occur. The purpose of the research is to study debris characterization of PCU. Wear particle is produced from testing the PCU material using a pin on disc wear tester within 50000 cycles. This study showed that the PCU wear debris gotten from the simulator had various different shapes, including laminar and spherical types. The morphology of worn surface and wear debris analysis showed that wear mechanism of PCU were fatigue wear. Thus we conclude that PCU is expected to be a lifetime implantation of artificial joint.

1. Introduction

Artificial joint replacement is the main method of therapy that can effectively relieve joint pain and restore joint function for severe osteoarthritis of the hip and knee joints [1]. During the use of hip and knee implants there is relative contact and movement between the metal surface and the polyethylene which results in the wear fragments of the polyethylene. These wear fragments migrate to the tissue around the implant, which can lead to a biological response to inflammation and bone osteolysis. Furthermore, osteolysis will lead to implant loosening and failure, so revision surgery is required. The failure of these implants made researchers work hard to search for new implant materials with better tribological characteristics. This search aims to reduce the presence of wear and tear during the implant wearing process.

A new type of polymer material has been developed recently which is given the name PCU. The PCU causal performance has been observed through testing with a pin on disc (POD) tester. The presence of wear flakes with different morphologies will have a major impact on the biocompatibility of the implant material. The wear debris characterization resulted after the sliding process. From the results of this characterization will be used as an experimental basis for PCU material which will be applied in the future medical world. These wear specimens can be collected as a result of wear testing via a simulator or from revision hip or knee implant surgery.

There are many studies that focus on the quantification, characterization and compatibility of wear fragments resulting from hip implants from both in vitro and in vivo wear [2][3][4]. One study found the amount of UHMWPE wear particles in the 0.1–1 μm range.

Cherif et al. [5] analyzed the alumina-zirconia material produced during an abrasion-induced wear test. These wear debris contributes to the redistribution of the load applied to more points of contact.

Based on the observations it is shown that debris reduces surface porosity at low loads and in turn reduces friction. At high loads, due to large plastic deformations and cracks, the surface becomes rough which causes increased friction. Colombie et al. [6]have studied the role of wear debris in fretting and concluded that the temperature rise during fretting wear is negligible and that the wear on the first body is governed by the shaping and maintenance of the third body (debris) and the abrasiveness of the third body.

Investigate the characteristics of the wear debris including quantity, size and morphology, then the wear status of mechanical components can be predicted [7–10]. There are various methods to characterize wear flakes, one of which is by using a SEM machine. This machine will provide excellent qualitative information about wear particles, and with the help of computer vision techniques can also provide quantitative analysis. The aim of this research is to characterize the wear debris of PCU materials for medical devices such as bearings in artificial hip joints.

2. Materials and Method

Particles are obtained from the results of wear testing using a pin on disc wear tester. The applied load was 500 gram for 50000 cycles. The test was carried out in dry conditions. The PCU disc were 100 mm in diameter and 10 mm in thickness. The counterparts to the PCU disc samples were pin made from SS 316 L. The counterparts had a 6 mm diameter and a smooth hemisphere on one side. They were 60 mm in length. To investigate the microstructure features on the fracture interface of PCU, the shape and size of the wear debris was characterized with scanning electron microscope (SEM). EDX analysis was used to determine the chemical composition of the particles. SEM and EDX tests were carried out using the JSM-6510LA tool which is a high performance multipurpose SEM with high precision optics.

3. Results and Discussion

The PCU material that has gone through the wear testing process is then carried out by microstructural observations of the wear parts using SEM. The results of the SEM test results for PCU disc specimen wear in the condition without lubrication can be seen in Figure. 1. Based on the image, a wear analysis was performed on the specimen. From the SEM test results, it can be seen that several phenomena occur in the wear track area of the specimen. There is a phenomenon of plastic deformation and some debris on the surface of the wear track. In addition, on the wear track surface there are a lot of abrasive particles because they have crossed the plastic deformation limit. The phenomenon of the appearance of abrasive particles indicates the occurrence of the abrasive wear process.

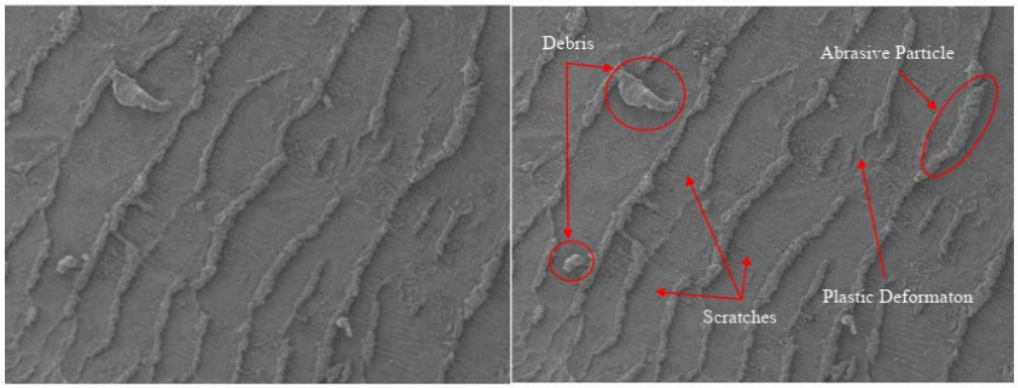

Figure 1. SEM results of wear track disc specimens without lubrication

During the pin on disc testing process, there is a phenomenon of reducing the material in the form of wear particles. The wear particle results from the pin on disc test for the PCU disc specimen were also carried out by SEM testing to determine the shape and size of the wear particle and EDX testing

find out what content was in the PCU disc specimen after pin on disc testing. Figure.2 until Figure.4 showed that the PCU wear debris obtained from the pin on disc wear tester

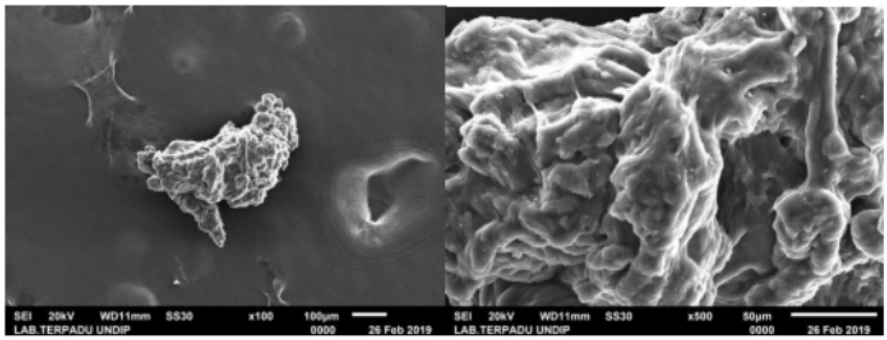

Figure 2. SEM results of 50 NL PCU wear particle disc specimens

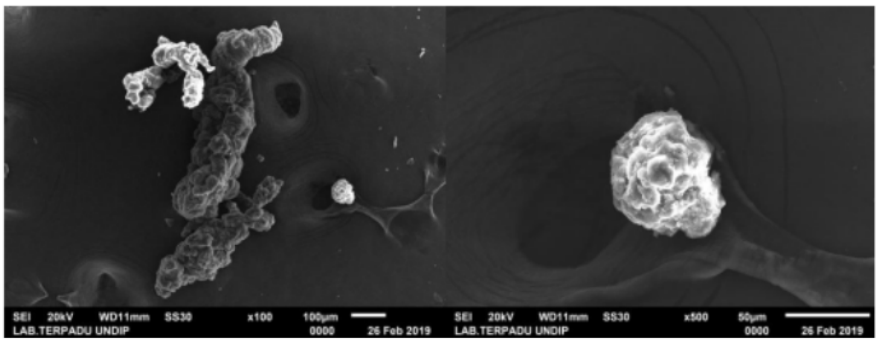

Figure 3. SEM results of 100 NL PCU wear particle disc specimens

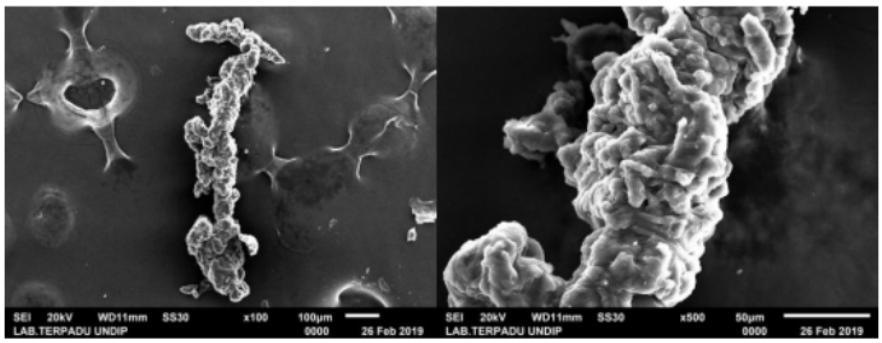

Figure 4. SEM results of 200 NL PCU wear particle disc specimens

Based on the results of the SEM test for the wear particles, then processing is carried out using measurement software to obtain size data from the wear particle. The results of SEM wear particle testing using measurement software are presented in Table 1. From the measurement results, it was found that the size of the wear particle of each PCU disc has a length and width of hundreds of micrometers. The forms of wear particles that are formed are laminar and spherical types. This type of

wear particle indicates the type of fatigue wear. This happens because of the continuous loading received by the PCU material when it undergoes a wear test of 50,000 cycles.

EDX testing is also carried out to determine the content contained in the wear particle of the PCU disc specimen. Overall, the EDX test results can be seen in the Table 2. In the EDX test on all specimens, there are no Fe, Cr and Ni elements which are the constituent elements of the AISI 316L stainless steel pin material attached to wear particle PCU specimen disc. Therefore it can be said that the contact mechanism in this pin on disc test is not at risk of producing highly reactive free radicals that can damage DNA, proteins and other cell components [11].

Table 1. Size of wear particle from SEM results

No.	Spesimens	Length (μm)	Wide (μm)
1.	50 NL	447.545	466.015
2.	100 NL	76.823	70.121
3.	200 NL	820.521	299.346

Table 2. EDX wear particle test results for each specimen

No.	Compounds	50 NL	100 NL	200 NL
1.	C	C (100%)	C (99.14%)	C (99.27%)
2.	O	-	O (0.17%)	O (0.20%)
3.	Cu	-	Cu (0.68%)	Cu (0.43%)
4.	Al	-	-	Al (0.10%)
5.	CuO	-	CuO (0.86%)	CuO (0.54%)
6.	Al_2O_3	-	-	Al_2O_3 (0.19%)

4. Conclusion

Based on the results of SEM, it shows that the wear particle for PCU disc specimens has a size ranging from 50 to hundreds of micrometers, so the wear particle for this type of PCU disc specimen is the type of fatigue. The EDX results show that there are no harmful substances or compounds in the PCU wear particle disc specimens. Further research is needed regarding pin on disc wear testing of polycarbonate urethane (PCU) materials in dry lubrication conditions in various variables, types of pin material and cycles. Thus, we consider the PCU have the potency to take place of UHMWPE, certainly, further research need to be done in the future.

5. References

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