The Effect of Induction Heating on Tensile Test Specimens' Clamping Products Through the Medium Carbon Steel Materials' Engineering Technique

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ABSTRACT
This study aims to determine the effect of induction heating on tensile test specimens' clamping products through the medium carbon steel materials' engineering technique from heating using induction heating to heat the medium carbon steel. The research method used observation, interviews, literature study, design of sample materials, experiments, and sampling of experimental data carried out on 30x60x5 mm medium carbon steel specimens using induction heating media, with variations in holding time of 30 and 60 seconds, and temperatures of 800 and 850 °C then proceed with the cooling process with water and oil. The test results were analyzed using the method of analysis of variance based on the experimental design type two factorial levels with a two-factor interaction design model and two responses. The analysis results showed that the combined value of the induction heating effect factor of each test response to the test specimen, that is, water media quenching; holding time; 19.298%, temperature; 29.824%, and the interaction of holding time with temperature; 1.754%. Oil media quenching; holding time; 14.893%, temperature; 30.851%, and the interaction of holding time with temperature; 7.446%.

Keywords: *medium carbon steel, the tensile test specimen clamp, induction heating, quenching, anova*

1. INTRODUCTION

In today's technological developments, much equipment is made of steel because steel has a vital role in supporting human needs. This has led people to keep trying to improve the mechanical properties of steel, such as hardness, strength, toughness, and heat treatment.

The metal heating process generally still uses conventional heating stoves fueled by coal and charcoal, which can reduce the metal's quality due to the combustion products.

Some of the uses of steel in helping social work are steel used as drill bits and gears. Carbon steel can be used as an alternative because it is easy to obtain, easy to form, or has good machining properties.

The hardness of machine components made of steel can be obtained through heat or surface treatment processes. The process of increasing the hardness using heat and then cooling it with a cooling medium and a determined holding time is the most common practice for medium and high carbon steels [1].

From various previous studies on the increase in hardness and strength of steel, it was found that there was a significant increase in hardness and strength of the steel, and this made it possible to increase the added value of steel for tool applications.

The purpose of this study is to determine the effect of induction heating on tensile test specimens' clamping products through the medium carbon steel materials' engineering technique.

2. LITERATURE REVIEW

Induction heating is a technology that is widely developed in various industries, such as surface hardening in the automotive component industry, welding in the metal manufacturing industry, heating technology in the casting industry, and heating technology in the metal forming industry [2].

In an induction heater, the heat arises in the metal due to the induction of a magnetic field caused by the emergence of eddy currents in the metal or the presence of a circular eddy current that surrounds the magnetic field. The cause of eddy current is due to the induction of a magnetic field, causing a magnetic flux to penetrate the metal, resulting in the metal's heat. Magnetic induction itself is stronger than the magnetic field due to the appearance of an electric current flowing in the conductor. This type of induction heating can also be a non-contact heating process using a high-frequency electric current to produce electrically conductive heat [3].

The heat treatment process to increase the metal's strength is done by heating the metal to its authentication temperature and then holding it for a while, then quenching it quickly on the cooling medium. This rapid cooling will cause the grain growth not to develop because the temperature drops quickly and cools down so that eventually, the grain size becomes more acceptable. The more sufficient the grain size of a material, the strength will increase [3].

3. MATERIALS AND METHOD

In this study, the methods to be used include observation, interviews, literature study, material sample design, experimentation, and experimental data sampling. The tools used in this research are milling machines and cutting machines, induction heating, hardness testing instruments, and a cooling medium tub, which functions as a place for the medium carbon steel material's cooling process. The materials used include, for example, 30x60x5 mm medium carbon steel specimens (see Figure 1), tie wire to bind the test specimens to make it easier to collect during the cooling process, and grade 100 iron sandpaper to clean the test specimens.

The purpose of this study was to determine the effect of induction heating on tensile test specimens' clamping products through the medium carbon materials' engineering technique. The resulting data will be analyzed using analysis of variance (Anova). The stages in the research carried out are; preparation, heat treatment process, and hardness testing.

Figure 1. Medium carbon steel specimen size 30x60x5 mm

In the process of making test specimens, a control factor was determined (see Table 1).

Table 1. Controllable factor

No	Parameter	Level 1	Level 2	Unit
1	Holding Time	30	60	(s)
2	Temperature	800	850	°C

The test data obtained were analyzed using the Anova method to test the hypothesis (Ho) of the mean difference between groups. The concept of variance analysis is based on the F distribution concept and can be applied to analyze the relationship between various observed variables.

4. RESULTS AND DISCUSSION

After the testing process (see Figure 2) is carried out on the test specimen, the data from the measurement results are analyzed so that the factors of the effect of induction heating on the chuck product of the tensile test specimen are known through the engineering technique medium carbon steel materials. Furthermore, a combination of parameters can be determined to obtain a parametric value of hardness that affects the test specimen.

1) Specimens before testing process 2) Specimens during testing process 3) Specimens after testing process

Figure 2. Specimen testing process

To determine the effect of factors on the test specimens' response value, data analysis of hardness testing results was carried out using Anova with two level factorial design experimental methods, using two interaction factors and two responses. Testing specimen points is carried out randomly according to the measurement design matrix in Table 2 and Table 3, with two repetitions so that 8 points of hardness are produced in the test specimen.

Table 2. Test result data at the specimen point

Std	Run	Factor 1	Factor 2	R1	R2
		A:Holding Time	B:Temp.	Water	Oil
		s	°C	HRC	HRC
5	1	30	850	60.1	50.7
3	2	60	800	60.3	51.6
2	3	30	800	60.7	51.5
7	4	60	850	60.3	51.6
8	5	60	850	60.1	51
6	6	30	850	60.4	50.9
4	7	60	800	60.9	50.8
1	8	30	800	60.2	50.7

Table 3. Mean and standard deviation of test results

Name	Units	Min	Max	-1 (Code)	+1 (Code)	Mean	Std. Dev
A: Holding Time	s	30	60	30	60	45	16.0357
B: Temp.	°C	800	850	800	850	825	26.7261

Table 4. Response testing with the 2FI model design

Name	Units	Obs	Min	Max	Mean	Std. Dev	Ratio
Water	HRC	8	60.1	60.9	60.375	0.286606	1.01331
Oil	HRC	8	50.7	51.6	51.05	0.3664	1.01775

To identify the effect of the holding time and temperature factors, analysis of the test results data was carried out with Anova. It is known that the hypothesis (Ho) tested is that there is an induction heating effect factor on the test specimen, as shown in Table 5 and Table 6.

Table 5. Water media quenching results

Source	Sum of Squares	df	Mean Square	F Value	p-Value Prob > F	
Model	0.50	3	0.17	9.62	0.0266	**significant**
A-Holding Time	0.18	1	0.18	10.29	0.0327	
B-Temp.	0.24	1	0.24	14.00	0.0201	
AB	0.080	1	0.080	4.57	0.0993	
Pure Error	0.070	4	0.018			
Cor Total	0.57	7				

In the data from the quenching results of water media, the F value of Model is 9.62, which indicates that the Model is relatively significant because the F value is 2.66% due to the interaction between factors.

Table 6. Oil media quenching results

Source	Sum of Squares	df	Mean Square	F Value	p-Value Prob > F	
Model	0.83	3	0.23	10.06	0.0247	**significant**
A-Holding Time	0.25	1	0.24	8.91	0.0405	
B-Temp.	0.40	1	0.32	14.73	0.0185	
AB	0.18	1	0.13	6.55	0.0627	
Pure Error	0.11	4	0.023			
Cor Total	0.94	7				

In the data from the quenching results of oil media, the F value of Model 10.06 shows that the model is relatively significant because the F value is 2.47% due to the interaction between factors.

From Table 5 and Table 6, it can be concluded that there are factors that have significant effect on the test specimen so that Ho is rejected. By using the equation, it can be calculated the percentage value of the contribution of each factor that affects the test specimen, that is;

1) Water media quenching factors:

$$\text{Holding Time} = \frac{(0.18-0.070)}{0.57} = 19.298\%$$

$$\text{Temperature} = \frac{(0.24-0.070)}{0.57} = 29.824\%$$

Interaction of holding time with temperature:

$$\frac{(0.080-0.070)}{0.57} = 1.754\%$$

2) Oil media quenching factors:

$$\text{Holding Time} = \frac{(0.25-0.11)}{0.94} = 14.893\%$$

$$\text{Temperature} = \frac{(0.40-0.11)}{0.94} = 30.851\%$$

Interaction of holding time with temperature:

$$\frac{(0.18-0.11)}{0.94} = 7.446\%$$

5. CONCLUSION

From the results of the study, it can be concluded that the combined value of the induction heating effect factor of each test response to the test specimen, that is;

1) Water media quenching; holding time; 19.298%, temperature; 29.824%, and the interaction of holding time with temperature; 1.754%.
2) Oil media quenching; holding time; 14.893%, temperature; 30.851%, and the interaction of holding time with temperature; 7.446%.

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