Development of a Dimensional Measurement Method for Ship Propeller Molds Using 3D Scanning Technology

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Abstract - **Near net shape casting is a manufacturing process capable of producing products that closely approximate the desired final shape, thereby reducing machining processes. However, achieving rapid dimensional and geometric accuracy measurement remains a challenge, especially for products with complex geometries. This study presents the use of a 3D scanner as an alternative method to expedite the measurement of dimensional and geometric accuracy. A ship propeller was chosen as the research object due to its relatively complex shape. Dimensional and geometric measurements were conducted on a ship propeller wax pattern made from a silicone rubber mold, simulating the near net shape casting process. The ship propeller wax pattern was scanned in 3D, and the resulting digital data was used to determine its dimensional and geometric accuracy. Measurement results using a 3D scanner on several parts of the ship propeller wax pattern indicated that the dimensional and geometric accuracy achieved was equivalent to manual measurements.**

Keywords: 3D Scanner, Dimensional Measurement, Product Geometry.

I. INTRODUCTION

The dimensional and geometric accuracy of a machine component significantly influences its functionality. Therefore, dimensional measurement is a critical activity in quality control. Products with simple geometries can be easily measured, and specialized tools can be designed for quick and straightforward determination of whether a product's dimensions and geometry meet the required standards. This technique is known as the "Go-No-Go" method. However, this approach is challenging to apply to products with complex shapes, such as gears [1].

Dimensional and geometric measurements of complex-shaped products are often conducted manually. Manual measurements require skilled operators and basic measurement tools such as micrometers, calipers, and gauge blocks. Manual measurement typically takes a significant amount of time, especially when a large number of product samples or numerous product features need to be measured. This can lead to inefficiencies in time and cost in the overall production process. Consequently, several alternative methods have been developed to improve the efficiency and effectiveness of the measurement process [2]. These include technologies such as interferometers [3], digital measurement [4], optical methods [5], and probe profiling [6].

The advancement of scanner technology has led to the development of 3D scanners. Complex-shaped objects can be easily scanned, producing digital data that represent the object in 3D. This digital data can be readily processed using CAD software. Generally, 3D scanning data is utilized for digital product documentation, reverse engineering, and design improvement [7].

The digital file generated by the 3D scanning process can also be converted into coordinate data for every point on the object. These coordinates can be used to determine the dimensions and geometry of the object. Thus, 3D scanners can serve as an alternative for dimensional and geometric measurements [8]. However, there has been limited research on the potential use of 3D scanners for object measurement [9, 10].

This article presents the procedures and accuracy obtained from using a 3D scanner for object measurement. A ship propeller was chosen as the case study due to its relatively complex dimensions and geometry. Measurements were conducted on a ship propeller wax pattern, which is used to manufacture propellers through the investment casting technique.

II. MATERIAL AND RESEARCH METHODS

The ship propeller wax pattern was created by pouring molten wax into a pre-prepared silicone rubber mold. The type of ship propeller used in the study was a three-blade propeller, as shown in Figure 1. The silicone rubber used was RTV 497. Figure 2 depicts the silicone rubber mold for the ship propeller.

The ship propeller wax pattern produced, as shown in Figure 3, was then subjected to the scanning process. The scanning was conducted using an EinScan 3D Pro 2X Plus scanner, which has a volumetric accuracy of 0.3 mm/m and a single-shot accuracy of 0.04 mm. The scanning results were subsequently processed using CAD software.

Figure 1: Three-Blade Ship Propeller

Figure 2: Silicone Rubber Mold for Ship Propeller Wax Pattern
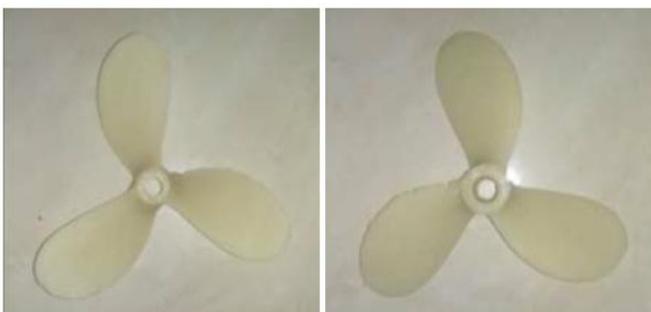

Figure 3: Ship Propeller Wax Pattern

Dimensional measurements were performed using the "create plane parallel to screen" and "smart dimension" features available in the CAD software. The measurement results were compared to manual measurements conducted with a caliper. The measured parts included the shaft hole diameter, outer shaft diameter, shaft length, and blade length. These parts were selected for measurement because they could still be measured manually. Figure 4 shows the measured section.
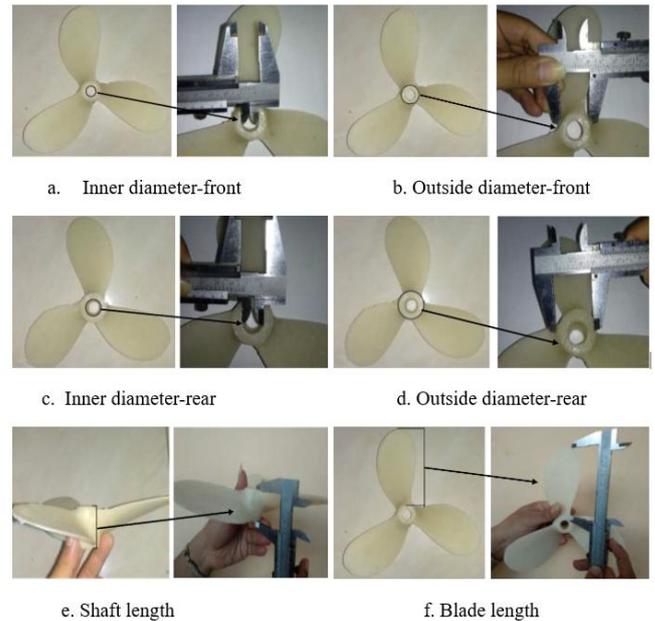

a. Inner diameter-front   b. Outside diameter-front

c. Inner diameter-rear   d. Outside diameter-rear

e. Shaft length   f. Blade length

Figure 4: Measured Section

III. RESULT AND DISCUSSION

The 3D scanning results of the ship propeller wax pattern are shown in Figure 5. The resulting 3D model of the ship propeller exhibits good geometry with minimal areas lacking contrast. This was achieved due to sufficient lighting intensity and the resolution of the laser scanner used during the scanning process. The output from the 3D scanning process is a file in .STL format.

Figure 5: 3D Scanning Result of the Ship Propeller Wax Pattern

The 3D scanning data in .STL format was further processed using CAD software to extract the coordinates of each point across the entire model. These coordinates were then processed to determine dimensions by calculating the distances between specific coordinate points. The data processing was performed using MS Excel.

The measurement results, both manual and digital, are presented in Table 1. The results indicate noticeable

differences between the two measurement methods. Measurements of the outside diameter (front section), inner diameter (rear section), and outside diameter (rear section) showed relatively larger differences of 0.22%, 0.24%, and 0.25%, respectively. Meanwhile, measurements of the inner diameter (front section), shaft length, and blade length showed smaller differences of 0.08%, 0.09%, and 0.07%, respectively.

Table 1: Measurement Results

Section	3D Measurement (mm)	Manual Measurement (mm)	Dimensional Difference (%)
Inner Diameter/Front	12.55	12.54	0.08
Outside Diameter/Front	22.69	22.74	0.22
Inner Diameter/Rear	16.16	16.20	0.25
Outside Diameter/Rear	29.30	29.37	0.24
Shaft Length	33.51	33.48	0.09
Blade Length	90.43	90.49	0.07

The differences in measurement results between manual methods and 3D scanning are inevitable. This is due to the characteristics of the caliper, which has a broader measuring surface, resulting in measured dimensions that represent an average of the surface area being measured. In contrast, 3D scanning can focus on specific points on the object. Nonetheless, 3D scanning techniques can achieve higher accuracy, provided the resulting 3D model has good contrast [11, 12].

Measurement discrepancies can also arise from variations in the tools used [13, 14, 15]. Since measurement differences are also influenced by the measurement tool or method, the most critical factor is how the measurement results affect the functionality of the product. Dimensional and geometric tolerances are key to the functional performance of the product. If the differences in measurement results are within the allowable tolerance limits, they are unlikely to affect the functional performance of the product.

Table 1 shows that the differences in measurement results between manual caliper measurements and 3D scanning range from 0.07% to 0.25%. The key dimensions determining whether the ship propeller can be installed on the shaft are the inner diameter (front) and inner diameter (rear). As shown in Table 1, the measurement differences are 0.08% and 0.25%, corresponding to dimensional differences of 0.01 mm for the inner diameter (front) and 0.04 mm for the inner diameter

(rear). Referring to the ISO 286-2 standard for fit tolerance (E6), these differences are within acceptable limits. This indicates that the dimensional accuracy achieved with 3D scanning is highly satisfactory.

IV. CONCLUSION

The comparison of measurement results between manual methods and 3D scanning shows some differences, ranging from 0.07% to 0.25%. However, these differences are relatively minor. Therefore, the dimensional measurement method for ship propeller wax patterns can effectively utilize the 3D model obtained from the 3D scanning process.

REFERENCES

[1] Hoover, S. (2000). Simplifying gear metrology, Quality, 39(2), 48-52.

[2] Kankar, P.K., Moona, G. & Desai, K.A., (2022), Measurement and Metrology in Advanced Manufacturing Processes, Mapan, 37, 703–705.

[3] Baath, L.B., and Rosén, B.G., (2012), Towards New Interferometer Technology for Surface Metrology, Proceedings of the 12th Euspen International Conference, 1-4.

[4] Engel, T., (2023), GEMIMEG-II – How Metrology Can Go Digital, Measurement Science and Technology, 34, 104002.

[5] Schwenke, H., Rube, U.N., Pfeifer, t. and Kunzmann, H., 2002, Optical Methods for Dimensional Metrology in Production Engineering, CIRP Annals, 51, 685-699.

[6] Fan, K.C., Chu, C.L., and Mou, J.I., (2001), Development of Low Cost Autofocusing Probe for Profile Measurement, Measurements Science and Technology, 12, 2137-2146.

[7] Verykokou, S., and Ioannidis, C., (2023), An Overview on Image Based and Scanner Based 3D Modelling Technologies, Sensor, 23 (2), 596, 1-22.

[8] András E. V., Cizmar, P., Villarrubia, J.S., and Postek, M.T., (2012), Can we get 3D-CD metrology right?, Proc. SPIE 8324, Metrology, Inspection, and Process Control for Microlithography XXVI, 832402.

[9] Isa, M. A., and Lazoglu, I., (2017), Design and Analysis of a 3D Laser Sacanner, Measurement, 111, 122-133.

[10] Larue, JF., Brown, D., Viala, M. (2015). How Optical CMMs and 3D Scanning Will Revolutionize the 3D Metrology World. In: Liu, Z., Ukida, H., Ramuhalli, P., Niel, K. (eds) Integrated Imaging and Vision Techniques for Industrial Inspection. Advances in Computer Vision and Pattern Recognition. Springer, London. https://doi.org/10.1007/978-1-4471-6741-9_5.

[11] Javaid, M., Haleem, A., Singh, R. P., Rab, S., Suman, R., and Kumar, R., (2023), Studies on the Metrological Need and Capabilities of 3D Scanning Technologies, Journal of Industrial Integration and Management, 08(03), 321-339.

[12] Beraldin, J. A., Rioux, M., Coumoyer, L., Blais, F., Picard, M., and Pekelsky, J., (2007), Traveable 3D Imaging Metrology, Proceeding Videometrics IX, 6491, 64910B.

[13] Stojkic, Z., Culjak, E., and Saravanja, L., (2020) 3D Measurement-Comparison of CMM and 3D Scanner, 31th DAAAM International Symposium on Intelligent Manufacturing and Automation, Katalinic, B. (Ed.), 0780-0787.

[14] Barbero, B.R. & Ureta E.S. (2011). Comparative study of different digitization techniques and their accuracy, Computer-Aided Design, 43(2), 188-206.

[15] Vagovsky, J.; Buransky, I. & Gorog A. (2014). Evaluation of measuring capability of the optical 3D scanner, Procedia Engineering, 25th DAAAM International Symposium on Intelligent Manufacturing and Automation, Katalinic, B. (Ed.), 1198-1206.

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