American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Measurement Profile of Surface Revolution by Laser Scan Micrometer Method

Le Xuan Cam[a]*, Nguyen Van Vinh[b], Hoang Hong Hai[c]

[a]*Msc. School of machanical engineering, Hanoi University of Science and Technology, Vietnam*

[b]*Assoc Prof Dr. School of machanical engineering, Hanoi University of Science and Technology, Vietnam*

[c]*PhD. School of machanical engineering, Hanoi University of Science and Technology, Vietnam*

[a]*Email: camlx@mcit.vn*

[b]*Email: xuancam.doluongvcn@gmail.com*

Abstract

Measurement profile of surface revolution by laser scan micrometer method is a non-contact measurement method that allows de-tailed profile measurements with fast measuring speed by using laser scanning and accuracy is much higher than other non-contact scanning methods. This paper presents the mathematical model profile of surface revolution and the application of the laser scan micrometer method for measuring this detailed profile. Fabricating complete equipment model according to the author's proposed method. Compare the results of measuring the profile of surface revolution on a construction measuring device with a roundness meter Jenoptik F315 to prove the feasibility of the construction measurement method.

Keywords: Measurement profile; Surface revolution; Profile of surface revolution; Laser scan micrometer; Mathematical model; Roundness; Straightness.

1. Introduction

Details of revolution are common details in mechaning engineering and profile deviations are important factors that greatly affect the quality of the work of this detail, especially for detail that require mounting accuracy high, participating in rotary movements such as the drive shaft of the processing machine, the tool axis, the axis of the measuring device, the printing device axis, ammuni-tion weapon details, ... Therefore, it is important to determine the profile and profile deviations of surface revolution in the pro-duction process to better control the quality of the detail after machining.

----

* Corresponding author.

In recent years, measurement profile method used by scanning lasers has been used extensively in industrial measurement due to the combination of the outstanding advantages of contactless measurement methods and the fast and accurate measurement speed high of laser. Currently, studies focus on profiling instruments by the method of analyzing the laser beam reflected from the surface of the measuring part, such as the measurement method of light wave transmission time, stereo imaging method, light structure method, ... Based on these studies, manufacturers of measuring equipment also offer a wide range of products for quick measure-ment of detailed profiles in industrial production. The above methods give fast measurement speed but the accuracy is limited to a few dozen micrometers. For details of revolution that require high profile accuracy, in addition to fast measurement speed, accuracy is also considered. The measurement profile method using laser scan micrometer is a new solution to overcome the above limitation.

2. Mathematical model profile of surface revolution

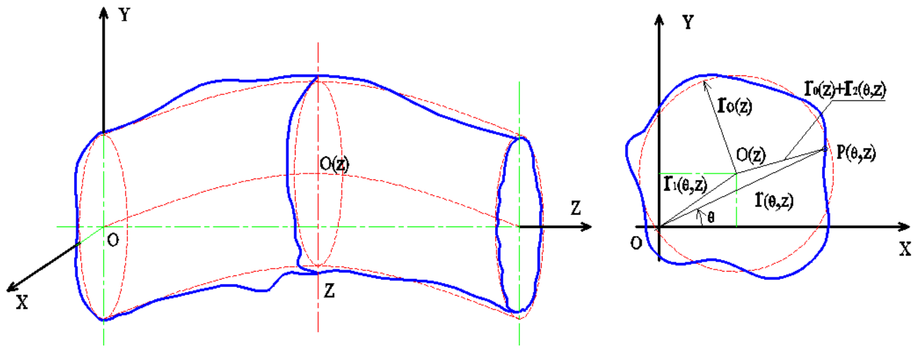

Figure 1: Modeling profile of surface revolution.

Considering the details in the coordinate system for OXYZ as shown in Figure 1, the profile of surface revolution is formed by the successive pairing of the OXY cross-sections along the Z axis. Mathematical model profile of surface revolution $r(z,\theta)$ as an extended Fourier function [1,2], shown by the following formula:

$$r(z,\theta) = r_0(z) + \sum_{p=1}^{\infty}\left[a_p(z)\cos(p\theta) + b_p(z)\sin(p\theta)\right] \quad (1)$$

Where: z is the cross-section position, θ is the angle of rotation of details and $r_0(z)$ is the medium radius of the cross-sectional profile, $a_p(z) + jb_p(z)$ is the pth harmonic vector of the cross-sectional profile and can be expressed by Legendre interpolation:

$$a_p(z) = \sum_{j=0}^{M_a} a_{pj} z^j \; ; \; b_p(z) = \sum_{j=0}^{M_b} b_{pj} z^j \quad (2)$$

Replace equation (2) into (1):

$$r(z,\theta) = r_0(z) + [a_{10}\cos(\theta) + b_{10}\sin(\theta)] + [a_{11}\, z\cos(\theta) + b_{11}\, z\sin(\theta)] + \left[\sum_{j=2}^{M_a} a_{1j} z^j\right]\cos(\theta) + \left[\sum_{j=2}^{M_b} b_{1j} z^j\right]\sin(\theta)$$
$$+\sum_{p=2}^{\infty}\left[a_p(z)\cos(p\theta) + b_p(z)\sin(p\theta)\right] \quad (3)$$

In equation (3), components 2 to 5 are first-order harmonic components that describe the Least Squares Center (LSC) of the cross-sectional profile in the OXYZ coordinate system. Components 2 and 3 are linear components along the Z axis. Although the direction and position of a part can generally vary in different coordinate systems, the detail profile will not change. Therefore, the mathematical model profile of surface revolution can be expressed by equations:

$$r(z,\theta) = r_0(z) + r_1(z,\theta) + r_2(z,\theta) \quad (4)$$

Where:

$$r_1(z,\theta) = \left[\sum_{j=2}^{M_a} a_{1j} z^j\right]\cos(\theta) + \left[\sum_{j=2}^{M_b} b_{1j} z^j\right]\sin(\theta) = a_1(z)\cos(\theta) + b_1(z)\sin(\theta) \quad (5)$$

is the first harmonic component characteristic of the center of the cross-sections and is determined by the least square center (LSC). The second component $r_2(z,\theta)$ represents the non-roundness of each section and is determined as follows:

$$r_2(z,\theta) = \sum_{p=2}^{\infty}\left[a_p(z)\cos(p\theta) + b_p(z)\sin(p\theta)\right] \quad (6)$$

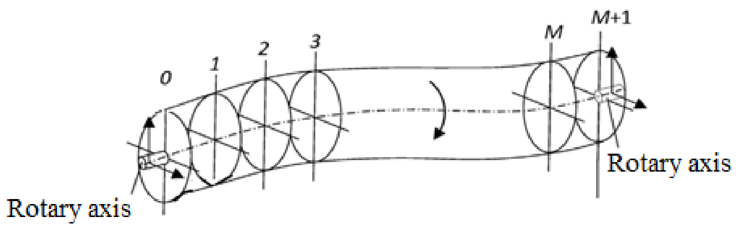

Figure 2: Profile of surface revolution.

Thus, profile of surface revolution may be considered as a collection of cross sections arranged along a curved centerline. We can use the cross section method to measure the eccentricity, the roundness and the LSC vector of each cross section along the rotating part, then rebuild the profile of surface revolution according to equation (4).

3. Measurement profile of surface revolution by laser scan micrometer method

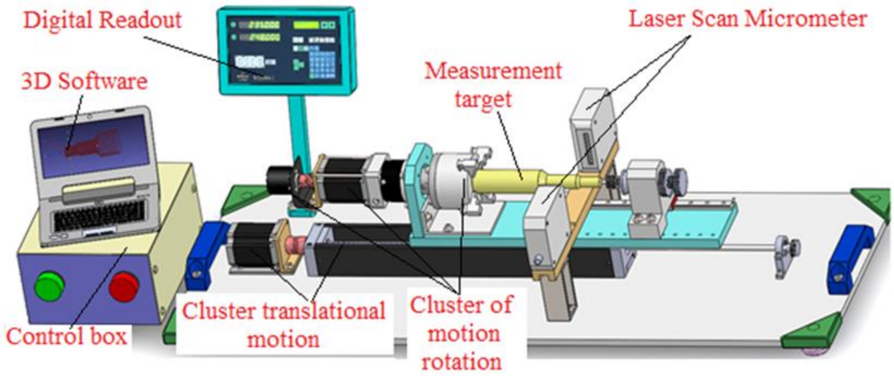

Figure 3: Structure measurement machine Profile of surface revolution.

As analyzed above, in order to construct a profile of surface revolution, we need to determine the position of the cross section and the profile of each section shown by the parameters: radial deviation, roundness and Least Square Centre LSC of the cross section. Therefore, two translational and rotating movements must be created for the measuring device. The translational motion is through a screw - nut movement mechanism and the position is determined by an electronic photometer. Using a rotating angle mechanism connected to the self-centering 4-spoke chuck to clamp the workpiece, the rotation angle is determined through the ecoder. With the diameter parameters determined by the method of laser scan micrometer combined with updated information from electronic optical ruler and ecoder, we can completely build a set of measurement data points at the measurement positions on the profile of surface revolution. Using the formula (4) from the set of measurement data points, we can completely reconstruct the measurement profile of surface revolution and at the same time be able to identify profile errors at different locations.

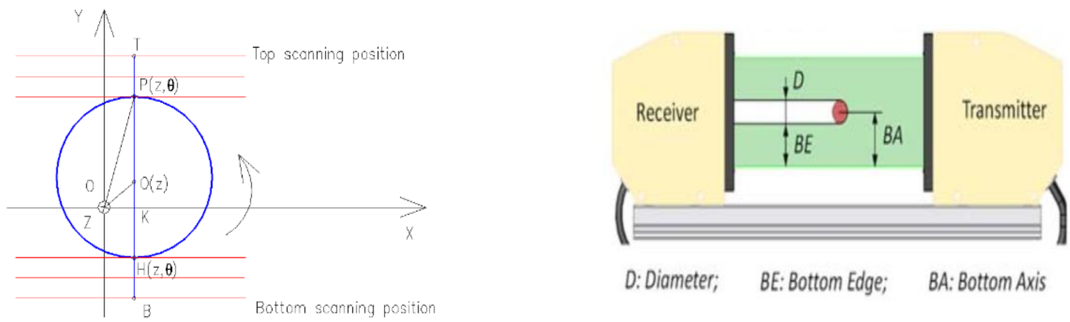

Figure 4: Machine Laser scan micrometer.

The average diameter of detail in a cross section in the position z:

$$r_0(z) = \frac{\sum_{i=1}^{n} P(z,\theta_i)H(z,\theta_i)}{2n} \qquad (7)$$

Determine the centers of sections using the Least Squares Center method (LSC) [4] from the measurement data set. The least square center of coordinates is defined as follows:

$$\begin{cases} a = \dfrac{2}{n}\sum_{i=1}^{n} r_i \cos\theta_i \\ b = \dfrac{2}{n}\sum_{i=1}^{n} r_i \sin\theta_i \end{cases} \tag{8}$$

The profile of the z-section is determined as follows:

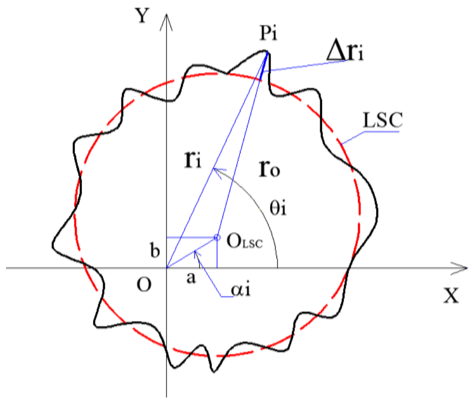

Figure 5: Cross section z.

$$\Delta r_i(\text{z}) = \frac{P(\text{z},\theta_i)H(\text{z},\theta_i)}{2} - r_0(\text{z}) \tag{9}$$

4. Experiment

3.1. Experiment equipment

Using the laser scan micrometer of Keyence model LS-5041T / R [3-5] with basic specifications:

+ The distance between the transmitter and receiver is: 160 ± 40 mm; Measuring range: (0,2 to 40) mm

+ Resolution: 0,05 µm; Repeatability: Maximum ± 0,3 µm; Accuracy: ± 2 µm

+ Laser scan speed: 1200 scans/second; Laser scanning speed: 121 m/sec

+ Laser source: 670 nm red semiconductor laser, 0,8 mW output, type II.

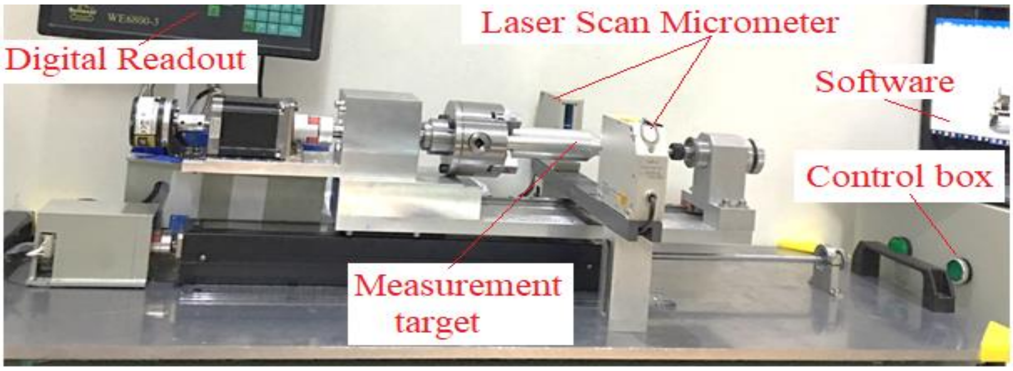

Figure 6: Experimental device model.

3.2. Experimental results

- Sample for experiment: Cylindrical with diameter of 20,004 mm; length 80 mm. Measure the profile at points 5 mm apart.

- The measurement results determine the detailed center position and the profile at some positions:

+ Measurement position 1:

Table 1: Measurement data at position 1.

Angle	**Diameter (mm)**	**Error profile Δ_{ri1} (µm)**	**r_{i1} (mm)**	**a_1 (µm)**	**b_1 (µm)**	**r_{01} (mm)**
30^0	20,0038	0,017	10,0040	1,49	-0,54	10,0019
60^0	20,0038	0,017	10,0026			
90^0	20,0038	0,017	10,0012			
120^0	20,0047	0,467	10,0002			
150^0	20,0038	0,017	9,9999			
180^0	20,0037	-0,033	10,0004			
210^0	20,0036	-0,083	10,0010			
240^0	20,0037	-0,033	10,0020			
270^0	20,0039	0,067	10,0025			
300^0	20,0036	-0,083	10,0031			
330^0	20,0032	-0,283	10,0028			
360^0	20,0036	-0,083	10,0025			

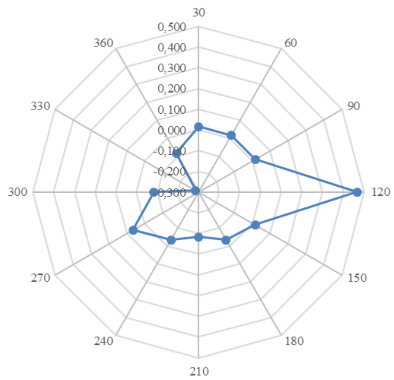

Figure 7: The cross-sectional profile is at position 1 with the roundness measured as 0,75 µm.

+ Measurement position 2:

Table 2: Measurement data at position 2.

Angle	**Diameter (mm)**	**Error profile Δ_{ri1} (µm)**	**r_{i1} (mm)**	**a_1 (µm)**	**b_1 (µm)**	**r_{01} (mm)**
30^0	20,0041	0,129	10,0022	1,57	-0,49	10,0019
60^0	20,0048	0,479	10,0003			
90^0	20,0038	-0,021	9,9992			
120^0	20,0038	-0,021	10,0024			
150^0	20,0037	-0,071	9,9986			
180^0	20,0031	-0,371	9,9987			
210^0	20,0038	-0,021	9,9993			
240^0	20,0040	0,079	10,0005			
270^0	20,0039	0,029	10,0017			
300^0	20,0035	-0,171	10,0021			
330^0	20,0040	0,079	10,0026			
360^0	20,0037	-0,071	10,0024			

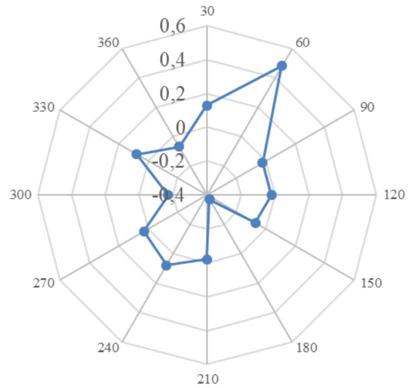

Figure 8: The cross-sectional profile is at position 2 with the roundness measured as 0,85 µm.

+ Measurement position 3:

Table 3: Measurement data at position 3.

Angle	**Diameter (mm)**	**Error profile Δ_{ri1} (µm)**	**r_{i1} (mm)**	**a_1 (µm)**	**b_1 (µm)**	**r_{01} (mm)**
30^0	20,0044	0,129	10,0029	1,42	-0,90	10,0021
60^0	20,0046	0,229	10,0019			
90^0	20,0044	0,129	10,0011			
120^0	20,0047	0,279	9,9998			
150^0	20,0041	-0,021	9,9996			
180^0	20,0041	-0,021	10,0006			
210^0	20,0042	0,029	10,0012			
240^0	20,0041	-0,021	10,0020			
270^0	20,0040	-0,071	10,0027			
300^0	20,0031	-0,521	10,0031			
330^0	20,0040	-0,071	10,0030			
360^0	20,0040	-0,071	10,0031			

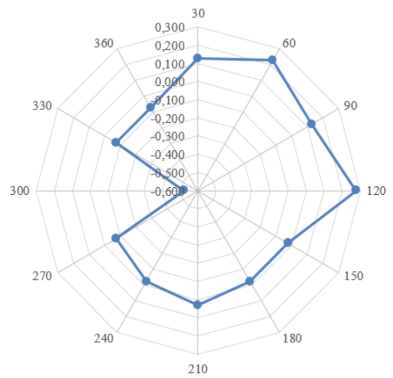

Figure 9: The cross-sectional profile is at position 3 with the roundness measured as 0,80 µm.

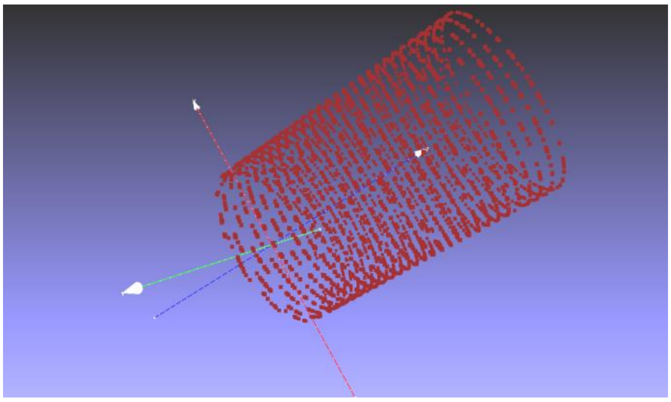

Figure 10: Cylindrical profile on straight line 15mm, Straightness is 2,1 µm.

The measured sample is defined on the JENOPTIK F135 roundness meter as a basis for comparison with the method of author construction. The result of the roundness at the three positions is respectively: 0,51 µm; 0,87 µm; 0,93 µm. Straightness is 1,95 µm.

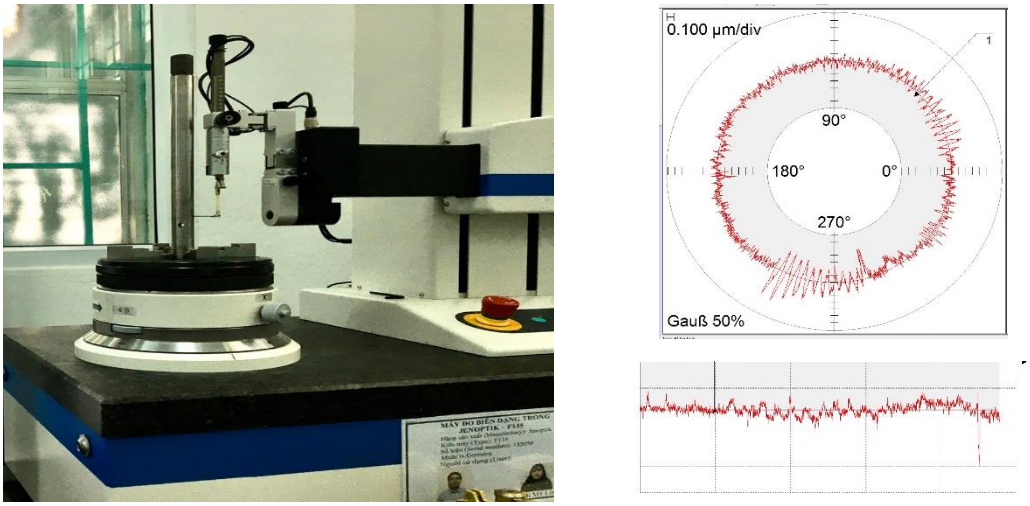

Figure 11: Roundness meter JENOPTIK F135.

Experimental results measurement the roundness and straightness on construction equipment compared with the measurement on the roundness meter JENOPTIK F135 are relatively similar.

4. Conclusion

The content of the paper presented the mathematical basis for building a profile of surface revolution. Analyze the components to determine whether a complete profile of surface revolution can be measured. Application of the laser scan micrometer method in combination with the rotation and translational movement of details in the profile measurement of these details. Building equipment models and experimenting in measuring the detailed contour of cylinders with diameter of 20,004 mm, length of 80 mm at different positions. Compare measurement results when measuring on JENOPTIK F135 circular measuring machine to prove the feasibility of the method of measuring the profile of surface revolution of the author proposed.

References

[1]. W. Liu, P. Hu, and K. Fan, "Comparison of current five-point cylindricity error separation techniques," Applied Sciences (Switzerland), vol. 8, no. 10. MDPI AG, 16-Oct-2018, doi: 10.3390/app8101946.

[2]. K. Endo, W. Gao, and S. Kiyono, "A new multi-probe arrangement for surface profile measurement of cylinders," JSME Int. Journal, Ser. C Mech. Syst. Mach. Elem. Manuf., vol. 46, no. 4, pp. 1531–1537, 2003, doi: 10.1299/jsmec.46.1531.

[3]. "1-s2.0-S2351978917307151-main.pdf." .

[4]. B. Muralikrishnan and J. Raja, "Computational surface and roundness metrology," Computational Surface and Roundness Metrology. pp. 1–263, 2009, doi: 10.1007/978-1-84800-297-5.

[5]. Laser Scan Micrometer– Keyence. Available online:https://www.keyence.com/ss/products/measure/measurement_library/type/optical/ (accessed on 02 May 2019).