Experimental Research on The Hardness of SCM 440 Material on The Level of Surface Roughness in The CNC Turning Process

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Abstract: - This research is motivated by the development of engineering science in industry which has experienced significant progress in the last few decades. Apart from that, there is still a lack of research related to the surface roughness analysis on materials influenced by hardening processes with different cooling media. This research aims to carry out the CNC Turning machining process on SCM440 material with different cooling media treatments and analyze the level of surface roughness on machining parameters. The machining variables from this research are spindle speed and feed rate in the CNC Turning machining process. The research process will start with the hardening process using the quenching method on the test sample, the machining process, the roughness test, and data analysis. The research results showed that the best hardness value for the room-temperature cooling media was 244.4 HB and the lowest hardness value for the water-cooling media was 172.82 HB. Apart from that, the hardness sample HB 172.82 has a rougher level and the highest hardness sample HB 244.4 has a low roughness level in Ra and Rq.

Key-Words: Quenching, SCM440 Steel, Surface Roughness

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1 Introduction

The toughness of the material in machine components is a determining factor in selecting the best material. By increasing the hardness value of a certain material, the toughness of that material will increase. Apart from that, increasing the hardness value of the material will affect the machining process in the manufacturing process into a component. One thing that influences it is the roughness value on the surface resulting from the machining process.

CNC machines have greatly influenced the development of the manufacturing industry because they can produce objects with high accuracy where the product manufacturing process uses CAD/CAM software to support the creation of CNC programs [1]. The CNC machining process method has several variations to obtain maximum objects, as stated by Okokpujie, during the machining process it is necessary to carry out multi-delivery cooling with various lubrication methods [2]. The use of CNC machines is currently the dominant product forming tool due to market demand, product quality according to standards, and costs [3].

Surface roughness is an important parameter in machining processes as it directly affects the performance and quality of the finished product. By measuring the surface roughness of a material, engineers and manufacturers can determine how smooth or rough the surface is, which helps in evaluating its suitability for particular applications, such as automotive components, aerospace parts, or medical devices. It found that higher tensile strength workpiece materials had better surface roughness values. Lower feed rates resulted in superior surface roughness, and alloy materials generally had better surface roughness values compared to metal materials [4]. The study emphasizes the importance of cross-validation in evaluating the performance of these algorithms and highlights the potential of these models in accurately predicting surface roughness and workpiece surface roughness in cylindrical turning operations [5].

Hardness testing is an essential part of machining processes, as it provides valuable information about the material's mechanical properties. The hardness of a material determines its resistance to deformation, such as cutting, shaping, or drilling. The results of both the experimental and FEA cases are compared to the theoretical Rockwell hardness of aluminum [6]. Using a range of cutting settings, the effects of heat treatments on hardness, surface finishing, cutting force, and microstructure were assessed both before and after heat treatment [7]. Both before and after heat treatment, the cutting force and other characteristics were assessed. The outcomes demonstrated that heat treatments had a direct impact on cutting force and machinability. Stated differently, a relationship was found between the specimens' heat treatment and machinability [8].

SCM440 is a low alloy steel that offers excellent strength, toughness, and wear resistance. The material is often chosen for machining CNC due to its impressive properties. According to the study, a key factor in influencing the resistance of SCM440 tempered martensitic steel to hydrogen embrittlement is its tempering temperature [9]. SCM440 steel was experimented with using a TiN-coated cutting tool with a 0.5 mm radius tip in the investigation of the effects of cutting depth, feed rate, and speed on cutting force. Two novel shear force models have been constructed using the cutting force model and two data transformations of Box-Cox and Johnson [10].

Based on the previously mentioned arguments, this study will experiment with the steel SCM440 process to demonstrate the relationship between quenching material in CNC turning and surface roughness following the turning process.

2 Methodology

The test sample material used SCM440 steel. The hardness value of SCM440 steel material is at a maximum annealing of 255HB, while tempering is 30-38 HRC. The hardness values carried out by the heating process are shown in Table 1.

Table 1. Heatreatment of steel SCM440

Method	Temperature (ºC)	Cooling
Normalizing	830-880	Air cooling
Annealing	830	Furnace cooling
Hardening	830-880	Oil quenching
Tempering	530-630	Rapid cooling

In this research, the hardening process was carried out using a heating technique in an oven followed by a cooling process using varied cooling media. The variations in cooling media in the hardening process are; 1) Room temperature, 2) Water, 3) SEA oil, and 4) Quenching oil.

The equipment used in this research is a thermos scientific oven and a hardness tester. The purpose of the thermos scientific oven is to heat the test sample by heating it in a closed manner. The heating time and heat temperature are set uniformly to get the same treatment for each sample. The purpose of the hardness test tool is to determine the hardness value of the heavy equipment component pins.

The equipment used in this research is a CNC Turning Hardinge machine. CNC machines are used to shape the sample material into pins. Apart from that, the test equipment used is the Mitutoyo surface roughness test. This tool functions to see the level of surface roughness of the machining results. From the level of roughness, it can be seen the influence of the cooling medium on the material hardening process.

The method used in this study is the analysis of the surface roughness level of machining parameters and cooling media in the material hardening process. In this study, the machining parameters that will be varied are spindle rotation and feed rate in CNC Turning machining. The hardened material will become a test sample in machining. The variations in cooling media in the test samples are; 1) Room temperature, 2) Water, 3) SEA oil, 4) Cold oil.

Specimen preparation is carried out by cutting material according to the size of the bulldozer pin product using a bandsaw machine. The next process is to carry out a heat treatment process using a Nabertherm furnace with a capacity of up to 3000 ºC. The heat treatment process begins with a furnace preparation process at 300 ºC for 2 hours 30 minutes. When the temperature has reached 300 ºC, the test sample is inserted into the furnace and then held for 20 minutes. Then increase the temperature to 400 ºC for 40 minutes. When the temperature of 400 ºC is reached, hold for 10 minutes. Then the cooling process is carried out using 4 variations of cooling media, namely oil, cold oil, water and room temperature.

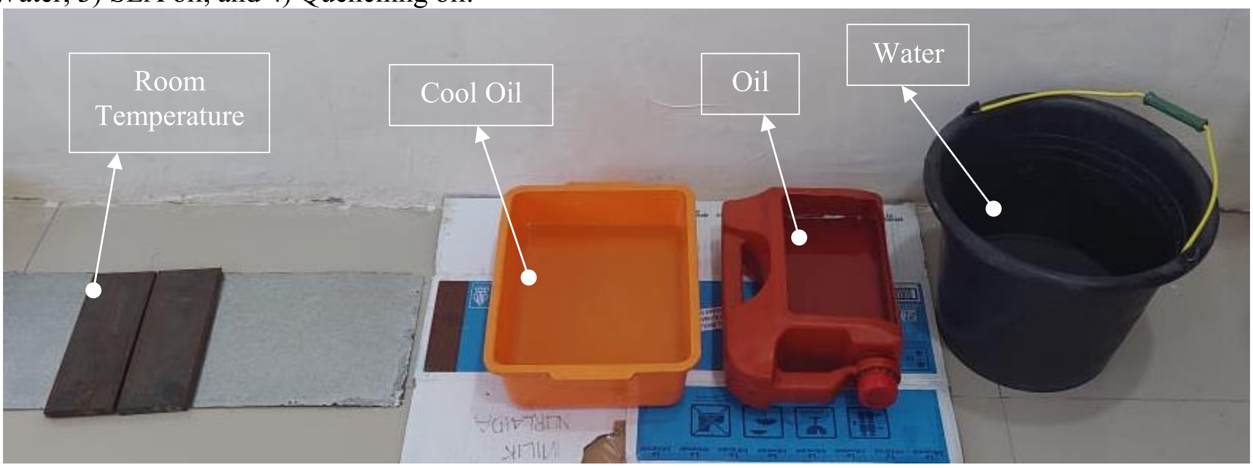

Figure 1. Cooling method of quenching process

The cooling process was carried out with a different initial temperature for each cooling as shown in Table 2. The cooling time was carried out for 110 minutes on each cooling medium. The final temperature of the cooling media after the cooling process produces room temperature cooling media which has a higher temperature value of 41.0 ºC and cold oil cooling media has the lowest temperature measurement of 32.2 ºC.

Table 2. First temperature before cooling process of the samples

Cooling Media	Beginning of temperature	End of temperature
Room Temperature	26.3 ºC	41.0 ºC
Cooling Oil	13.2 ºC	32.2 ºC
Oil	27.2 ºC	38.5 ºC
Water	27.0 ºC	34.5 ºC

After the quenching process is carried out, sample formation and surface roughness testing are carried out. The equipment used is a CNC Turning Hardinge machine to form the sample material into pins. After forming the material, surface roughness testing was carried out using a Mitutoyo SJ-310 surface roughness tester. From the level of surface roughness of the material, it can be seen the influence of the cooling medium on the material quenching process. Each test sample with different hardness due to differences in cooling media for the hardening process will be machined in 3 samples with an ingestion depth of 1 mm.

The machining parameters in this research use variations in feed speed of 0.1 mm/rev, 0.2 mm/rev, and 0.3 mm/rev. This variation is to see how fast the cutting speed is, which will affect the time and surface roughness results on the product. The engine speed used was 1000 RPM in each research sample. Based on the formula for calculating tool speed in production, it is the amount of tool displacement multiplied by the machine rotation in mm/minute. so the formula is;

$$F = f \times N \quad \text{…………(1)}$$

From this equation, the tool speed obtained if calculated to determine the production time is for a speed of 0.1 mm/revolution of 100 mm/minute, a speed of 0.2 mm/revolution of 200 mm/minute, and a speed of 0.3 mm/revolution of 300 mm/minute.

The feed thickness for the cutting process is 1 mm for each test sample. Apart from that, the insert used is the VNMG finishing type with a cutting radius of 0.8 mm. According to the plan, the sample diameter is 60 mm. The test sample uses a dry cooling system where there is no cooling in the form of liquid or compressed air. The cutting length was 800 mm for each research sample.

3 Result and Discussion

3.1 Hardness Test

The hardness test was carried out using a Bohler EMS45 Hardness Tester machine. The hardness test process is to determine the hardness value of test samples that have gone through a quenching process with various cooling media. The hardness value taken on the machine is carried out digitally by placing a steel ball on the test sample. Before testing, the machine is first calibrated using a material tester from the machine.

The type of hardness tester used is Brinnel (HB30). The load on the 1226 N hardness tester machine with the machine settings is HB5. The testing process was carried out 5 times repeatedly on each sample with different location points on the sample surface. This is done to obtain an optimal average hardness value for each sample.

Table 3. HB of every cooling media

Cooling media	HB	Average of HB
Room Temperature	231.4	244.4
	254.6	
	234.5	
	245.3	
	256.2	
Water	197.3	172.82
	176.3	
	139.4	
	176.3	
	174.8	
Cooling Water	181.2	205
	219.2	
	215.9	
	208.3	
	200.4	
Oil	254.6	233.58
	226.8	
	206.6	
	253.1	
	226.8	

In Table 3, the hardness value of each test sample with various cooling media. The average hardness value was obtained, where the lowest hardness was for water cooling media of 172.82 HB. Meanwhile, the highest average level of hardness is the room temperature cooling media of 244.4 HB.

The graph shown in Figure 2 shows that the hardness values are not much different between room temperature cooling media and oil, namely 244.4 HB and 233.58 HB. This effect is almost related to the rate of decrease in temperature during the quenching process, where the cooling rate is gradual.

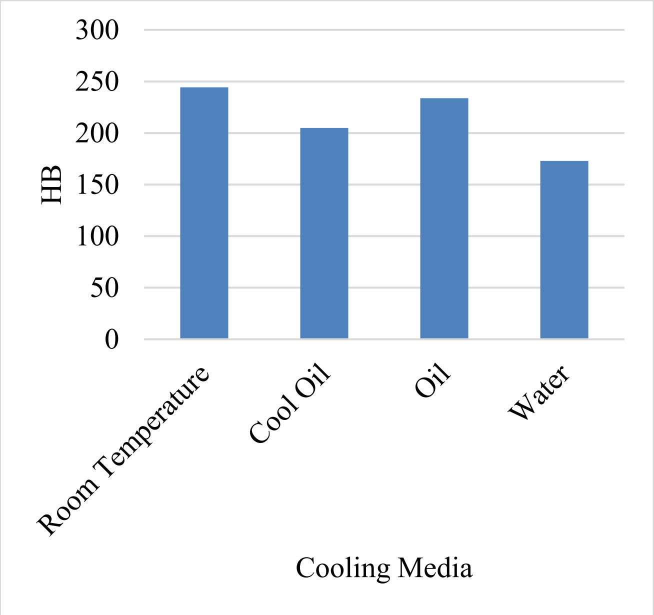

Figure 2. Graph of the hardness test reslt

3.2 Hardness Test

The roughness testing process is carried out to determine the amount of roughness that occurs in test samples that have been machined by looking at variations in cutting speed. Apart from that, the test samples have different hardness values to determine the influence that occurs on the level of roughness. This can be a guide and reference for decision makers in making products on CNC Turning machines.

Figure 3. Mitutoyo SJ-310

The roughness test tool used is Mitutoyo SJ-310. The standard used is ISO 1997 to find the roughness values Ra and Rq after testing. The principle of testing is to scratch the surface of the test sample to see the surface roughness. The test equipment parameters are a scratch length of 5 mm and the method used is GAUSS. The tool cut-off is set up at 0.8 mm. Before testing, the tool is first calibrated using a standard surface for the tool.

Table 4. Surface roughness of samples

Sample	Feed Rate (mm/rot)	Surface Ra (µm)	Rq (µm)
Sample 1	0.1	0.427	0.566
	0.2	0.578	0.688
	0.3	0.616	0.738
Sample 2	0.1	0.329	0.469
	0.2	0.475	0.564
	0.3	0.575	0.719
Sample 3	0.1	0.389	0.536
	0.2	0.53	0.631
	0.3	0.538	0.648
Sample 4	0.1	0.367	0.467
	0.2	0.402	0.507
	0.3	0.514	0.633

The main difference between Ra and Rq is in the calculation method and deviation weights. Although both provide information about surface roughness, Rq can provide a more comprehensive view of surface fluctuations due to its quadratic nature. The two are generally used together to provide a more complete understanding of surface roughness characteristics.

In Table 4 you can see the roughness data for each test sample which has varying hardness values. It can be seen that the deviations that occur between Ra and Rq are not much different. So that the surface roughness value that occurs in each sample has almost the same surface fluctuation characteristics. However, from table 3 it can be seen that there was an increase in the roughness value from 0.1 mm/rev to 0.2 mm/rev at the feed rate for each sample.

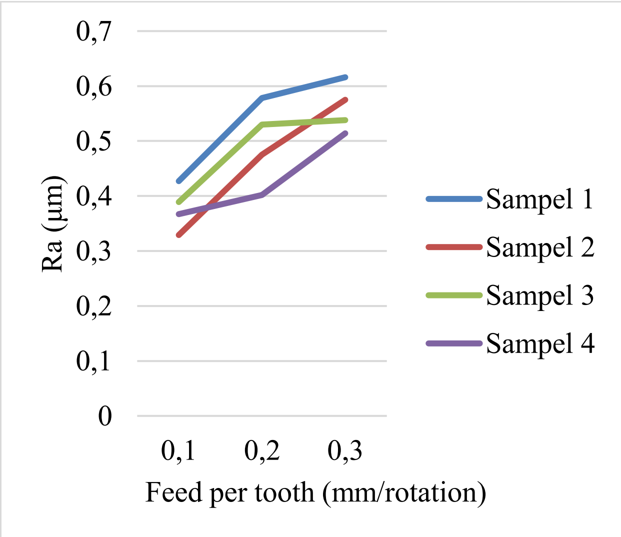

Figure 4. Graph of surface test Ra

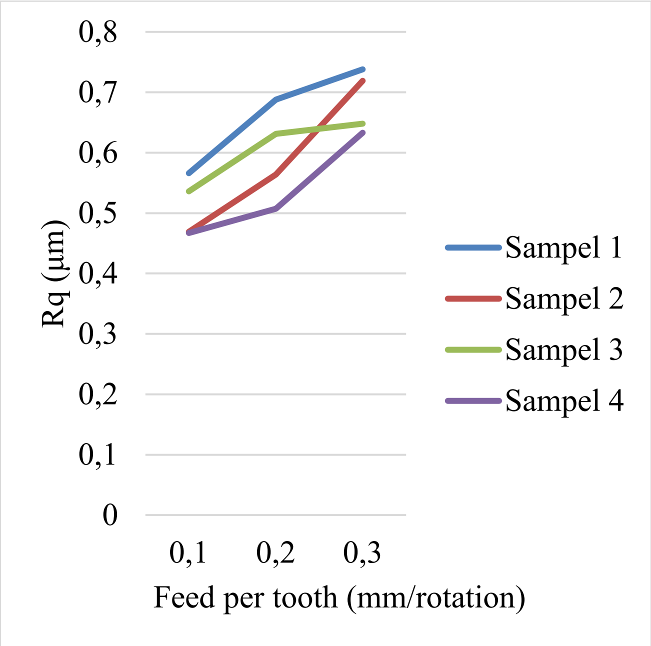

Figure 5. Graph of surface test Rq

It can also be seen in Figures 4 and 5 on the surface roughness test graphs for Ra and Rq that the roughness value increases with each additional feed rate. Each test sample results in relatively the same value between Ra and Rq. Sample 1 which has a hardness value of HB 172.82 has a rougher level in Ra and Rq. The roughness is good for feed rate variations of 0.1 to 0.3 mm/rev. Meanwhile, sample 4 with the highest hardness value of HB 244.4 has a low level of roughness in Ra and Rq.

If it is related to the time needed to cut, according to calculations it is found that a feed rate of at most 0.3 mm/revolution has the highest level of roughness. So, the greater the feed rate, the greater the level of roughness that will be produced.

4 Conclusion

This research obtained the following conclusions; (1) Heat treatment using the quenching method on SCM440 material as a test sample has been carried out at a certain heat temperature and time. Apart from that, the process of cooling the test samples was carried out in various desired media, namely room temperature, water, oil and cold oil. Then the cutting process using a CNC Turning machine on the hardened SCM 440 material was carried out. (2) The hardness value for each sample was obtained on different cooling media, namely the best hardness value was at room temperature of 244.4 HB. The lowest hardness value for water cooling media is 172.82 HB.

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