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The Influence of the Hardness on Tool Steel (DF-3 Assab Steel) in Heat Treatment

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ABSTRACT

This paper reports the results of experiments to investigate hardness on Df-3 Assab Steel in heat treatment. The experiment was carried out with the parameters of hardening temperature, quenching oil and tempering temperature in the heat treatment process. Generally the parameters will influence from the value that has been concluded into Taguchi Orthogonal Array. The experimental result was founded at the highest hardening temperature and lower quenching oil, the value for hardness was 60.45HRC. It has improved in the statistica software. The conclusion that can be was more strength, toughness and ductility to the DF-3 tool steel.

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INTRODUCTION

DF-3 Assab steel or know as high carbon steel generally purpose oil-hardening tool steel is a versatile manganese-chromium-tungsten steel suitable for a wide variety of cold-work. The main characteristics were including the good machinability, good dimensional stability in hardening and also a good combination of high surface hardness and toughness after hardening and tempering. These characteristics combine and give steel suitable for the manufacture of tooling with good tool-life and high production economy.

Heat treatment operation is a means of controlled heating and cooling of materials in orders to effect changes in their mechanical properties. It was however known that mechanical properties of steel were strongly connected to their microstructure obtained after heat treatments which are performed to achieve good hardened and tensile strength with sufficient ductility (D. A. Fadare et al., 2011). In the harden condition, the steel should have 100% martensite to attain maximum yield strength, but it is very brittle too, and thus, as quenched steels are used for very few engineering applications. By tempering process, the properties of quench steel could be modified to decrease hardness and increase ductility and impact strength gradually (Min Shan Htun et al., 2009; S.A. Bashu et al., 1990). Siriporn Kuntongkum et al., 2009 was examined the influence of heat treatment processing parameters on the hardness and the microstructure of semi-solid aluminums alloy A356. The result could be explained by the precipitation hardening process of aged specimen which depends greatly on the aging time and temperature. Girisha. H. N and K. V. Sharma, 2013 was investigated the influence of process parameters on the mechanical properties of heat treated aluminums copper magnesium alloy. The results show that parameters such as % Magnesium addition and ageing duration has significant effect on mechanical properties.

Experimental:

The DF-3 as high carbon steel with the composition mentioned in Table 1 was received as 16mm thickness from the product. The samples of 35 mm x 25 mm x 16 mm were prepared and subjected to heat treatment process. This study chose three levels for three factors. The standard experiment layout 3 level OA L9 (3^3) for factors is listed for this case and shown in Table 2. The interaction between the parameters was neglected. Table 3 gives the factors and their levels. Table 4 gives the details of the experiment design and approach. The factors under consideration, including hardening temperature, quenching oil and tempering temperature are listed in the parameters table. The output was including the hardness values as the test results.

All the experiment were been done in one processes of heat treatment before hardness. The process of heat treatment will be going on hardening temperature, quenching oil and tempering temperature. The standard parameter values of hardening temperature were 790°C, 820 °C and 850°C for DF-3 steel. The time recorded for quenching oil were 60 minute, 90 minute and 120 minutes (28°C - 42°C). After quenching, tempering will

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continue with temperature 300°C, 250°C and 200°C (time taken base on temperature). During heat treatment, the aging times give an important to the specimens.

The hardness is measured according to the depth of indentation, under a constant load (S.Z. Qamar et al., 2009). The hardness of steel is generally determined by testing its resistance to deformation. A number of methods are employed including Brinell, Vickers and Rockwell. The steel to be tested is indented by a hardened steel ball or diamond under a given load and the size of the impression is then measured (O.O. Daramola et al., 2010). This experiment was used Rockwell hardness to get the result.

Table 1: Chemical composition for DF-3 (Assab Steel)

Grade	C	Mn	Cr	Mo	V	W	Other
Assab (DF-3)	0.9	1.1	0.6	-	0.1	0.6	-

Table 2: Experimental layout using L9 (3^3) orthogonal Array

Experiment	Heat Treatment Parameters		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3: Heat treatment parameters and their level

Heat Treatment Parameters	Level		
	1	2	3
Hardening Temp. (A), º C	790	820	850
Quenching Oil (B), min	60	90	120
Tempering Temp. (C), º C	200	250	300

Table 4: Result of the hardness for Assab Steel (DF-3)

Expt.	Heat treatment Parameters			Hardness (HRC)
	A (º C)	B(min.)	C(º C)	
1	790	60	200	53.21
2	790	90	250	53.05
3	790	120	300	54.09
4	820	60	250	54.12
5	820	90	300	57.55
6	820	120	200	54.95
7	850	60	300	60.45
8	850	90	200	53.33
9	850	120	250	56.78

RESULT AND DISCUSSION

The experiment was shows after identify from the level of parameters, the value gives a different measure on hardness test. Figure 1 shows the result of observed and predicted value of hardness test for DF-3 steel. In this case, the plot of observed value is lies near to the predicted value line. This shown the data of hardness is success achieves an objective of experiment.

For the confirmation of final optimal process parameter setting, this process was come out with the graph of statistica software. For this experiment, Rockwell hardness are used to determine the value of hardness after heat treatment process. From the figures below, it determine wether the hardness are acceptable for DF-3 steel.

By using the data, an effect estimate table had been generated. The Table 5 below shows the result from the analysis in STATISTICA for effect estimates from the all the independent variables against hardness.

Table 5: Heat treatment parameters and their level

Factor	Effect	Std. Err.	t(2)	P
Mean/Interc	55.2256	0.70267	78.5941	0.00016
Hardening	3.4033	1.72118	1.9773	0.18662
Quenching	-0.6533	1.72118	-0.3796	0.74077
Tempering	-3.3667	1.72118	-1.9560	0.18962

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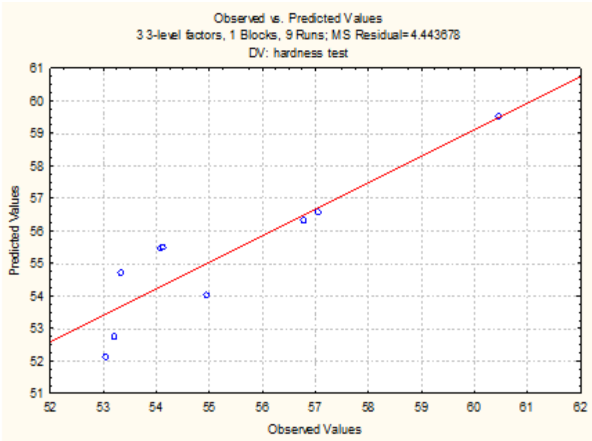

Fig. 1: Observed vs. Predicted Value for DF-3

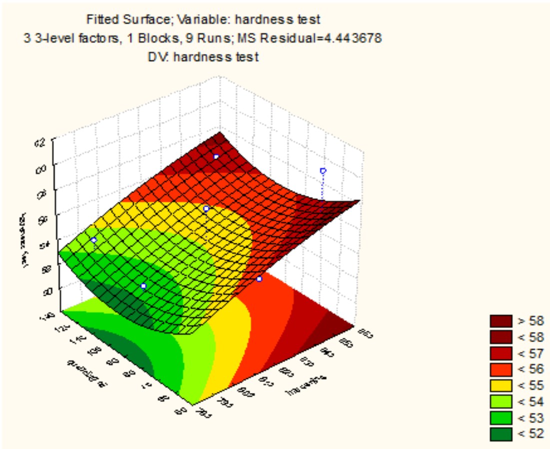

Fig. 2: Hardening temperature vs. quenching oil for DF-3

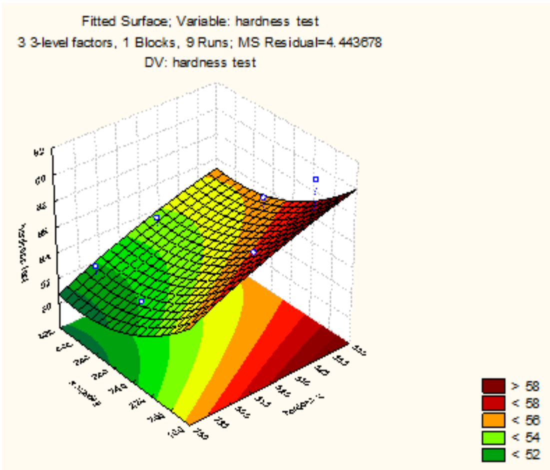

Fig. 3: Hardening temperature vs. tempering temperature for DF-3

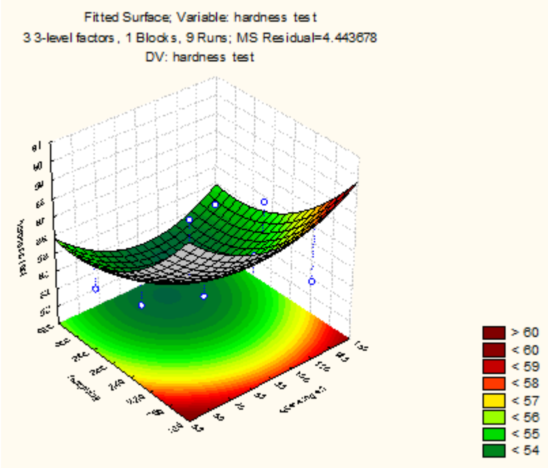

Fig. 4: Quenching oil vs. tempering temperature for DF-3

From the table 5 showed that the result give significant effect to the generated hardness. In addition, figures 2, 3 and 4 show the surface plot for hardness data against the independent variables.

The surface plot of hardness for DF-3 steel was shown in figure 5. From the graph, it can determine for figure 2, when higher hardening temperature and lower quenching oil was apply, the highest value hardness will come out with 58HRC. Meanwhile, at figure 3, lower hardness applies when quenching oil become higher and hardening temperature was lower. For figure 4, result shows the hardness values are lower when applied higher tempering temperature and medium quenching oil.

From the figures above, the relation between the independent variables and the dependent variable can be examined. Meanwhile, table 6 below shows the regression coefficient the generated hardness.

Table 6: Regression coefficient table of generated hardness

Factor	Regress. coefficient	Std. Err	t(2)	P
Mean/Interc	-116.983	1113.56	-0.1051	0.92592
Hardening	0.46100	2.716	0.1696	0.88094
Quenching	-0.2360	0.299	-0.7865	0.51396
Tempering	-0.2060	0.299	-0.6910	0.56101

From STATISTICA, the surface plot for dependent variable can be generate. By referring to the general model, equation factorial design,

$$H = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + € \quad (1)$$

and substitute the value of the regression coefficient into model. In this case, x_1 is the hardened, x_2 is the quenching and x_3 is the tempered. The model after the substitution is,

$$H = -116.983 + 0.461A - 0.236B - 0.206C + € \quad (2)$$

where H is the generated hardness, A is the Hardened, B is the quenching, C is the tempered and € is the random disturbance or error.

The data that had been gathered are based on the experiment and, even with all the precaution had been taken before starting the experiment, there is always a chance for an error occurs. Since this experiment is using the STATISTICA software to design the experiment, it had reduced the number and percentage of an error occurs. In addition, STATISTICA also had been used in designing the experiment because it helped in making the experiment is in systematically order. But it is only for the general error regarding to the flow of the experiment. By using a machine for this experiment, it is a must to check the reliability and the repeatability of the machine. So, the data from the experiment need to be used to analyze whether the machine is reliable or not. From the ANOVA table generated by the STATISTICA software, it can be used to determine the machine reliability. The table 7 below shows the ANOVA table for the dependent variables in the experiment.

Table 7: ANOVA table of hardness for DF-3

Factor	SS	F	P
Hardening	17.3740	3.9010	0.1866
Quenching	0.6403	0.1441	0.7408
Tempering	17.0017	3.8260	0.1990
Error	0.8874		
Total SS	48.0160		

By referring to the table 7, notice that there are row of Error and the value for the Error. The value of the Error can be used to determine the reliability of a machine that had been used for each experiment. The par number for the Error is 1 less than 1(<1). Therefore, it can be said that the machine is reliable for this experiment. To justify the normal distribution assumption, the Normal Probability plot can be used and the graph can be generated from the STATISTICA software. Normal distribution is acceptable as the normal value are scattered nearby to the solid line.

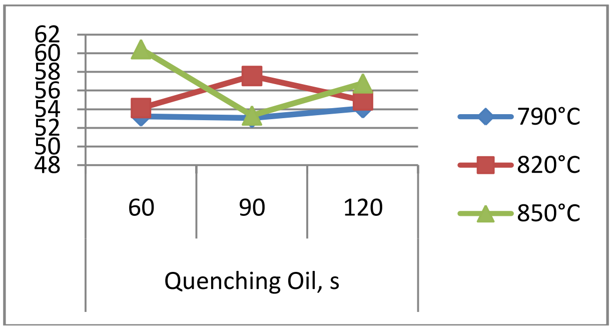

Fig. 5: Quenching oil vs. tempering temperature for DF-3

Conclusions:

1. The process variables affecting the hardness are identified. The result indicates that at low hardening temperature 790°C and medium tempering temperature 250°C gives the hardness result was 53.05HRC.
2. It was found that at high hardening temperature 850°C and low tempering temperature 200°C give a higher result for hardness 60.45HRC. For the medium result, it can show that at medium hardening temperature 820°C and medium of tempering temperature, the result of hardness 54.12HRC.
3. All the machine parameters play important role in determining the hardness of tool steel DF-3.

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