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Analysis of the Effect of Cutting Variables against Surface Hardness

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ABSTRACT

Indonesia is one of the developing countries and is actively pioneering development, especially development in the industrial sector. The industry that is quite developed at this time is the manufacturing industry which produces a finished product that can be directly used by consumers. These products are expected to have a high enough quality level so that they can compete in the market. To support this quality, one of the factors is to pay attention to the level of precision of the workpiece in this case is the level of surface roughness of the object or product produced. The surface roughness value is obtained from the tests carried out on the product which has an average surface value (Ra) and a maximum roughness value (Ry). To achieve the desired roughness value, it is necessary to make improvements in metal forming work. In the variable cutting with variations in cutting speed, it is said that the cutting speed on work with smaller diameter objects should use a high cutting speed. Feeding thickness that is too large can cause high surface roughness values and high rotation at low cutting speeds to produce a smooth surface but takes a long time. With the selection of the speed of ingestion that varies for the price of the ingestion speed of 43.52 m/minute, the surface roughness value is 6.78 m, the speed is 48.32 m/minute, the surface roughness value is 3.64 m and the ingestion speed is 59.25 m. /min the surface roughness value is 6.14 m. Meanwhile, for the infeed thickness which varies for a feed thickness of 1.2 mm, the surface roughness value is 4.06 m; a feed thickness of 2.4 mm obtained a surface roughness value of 27.82 um and a feed thickness of 3.2 mm obtained a surface roughness value of 7.02 m.

INTRODUCTION

The lathe is one of the machine tools that is widely used in the workshop, with various shapes, types and specifications according to needs. Lathes began to be known since 1800, but at that time their capabilities were not sufficient for the needs. Further development was pioneered by Mr. Henry Maudsley, both in terms of functions and other abilities, especially he created the Sliding Cariage (sled) [1-3].

A few years later he was able to increase the ability of the lathe to be able to turn threads. In 1830 he added to the development of the lathe of certain machining abilities, among others, for large machining. As for what is meant is a head lathe that is capable of working on workpieces with a diameter of 9 feet (2743 mm), to get an overview of a previous lathe, namely a lathe that ranged from 1837 to the production of Piere Hure who was involved in machine tools in 1846 to with 1934. Until this latest development, the lathe is prioritized to increase the accuracy of the work/smoothness and control of the movement of the operating system, the lathe with multi-chisel and the control system in its operation [4-6].

This machine has a main motion and functions as a modifier of the shape and size of objects by cutting the object with a cutting chisel, the position of the workpiece rotates according to the axis of the machine and the stationary chisel moves left/right in the direction of the lathe axis. The size of the lathe can be seen in the figure measured from the distance of the flashlight from the fixed head to the head flashlight off, this is the longest distance from the workpiece that can be turned. And it also depends on the height/distance from the tip of the flashlight to the surface of the machine (bed) [7-8].

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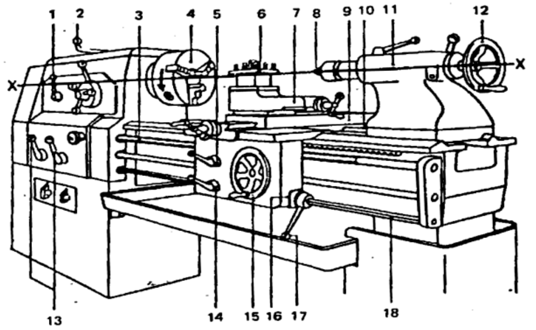

Fig. 1. Lathe [7]

Information :
1) Handle to reverse the direction of rotation of the main axle; 2). Lever to move the main axle; 3) Lathe cutting shaft or delivery couplers; 4) Three self-centered grips; 5) Handle for lock nut; 6) Chisel holder; 7) Top sledding; 8) flashlight in head off; 9) Cross sledding; 10) Machine base (engine base; 11) Head off; 12) Hand wheel to move the head off; 13) Lever for adjusting the number of rotations of the starting supply shaft; 14) Lever for starting supply shaft; 15) Hand wheel for moving support; 16) Lock cabinet; 17) Lever for starting supply; 18) The starting supply shaft.

Turning

Turning is a process that is often carried out in the formation of a material, both metal and non-metal. The lathe process is said to be the most frequently performed process and plays an important role in the construction of a machine because most of its parts are cylindrical, such as machine shafts. On machine tools whose use is relatively simple by using a turning machine, and also seeing the ability of the form that can be produced that the function of use is very useful [9].

The basic workings of this lathe is the rotation of the workpiece which is clamped on the clamping disc (had stock), and the rotating workpiece (which is the main movement of the lathe) is given a cutting force from the chisel which is placed in the tool post. is on the top sled.The process of feeding or cutting the workpiece can be done with several cutting directions, namely the transverse direction (perpendicular to the main axis), and feeding can also be carried out parallel to the main axis.

Chisel

Chisel is a tool used as a cutter during the process of cutting metal or workpieces. In practice, the use of chisels is required to be able to have high criteria/ability during the cutting process, these criteria include [10]:

1. Capability to high temperature
2. High resistance to friction
3. High resistance to cracking
4. Low coefficient of friction

Cutting tools with good workability are very suitable for use in mass production processes, because in mass production it can be seen the influence of the quality of the cutting tools. The materials of cutting tools/chisels vary and each material has its own advantages.

The following are the various materials of the cutting tool? Commonly used chisels:
1. High Speed Steel (HSS)
2. High carbon steel
3. Non-iron cast alloy
4. Carbide steel
5. Ceramic

Cutting Chisels and Elements

In the cutting process, the cutting tool moves relative to the workpiece and removes (separates) a portion of the workpiece material which is commonly referred to as a chip. The part of the cutting tool that cuts to the depth of the workpiece material is called the cutting element of the tool. For the cutting element of a single-edged tool is the cutting edge. The sizing of the element of a cutting tool helps to correct the errors of the cutting element after sharpening, forms the finish for the cut surface and improves direction in tool operation. Overall cutting and sizing are called working elements [11]. The cutting element of each cutting tool forms a wedge shaped from the phase and flange, as shown in the **Fig. 2**.

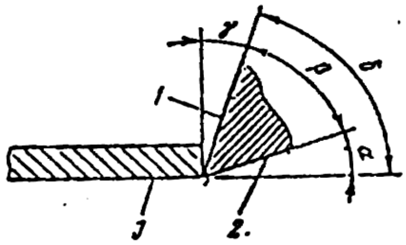

Fig. 2. Chisel cutting elements [11]

Description:
1. Face
2. Flank
3. Surface of cut

α = Relief angle ; γ = rake angle; δ = Nose angle; β = Plant angle

The surface 1 of the cutting edge where along the chip is displaced after separating from the

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workpiece after being cut, is called the face. The surface 2 of the cutting edge opposite the cut surface is called the flank. The surface 3 which along the chip is separated from the workpiece is called the surface of the cut. The plane that passes through a certain point on the cutting edge and touches the cutting surface is called the plane of the cut. At the time of cutting there will be a cutting force needed to fight the frictional resistance that arises when the tool cuts the work piece, which is equal to the product of the specific cutting resistance and the cross-sectional area of the cut [12]. There are three types of cutting forces that work when cutting (see **Fig. 3**), namely:

a. Feeding force/axial force (axial force/feed force = Fx); namely the force that occurs due to the process of feeding the workpiece. The direction of the force is usually opposite to the direction of the feed.
b. Radial force (radial force = Fx); is the force due to rotation of the workpiece. The direction of the force is perpendicular to the axial (cutting) force.
c. Cutting force/tangential force (cutting force/tangential force = Fz); is the force that occurs when the workpiece chip. The direction of the force is perpendicular to the radial force.

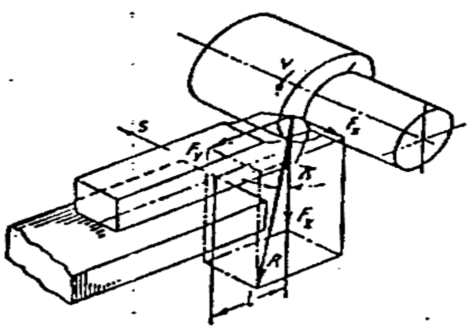

Fig. 3. Cutting styles [12]

In fact, the development of the use of machine tools is also accompanied by the development of the need for the use of cutting tools or chisels. The chisels used in the lathe are high-speed steel (HSS) chisels.

Effect of Cutting Variables on Surface Roughness

When working on a workpiece, a surface roughness parameter value will be produced. The price of the roughness parameter will be influenced by the cutting variables. The cutting variables that occur during the cutting process are variables that affect the cutting process, namely the cutting speed variable (V), machine speed (n), and cutting depth variable (a).

Cutting Speed

The average diameter of the workpiece, the type of material/workpiece, the type of rotary cutting tool, will affect the amount of cutting speed to be used. To calculate the value of cutting speed, the following formula can be used [13]:

$$V_S = \frac{\pi \cdot D \cdot n}{1000} \quad \text{(mm/minute)} \qquad [1]$$

With:

Vs = cutting speed
N = main axis rotation
D = workpiece diameter

$$= \frac{(do + dm)}{2} \quad \text{(mm)} \qquad [2]$$

do = initial diameter of workpiece (mm)
dm = final diameter of workpiece (mm)

Depth of Cut

The depth of cut is an important parameter that must be considered, the parameters that affect the depth of the feed include the type of hardness of the workpiece, the cutting tool/chisel, the cutting speed of the feed, and the rotation of the main axis. The depth of cut can be defined as the depth reached by the chisel that penetrates the depth of the workpiece in the machining process, but it can also be interpreted as the thickness of the chip that is cut by the chisel in a machining process, we can see in the formula below [14]:

$$a = \frac{(do + dm)}{2} \qquad [3]$$

With:

a = feeding depth (mm)
do = initial diameter of workpiece (mm)
dm = final diameter of workpiece (mm)

As in determining the price or feed value, the determination of the price or depth of cut is also largely determined by the price of the surface roughness parameter. For rough cuts, with low surface smoothness, the price or value for the depth of cut will be greater than the value or depth of cut for fine cuts (Finishing cut).

Feeding

Feeding motion is the distance traveled by the tool along the workpiece in a main rotation of the lathe (spindle). As an example, we can take the following if the lathe is conditioned for a feed

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motion of 0.50 mm/rev, then the tool will move along the workpiece with a distance of 5.50 mm for every one complete revolution made by the workpiece locked in tense. Feeding motion which is conditioned to a large value will affect the price of the resulting surface smoothness. In small cuts where the expected surface results have a high level of smoothness (finishing cut), the value will be smaller if we make a rounding cut that has a not too high level of smoothness. Usually rough cutting is done at the beginning of the process where the surface roughness price has not been the main assessment because usually the main assessment is approaching the desired size, almost reaching the final cut that demands the desired size and a certain level. The value of the feeding speed is determined by the magnitude of the feeding motion, as in the formula (4) [15].

$$V_f = f \cdot n \quad [4]$$

With:
Vf = Feeding speed (mm/minute)
f = Move eat (mm/rotation)
n = Main shaft rotation (lap/minute)

Surface roughness

Surface is a boundary that separates solid objects around it, the characteristics of a surface play an important role in the design of a machine element. Namely those related to friction, wear, lubrication, the ability of components to melt adhesive from two or more engine components and so on. The irregularity of the configuration of a surface in terms of its profile can be broken down into several levels, as shown in the table below [15]:

Table 1. Irregular configuration of a profile [15]

Level	Shape Measured Profile	Term	The cause
1		*Form error*	Error guiding plane of the machine tool bending of the tool and workpiece, position error when holding the object, distortion during the hardening process.
2		*waveness*	Tool malformation, tool centering error, vibration during cutting.
3		*grooves*	Traces or marks from the cut (tool tip shape and feed motion)
4		*flakes*	The process of formation of deformation rage due to sand emission module formation in the electroplating process
5			Combination of irregularity of levels 1-4

Surface Profile and Parameters

Measurement of surface roughness can be done by pulling the touch line (stylus), following a trajectory in the form of a straight line with a certain distance called along the measurement line (traversing length). The part of the measurement length is called the sample length.

The reproduction of the surface can be seen in the image and the terms on the surface profile are as follows:

1. An ideal geometric profile (geometrically ideal profile), is a profile of an ideal geometric surface (can be a straight line, a circle or a curved line)
2. The measured profile, is the profile of the measured surface
3. Reference profile, is a profile used to analyze the irregularity of the surface configuration.
4. The root profile is a reference profile that is shifted down so that the tangent is the lowest point of the measured profile.
5. Center profile, is the name given to the reference profile which is shifted in such a way that the total area of the areas above the middle profile reaches the measured profile.

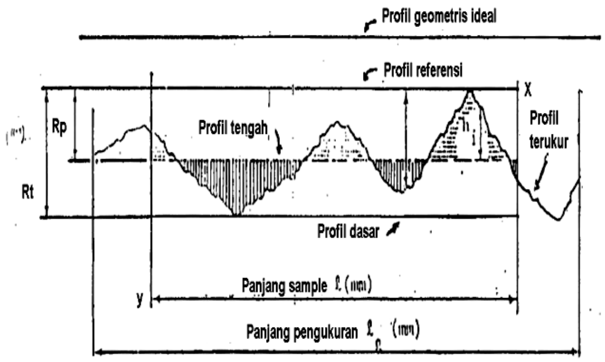

Fig. 4. Surface profile [16]

Measuring Instruments Accuracy

The accuracy of the measuring instrument used can affect the measurement value produced, this is indeed directly related to the measurement system but is more likely to be from the measuring instrument itself, and calibration of measuring instruments is absolutely necessary so that both alt-measuring devices that have used a digital system in reading the measurement results or measuring instruments must be calibrated. Measure that still uses a mechanical system [16].

Deviation Value

It has been discussed previously that the measurement allows deviations to occur. The magnitude of the deviation can be seen by using the average arithmetic value with the following values:

$$X_m = \frac{1}{N}\sum_{i=1}^{N} X_i \quad [5]$$

With:
Xm = Test average score

N = Number of tests on measuring objects
Xi = Measurement results

Limitation of deviation value

$$di = Xi - Xm \qquad [6]$$

With:
di = deviation
Xi = results of measurements taken
Xm = average value

The value of the standard deviation or the square root of the mean is overcome by

$$Ra = \left[\frac{1}{N} \sum_{i-1}^{1} (Xi - Xm) \right]^{0.5} \qquad [7]$$

With:
Ra = mean deviation of surface hardness
N = number of measurements
Xi = measurement results
Xm = average value

Dimensions and Size of Test Objects

It is concerned with determining the dimensions and workpiece sizes for geotmetric elements (lines/planes, radius, diameter, and so on). So that by studying the geometric can be determined the outline of the type of machining process and the sequence of work and the selection of the appropriate machine tool. The shape of the workpiece and the volume of the workspace determined by the dimensions of the spindle where the workpiece is installed (positioning) must be considered, so that the forbidden area can be identified to avoid tool collisions on the surface of the fixture.

The material used as written above is in solid form with a length of 130 mm and a diameter of 30 mm for the first test object, 33 mm for the second test object. The part of the workpiece that is clamped to the workpiece clamp and the Forbidden area is about 40 mm long, while the size of the workspace volume of the workpiece is 90 mm from the end of the workpiece that is not clamped with a chuck (free) so that the distance between the end of the cutting length and the surface is the workpiece clamp is still considered safe. Because the part that is turned is longer than the clamped part, the free end is supported by a loose head flashlight in order to keep the rotation of the workpiece centric and the workpiece is not damaged or deformed during cutting. The shape of the test object to be worked on is stratified with different diameters and a cut length of 30 mm/level, a picture of the workpiece can be seen in **Fig. 7**.

EXPERIMENTAL METHOD

The research flowchart is done as in **Fig. 5**.

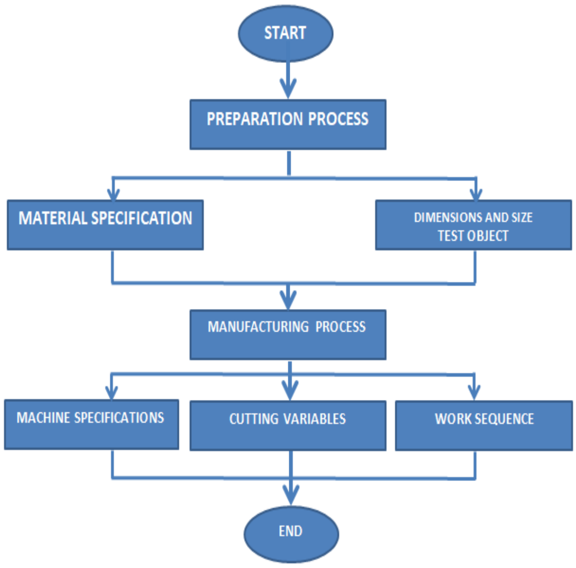

Fig. 5. Flowchart of the process of making test objects

RESULTS AND DISCUSSION

Samples of test specimens can be seen in **Fig. 6-7**.

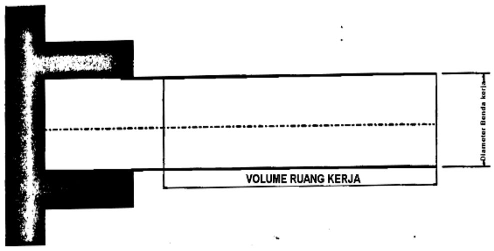

Fig. 6. The position of the workpiece on the chuck

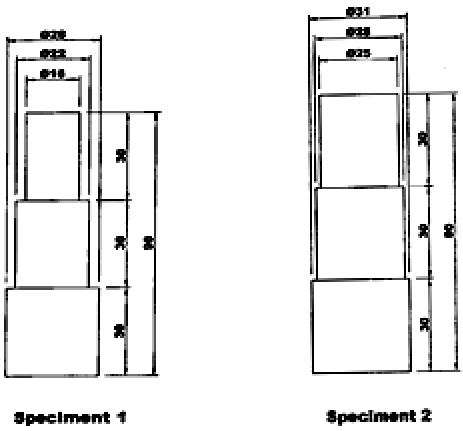

Fig. 7. Specimen of the test object

The following are the test results of the sample can be seen in the **Table 2-3.**

Table 2. Cutting Variables on Test Object I (Specimen I) (Spindle rotation, n: Fixed feed, a, changing)

Initial Diameter (mm)	Final Diameter (mm)	Diameter rata-rata (mm)	Average diameter (mm)	Subtraction (mm)	Spindle Round n(rpm)	Cutting Speed vc(m/min)
30	29.2	29.6	0.4	0.8	540	50.19
29.2	28	28.6	0.6	1.2	540	48.49
28	26.4	27.2	0.8	1.6	540	46.12
26.4	24.4	25.4	1	2	540	43.06
24.4	22	23.2	1.2	2.4	540	39.34
22	19.2	20.6	1.4	2.8	540	34.92
19.2	16	17.6	1.6	3.2	540	29.84

Table 3. Cutting Variables on Test Objects II (Specimen II) (Depth of Cut, a: Fixed, engine speed, n, change)

Initial Diameter (mm)	Final Diameter (mm)	Diameter rata-rata (mm)	Average diameter (mm)	Subtraction (mm)	Spindle Round n(rpm)	Cutting Speed vc(m/min)
33	32	32.5	0.5	1	440	44.90
32	31	31.5	0.5	1	440	43.52
31	30	30.5	0.5	1	540	51.71
30	29	29.5	0.5	1	540	50.02
29	28	28.5	0.5	1	540	48.32
28	27	27.5	0.5	1	740	63.89
27	26	26.5	0.5	1	740	61.57
26	25	25.5	0.5	1	740	59.25

Surface Roughness Test

In this testing process, the steps taken are as shown in the flow chart (**Fig. 8**).

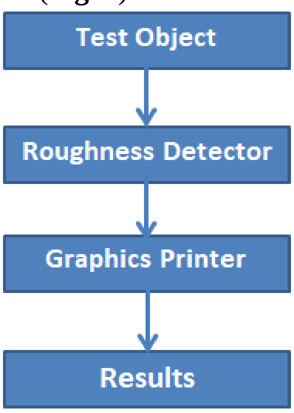

Fig. 8. Flowchart of the Testing process

The testing process carried out is the result of the turning process with variable cutting speed (Vc), turning with variable depth of feed (a), spindle rotation (n), which is used in each step of the process so that changes in the value of cutting speed and diameter will be obtained.

Table 4. Surface roughness test data on test object I

Test object sample code	tier/ Test Point	Surface roughness value (μm)	
		Ra	Ry
I	I	4,06	21,66
	II	7,82	26,84
	III	7,02	29,86

Table 5. Surface roughness test data on test objects II

Test object sample code	tier/ Test Point	Surface roughness value (μm)	
		Ra	Ry
I	I	6,78	31,44
	II	3,64	16,74
	III	6,14	29,40

Table 6. Calculation of Statistical Data Test Results of Test Objects

Test Object	Surface roughness value (μm)				
	Ra1	Ra2	Ra3	Total Ra	Average Ra
A	4.06	7.82	7.02	18.9	6.3
B	6.78	3.64	6.14	16.56	5.52

Table 7. Arithmetic calculation results of the average test object I

Number	(Xi-Xm)	(Xi-Xm) ^{2}
1	-2.24	5.0176
2	1.52	2.3104
3	0.72	0.5184
Total	0.000	7.846

Notes :

Xi = Surface roughness value; Ra each level

Xm = Average roughness value; Average Ra

Table 8. Arithmetic calculation results of the average test object II

Number	(Xi-Xm)	(Xi-Xm) ^{2}
1	-1.26	1.5876
2	1.52	3.5344
3	0.72	0.3844
Total	0.980	5.506

Analysis

The data obtained after the surface roughness test and calculation were divided into the treatment carried out according to the cutting variables, namely the cutting variable with cutting speed variable (a), cutting depth variable (a), and engine speed (n). The surface roughness results obtained from the results of the tests carried out are the average surface roughness value (Ra), the maximum roughness value (Ry), from each surface of the test object obtained from each surface of the test object.

The average value of the surface area is symbolized by (Ra), which is the arithmetic mean of the measured plane. This roughness price is usually used as a reference for measuring fields. The tests that have been carried out have produced a series of graphs, from these graphs it can be seen the effect of the results of the variations in the cuts made.

Table 9. Results of the analysis of the average surface roughness (Ra) On the test object I (against the thickness of the feed; a)

Test Object	Surface Roughness Value (μm)				
	Ra 1	Ra 2	Ra 3	Total Ra	Average Ra
I	4.06	7.82	7.02	18.9	6.3

Table 10. The results of the analysis of the average surface roughness (Ra) On the test object II (against cutting speed; Vc)

Test Object	Surface Roughness Value (μm)				
	Ra 1	Ra 2	Ra 3	Total Ra	Average Ra
II	6.78	3.64	6.14	16.56	5.52

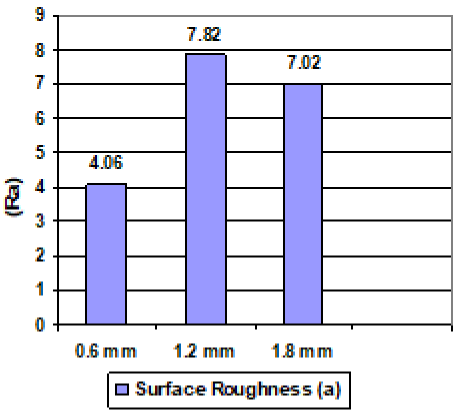

Fig. 9. Graph of Surface Roughness Value on Test Object I (Against the Thickness of Feeding; a)

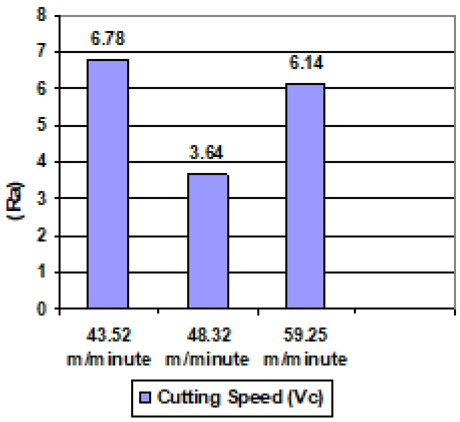

Fig. 10. Graph of Surface Roughness Values on Test Objects II (to cutting speed; Vc)

CONCLUSION

Surface hardness resulting from the graph of cutting results with several cutting variables that have been carried out, namely by turning with a conventional lathe with several cutting variables, namely cutting speed (V), cutting with variable depth of feed (a) and against machine speed (n). . So from these tests can produce several conclusions including:

1) Selection of good cutting variable prices will result in good surface hardness prices. For variable cutting with speed variations with smaller object diameters, it is better to use a higher cutting speed.
2) With the selection of speed values that vary for the price of the feed speed of 43.52 m/minute, the surface hardness value is 6.78 m, the feed speed is 48.52 m/minute the surface hardness value is 3.64 m and the feed speed is 59.25 m/min, the surface hardness value is 6.14 m.
3) For the thickness of the feeder that varies, namely for the thickness of the feeder of 4.06 m, for the thickness of the feeder of 2.4 mm, the surface hardness is 27.82 m and for the thickness of the feeder is 3.2 mm, the value of the surface hardness is 7.02 m.
4) Machine vibrations that occur during machining will also result in poor surface hardness.
5) Errors in placing the object (positioning error) will affect the price of the resulting hardness, both the placement of the resulting hardness of the workpiece, the placement of the workpiece during cutting or the placement of the workpiece at the time of measurement.
6) On the graph of the test results, odd results are obtained, namely, on the graph of surface hardness VS thickness of the feeder where the result that should be obtained is that the greater the thickness of the feeder, the greater the value of the surface hardness (with a note that the speed of rotation of the chuck/machine is fixed). Similarly, the graph of surface hardness VS cutting speed, the greater the value of the cutting speed, the greater the value of the surface hardness (spindle rotation speed varies).
7) The advantage of this test is that the results of the surface hardness due to the turning process with a conventional lathe are known, so that an examiner's maturity and self-care are required to obtain maximum testing results.

8) The factors that cause the test results are not optimal due to several things:
   a. The condition of the lathe that we use
   b. Condition of the testing equipment used
   c. The human error factor during the test object testing process and the test object testing process.

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