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Analysis of Workbench Flatness Measurement and Product Result of 3 Axis CNC Router Machine

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ABSTRACT

The development of technology in the industrial sector is increasing rapidly, especially the application of computers in the field of machinery. Demands from consumers who want good quality workpieces, precision, completed in a short time and in large quantities, will be easier to work with a CNC Router machine. Surface flatness is an absolute thing that must be considered in the machining process, especially the 3 Axis CNC Router machine. This type of research is an experimental research, using Dutch teak wood as a workpiece with a height of 15 mm, a length of 100 mm and a width of 80 mm, the machining process uses a 3 Axis CNC Router Machine. The flatness of the workbench is first measured, then the product is prepared with a depth of 2 mm in the product area. The research uses a variation of the spindle speed of 600 rpm, 800 rpm and 1000 rpm. After that, measurements are taken to obtain the flatness value. Measuring flatness using a Dial indicator measuring instrument with accuracy (1µm). The best product flatness test or the lowest value is (32.00 µm) obtained from the spindle speed of 1000 rpm and the most uneven product evenness is (56.00 µm) obtained from the spindle speed of 600 rpm, knowing the effect of the flatness value of the workbench on the product flatness value 3 Axis CNC Router Machine, that the flatter the workbench, the flatter the product results. The results of the research can be used to refine machining strategies to achieve optimal machining.

KEY WORDS: *Flatness value, Spindle speed, 3 axis CNC router machine.*

1.0 INTRODUCTION

The development of science and technology at this time is growing rapidly. One of them is the use of CNC machine tools, which is an effort to meet increasingly high consumer demands, both in terms of quality and quantity [1-7]. This era of industrialization has increased the need and use of CNC machine tools along with the demand for precision machined component products. CNC machine tools can produce and repair machine components with quality that depends on several factors, including: the quality of the geometry of CNC machine tools, the quality of cutting tools, and the expertise of the operator/programmer [8].

The CNC machine tools are prone to unevenness produced, for example when CNC machines are used for a long period of time and repeatedly can result in the results of the feeding process. Deviations that occur in the results of the feeding process greatly affect the quality of the workpiece. In the machining process, the size of the product quality can be seen from the roughness / smoothness and flatness of the resulting surface. The flatness of the surface is the main factor for the evaluation of acceptable machining products or not. Therefore, flatness and surface roughness are absolute things that must be considered in the machining process, because the resulting product has a very important use. For example, the high level of roughness and unevenness of the surface on the components/parts of a machine can cause rapid wear and tear, so that the components of the machine are quickly damaged and eventually the working efficiency of the machine will decrease [9].

The flatness of the surface of a plane can be determined by analyzing the alignment data of several lines formed by a certain pattern. The simplest line pattern to determine the flatness of a field is the pattern of the Union Jack [10-12]. In this case only the required data straightness 8 (eight) pieces of line that is systematically adjusted reference to obtain a general reference field. Based on these general references, the height of the points can be further analyzed to determine the quality (tolerance) of the flatness of the fields examined through measurements [13].

Measurement is comparing a quantity with a reference or comparator or reference quantity. Measurement is an activity aimed at identifying the size of an object or symptom. The measurement process is an activity that aims to obtain the value of a quantity. Measurement activities have a broad impact on science, human personal life and society in improving efficiency. Modern life is increasingly characterized by

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sophisticated devices for obtaining data. Based on the above description of CNC machines need to be flatness testing, machining process the size of the product quality is widely seen from the flatness. Flatness is a major factor for the evaluation of whether or not a machining product is acceptable for production [14-16]. Therefore, this paper objective is to analyze a workbench by making a line on the plane with the union jack method by determining the point to be measured for product result of 3 axis CNC router machine.

2.0 LITERATURE REVIEW

2.1 Measurement

Measurement is a process that includes three things or parts, namely measuring objects, measuring instruments, and gauges or observers. Because of the imperfection of each of these parts coupled with the influence of the environment, it can be said that none of the measurements gives absolute accuracy. Accuracy is relative that is the similarity or difference between the price of the measurement results with the price that is considered correct, because the (absolute) true do not know each measurement, with sufficient accuracy, has inaccuracy that is the existence of errors that can vary, depending on the condition of measuring instruments, measuring objects, measurement methods, and skills of the measurer [13, 17-19] Measurement is the activity of the value of a quantity. Measurement activities have a broad impact on science, human personal life and society in improving efficiency. Modern life is increasingly characterized by sophisticated devices to obtain data. The measurement is comparing a quantity with a reference or comparator or reference quantity. Measurement is an activity aimed at identifying the size of an object or symptom. Measurement can be done in two ways, namely [13]:

1) use standard tools.
2) use non-standard tools.

The measurement process is an activity that aims to obtain the value of a quantity. Measurement activities have a broad impact on science, human personal life and society in improving efficiency. Modern life is increasingly characterized by sophisticated devices for obtaining data. Modern humans increasingly rely on the activity of obtaining data, which is technically called measurement. The role of measurement in human life increasingly feels vital and imperative. If a measurement, with sufficient precision, is repeated for a second, third and so on for n identical measurements. The results are not always "exactly" the same, it will be more or less scattered around their average value. If there are m measurement groups that each consist of n times a single measurement, the average value of each measurement group will also be spread around its total average value. This average value distribution is more aggregating when compared to the distribution of single measurement results. This is a general property of measurement processes related to accuracy or repeatability, namely the ability to repeat the same thing [25-27].

2.2 Flatness, Flatness and Straightness

Flatness is "flat water " or horizontal, the Earth's attraction (gravity) is considered perpendicular to the flat water. A flat plane of water is an ideal plane, so it is used as a reference plane in almost all engineering work. The flatness of a plane is determined based on the analysis of data on the straightness of several lines that form a certain pattern. Pattern or arrangement of the simplest lines to determine the flatness of a field is the pattern of "Union Jack" in this case only the required data straightness (8) fruit lines are systematically carried out reference to obtain a general reference field. Based on these general references, the height of the points can be further analyzed to determine the quality (tolerance) of the flatness of the field being examined. Straightness is measuring the extent to which a line or surface deviates from the ideal condition of a straight line or surface.

1. Flatness
   Flatness is "flat water' or horizontal, the Earth's attraction (gravity) is considered perpendicular to the ideal plane, so it is used as a flat plane of water. A flat-water field is an ideal field, so it is used as a reference field in almost all engineering work, for example in the manufacture of skyscrapers, bridges, dams and residential homes, in the field of installation of equipment and machinery, to the field of measurement, land topography and industrial metrology (Surface plate topography). However, because the angle measured is relatively small and the field of the wearer is not to measure the angle, then the background will be reviewed as the opening sub-chapter of the straightness and flatness measuring instrument [13].
2. Flatness
   The flatness of the surface of a plane can be determined by analyzing the alignment data of several lines formed by a certain pattern. A theoretical flat plane can be created by moving a straight line over two other parallel lines (edge lines). A straight line is called a generator line. If the two edge lines are not parallel then what is formed is a twisted plane. Two diagonal lines will be made on the measuring plane to check the evenness of the plane. If the two diagonal lines intersect each other, it means that the plane is flat and vice versa, if they do not intersect, it means that the plane is twisted, relative to the general reference plane, an analysis can be carried out. Analysis of the flatness of the plane is determined based on measurements of the straightness of the generator lines covering the measuring plane. Several generator lines can be selected as line patterns to check the flatness of the plane. The position (height) of each point on each line needs to be corrected to the general reference plane (reference for all measurement lines) by knowing the height of each point relative to the general reference plane, an analysis can be carried out to determine the quality of the flatness of the measuring plane [13].
3. Straightness
   A line is said to be straight when the price changes from the distance between points on the line to a plane parallel to the line. It is always below a certain value. Testing of straightness consists of:
   a) the relationship between two fields
   b) straightness of each component
   c) the straightness of the movement of each component and between components.

2.3 Union Jack Method

The union Jack pattern requires 8 lines, two diagonal lines are needed to find out whether the checked plane is twisted or not, that is, by checking the similarity of the height of the midpoint. Thus, in order to know the height of the midpoint (from 4 lines BF, AE, HD and GC), the ratio of the number of intervals on the lines of length, width and diagonal of the rectangle is at

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least 8 : 6 : 10. At least the size of the union jack pattern (when possible the length of the legs can be adjusted). Compared to the woven pattern that can check almost the entire measuring field, the union jack pattern only checks a part of the measuring field where the four quadrants are only checked by diagonal lines. However, during the process of making the measuring field follow the technology commonly used (for measuring objects of granite or steel/cast iron can be processed with surface grinding and lapping [13].

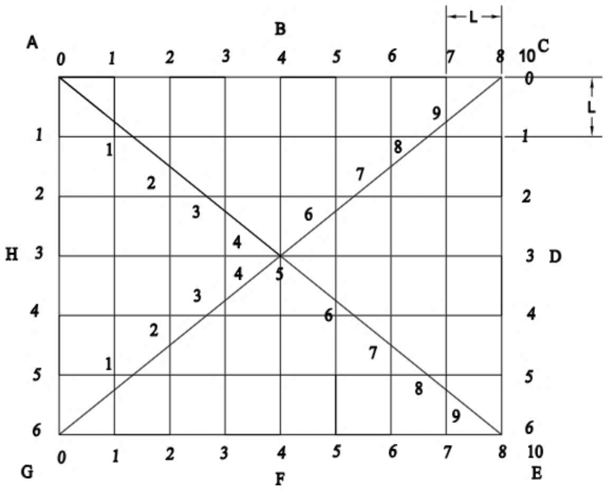

Figure 1: Line arrangement pattern to analyze the flatness of the measuring field

Union jack pattern analysis procedure by selecting the reference plane through the three points set at zero, namely point A, C and G as shown in Figure 1 pattern of line arrangement to analyze the average of the measuring plane. Another method of analysis can be chosen, namely by assuming a zero-reference plane through points A, C and I, and the adjustment/correction procedure will be slightly different. The results obtained from the latter method will provide data on the height of the points (flatness data) are different from the results obtained from the adjustment method above

3.0 METHOD

This study adopted experimental method. Preparation of tools and materials was carried out before the flatness measurement process. 3 Axis CNC Router Machine was used to make products with a variety of spindle speeds of 600, 800 and 1000 rpm. The GRBL software program used in manufacturing products with manual operation carries out ingestion of products with an area of 80 mm x 60 mm in 2 mm. The stepper motor functions to feed the product to be made using the commands given by the Arduino Microcontroller to be able to make the product properly.

Dutch teak wood was a product material for 3 Axis CNC Router Machine because it has a soft character and relatively easy to obtain at an affordable price, which widely used by wood craftsmen as a product. The dial indicator was used as a tool to measure the flatness of the work table and the flatness of the product. To determine the flatness value, the straightness data on the workbench and product area was analyzed using the Union Jack method as a reference in measuring flatness.

Measuring product flatness can be described through the following stages:

1. Preparation of tools and materials such as: a. 3 Axis CNC Router Machine, b. Laptops, c. GRBL Software, d. Arduino microcontroller, e. Stepper motor, f. Endmill cutting tool, g. Dial indicator, h. Flat Table, and i. Teak wood.
2. Making the product, at this stage the product is made using a 3 Axis CNC Router machine, with variations: 600 rpm, 800 rpm and 1000 rpm. The feed speed was set at 0.08 m/s with a feed area of 80 mm x 60 mm, and a feed depth of 2 mm.
3. Make a Union Jack pattern, this stage makes lines and points on the product area as a reference in measuring.
4. Take measurements 3 times for each point and obtain an average value. The measuring instrument uses a dial indicator.
5. The flatness values of the 3 products are totaled and the average of the 3 measurements is found.
6. Record the results obtained during measurement. Next, the results data were processed and analyzed the influence of the flatness of the work table on the product results on the 3 axis CNC Router machine.
7. Analysis of the measurement results was carried out by comparing the evenness of each spindle speed variation in the product with the data obtained and processed using Microsoft Excel.

4.0 RESULT AND DISCUSSION

The machine working table was prepared a workbench by making a line on the plane with the union jack method by determining the point to be measured, with a table length of 300 mm, width 180 mm and thickness 20 mm. Contour of workbench side 1 and side 2 shows in Figure 2 and 3 respectively. The results of measuring each point on the work table using the union jack method to find the highest value of flatness. Next, calculations were carried out to find the standard deviation of the workbench measurements. The results obtained for the standard deviation on side 1 are 69.51 µm and side 1 was 67.65 µm. It has a variance value on side 1, namely 4831.86 µm and side 2, namely 4576.29 µm. From Table 1, the results of measurements on the work table show that the influence of the flatness value, which the greatest or most uneven at point AG with values on (side 1) 119.28 µm and (side 2) 120.56 µm. Then the value of flatness was smallest or flattest at point AE with values on (side 1) -86.10 µm and (side 2) -87.73 µm.

Product Yield and Working Table

1. Product at 600 rpm

   Before measuring the flatness of the product at 600 rpm, then do the feeding in the field of product with the size of the feeding depth of 2 mm, length of 80 mm and width of 60 mm, after finishing feeding on the surface of the product and the product is outlined and measured using the dial indicator with the union jack method by determining the point to be measured using the dial indicator. The contour image to show the height of flatness in the plane on each side can be seen in Figures 4-9.

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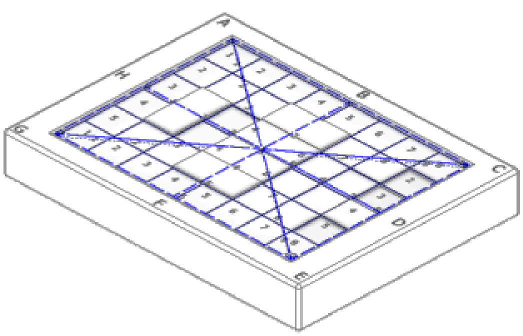

Figure 2: Contour of workbench side 1

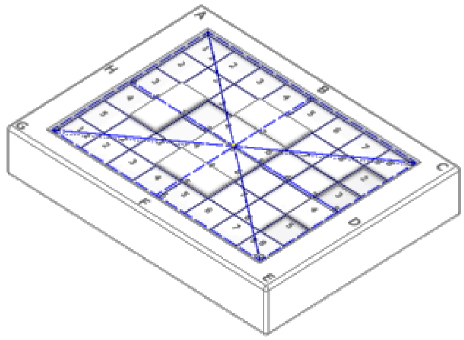

Figure 4: Product contour at 600 rpm side 1

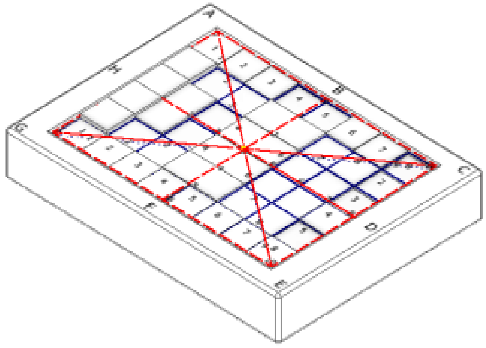

Figure 3: Contour of workbench side 2

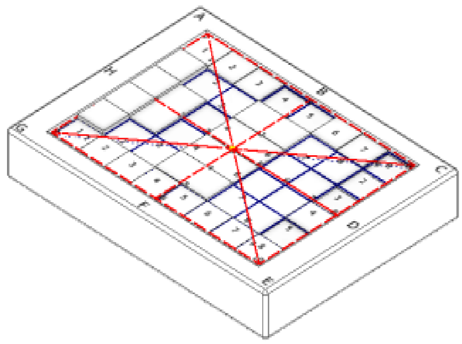

Figure 5: Product contour at 600 rpm side 2

Table 1: Working table flatness measurement recapitulation data

Machine Working Table (µm)		
POINT	**SIDE 1**	**SIDE 2**
AC	5.04	1.00
HD	-13.96	14.96
GE	23.25	22.83
AG	119.28	120.56
BF	58.06	53.94
CE	-83.72	-73.28
AE	-86.10	-87.73
GC	38.73	44.00
Average	7.57	12.04
Standard Deviation	69.51	67.65
Variants	4831.86	4576.29

Table 2: Recapitulation data for 600 rpm product flatness measurement

Product 600 rpm (µm)		
POINT	**SIDE 1**	**SIDE 2**
AC	-4.25	1.04
HD	-0.33	1.04
GE	-1.08	-2.42
AG	122.78	126.61
BF	123.17	131.61
CE	116.28	112.61
AE	38.10	38.50
GC	45.67	47.23
Average	55.04	57.03
Standard Deviation	57.43	58.23
Variants	3298.01	3390.88

It can be seen in Table 2 that the measurement results on the 600rpm product show that the influence of the flatness value, which greatest or least flat at the BF point with values on (side 1) 123.17 µm and (side 2) 131.61 µm. Then the flatness value was smallest or flattest at the AC point with values on (side 1) -4.25 µm and (side 2) 1.04 µm. From Table 3, the measurement results on the 800rpm product show that the influence of the flatness value, which greatest or most uneven at point AE with a value on (side 1) 60.10 µm and (side 2) 54.23 µm. Then the flatness value was smallest or flattest at point AG with values on (side 1) 46.33 µm and (side 2) 46.33 µm.

The results of measuring each point on the 1000 rpm product using the union jack method have the highest value of flatness.

After the data processing result was known, calculations can be carried out to find the standard deviation or with the help of Microsoft Excel to calculate. The results obtained for the standard deviation on side 1 are 29.83 µm and side 2, namely 29.50 µm, has a variance value on side 1, namely 889.59 µm and side 2, namely 870.44 µm. After the flatness measurement data was obtained and the average value, then the data was made into a graph. From Table 4, the measurement results on the 1000 rpm product show that the influence of the flatness value was greatest or most uneven at the GC point with values on (side 1) 57.40 µm and (side 2) 58.17 µm. Then the flatness value was smallest or flattest at the CE point with values on (side 1) -15.00 µm and (side 2) -17.89 µm.

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2. Product at 800 rpm

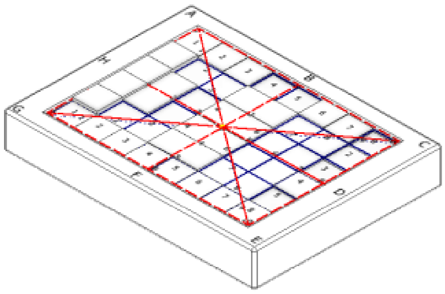

Figure 6: Product contour at 800 rpm side 1

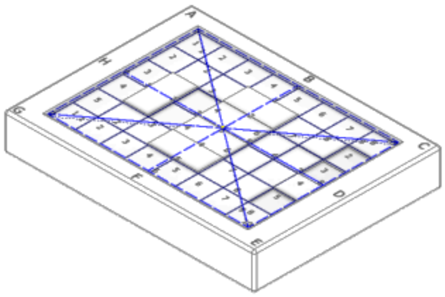

Figure 7: Product contour at 800 rpm side 2

3. Product at 1000 rpm

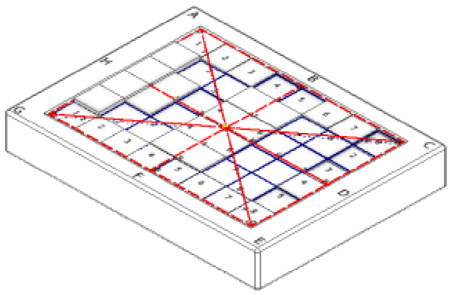

Figure 8: Product contour at 1000 rpm side 1

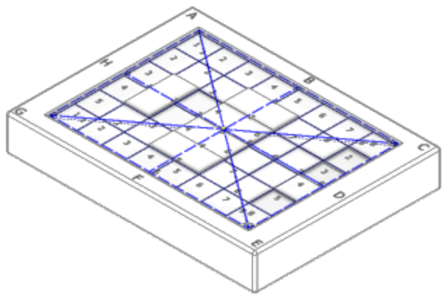

Figure 9: Product contour 1000 rpm side 2

Table 3: Recapitulation data for 800 rpm product flatness measurement

Product 800 rpm (µm)		
POINT	**SIDE 1**	**SIDE 2**
AC	48.71	49.96
HD	58.04	58.04
GE	53.88	53.88
AG	46.33	46.33
BF	56.67	56.67
AE	60.10	54.23
GC	54.23	60.10
Average	54.29	54.44
Standard Deviation	4.66	4.47
Variants	21.76	19.96

Table 4: Recapitulation data for 1000 rpm product flatness measurement

Product 1000 rpm (µm)		
POINT	**SIDE 1**	**SIDE 2**
AC	40.33	42.63
HD	32.46	28.79
GE	-0.08	1.46
AG	60.50	59.89
BF	55.56	55.28
CE	-15.00	-17.89
AE	0.70	57.60
GC	57.40	58.17
Average	28.98	35.74
Standard Deviation	29.83	29.50
Variants	889.59	870.44

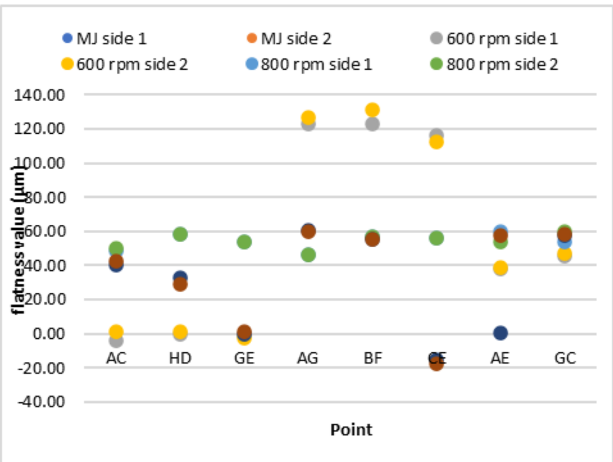

Figure 10: Flatness measurement chart with spindle speed variation

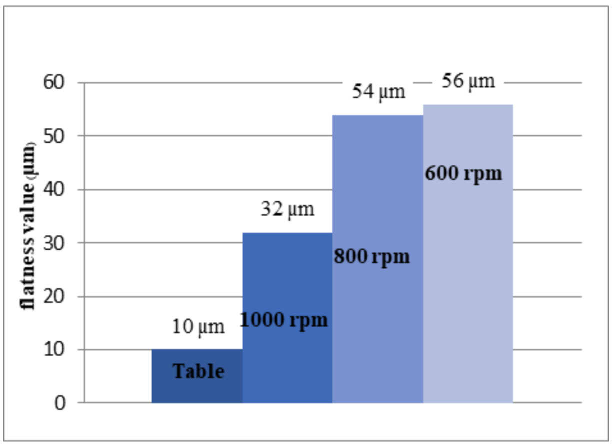

Figure 11: Graph of the effect of the flatness of the workbench on the flatness of the product with variations in spindle speed

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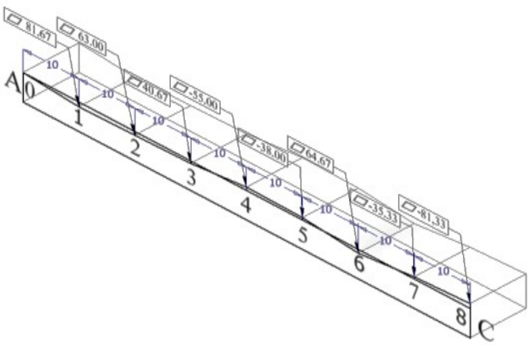
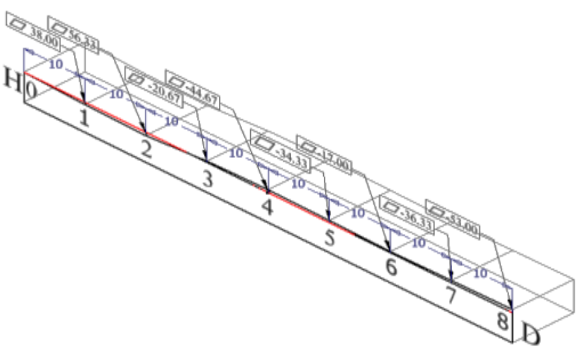
From the total of all flatness test data obtained the average value and then used as a graph of the effect of the flatness of the work table to the flatness of the product with variations in speed with variations in spindle speed 600 rpm, 800 rpm and 1000 rpm. Flatness measurement results showed the effect of variations in spindle speed 600 rpm, 800 rpm and 1000 rpm. That the highest flatness value or the most uneven was found at the spindle speed of 600 rpm with a value of 56.00 µm and 800 rpm with a value of 54.00 µm and the lowest value is found at a speed of 1000 rpm with a value of 32.00 µm.

Then the value of flatness on the workbench with a value of 10.00 µm. It can affect the results of the product that the higher the spindle rotation, the flatter the product, vice versa, the lower the spindle rotation, the more uneven or the higher the flatness value. The flatness value of the workbench is also very influential on the flatness of the product that the flatter the workbench on the 3 axis CNC router machine, the flatter the product because of the machining process, the workbench participates in the manufacture of functioning as a 3 axis CNC Router machine base. Dutch teak wood material also affects the flatness because it has a soft wood fiber and texture so as to obtain a high flatness value by using a dial indicator measuring instrument with an accuracy of 1µm.

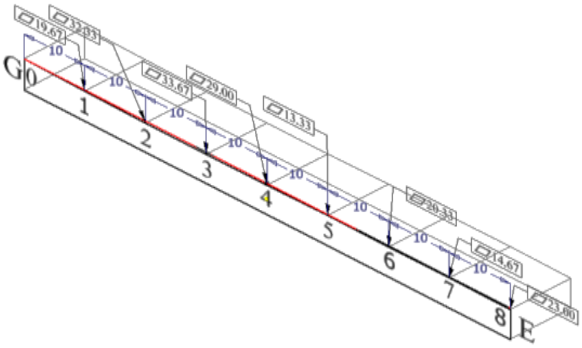
In the 3 Axis CNC Router machine also used a 4 mm diameter End mill blade, the condition of the Endmill blade and the length of the feeding path are directly proportional to the time of effect on each feeding because every movement or displacement of the blade changes into an influence on the precision and accuracy of the product. The contour example to see the height of the flatness of the workbench side 1, it can be seen in Figure 12-19.



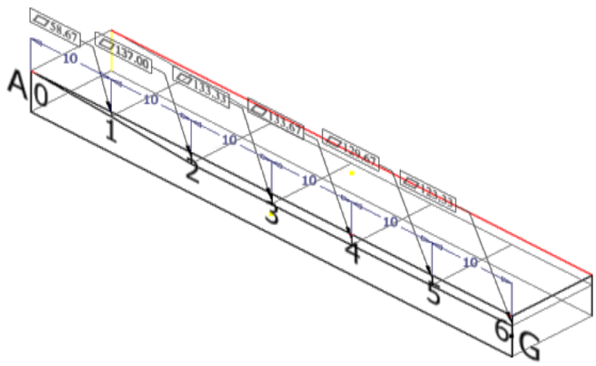
Figture 12: Point A and C



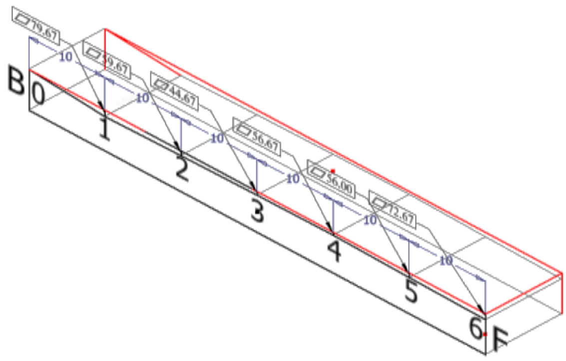
Figture 13: Point H and D



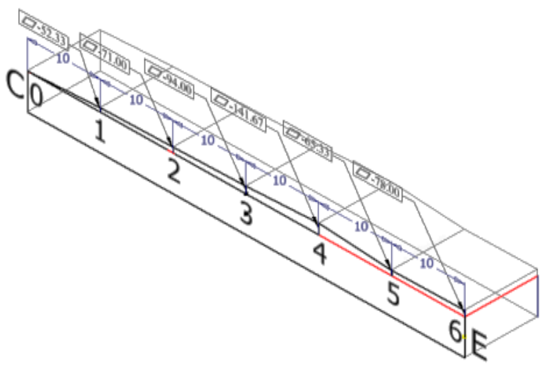
Figture 14: Point A and C



Figture 15: Point A and G



Figture 16: Point B and F



Figture 17: Point C and E

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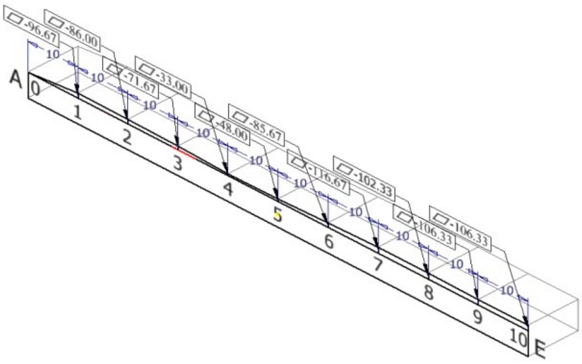
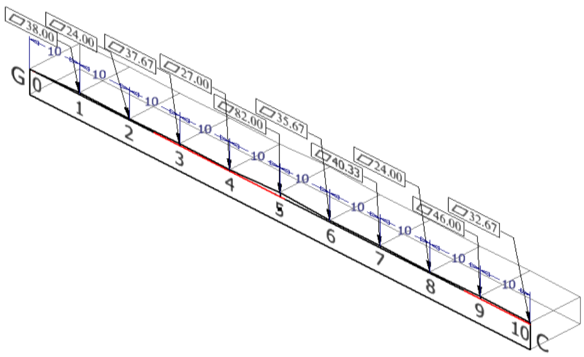


Figture 18: Point A and E



Figture 19: Point G and C

5.0 CONCLUSION

The flatness of the workbench obtained the smallest value of 10 µm was compared with the product. It was due to the manufacture of the workbench through the factory machining process with the standard provisions of the factory. Flatness of the product with spindle speed variations of 600 rpm, 800 rpm and 1000 rpm. That the higher the spindle speed, the flatness value was lower or flatter. The lowest product flatness value was 28.98 µm with a spindle speed of 1000 rpm. The highest or uneven product flatness value was 56.04 µm with a spindle speed of 600 rpm. The effect of the workbench value's flatness on the product with variations in spindle speed was that the flatness of the workbench obtained a flatness value of 10 µm, which was the lowest value of flatness. So, it can be concluded that the workbench is very influential in making products because the table serves as a base or place where the product is located in 3 3-axis CNC router machine.

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