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Machinability Analysis of SUH 35 Material Subjected to Annealing Process on Engine Valve Making Surface Grinding

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Abstract-- *Steel has various physical and mechanical properties. The very high hardness of steel makes it difficult to form or process with a machine. Based on these problems, there needs to be a treatment (treatment) that can improve the mechanical properties of steel. The annealing process is the process of heat treatment of metals or alloys by heating the metal to austenite temperatures, holding it at that temperature for a while, and cooling the metal at a very slow cooling rate. The heat treatment process aims to improve the mechanical properties of the metal or alloy. In this study, SUH 35 steel was used as the test material. Eight test materials are prepared, namely four materials Unannealed and four materials treated with annealing. Annealing specimens are given heat treatment with a temperature of 750 ° C ± 10 ° C with a holding time of 60 minutes. This specimen is carried out by turning process with variable machining feeding that varies 0,25 mm/revolution, 0.50 mm/revolution, 0,75 mm/revolution, and 1 mm/revolution. The results of this study show that the annealed material has a lower roughness value of 311.49 VHN. In comparison, the Unannealed sample has a hardness value of 607.59 VHN, which shows better machinability in the annealed material. The results of the feeding variation show that the greater the feeding value, the more it will affect the increase in the roughness, resulting in the surface grinding process.*

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1. INTRODUCTION

The material used in the engine valve manufacturing process is SUH 35 steel. Steel is one of the many materials used, especially in industries that require primary materials with high hardness, stiffness, and ductility values. Steel's very high hardness makes it difficult to shape or process by machine. In other words, its machinability is very low. Machinability affects cutting tool life, cutting effort, and surface roughness, which results in the machining process [2].

Steel materials can be improved in various ways, one of which is by heat treatment [5]. During the heat treatment process, a factor that affects a material's properties is temperature. A suitable heat treatment method to increase the ductility of a material is to use annealing[2]. Annealing is a process of heating and cooling, usually applied to produce softness. The term also refers to treatment methods intended to change mechanical or physical properties, to produce a defined microstructure, or to remove gases. The operating temperature and cooling rate depend on the material being annealed and the purpose of the treatment[8]. Annealing can also reduce the hardness value of the material and even damage it if the hardness value of the steel becomes very low and is no longer suitable for its purpose[3].

Various machinability tests have been developed to assess specific cutting conditions, while others are used for more general machining assessments. However, the three assessment parameters of machinability are i) cutting force, ii) tool life, and iii) surface finishing[10]. The roughness of a machining process is also affected by machining variables. One of the variables that affect roughness is the feeding value[3], Where heat treatment of steel material also affects the machinability of the material[10]

2. METHODOLOGY

This research uses experimental methods to make engine valves. It uses SUH 35 annealed material and an Unannealed sample, with a composition of C 0.56%, Si 0.20%, Mn 8.52%, P 0.026%, S 0.001%, Ni 3.71%, Cr 21.13%, and N 0.42%. Then, the surface grinding process is carried out on both types of material. The following are the process stages of this research.

1. Starting stage. At this stage, the researcher determines the field, research topic, and formulation of research methods to be carried out.
2. Literature study stage. In completing the research, researchers tried to solve the problem by looking at the literature that had been studied, including literature on steel science, machining processes, and annealing processes.
3. Preparing the test material. This study uses the same type of SUH 35 material but with different treatments. SUH 35 material with annealing treatment and Unannealed will be prepared for a series of tests, including hardness test, microstructure Observation, and surface grinding process.
4. The hardness testing stage. The test materials with annealing treatment and Unannealed will be subjected to a hardness test process to obtain the hardness values of the two types of specimens. The hardness test is conducted using the Vickers hardness test method,
5. At this stage, microstructure observations were carried out on materials using an unannealed treatment. The microstructure Observation process was carried out at the Mercubuana campus lab,
6. The surface grinding process is carried out on materials with annealing treatment and Unannealed, where the process is carried out with predetermined parameters.
7. Roughness measurement stage. Roughness measurement is carried out after the surface grinding process. Where the roughness taken is arithmetic roughness (Ra). In the roughness measurement process using the Mitutoyo SJ 2100P surface roughness tool.
8. Data analysis stage: At this stage, the material roughness data generated from the surface grinding process will be analyzed. The roughness results obtained from SUH 35 materials that have been annealed and Unannealed will be compared. Which roughness is one of the machinability parameters.
9. The last stage of this research is to conclude this research process. Then, proceed with providing suggestions on the following research to improve existing deficiencies.

2.1 Hardness test

Hardness testing was carried out on specimens that were unannealed, as well as material specimens that had been annealed. Hardness testing is done using the Vickers hardness test method. The Vickers test is carried out by pressing the test object or specimen with a pyramid-shaped diamond indenter with a rectangular base. The angle of the facing surfaces is 136°. Pressing by the indenter will produce a trace or indentation on the test object's surface. The annealing process can affect the hardness number of a steel material [8].

Hardness testing was carried out on three Unannealed samples and three annealed specimens. Hardness testing aims to collect data on the hardness of the annealing effect on the material before and after the Full Annealing process [8].

For Vickers hardness testing, the surface of the specimen needs to be well prepared. If the surface of the specimen is not flat, it needs to be leveled with a grinding machine. Furthermore, the surface of the specimen is smoothed with a polishing machine to remove scale, oil, paint, and other impurities using a polishing machine.

Testing steps:

1. Carefully prepare the surface of the specimen.
2. Press the power button to start the machine.
3. Set the test load through the load selector knob by turning the load selector knob and then select the appropriate test load size.
4. Place the specimen on the test table, then turn the hand wheel of the lifting screw rod to raise the specimen close to the indentor.

5. Manually rotate the turret until the microscope's objective lens is perpendicular to the specimen surface.
6. Observe the specimen surface through the ocular, then slowly raise the specimen until the proper focus is obtained.
7. Turn the turret again until the indenter is in a position perpendicular to the surface of the specimen.
8. Press the start button. The indenter will begin pressing the specimen, and the machine will automatically apply the test load.
9. Wait a few moments (usually 10 - 15 seconds) until the dwell time is reached.
10. After completing the loan application process, rotate the turret to place the objective lens perpendicular to the specimen surface.
11. Measure both diagonals of the indentation resulting from pressing the indenter. First, measure the diagonal of the horizontal direction of the trace by looking through the ocular and rotating the microscope drum wheel to measure the diagonal of the trace.
12. Next, rotate the microscope 90° so that its position becomes upright, then measure the diagonal of the upright direction of the trace in the same way as above.
13. After obtaining the average diagonal size of the trace (indentation), the Vickers hardness number of the material tested can be determined by looking at the Vickers hardness testing table or by formula.

2.2 Microstructure Observation

Before doing the microstructure Observation, we should cut the engine valve parts. The part used for the sample is the valve head. The valve head then leveled and smoothed the surface until it met the specimen requirements using sandpaper sizes 60, 240, and 1000. Then, it was cleaned with a fine lab cloth and given H_2SO_4 liquid, dissolved in distilled water to make it shiny. Then, it was viewed with an SEM microscope (Scanning Electron Microscope) to get a structural image of the SUH 35 steel specimen.

2.3 Surface grinding process

The surface grinding process is carried out on two types of materials that are different in treatment: SUH 35 material without an annealing process and SUH 35 material that has been annealed. The surface grinding process was done on an AIDA 4CV surface grinding heat and seat machine. Using the following parameters. As follows:

Grinding wheel revolution: 3200m/min
Oscillation feed: 2mm - 4mm
Diameter of stem : 4,5mm – 7mm
Diameter of heat : 16mm – 39mm
Overall length : 64mm – 130mm

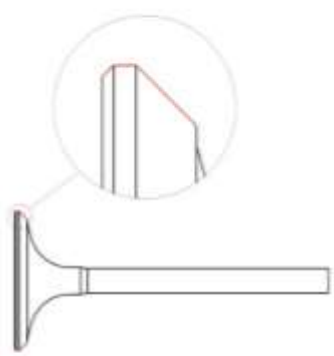

Figure 1 Engine valve parts that will be subjected to surface grinding

Diamond grinding wheels are used in this surface grinding process. A GW 410x23x160 CBY 80PC5 (NK-001) NORITAKE grinding wheel is used. This process can be observed to demonstrate the capability of the machine when processing material with annealing and Unannealed.

This research is focused on the surface grinding process of the valve head using two types of materials that experience differences in heat treatment between annealing and no annealing. The material was subjected to a surface grinding head process with a constant cutting speed against the workpiece material to obtain a correlation between surface roughness and workpiece material.
This study consisted of 2 experimental stages, namely:

1. In the first experiment, surface grinding the test Unannealed sample with machine parameters of depth of cut 0.2 mm, feeding varies between 0.25mm/rev, 0.50mm/rev, 0.75mm/rev, 1mm/rev, and constant speed.
2. Experiment Two, surface grinding the annealed test material with machine parameters of the depth of cut 0.2mm, feeding varied between 0.25mm/rev, 0.50mm/rev, 0.75mm/rev, 1mm/rev, and constant speed.

2.4 Roughness measurement

The tactile method is the industry's most straightforward and most frequently used method of measuring surface roughness. In this method, a special needle-shaped stylus crosses the material's surface and shows the surface roughness value.

3. RESULT AND DISCUSSION

3.1 Hardness test

a. Hardness test of Unannealed sample

From the results of the hardness testing of materials Unannealed, the average hardness value is 607.59 VHN, and from the results of hardness testing of annealed materials, the average hardness value is 311.49 VHN, as shown in Table 1 below,

Tabel 1 Hardness value of Unannealed sample

Point	D1	D2	Average D	Average diagonal	VHN	Average VHN
forging (head) 1	125.67	122.60	124.13	123,53	601.71	**607,59 VHN**
forging (head) 2	124.78	122.60	123.69		606.09	
forging (head) 3	122.98	122.60	122.79		614.98	

Table 1 shows the hardness test results on specimens Unannealed in the area (HEAD). Column one is diagonal indent 1 (one), column two is diagonal indent 2 (two), and the third column is the average of diagonals one and two. The results of this diagonal average will later be used to calculate the Vickers hardness value. This average data will be recorded, and then the Vickers hardness tool will automatically calculate the hardness number of the material that has been tested. The measurement results of the hardness test on the Unannealed sample showed a high hardness value of 607.59 VHN, and the hardness test on the annealing treatment material became lower at 311.49 VHN. This shows that the annealing heat treatment can affect the hardness value of SUH 35 metal.

b. Hardness test of annealed material

In the hardness test process, the annealed SUH 35 material obtained a hardness value of 311.49 VHN. This can be observed in Table 2.

Tabel 2 Hardness value of annealed material

Point	D1	D2	Average D	VHN	Average VHN
annealing (head) 1	173.25	170.92	172.53	313.11	**311,49 VHN**
annealing (head) 2	172.37	172.71		311,49	

annealing (head) 3	173.25	172.71	309,88

Table 2 shows the hardness test results on specimens that have passed the annealing process in the area (HEAD). Column one is diagonal indent 1 (one), column two is diagonal indent 2 (two), and the third column is the average of diagonals one and two. Furthermore, the results of this diagonal average will later be used to calculate the Vickers hardness value. This average data will be recorded, and then the Vickers hardness tool will automatically calculate the hardness number of the material that has been tested.

3.2 Microstructure Analysis

a. Microstructure analysis of Unannealed specimens

This forging specimen is to form the head valve part, where the end of the product is heated first (upsetter) to a temperature of 1200^0C with a heating time of 14 seconds, then forms a dango (name of the product) then inserted into the forging dies to be pressed. Microstructure observation is carried out on unannealed materials, namely materials that have gone through the forging process. The results of the microstructure of SUH 35 material can be observed in Figure 2.

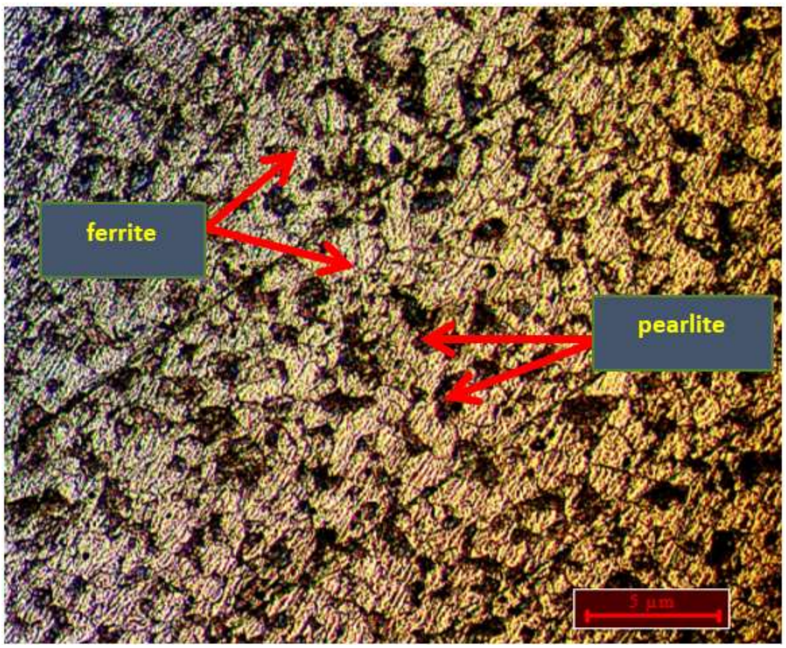

Figure 2 Microstructure of SUH 35 Steel Forging Specimen Head Section (Valve Head)

Low carbon steel material is given heat treatment with a temperature of 1200 ° C on the valve head, with a heating time of 14 seconds. The heating process forms a dango and then is pressed using a press machine. Based on Figure 3, this heat treatment process changes its microstructure to martensite and pearlite. Changes in the structure of ferrite to cementite after heating to austenite temperature, making the character of low carbon steel harder than before heat treatment, is proven by an increase in the average value of hardness in raw materials with raw materials that have undergone heat treatment.

b. Microstructure Observation of annealed material

This annealing specimen is heat treated at a temperature of 750 ° C with a holding time of 60 minutes and then cooled slowly using a cooling fan. Then, the microstructure observation was carried out on the SUH. 35 material that had passed the annealing process. The results of the observation of the microstructure of the SUH 35 material can be observed in Figure 3.

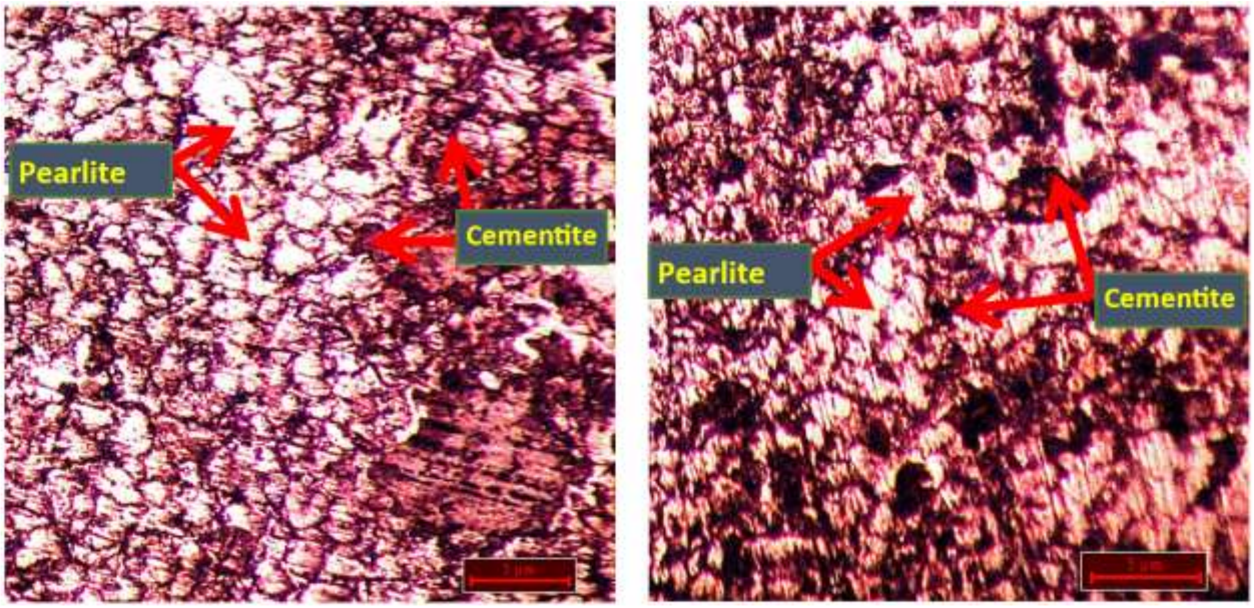

Figure 3. Microstructure of SUH 35 Steel after Annealing Head Section

Based on figure 3, the heat treatment process has a cementite and pearlite structure. At austenite temperatures, it gets a slow cooling rate with air, and the structure formed is perlite. After the annealing process, perlite is a mixture of ferrite and cementite in the material. This shows that the test specimen has high ductility but a low hardness value. This shows a change in the material's microstructure. Unannealed pearlite and ferrite were added to the material after annealing cementite and pearlite.

3.3 Roughness measurement

After taking the roughness value according to the feeding variation value, the average value is taken as the result of the roughness data that has been carried out. The average results can be seen in Table 3 below.

Tabel 3 Roughness measurement results.

type of material	hardness value Ra (µm)			
	Feeding (0.25 mm/rev)	Feeding (0.50 mm/rev)	Feeding (0.75 mm/rev)	Feeding (1 mm/rev)
Unannealed sample	0.89	1.10	1.84	1.95
materials annealed	0.46	0.45	0.56	0.74

Table 3 shows the results of the average roughness value obtained. The results of the average roughness value of the Unannealed sample are shown in row number one, starting in column three to column six, which contains the results of the average roughness value of each feeding variation. Row two contains the average roughness value results from the third to the sixth columns. The roughness value results are obtained from each feeding variation. A comparison of the roughness value of SUH 35 material annealed and Unannealed can be seen in Figure 5 below.

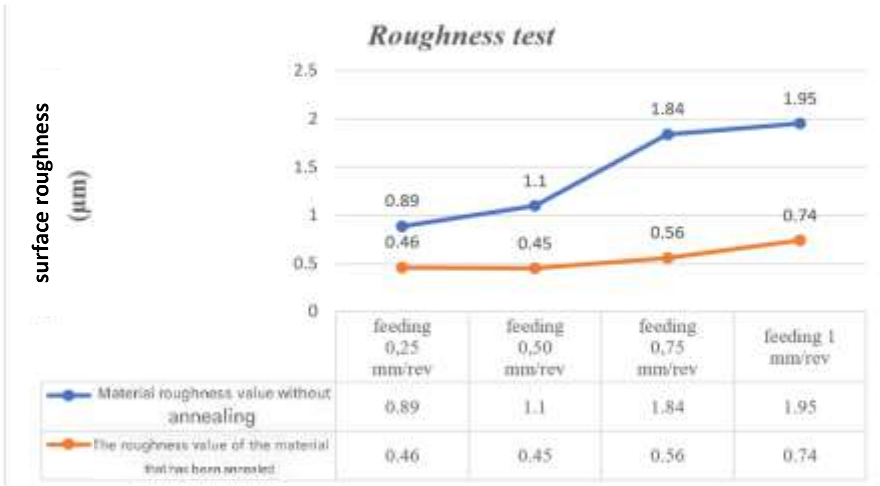

Figure 4 Comparison graph of the average roughness of the surface grinding process.

Based on Figure 4. It can be observed that the roughness results of the surface grinding process that has been carried out on the SUH 35 Unannealed sample have a higher roughness value compared to the annealed SUH 35 material. The roughness value of the SUH 35 Unannealed sample at each feeding variation has a much higher increase than the annealed SUH 35 material. Figure 4 shows that the greater the feeding value, the effect on the increasing roughness value. This occurs in unannealed or annealed materials.

4. CONCLUSION

Based on the results of the machinability analysis of SUH 35 material, which undergoes an annealing process on the surface grinding of engine valve manufacturing, it can be concluded that:

1. The annealing process affects the hardness value from 607.59 VHN to 311.49 VHN. It changes the structure of ferrite and pearlite to cementite and micro pearlite of SUH 35, which is used as raw material for making engine valves.
2. When surface roughness is measured, SUH 35 material that undergoes the annealing process has a lower roughness value of 311.49 VHN than SUH 35 Unannealed sample, which is 607.59 VHN.
3. The surface roughness measurement results show the feeding variation used in the surface grinding process of engine valves. The greater the feeding number, the higher the surface roughness value. In the Unannealed sample using a feeding variation of 0.25 mm/rev has a roughness value of 0.89 Ra, a feeding variation of 0.50 mm/rev has a roughness value of 1.10 Ra, a feeding variation of 0.75 mm/rev has a roughness value of 1.84 Ra, a feeding variation of 1.00 mm/rev has a roughness value of 1.95 Ra. In annealing treatment material using 0.25 mm/rev feeding variation has a roughness value of 0.46 Ra, 0.50 mm/rev feeding variation has a roughness value of 0.45 Ra, 0.75 mm/rev feeding variation has a roughness value of 0.56 Ra, 1.00 mm/rev feeding variation has a roughness value of 0.74 Ra.

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