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Analysis of Performance of Harrison T300 Lathe by Static and Dynamic Testing

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Abstract
This paper discusses the testing of the geometric accuracy of the Harrison T300 lathe in the Mechanical Laboratory of the Department of Mechanical Engineering, Bali State Polytechnic. The results of this test will be used as a reference for evaluation in carrying out appropriate maintenance actions for the machine. The testing methods and procedures used are based on the standard test chart according to the Schlesinger method, both through static testing and dynamic testing. Static testing includes, among others; testing the alignment of the glide plane, testing the alignment of the main spindle to the top sled, testing the alignment of the main spindle to longitudinal sledding, testing the main axis of rotation at the end of the centre sleave, testing the swivel at the end of the centre, testing the straightness of the axis between the headstock and tailstock, testing tailstosck alignment with longitudinal sledding, testing tailstocks alignment to the slide ways base. Meanwhile, dynamic testing includes, among others; measuring spindle rotation speed and testing the workpiece geometry of the turning results. Based on the evaluation results of the Harisson T300 lathe, it was found that all the tests carried out had deviations. Thus, the conclusion of this study is that the Harisson T300 lathe which is the sample in this study is no longer standard and needs to be reconditioned.

Keywords: *maintenance, lathe, Schlesinger method, static test, dynamic test.*

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I. INTRODUCTION

One type of machine tool used in the Mechanical Laboratory of the Department of Mechanical Engineering, Bali State Polytechnic is the Harisson T300 lathe. This lathe is more than 30 years old. This lathe is used as a practical learning medium for students as well as in supporting research and community service activities in the Mechanical Engineering Department.

The reliability of a machine tool, especially a lathe, is very necessary, considering that the workpiece made must have good dimensional quality and comply with the specified product standards. The reliability of the machine will decrease if the machine has been used for a long time. Likewise with the lathe in the machine shop [1]

The ability of a lathe in carrying out the material processing process for production is influenced by the good components of the lathe itself. lathe components consist of stationary components and moving components, moving components consist of bearings, motors, transmissions, stationary components consist of tool passes, cross slides, tailstock, saddles, beds.

These components greatly affect the rigidity. Rigidity of the lathe is influenced by the force generated by the stationary component (static) and the force generated by the moving component (dynamic). To determine the rigidity of the lathe, it is necessary to test the production results in accordance with the standards set by the company [2-4]

Continuous use of equipment will cause a decrease in the quality of the machine. A decrease in machine quality can be caused by an increase in the deviation of the machine geometry. An increase in deviation can be interpreted as a decrease in the ability of the machine tool, this decrease if not addressed will result in a continued decline in the quality of the machining process product. Besides being caused by machine tools, product geometric deviations can also be caused by the type and condition of the cutting tool, tool holder, cutting speed, feed and chipsection, material being cut, shape, size and stiffness of the workpiece, clamping equipment, operator skills [5].

To be sure that a machine tool still has high performance and geometric accuracy and is able to produce machining products of appropriate quality, it is necessary to inspect or test the machine. The data from these inspections and tests are not only used to determine the performance, accuracy and condition of the machine, but more than that it can be used by the owner or manager of the machine in determining more appropriate rehabilitation and maintenance measures so that the condition of the machine can be returned to a better condition.

This research was conducted with the aim of evaluating the performance and geometric accuracy of the Harisson T300 lathe in the Mechanical Laboratory of the Department of Mechanical Engineering, Bali State Polytechnic. The results of this study will be used as a reference and reference in maintaining and reconditioning the lathe, as well as material for developing Textbooks and Practicum Modules for the "Machine Tooling Maintenance Practicum" course for students of the Mechanical Engineering (D3) study program, and students of the Engineering study program. Manufacturing Design (D4) Bali State Polytechnic.

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II METHODOLOGY

2.1 Testing Method

In general, the method of testing the geometric accuracy of machine tools is carried out based on ISO standards. In the ISO 230 guidelines there are two types of testing for the geometric accuracy of machine tools, namely [6]:

- Dynamic accuracy test. This test is carried out using a test work piece that has been done in a finishing condition
- Static accuracy test (geometric test). This test is carried out without loading and the machine is not working. What must be tested is the geometric deviation of each displacement component relative to one another.

One of the standard procedures for testing the feasibility of machine tools (standard acceptance) that is often used is the method that has been developed by Schlessinger, 1901 [5]. published in the book Testing Machine Tools by Dr. Georg Schlesinger and ISO recommendations numbered 230 and R 1708. Thus the measurement system used in the measurement of the machine above is a measurement system that has been recognized by ISO (International Organization for Standardization).

2.2 Materials and Tools

Materials and tools used in this test are: Harrison T300 lathe, dial indicator with 0.01 mm resolution, dial indicator magnetic stand, digital spirit level, iron steel St 37 with length 64cm and 16 cm x 1 inch in diametre, a rag for cleaning the measured part, and tachometer.

2.3 Static Test Procedure

In order for the results of the geometric accuracy test carried out in this study to get optimal results, the correct testing procedure needs to be applied. For this reason, the following describes the procedure for testing geometric accuracy in accordance with the purpose of geometric measurements of the lathe developed in the Schlessinger method, namely [5]:

2.3.1 Testing the straightness of the slide runway

Testing the straightness of the runway in the longitudinal direction (Figure 1).

a. The back of the glide plane (farthest from the operator), for example in figure 1 in positions a and b.
b. The front runway (closest to the operator).
c. Testing the straightness of the glide plane base on the transverse glide plane (in Figure 1 at positions c and d).

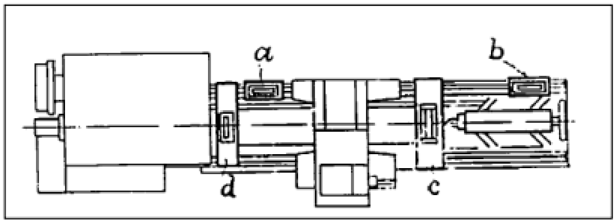

Figure 1: Test method for the straightness of the glide plane base [5]

2.3.2 Main spindle alignment test against upslide

Testing the alignment of the main spindle against the top slide in the vertical and horizontal directions is carried out using a dial indicator measuring instrument mounted on a magnetic stand and test object (Figure 2). An important point to note before carrying out this test is that the machine must be turned on for 1 (one) hour in order for the main spindle bearing to reach its working temperature. The test steps are as follows:

a. Testing the alignment of the main spindle against upslide in the vertical plane
b. Test the alignment of the main spindle against the top slide in the horizontal plane.

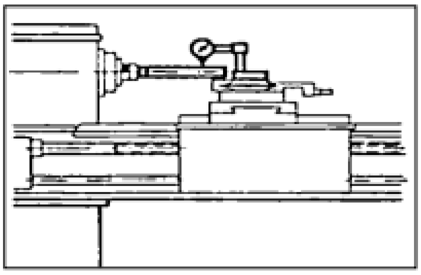

Figure 2: Method of alignment test the of the main spindle against the top sled [5]

2.3.3 Alignment Test of the main spindle against longitudinal sled

The main spindle alignment test against longitudinal sledding in the vertical and horizontal directions is carried out using a dial indicator mounted on a magnetic stand with the tip of the dial indicator sensor positioned on the measuring plane of the test object (Figure 3).

a. Test the alignment of the main spindle against longitudinal slid in the vertical plane.

b. Test the alignment of the main spindle against longitudinal sled in the horizontal direction.

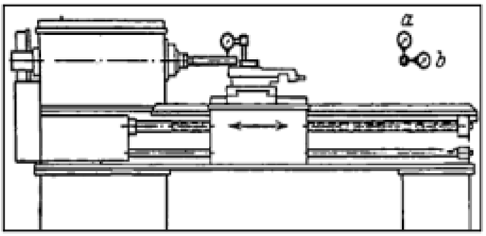

Figure 3: Method of alignment test of the main spindle against longitudinal sled [5]

2.3.4 Testing of the rotation main axis at the end of the centre sleave

The rotation main axis test at the end of the centre sleave is carried out using a dial indicator, where the tip of the dial indicator sensor is placed at the end of the centre sleave (Figure 4).

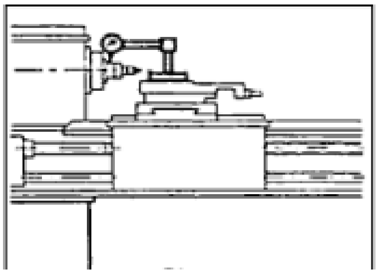

Figure 4: Testing method of twisting at the end of the centre sleave[5]

2.3.5 Testing of the rotation centre

Almost the same as the previous test, the test of the turning intersection at the end of the centre is carried out using a dial indicator, where the tip of the dial indicator sensor is placed at the end of the centre (Figure 5).

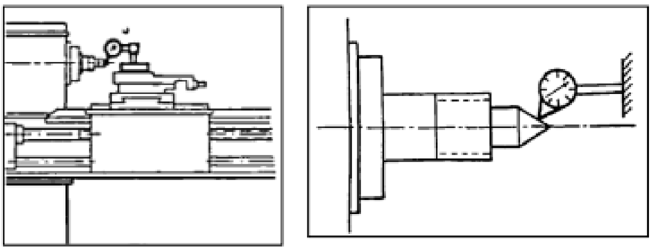

Figure 5: Testing method for rotation deviation on the centre [5]

2.3.6 Testing of the axis alignment between the headstock and taistock

Alignment testing of the axis between the headstock and taistock is carried out using a dial indicator mounted on a magnetic stand with the tip of the dial indicator sensor positioned on the measuring plane of the test object (Figure 6).

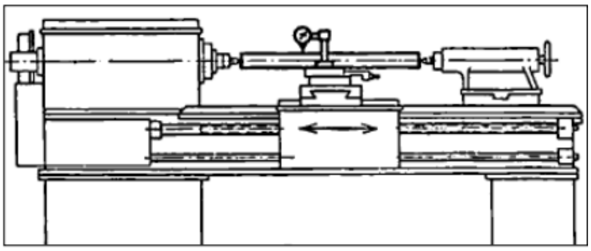

Figure 6: Test method for the straightness of the axis between the headstock and taistock[5]

2.3.7 Testing of taistock alignment with longitudinal sled motion

Alignment test of the tailstocks with longitudinal sledding in both the vertical plane (position a) and in the horizontal plane (position b), was carried out using a dial indicator mounted on a magnetic stand with the tip of the dial indicator sensor positioned on the tailstock sleave as shown in Figure 7.

a. Testing the alignment of the taistock with longitudinal sledding in the vertical plane (position a)

b. Testing the alignment of the taistock with longitudinal sledding in the horizontal plane (position b)

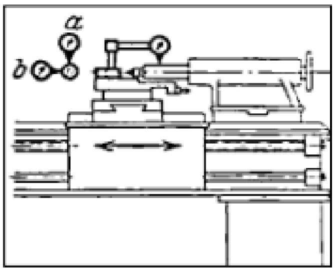

Figure 7: Test method for taistock alignment with longitudinal sledding [5]

2.3.8 Testing the alignment of the taistock against carriage movement

The taistock alignment test against the slide ways base was carried out using a dial indicator mounted on a magnetic stand with the tip of the dial indicator sensor positioned on the slide ways base (Figure 8).

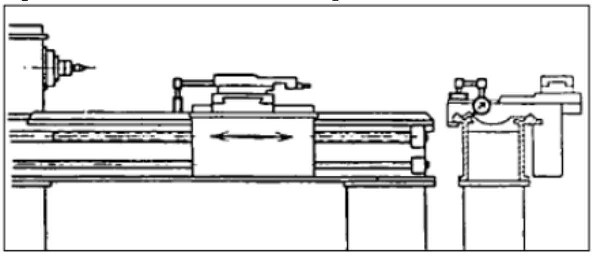

Figure 8: Method of testing the alignment of the taistock to the base [5]

2.4 Dynamic Test Procedure

2.4.1 Measurement of Spindle Rotation Speed

The spindle rotation speed measurement refers to the spindle rotation table listed on the Harrison T300 lathe. Each spindle revolution listed on the machine table, the actual speed is measured using a tachometer. The rotation of the measurement results is compared to the rotation of the theoretical spindle, so that deviation analysis can be carried out [7].

2.4.2 Workpiece Geometry Test

The first step is the process of turning the workpiece with St. iron. 37 and 16 cm long. The initial diameter of the workpiece is 25.4 mm and the final diameter is 24 mm. The geometry tests carried out on the test objects include; surface straightness at 0^o, 90^o, 180^o, 270^o angle positions, parallelism, and roundness of the test object.

III RESULTS AND DISCUSSION

3.1 Static Testing

3.1.1 Straightness Test the of the Glide Platform

The purpose of checking the straightness of the glide plane is to check whether the bed as the reference plane of the components it supports is horizontal and not twisted. The test results are shown in table 1 and table 2.

Table 1: The results of testing the straightness of the glide plane runway in the longitudinal direction of the back plane runway

	Deviation on spirit level	Deviation (mm)
Position a	2	0.03
Position b	2	0.03

Back plane runway

	Deviation on spirit level	Deviation (mm)
Position a	2.5	0.06
Position b	2	0.03

Table 2: The results of the test for the straightness of the runway in the transverse direction of the glide plane

	Deviation on spirit level	Deviation (mm)
Position c	2	0.04
Position d	1.5	0.03

The test data in both the longitudinal and transverse directions (Tables 1 and 2) show that the position of the spirit level has deviated from a minimum of 0.03 mm and a maximum of 0.06 mm. This shows that the glide plane base has deviated from the standard provisions that are filled in, namely 0.02 mm per 1000 mm. So that the Harrison T300 type lathe needs to be leveled again.

3.1.2 Main Spindle Alignment Test Against Upper Sliding

The results of the parallelism test between the top slide to the main axis (Figure 9), it was found that the maximum deviation for the vertical direction was -0.20 mm on the test object and the minimum deviation of -0.01mm at the end of the test object near the headstock. In the horizontal direction (Figure 9), the maximum deviation occurred at 0.02 mm at the end of the specimen, while the minimum deviation was 0.00 mm at the end of the specimen near the headstock.

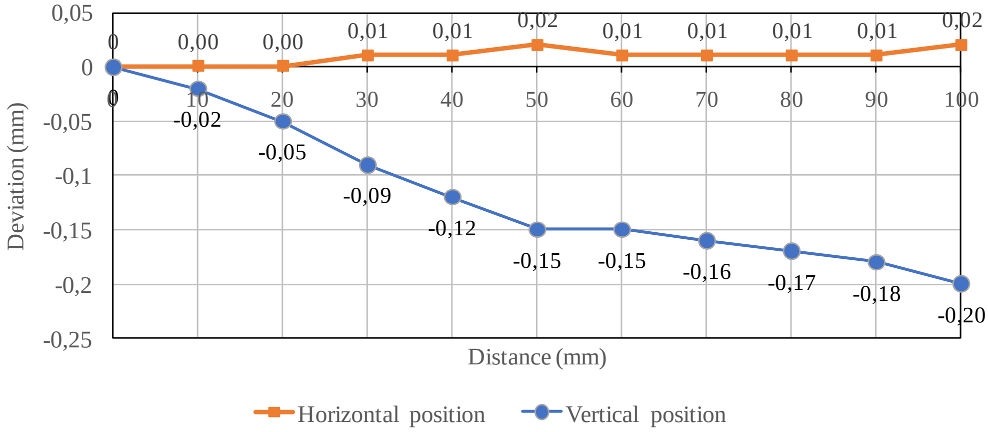

Figure 9: Alignment of the main axle to the top sled

The maximum allowable deviation according to the Schlesinger standard is 0.03 mm / 1000 mm for the vertical direction and 0.02 / 1000 mm in the horizontal direction, with the direction of deviation allowed according to the standard is towards the front (away from the headstock). Thus, the data from the test results indicate that the sledding movement is no longer parallel to the main axis. In addition to the magnitude of the deviation has exceeded the standard, the deviation direction of the sledding movement has been wrong so that the lathe is no longer able to compensate for the deflection that occurs due to the cutting force.

3.1.3 Main Spindle Alignment Test for Longitudinal Sliding

The results of the parallelization test between the longitudinal sleds with respect to the main axis show that: the maximum deviation for the vertical direction (Figure 10) is -0.07 mm on the test object and the minimum deviation of -0.02 mm at the end of the test object near the headstock . While in the horizontal direction (Figure 10) the maximum deviation occurred at 0.09 mm at the end of the test band, while the minimum deviation was 0.01 mm at the end of the test object near the headstock.

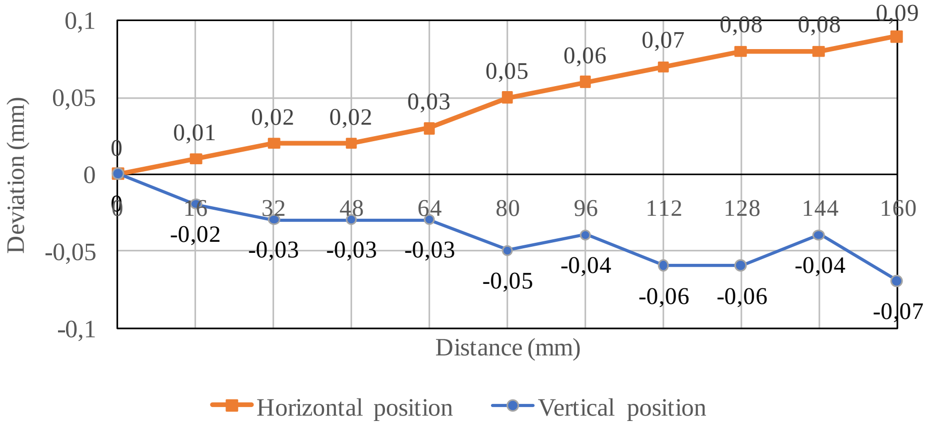

Figure 10: Results of the main spindle alignment test for longitudinal sledding

The maximum allowable deviation according to the Schlesinger standard for the longitudinal sled parallel to the main axis is 0.02 mm / 300 mm for the vertical direction and 0.02/300 mm in the horizontal direction, with the direction of deviation allowed according to the standard is towards the front (away from the head). permanent). Thus the data from the test results indicate that the transverse sledding movement is no longer parallel to the main axis.

3.1.4 Main axis test of rotation at the end of the sleave centre

The purpose of this test is to find out whether the rotation of the main axis at the end of the sleave centre is still normal according to the standard or has deviated from the predetermined standard size. The maximum standard deviation of the main axis rotation on the sleave centre section (centre sleave for true running) according to the Schlesinger method is 0.01 mm.

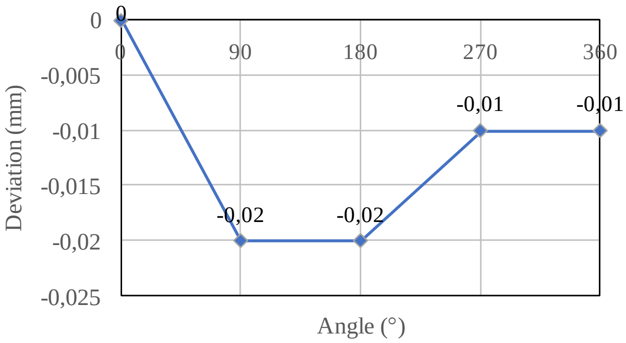

Figure 11: Test results of the main axis rotation intersection at the end of the centre.

The test data shows that the maximum deviation is 0.02 mm (Figure 11), thus it can be said that the rotation of the main axis in the sleave centre section does not meet the standards.

3.1.5 Run out Test of the Centre

The rotational deviation test on the center is carried out with the aim of checking the magnitude of the rotational deviation at the end of the centre mounted on the main axis of the lathe as shown in Figure 12. An important factor that needs to be considered when testing the rotational deviation of this centre is that the lathe must be in operating temperature so that the main spindle position is in a normal position on the bearing.

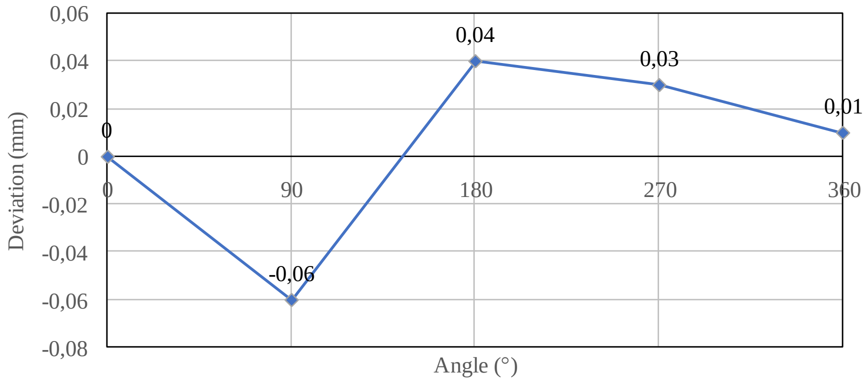

Figure 12:. The results of the run out test on the center.

The maximum standard deviation of the rotational deviation of this centre according to the Schlesinger method is 0.01 mm. The test data shows that the maximum deviation is -0.06 mm, thus it can be said that the rotation of the main axis in the centre does not meet the standards.

3.1.6 The alignment Test of the axis between the headstock and taistock

The purpose of this test is to check whether the position of the headstock axis and the taistock axis is the same level or straight. The test data shows that the maximum deviation occurs is 0.10 mm (Figure 13). This condition has deviated far from the standard or the maximum allowable deviation tolerance according to the standard in the Schlesinger method, which is 0.02 mm. From the test data, it is known that the position of the headstock axis and the taistock axis are not the same height or are not straight anymore.

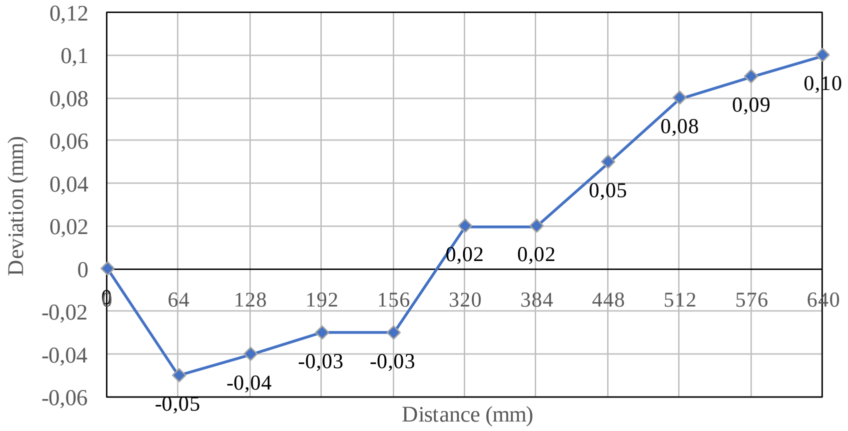

Figure 13: Test results of the main axis alignment between headstock and taistock

Thus, the alignment between the axes of the headstock and the taistock needs to be re-arranged by rearranging the adjusting bolt on the taistock. One of the causes of the misalignment between the headstock axis and the tailstock axis is the machine foundation or uneven machine level.

3.1.7 Testing of the alignment of the taistock with the longitudinal sled movement

The purpose of this measurement is to determine the parallelism of the horizontal longitudinal sled movement to the axis of the loose head in both the horizontal and horizontal directions. The maximum deviation tolerance for the parallelism of the longitudinal sled movement with respect to the tailstock axis is 0.02 mm in the horizontal direction, and 0.01 mm in the horizontal direction. The direction of movement of the horizontal dial sensor tip is from the tailstock to the headstock.

The allowable deviation directions according to the standard in the Schlesinger method are: in the horizontal direction the allowable slope direction is the higher towards the loose head; while for the horizontal direction the slope direction is the higher the horizontal head is off / against the direction of tool pressure.

The test data show that the minimum deviation for the horizontal direction is 0.00 mm at the taistock sleave end (close to the headstock) and the maximum deviation is 0.03 mm at the other tailstock sleave end (Figure 14).

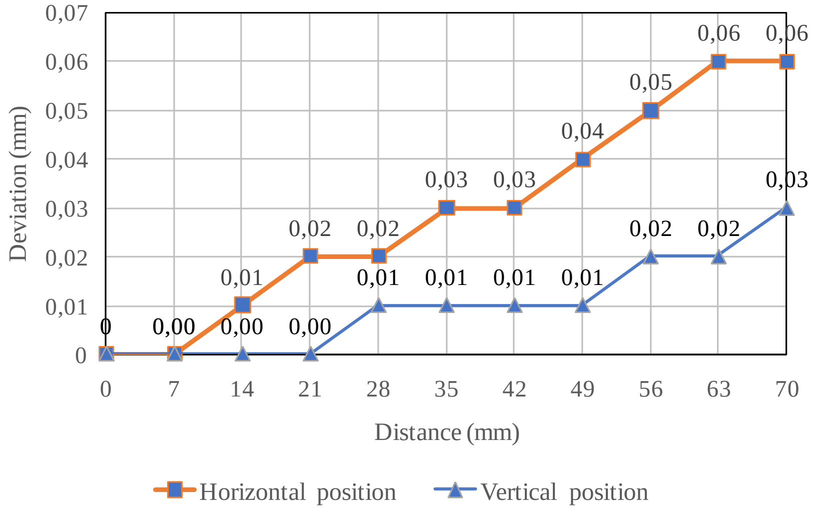

Figure 14: Results of testing the alignment of the taistock with a longitudinal sled movement

For the horizontal direction, the test data shows a minimum deviation of 0.00 mm occurs at the tailstock sleave end (the initial position of the horizontal dial sensor) and a maximum deviation of 0.06 mm (at the end position of the horizontal dial sensor). Just as in the horizontal direction, both the magnitude of the deviation and the direction of the deviation are out of the tolerance limit.

3.1.8 Testing of the alignment of the taistock against carriage movement

This test aims to determine whether the slide ways are still parallel to the tailstock movement or not. This alignment is necessary to ensure product quality, especially when drilling. The maximum deviation of the taistock alignment with the slide ways according to the standard in the Schlesinger method is 0.02 mm / 1000 mm. The direction of movement of the dial indicator sensor which is touched on the slide ways plane of the lathe is from the direction of the tailstock to the headstock.

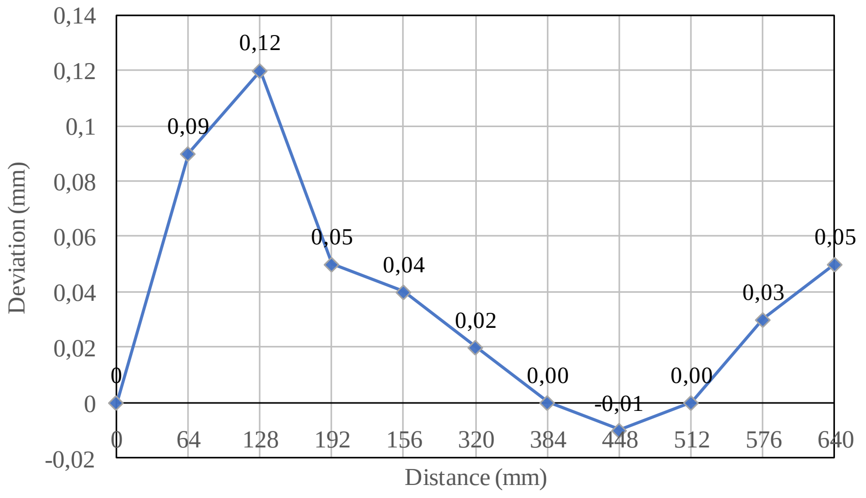

Figure 15: Results of testing the alignment of the taistock to the base

The test data shows that the tailstock movement in the slide ways has deviated from the standard value, which is 0.008 mm / 1000 mm in the length of the slide ways (Figure 15). Maximum misalignment occurs in parts of the slide ways that approach the headstock or in the work plane. This is due to the slide ways experiencing the greatest wear and tear.

3.2 Dynamic Testing

3.2.1 Spindle rotation speed

The spindle rotation speed test aims to determine whether the spindle rotation speed is still in accordance with that in the rotation speed table on the machine. This test needs to be carried out to ensure product quality, especially when drilling and turning the face (facing). The test data shows that the spindle rotation has deviation from the table on the machine (Figure 16).

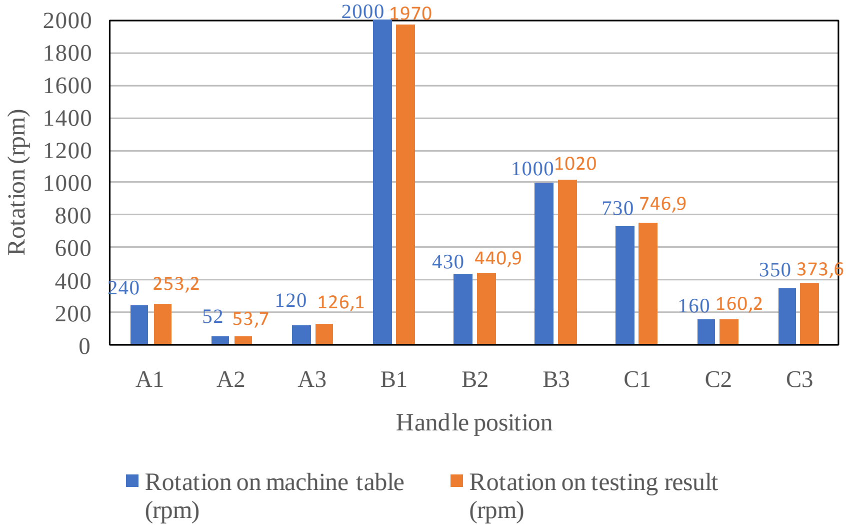

Figure 16: Comparison of the spindle rotation of the test results with the rotation on the machine table.

3.2.2 Inspection of Test Objects

This test is carried out to determine the geometric accuracy of the work of the lathe. What is tested in this case is the workpiece that has been cut with the relevant machine tool. The results of turning the workpiece can be seen in Figure 17 and the turning data in table 3.

Figure 17: The result of turning the workpiece.

The test data show that the largest deviation is 0.17 mm. This is because the accuracy of the machine geometry has deviated and experienced the greatest wear and tear.

Table 3: Workpiece geometry test data

Distance (mm)	Deviation on 0°	90°	180°	270°
0	-0.03	-0.02	-0.02	0.00
13	0.02	0.02	0.04	0.02
26	0.02	0.02	0.01	0.06
39	-0.04	-0.03	-0.02	0.01
52	-0.03	-0.02	-0.03	0.01
65	-0.03	-0.01	0.04	0.05
78	-0.03	0.00	0.06	0.07
91	0.06	0.01	0.09	0.12
117	0.03	0.06	0.15	0.15
130	0.02	0.05	0.16	0.17
Average	0.00	0.01	0.05	0.07

3.2.2.1 Straightness of Test Object

A line is declared straight if the value of the change in the distance from the points on the line to the plane of projection parallel to the direction of the line is always less than a certain limit value [8].

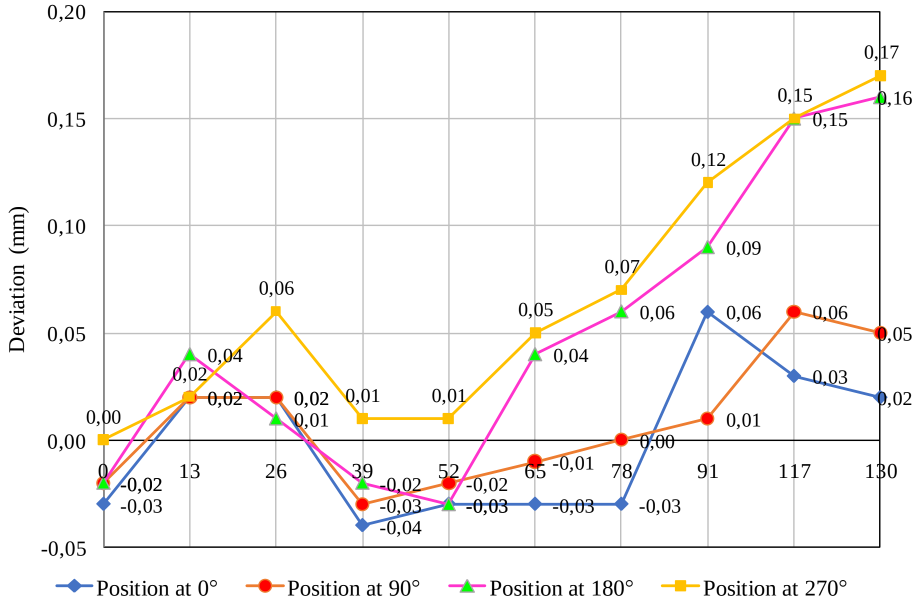

Figure 18: The deviation of the measurement results of the test object

In practice, the straightness test is carried out by taking measurements on a turned test band whose straightness you want to know by comparing it to a reference straight line. The test results obtained on the straightness on the 0° axis the minimum deviation is 0.02 mm and the maximum is 0.06 mm. From the test data, it is known that the straightness at the 0° axis position is wavy (Figure 18).

The test results obtained on the straightness on the 90° axis the minimum deviation is 0.00 mm and the maximum is 0.06 mm. From the test data, it is known that the straightness at the 90° axis position is wavy (Figure 18).

The test results obtained on the straightness on the 180° axis the minimum deviation is 0.01 mm and the maximum is 0.06 mm. From the test data, it is known that the straightness at the 180° axis position is wavy (Figure 18).

The test results obtained on the straightness on the 180° axis the minimum deviation is 0.00 mm and the maximum is 0.17 mm. From the test data, it is known that the straightness at the 180° axis position is wavy (Figure 18).

3.2.2.2 Alignment of the surface of the test object

A line is declared parallel to a plane if the maximum difference between the distances of each point on the line relative to the plane does not exceed a certain limit value [9]. Similarly, by using the notion that a line can be a secant of two non-parallel planes, the meaning of two parallel lines is if one of the lines is parallel to the two planes that pass through the other line.

The test data shows a minimum deviation of 0.00 mm occurs from the starting point of the measurement and 0.17 mm at the end point of the measurement. (Figure 18).

3.2.2.3 Surface roundness of the test object

Generally a spherical profile is said to be perfectly round if the distance of the points contained in the geometric shape have the same distance from a point called the center point [10].

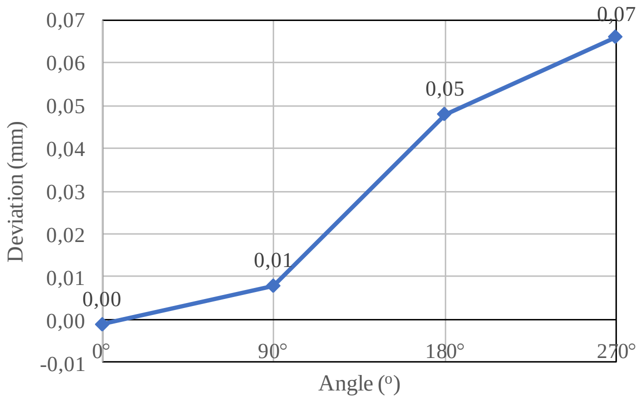

Figure 19: Test results for the surface roundness of the test object

The test results obtained on the roundness of the working band are the minimum deviation of 0.00 mm and the maximum deviation of 0.07 mm. (Figure 19).

IV CONCLUSION

The results of the tests carried out on the Harrison T300 lathe in the Laboratory of the Department of Mechanical Engineering at the Bali State Polytechnic, it was found that all tests carried out had deviations.

The main factor causing the deviation of geometric accuracy is thought to be due to the unevenness (not level) of the machine foundation. The unevenness of the foundation that is not reset for a long period of time will cause the base to be twisted so that the other components supported by the machine bed change position.

The test results indicate that in order to obtain good product quality, the lathe needs to be reconditioned, then retested for accuracy to determine whether the reconditioning efforts have been successful or not.

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