Investigation of dimensional accuracy on simultaneous five-axis tool paths strategies for biomedical product utilizing CATIA V5

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ABSTRACT – A sample of biomedical product was chosen to be machined by five-axis CNC milling machine with two multi-axis surface tool paths strategies offered by CATIA V5 namely Isoparametric and Multi-Axis Sweeping in order to investigate the effect of dimensional accuracy of machined parts for both mentioned strategies. Femoral knee part is chosen due to its sculptured shape which indirectly proves capability of five-axis machining in producing complex shapes. Rexscan CS2 3D-scanner device and Geomagic Control X software are utilized to qualitatively analysed the dimensional accuracy of the machined samples. From the graphical results obtained, Isoparametric tool paths strategy illustrates slightly better dimensional accuracy than Multi-Axis Sweeping.

1. INTRODUCTION

CAD is now being used extensively in the biomedical industry in applications ranging from clinical medicine, customized medical implant design to tissue engineering. Several studies have been reported in the literature that has made use of 3D reconstruction to help in a better understanding of anatomical functionality and morphological analysis [3].

CAD/CAM systems, which are an intricate preparation of production process. With the combination of 5-axis machine and the use of integrated CAD/CAM/CNC systems, the machining efficiency and accuracy has increased significantly. As a result, the machine tool technology has also got the benefits due to this improvements. Tool axis orientation played an important role in the efficiency and quality of 5-axis machining. The foremost objective is to outline the tool orientation at each cutter contact point in order to reduce machining period within tolerances [5].

Biomedical part machined from bar stock requires a lot of material to be removed, resulting in an expensive process because of the low machinability rating of many of the materials involved. Accuracy is one of the most crucial aspects for any biomedical parts as any imperfection will cause health hazards. As most of the biomedical have complex geometry and contours, it will suit with the capability of the five-axis CNC milling machine. Sharp edges or inside radii on any implant must be justified. Any failure will serve as a stressor to the implant activity and noticeable in premature failure in a poorly designed implant. [6]

2. METHODOLOGY

The tool paths strategies chosen to be evaluated in this research were Isoparametric and Multi-Axis Sweeping. The main analysis carried out was of dimensional accuracy in determining better tool paths strategy for machining femoral knee. The ability of latest technology in 3D scanning which not only performing reverse engineering (RE) activity but also metrology capability to measure and compare certain given CAD model in stereolithography (STL) format. Overall methodology in this study was divided into two (2) phases. The 1st phase were focusing on searching and selection of the most appropriate CAD model – biomedical product. The CAD model of femoral knee (Figure 1) was obtained from open source website in CAD interchangeable format. The common interchangeable formats normally used by CAD users are IGES (initial graphics exchange specification) and STEP (standard triangle language. STEP file is always chosen to be the best interchangeable CAD format due to the stability of the data converted from the original CAD data model. The overall dimension of the femoral knee was 70mm x 60mm x 54mm.

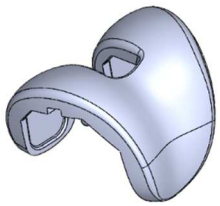

Figure 1 Selected 3D CAD model – femoral knee

Meanwhile, in the 2nd phase of the research milestone, the core activities in achieving the research's objective was the main focus such as completion of the jig & fixture design and fabrication, physical five-axis machining of sample parts – femoral knee, selection of suitable cutting tools, CAM program preparation with both tool paths strategies in-placed and finally the dimensional accuracy analysis. Aluminium 6063 is used as raw material whilst five-axis CNC milling; DMU eVo 60 is used to perform the physical machining. Cutting tool used for the selected machining strategies was

uncoated carbide ball nose mill with diameter of 10mm.

3. RESULTS AND DISCUSSION

In this section, the qualitative results of dimensional accuracy analysis are discussed according to the final analysis presented by Rexscan CS2 3D scanner device and Geomagic Control X software. The machined specimens of femoral knee (Figure 2) were gone through a reversed engineering process (RE) which is 3D scanning process in order to obtain the surfaces data of the machined part. This raw scanned data then undergone a thorough dimensional analysis or metrology process by utilizing the Geomagic Control X software. The initial design of CAD model is now being comparing with the scanned data obtained from the 3D scanning process. Allowable tolerance set was ± 0.05mm. The software then automatically measured and compared the data provided referring to the tolerance set. Final graphical results generated which illustrate the quality of the scanned data provided compared to the initial given CAD data (Figure 3 & 4).

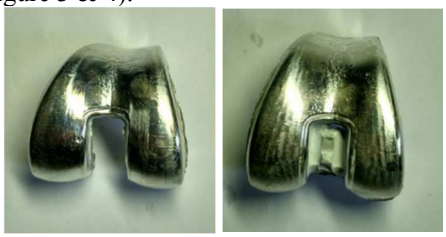

Figure 2 Machined femoral knee – Isoparametric (left) Multi-Axis Sweeping (right)

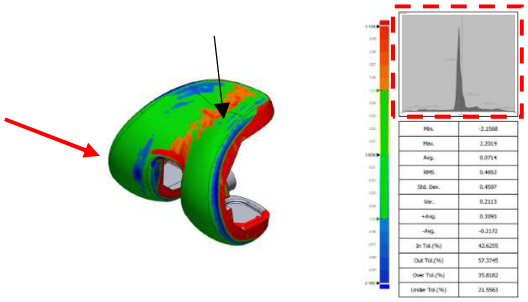

Figure 3 Result of dimensional accuracy analysis – Isoparametric

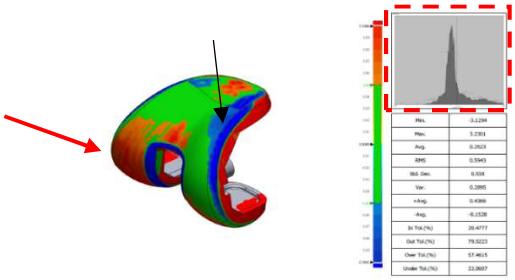

Figure 4 Result of dimensional accuracy analysis – – Multi-Axis Sweeping

From Figure 3 and 4 above, green colored region is the most favorable color coding to be viewed which indicates the accuracy of scanned data and initial given CAD data is in the acceptable range of the defined tolerance. Meanwhile, red to orange region representing the area of excess materials remained or also known as under-cut areas. Red colored arrows show the different results obtained for both meant machining strategies. Obviously, Isoparametric strategy exhibits better result than Multi-Axis Sweeping. On the other hand, blue region indicating the over-cut area which means more that desired materials being cut. This time, black colored arrows are pointed to the respective area to show the difference of both obtained results. Once again, Isoparametric strategy resulted better dimensional result. This result also supported by the graph shown on the right-hand side which marked by doted red box. From the overall observation, it could be concluded that Isoparametric tool paths strategy shows better dimensional accuracy than the by Multi-Axis Sweeping tool paths strategy as far as the chosen CAD model is concerned. The main reason contributed to the above result was believed due to the to the outline of the tool orientation at each cutter contact point as concluded by Grandguillaume et. al. [5]

4. CONCLUSION

Isoparametric tool paths strategy resulted better dimensional accuracy compared to Multi-Axis Sweeping in machining a sculptured surfaces example of biomedical product; femoral knee. Surface finish quality analysis was also performed and shall be discussed in separate paper. It is hoped that this research outcome could be benefited biomedical product manufacturer especially knee prosthetic implant in choosing the right tool paths strategy to produce better product. Although the actual material used in medical application is made of titanium alloy but the machining tool paths always remain the same except the machining parameters.

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