Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, Vol. 1, No.2, October 2021, pp 12-16

Manufacturing Acetabular Liner UHMWPE using CNC Milling

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Abstract. Ultra High Molecular Weight Polyethylene (UHMWPE) is a biomedical polymer that is useful in the orthopedic field as a bearing component in artificial hip joints. In general, these polymers pair up and rub against each other with metallic biomaterials, namely 316L stainless steel, cobalt chromium (CoCr) and titanium, which can cause material wear problems. One way to increase the wear resistance of UHMWPE is through the manufacturing process. The purpose of this research is to manufacture acetabular liner products using a CNC milling machine to obtain high surface quality and dimensional accuracy. The CNC milling machine used is the type of YCM 1020 EV 20. The manufactured specimen is then measured for roughness and dimensional accuracy. Based on the measurement results, it is found that the acetabular liner specimens from the CNC milling process are still in accordance with the standard ASTM standard (F 2033-12).

Keyword: *UHMWPE, CNC Milling, Acetabular Liner*

1. Introduction

Arthroplasty is a surgical procedure that replaces unhealthy human natural joints with artifi-cial joints. Artificial joints must have the properties of bicompatibility, stability, minimal friction and wear [1] Regarding total hip replacement (THR), the most commonly used types of biomaterials are polymers, metals, and ceramics. Interesting reviews of biomaterials in THR are available in the literature [2,3] The most common combination of materials used in THR is a type of polymer (UHMWPE) paired with metal or ce-ramic [4]. Although UHMWPE polymer has high wear resistance, so far it still produces debris that is detected as a source of infection that can cause osteolysis [5].

The durability and reliability of metals on UHMWPE in THR are strongly influenced by tribo-logical properties [6]. The current lifetime of hip joint implant products is be-tween 15 to 20 years [7]. The development of hip joint implant research in the last few decades has significantly reduced this problem, but the problem of wear resistance is still a serious obstacle to this day. The worn particles of UHMWPE material are non-toxic, but if the number or volume of these particles is large enough, they will cause reactions in the surrounding organs such as aseptic loosening. If this happens, a revision operation is required which requires a fairly high cost and quite complicated handling. The wear resistance of UHMWPE can be im-proved by improving its mechanical properties. However, it is known that changes in the me-chanical properties of UHMWPE materials can be significantly altered through manufacturing processes, sterilization by irradiation and thermal treatment [8].

The current UHMWPE acetabular liner manufacturing process is focused on improving sur-face properties that can affect tribological and mechanical properties. As a result, a lot of research has been carried out with the application of theoretical models and experimental research on the effect of surface roughness on the biomaterials wear resistance [9-11] Surface roughness is one of the evaluation criteria for determining product quality and factors that critically affect production costs. This is because surface rough-ness can affect the tribological and mechanical properties of the product such as friction, wear, and fatigue.

One of the UHMWPE acetabular liner manufacturing processes offered to get a good surface quality is to use a CNC milling machine. The use of CNC machines as machine tools in modern machining processes is increasingly being found in the manufacturing industry. CNC milling in this case has a function to work on a component efficiently, save time, and save costs. With a pre-prepared program, the same components can be produced many times with precise accuracy [10]. One of the measurement references in the machining process that the quality of the resulting product is good or bad can be seen from the surface roughness value. This value can be influenced by many things such as cutting speed, feed rate, step over. The smaller the value of the product surface roughness, the better the product quality. Low product surface roughness values can be obtained from suitable and optimum parameter conditions [12]. The purpose of this research is to manufacture acetabular liner products for bearing components in artificial hip joints using a CNC milling machine. The use of CNC milling operations has the aim of producing products that have satisfactory quality and precise dimensions.

2. Research Method

The acetabular liner manufacturing process is carried out by a machining process using a milling machine. The material used is UHMWPE in the form of a cylindrical rod with a diameter of 100 mm. Based on the design requirements according to the ASTM standard (F 2033-12), the acetabular liner is required to have a size tolerance of + 0.3 and -0.0 and a surface roughness of below 2 μm. High enough accuracy is applied to the acetabular liner manufacturing process so that the resulting mechanical properties do not have a significant difference from the design that has been made with the results of the manufacturing process. This high dimensional accuracy can be met by computer numerical control (CNC) machines. CNC machine is a machine that is used in the manufacturing process where the process is controlled using a controller (numerical con-trol). The CNC machine needed to process the acetabular liner is a CNC milling machine (the 3 axes CNC vertical milling YCM 1020 EV 20).

The CNC machining process begins with designing objects using Computer Aided Design (CAD) based software and then proceeding to the manufacturing process using Computer Aided Manufacturing (CAM) based software. The CAM software simulates the machining process that will run on a CNC machine and the output is in the form of program lines. The program lines are stored on a compact flash memory card and entered on the CNC machine control panel which is then read by numerical control. The quality of the product machining with CNC milling is deter-mined by cutting parameters such as toolpath strategy, spindle speed, feed rate, and step over. Furthermore, the acetabular liner product resulting from the machining process using a CNC mill-ing machine is measured for surface roughness and dimensional accuracy. Surface roughness was measured using Mark Surf PS1 surface roughness tester. The accuracy dimensions were meas-ured using coordinate measurement machine (CMM). All stages of this research are clearly illus-trated through the flow chart in Figure 1.

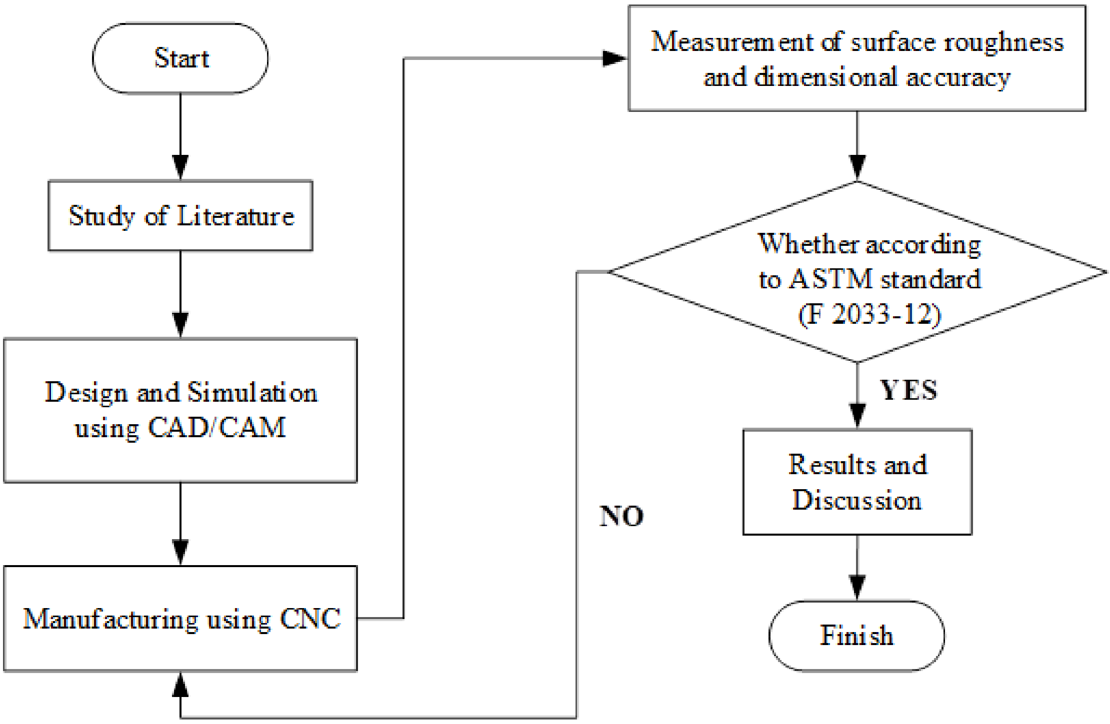

Figure 1. Research Flowchart

3. Result and Discussion

The use of machines that are controlled using a computer further increases the productivity value and the higher the accuracy level resulting from the manufacturing process. In addition, complex shaped workpieces that cannot be machined manually can be machined using automat-ed machines such as CNC machines. To be able to make acetabular liner, absolutely manufactur-ing technology must be mastered. By mastering manufacturing technology, you will be able to produce acetabular liners according to the designs that have been made and in accordance with what is expected.

As far as studied based on the literature, not many researchers have used CNC milling ma-chines to make acetabular liner products. This study presents the process of making acetabular liner products using a CNC milling machine. The dimensions specified on the product are having an inner diameter of 14 mm and an outer diameter of 18 mm. The cutting parameters used in the operation of the CNC milling machine are shown in Table 1. The UHMWPE acetabular liner prod-uct produced from the machining process using a CNC milling machine in this study is shown in Figure 2.

Table 1. The CNC milling parameters for manufacturing of acetabular liner UHMWPE

Parameters	Value
Toolpath Strategy	Raster
Spindle Speed (rpm)	6500
Feed rate (mm/rev)	1500
Step Over (mm)	0.1

Figure 2. Acetabular Liner UHMWPE result from CNC milling

Table 2. The surface roughness and dimensional accuracy measurement results

Part of Acetabular Liner	Surface Roughness (µm)	Dimensional Accuracy (mm)
Inner	1,193	14.396
Outer	1,516	18.466

The measurement purpose is to find out whether the product is in accordance with the specified standards or not. If not, a re-machining process will be carried out by improving the cutting parameters. The results of surface roughness measurements and dimensional accuracy are shown in Table 2. Based on the table, it can be seen that the surface roughness and dimensional accuracy of the UHMWPE acetabular liner product produced from the manufacturing process using a CNC milling machine are in accordance with the specified standard, namely the ASTM standard (F 2033-12).

4. Conclusion

The manufacturing process is one of the keys in making products that are in accordance with the design and expected results. Acetabular liner is one of the biomedical products that is still a challenge for researchers in terms of the manufacturing process to get products that have a long service life. Based on the results obtained in this study, it can be concluded that CNC milling ma-chines can be used as a solution in making acetabular liner products made from UHMWPE. The UHMWPE acetabular liner product is the result of the manufacturing process using CNC milling machines in the research in accordance with predetermined standards.

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