THE EFFECT OF QUENCHING TREATMENT BY VARIATION OF COOLING MEDIA (WATER, USED OIL, COOKING OIL) ON EGREK HARDNESS

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ABSTRACT

By using water on the gilding, the blacksmith's Egrek was hardened. The Egrek must have tough hardness. The low hardness causes the Egrek to wear out frequently, so consumers criticize the hardness and toughness of blacksmith products. Due to the wrong heat treatment, the Egrek cause is easily destroyed. The purpose of this study was to determine the effect of quenching treatment with various cooling media such as water, used oil, and cooking oil on increasing the hardness of blacksmith products. This research method is an experimental quenching using water, used oil, and cooking oil at 800°C, 850°C, and 900°C, with a holding time of 30 minutes. Rockwell hardness test, statistical data processing using ANOVA and supported by the use of expert design software. Having an average carbon content of 0.379%, Egrek's raw material is made of medium carbon steel. Based on the results of the quenching process with water, used oil, and cooking oil affect hardness. The quenching process of the cooking oil cooling medium that occurs at 800°C with a hardness value of 50.1 HRC produces a minimum hardness value, while the maximum average hardness lies in the water cooling medium with a temperature of 900°C of 60.4 HRC. The results of the percentage contribution of each are used oil by 96.37%, cooking oil by 96.61%, while water cooling media contributed by 88.41%. So that the cooling media for used oil and cooking oil can also be used as an alternative choice of cooling media.

***Keywords**: Egrek, Quenching, Method Anova, Rockwell, Medium Carbon Steel.*

1. INTRODUCTION

According to the BPS (Central Statistics Agency), oil palm plantations would dominate Indonesian crops by 2020. Which reached 8.9 million hectares, a 300,000 hectares rise from the previous year's 8.6 million hectares (Pusparisa 2021). The increasing demand for oil palm harvesting equipment provides a commercial opportunity for the residents of the Tanjung Pinang Village, who have access to a vast amount of land. The Egrek has the appearance of a sickle-shaped knife. Used by farmers to gather and clip the bunches and fronds from their gardens. According to Suherman et al. (2012), the composition of materials for domestically produced or imported Egrek is very similar to that of medium carbon steel. Steel from old vehicle leaf springs is a common ingredient in Tanjung Pinang Village's production of Egrek palm. In Tanjung Pinang Village, Ogan Ilir Regency, Egrek is not only employed as a plantation tool in day-to-day life but also becomes a selling point.

EGREK at blacksmith is created using an ancient process called forging, and it is only capable of producing the finished product thanks to the raw material utilized, which is leftover steel from old vehicle leaf springs. Its use of basic tools and lack of material technology during the manufacturing process makes it challenging to compete on the national and even international market levels. Blacksmiths still rely on the expertise that has been handed down from one generation to the next to create Egrek.

The Egrek can be submerged in water to harden it. Blacksmiths frequently produce Egrek that is tarnished and worn out. Because of this, oil palm producers frequently need to replace them with new equipment. In this manner, the product loses its value and is rendered useless for an extended period of time. The trigger for this Egrek is thought to be readily damaged as a result of incorrect heat treatment. Because the level of global competition is greatly influenced by the mechanical properties of metals, researchers are working to find solutions. One such solution is to conduct research on materials made from palm Egrek and test the Egrek mechanical properties in order to assist blacksmiths in improving the caliber of their trade through the use of heat treatment.

Process (heat treatment) can also make steel stronger and less brittle, or it can change mild steel's characteristics to make it harder, and so on (Yogantoro, 2010). The goal of the heat treatment procedure is to give the necessary metallic characteristics of the material. The carbon steel is rapidly cooled after been heated to the Austenite temperature to create a Martensite structure which has a harder structure than ferrite or pearite, quenching is the name of this procedure (Suherman et al, 2012). Heat treatment, hardening, and quenching are methods used to improve the continuing changes in physical and mechanical properties. So that the goods of the blacksmith can have good and durable hardness. The quenching approach was applied by the researchers in this investigation.

According to Suryani (2018), the Blacksmithing activities in the Tanjung Pinang Village have produced a range of goods that capture the distinctive features of a particular area. To ensure that Egrek is resistant to wear, the SNI standard (Indonesian National Standard) stipulates that it must have a minimum hardness of 45.3 HRC (Nurmalasari, 2017). A medium carbon steel (medium carbon steel) has a carbon content of between 0.30 and 0.60 percent C (Murtiono, 2012).

The maximum hardness that quenched steel can acquire is nearly entirely governed by the amount of carbon present, the temperature at which it is heated, the amount of time it is held at that temperature, and the alloy's critical cooling rate (Pramono, 2011). When the cooling medium viscosity is higher, the cooling speed will be slower and have a smaller impact on the level of steel hardness. Conversely, when the cooling medium density is higher, the cooling speed will be faster and have a larger impact on the level of steel hardness (Haryadi et al, 2021). Therefore, in this research of the quenching treatment using water, used oil, and cooking oil was used to obtain the optimal level of hardness and toughness in the manufacture of Egrek from the blacksmiths of Tanjung Pinang. Because the Egrek production process still uses simple tools and it is suspected that the treatment method has not been carried out properly. So that the hardness level of blacksmith products is still relatively low. The material used by the blacksmiths is leaf springs from used cars which are classified as medium carbon steel so that the Egrek does not have a high enough hardness.

The low hardness causes Egrek to wear out frequently, so Egrek consumers who are palm oil producers criticize the hardness and toughness of Egrek, a blacksmith product used to harvest palm oil. The blacksmith process is still done in a simple way and usually uses water cooling media. Blacksmiths also haven't used parameters in the quenching process. Therefore, this research is expected to help blacksmith products produce products that are tough, namely hard but not brittle with the parameters used, and several cooling media as an alternative choice of cooling media. Maximum hardness can be achieved by holding a material for a period of time while the hardening method maintains the hardening temperature to achieve uniform heating and homogeneous Austenite structure, or by forming carbide solubility in the Austenite and carbon diffusion, as well as its alloying components (Pramono, 2011).

Hardness is the resistance of a material to abrasion, penetration, and scratching (Murtiono, 2012). To obtain good hardness, employ Austenite, which is capable of transforming into Martensite, therefore it is required to achieve an Austenite structure during heating (Pratowo et al, 2018). The Austenite is a solid solution with a maximum solubility limit of 2% Carbon at 1130 °C, and its crystal structure is Face Center Cubic (FCC) (Umartono et al, 2015). Analysis of variance (ANOVA) is the approach used to investigate variations in more than two separate population groups. Ronald Fisher, a statistician, initially invented ANOVA (Rahmawati et al, 2020).

From the description of the background of the problem above, the aim is to determine the effect of quenching treatment with various cooling media such as water, used oil, and cooking oil on the increase in the hardness of the blacksmith's Egrek product.

2. MATERIALS AND METHODS

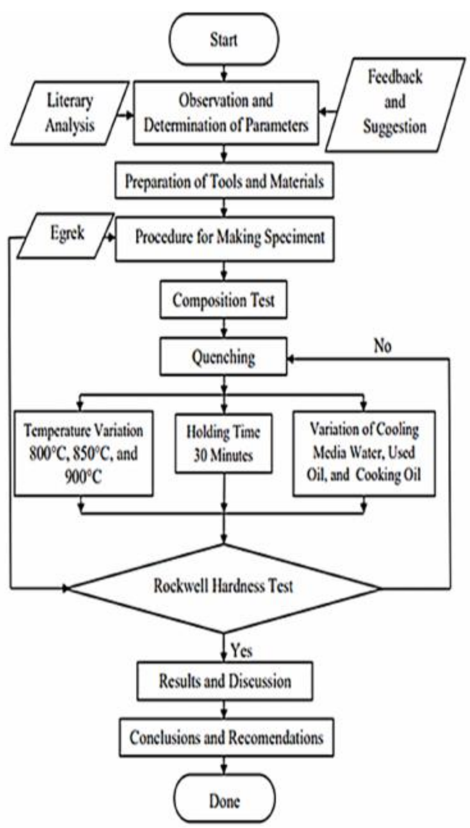

Figure 1. Research Flowchart

2.1. Research Tools and Material

2.1.1 Tools

Support equipment used in this research is as follows:

Table 1. Research Tools

No	Tool's name
1.	Heating Kitchen Nabertherm L3/11/S27
2.	Clamp
3.	Vernier calipers
4.	Hand Grinder
5.	Rockwell Hardness Tester Model HR-150 A
6.	Polyspek Chemical Composition Test Equipment
7.	Sharpener
8.	Vise
9.	Sandpaper
10.	Pliers
11.	Wire Scissors
12.	Container For Quenching Media
13.	Digital Thermometer
14.	Application Polyspek Analytical
15.	Stopwatch
16.	Gloves
17.	Application Design expert

2.1.2 Material

This research uses several materials which can be seen in the table below:

Table 2. Research Material

No	Material Name
1.	27 test specimens
2.	10 liters of water
3.	Used oil 10 liters
4.	Cooking oil A 10 liters
5.	Wire
6.	Egrek is the agricultural tool discussed

2.2. Queching Process

Prior to the quenching process, the temperature of the cooling medium is measured first. The cooling media used in this study were water, used oil, and cooking oil as an alternative cooling medium because blacksmiths usually use water as a cooling medium. The initial temperature of the cooling medium can also affect the level of hardness of a material (Rendisetyo, 2020). So the researchers measured the initial temperature of the cooling media using a digital thermometer in order to find out the initial temperature of the cooling media. Then it is obtained that the water temperature is 28.3°C, used oil is 28.4°C, cooking oil is 28.8°C which can be seen in the image below.

Figure 2. The initial temperature of water cooling media, used oil, and cooking oil.

The cooling media for water, oil and cooking oil have different densities and viscosity. The water cooling medium has a density of 998 kg/m³ and a viscosity of 1.01 Pa.s, the oil cooling medium has a density value of 981 kg/m³ and a viscosity of 4.01 Pa.s (Haryadi, et al, 2021). Meanwhile, for cooking oil cooling media, it has a density of 877 kg/m³ and a viscosity of 4.71 Pa.s (Firdausi, et al 2008). The higher the viscosity value of the cooling medium, the cooling rate will be moderate, this will affect the hardness level of steel, whereas if the density value of a cooling medium is higher, the cooling rate will be faster, this will affect the hardness level of steel to increase (Haryadi, et al, 2021). This test is carried out using the quenching process. This quenching process uses an electric oven with a temperature of 800°C, 850°C, 900°C and a holding time of 30 minutes. The cooling media used are water, used oil and cooking oil. The quenching process can be seen in the image below.

Figure 3. Quenching Treatment Proces.

The longer the cooling holding time, the hardness will increase, because the specimen is lifted before it cools which allows the air to provide an opportunity for the metal to form crystals and the possibility of binding other elements from the air (Agustian, 2021). Therefore, this study uses a cooling hold time of 5 minutes because it is expected to produce a tough product that is hard but not brittle.

3. RESULTS

3.1 Chemical Composition Test Results

We can determine the type of material based on the findings of the composition test by examining the percentage of the constituent elements (Amalia, 2018). In addition to being tested for hardness, the chemical composition of untreated Egrek material is examined to ensure that it belongs to the medium carbon steel group.

In the Mechanical Laboratory of the Sriwijaya State Polytechnic, the Egrek material was examined utilizing a composition test apparatus. The average carbon content of the twice-tested material was 0.379%. This assures that the material used in the production of the blacksmith's Egrek, namely old vehicle leaf springs, is classified as a medium carbon steel with a C (carbon) value between 0.3% and 0.6%. The following table summarizes the results of the composition examination:

Table 3. Chemical Composition Test Results

No	Name	Element	Percentage (%)
1.	Iron	Fe	81,06
2.	Carbon	C	0,379
3.	Silicone	Si	0,785
4.	Manganese	Mn	0,942
5.	Phosphor	P	<0,002
6.	Sulfur	S	<0,002
7.	Chrome	Cr	5,61
8.	Molybdenum	Mo	1,18
9.	Nickel	Ni	3,11
10.	Aluminum	Al	0,097
11.	Boron	B	<0,0005
12.	Cobalt	Co	0,010
13.	Copper	Cu	0,076
14.	Niobium	Nb	5,82
15.	Led	Sn	0,002
16.	Thallium	Ti	0,113
17.	Vanadium	V	0,665
18.	Wolfram	W	0,032
19.	Calsium	Ca	0,004
20.	Lead	Pb	<0,001

3.2 Rockwell Hardness Test Results

Testing the hardness of untreated specimens and 27 quenched Egrek specimens. The quenching procedure was conducted at 800°C, 850°C, and 900°C, with a holding time of 30 minutes, and water, used oil, and cooking oil were utilized as the cooling media. Hardness testing utilizing a Rockwell Hardness Tester Model HR-150A with a penetration duration of 15-20 seconds, a diamond Indenter at 120 degrees, and a main load of 150 kg. The following are the findings of the specimen's hardness test:

Table 4. Results of Hardness Tests Without Treatment

Speciment	Indentor	P (Kg)	HRCr
Raw Material	Intan 120°	150	31,5
Blacksmith Product	Intan 120°	150	39,5
			40,0
			38,8

Table 4 is the hardness test data without treatment where the raw material is used car leaf springs which were tested to determine the hardness of the basic material for making egrek at the blacksmith. Then tested the hardness of the Egrek blacksmith product as many as 5 test points from 3 specimens to compare it with the results of the hardness level after quenching treatment with variations in water cooling media, used oil, and cooking oil. Having obtained Table 4, the following is a record of the hardness test results after the quenching process shown in table 5:

Table 5. Results of Hardness Testing on Egrek Specimens Following Quenching

Speciment	Temperature	Media	HRCr
After Quenching Process	800°C	Water	58,4
			58,7
			58,5
		Used Oil	54,3
			53,9
			54,4
		Cooking Oil	50,1
			49,3
			50,8
After Quenching Process	850°C	Water	58,9
			59,5
			59,1
		Used Oil	56,3
			56,7
			56,5
		Cooking Oil	55,9
			56,2
			55,5
After Quenching Process	900°C	Water	60,2
			60,3
			60,6
		Used Oil	58,5
			59,4
			59,1
		Cooking Oil	57,3
			56,9
			57,3

Table 5, in which there is an average HRC result of 5 hardness test points carried out on 3 specimens. The table above shows the test averages for each quenching treatment of water, used oil, and cooking oil cooling media at temperatures of 800°C, 850°C, and 900°C and a holding time of 30 minutes.

3.3 Analysis of Hardness Test Result Data

To expedite the ANOVA calculation, the hardness test results are classified according to the treatment received as follows:

Table 6. Grouped Results of Hardness Testing of Water Cooling Media

Factor	A_{11}	A_{12}	A_{13}	Total
B_1	58,4	58,9	60,2	534,2
	58,7	59,5	60,3	
	58,5	59,1	60,6	
Total (∑)	175,6	177,5	181,1	T_1 = 534,2

Table 6 is the result of grouping the hardness test data after the quenching treatment before being processed with an expert design application. **B_1** = water factor, A_{11} = temperature 800°C, A_{12} = temperature 850°C, A_{13} = temperature 900°C, ∑ = amount of hardness test data for each temperature, T_1 = total amount of hardness test results.

Table 7. Grouped Hardness Test Results for Used Oil Cooling Media

Factor	A_{21}	A_{22}	A_{23}	Total
B_2	54,3	56,3	58,5	509,1
	53,9	56,7	59,4	
	54,4	56,5	59,1	
Total (∑)	162,6	169,5	177	T_2 = 509,1

Table 7 is the result of grouping the hardness test data after the quenching treatment before being processed with an expert design application. **B_2** = used oil, A_{21} = temperature 800°C, A_{22} = temperature 850°C, A_{23} = temperature 900°C, ∑ = amount of hardness test data for each temperature, T_2 = total amount of hardness test result data.

Table 8. Grouped Hardness Test Results for Cooking Oil Cooling Media

Factor	A_{31}	A_{32}	A_{33}	Total
B_3	50,1	55,9	57,3	489,3
	49,3	56,2	56,9	
	50,8	55,5	57,3	
Total (∑)	150,2	167,6	171,5	T_3 = 489,3

Table 8 is the result of grouping the hardness test data after the quenching treatment before being processed with an expert design application. **B_3** = cooking oil, A_{31} = temperature 800°C, A_{32} = temperature 850°C, A_{33} = temperature 900°C, ∑ = amount of hardness test data for each temperature, T_3 = total amount of hardness test result data.

3.4 Analysis Results ANOVA

The ANOVA approach is excellent for evaluating and determining which variables influence the size of a dimension. This analysis is a computational approach that calculates the participation of each element in all measures, so that the response is determined by validating the hypothesis regarding the influence of control factors and their interactions (Sandy, 2019). The findings of ANOVA utilizing the application design expert are displayed in the table below.

Table 9. ANOVA Water Cooling Media Sample for Testing

ANOVA for selected factorial model						
Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5,20	2	2,60	48,77	0,0002	significant
A-Air	5,20	2	2,60	48,77	0,0002	
Pure Error	0,3200	6	0,0533			
Cor Total	5,52	8				

Table 10. ANOVA Used Oil Cooling Media Sample for Testing

ANOVA for selected factorial model						
Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	34,58	2	17,29	162,09	< 0.0001	significant
B-Oli Bekas	34,58	2	17,29	162,09	< 0.0001	
Pure Error	0,6400	6	0,1067			
Cor Total	35,22	8				

Table 11. ANOVA Cooking Oil Cooling Media Sample for Testing

ANOVA for selected factorial model						
Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	85,74	2	42,87	173,80	< 0.0001	significant
C-Minyak Goreng	85,74	2	42,87	173,80	< 0.0001	
Pure Error	1,48	6	0,2467			
Cor Total	87,22	8				

Based on the results of ANOVA F Count (F0) > FTable, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, therefore it can be concluded with a 95% level of confidence (α = 0.05) that the variation factor of water cooling media, used oil, and cooking oil has an effect on the hardness of the Egrek specimen. The highest F_{Count} value is achieved in the used oil and cooking oil quenching media, indicating that the most influential factors on the hardness of the test specimens are the used oil quenching media and cooking oil. The percentage contribution value for each influencing element can be determined:

Factor, Water $= \frac{(5,20-0,32)}{5,52} = 88,41\%$

Factor, Used Oil $= \frac{(34,58-0,64)}{35,22} \approx 96,37\%$

Factor, Cooking Oil $= \frac{(85,74-1,48)}{87,22} \approx 96,61\%$

The graph of the average hardness of test specimens for blacksmith products and Egrek with quenching treatment is depicted below.

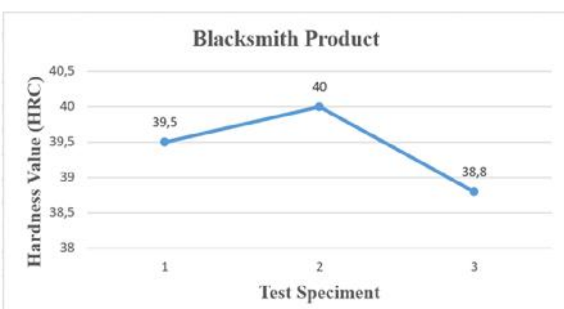

Figure 4. Hardness Graph of Blacksmith Products

From Figure 4, there is a graph of 3 test objects for blacksmith products carried out at 5 points to get the average hardness test. Then it can be seen the average difference of each specimen to obtain accurate data and graphs. From the 3 test specimens the blacksmith product was taken to be compared with the graphical results of the hardness level after the quenching treatment which can be seen in the following figure. Therefore, it can be seen that there is an increase in hardness after quenching treatment with variations of water, used oil, and cooking oil cooling media. Of the three specimens, the difference is only from 3 specimens taken from each part of one of the products of the blacksmith Egrek.

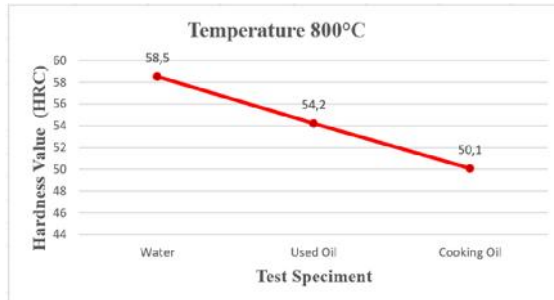

Figure 5. Graph of Specimen Hardness at 800°C

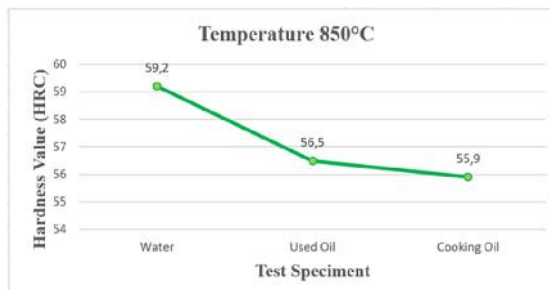

Figure 6. Graph of Specimen Hardness at 850°C

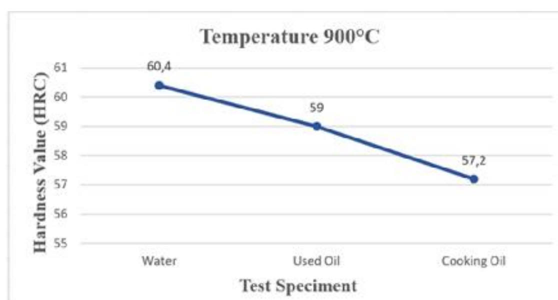

Figure 7. Graph of Specimen Hardness at 900°C

The graphs in Figures 5, 6, and 7 demonstrate that following quenching, the average hardness of the test specimen increased significantly. From the temperature differential of 800°C, 850°C, and 900°C with a holding time of 30 minutes and differences in the cooling media of water, used oil, and cooking oil with a volume of 10 liters and a cooling holding time of 5 minutes, each specimen can be affected. The average test results from the Rockwell hardness test (HRC) were inconsistent. The hardness level of the raw material was 31.5 HRC on average, and the hardness level of the blacksmith's product was 39.5 HRC, 40 HRC, and 38.8 HRC. Furthermore, the level of hardness after quenching water cooling media has an average value of 58.5 HRC at a temperature of 800°C, 59.2 HRC at a temperature of 850°C, and 60.4 HRC at a temperature of 900°C. The next level of hardness using used oil cooling medium has an average value of 54.2 HRC at a temperature of 800°C, 56.5 HRC at a temperature of 850°C, and 59 HRC at a temperature of 900°C. The hardness level using cooking oil cooling media has an average value of 50.1 HRC at a temperature of 800°C, 55.9 HRC at a temperature of 850°C, and 57.2 HRC at a temperature of 900°C. The lowest average hardness value is discovered in the quenching process of cooking oil cooling media at 800°C at 50.1 HRC, while the highest average hardness value is found at 900°C at a water cooling medium at 60.4 HRC.

4. CONCLUSION

The following conclusions can be drawn from this study's results and data analysis. Based on the results of testing the composition of the raw material specimen or raw material for making Egrek is a medium carbon steel with an average percentage of Fe (Iron) 81.06% and C (Carbon) 0.379%. According to the results of the hardness tests, the average minimum hardness value obtained from the quenching process of cooking oil cooling media at a temperature of 800°C is 50.1 HRC, while the maximum average hardness value obtained from the quenching process of water cooling media at a temperature of 900°C is 60.4 HRC.

According to the SNI (Indonesian National Standard), the minimum hardness for Egrek is 45.3 HRC. It can be shown that different cooling fluids have an effect on the hardness of the quenched Egrek specimens. According to the percentage contribution calculation, the cooling media that affect the hardness are using oil and cooking oil, with the percentage contribution from used oil being 96.37% and the percentage contribution from cooking oil being 96.61%, while the percentage contribution from water cooling media is 88.41%.

The effect of increasing this hardness can be influenced by the initial temperature of the cooling medium, the difference in viscosity and density of the cooling medium and the holding time of the cooling medium used, which is 5 minutes. In addition, the heating temperature used also affects the level of hardness, the higher the temperature, the higher the hardness. So that the cooling medium for used oil and cooking oil can also be used as an alternative choice of cooling media which is expected to produce Egrek products that are hard but not brittle.

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