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Metallographic Analysis Of Coil Springs Against Temperature Variations Using ASTM E-122 and ASTM E-562

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A B S T R A C T

This research was conducted to determine the effect of temperature variations on the manufacture of agricultural equipment products made from coil springs on their mechanical properties. This analysis of the coil spring steel was carried out. The research methods used included sample pieces, heat treatment with temperature changes, hardness test, and metallographic test. The results are the highest percentage with a value of 64% and the lowest percentage was at 830 OC temperature specimens with a value of 42%. The high percentage of bainite microstructure with a value of 58% and the lowest percentage with a value of 36%. Meanwhile, the lowest percentage is in non heat treated specimens with a value of 40%.

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1. Introduction

Industry 4.0 has a very large and broad impact, especially in the industrial sector, where this industrial revolution must be addressed by industry players wisely and carefully (Satya, 2018). The development of industry 4.0 is so fast over time to help facilitate human activities. With the development of the industry, there will be very tight competition, one of which is the industry in the field of making agricultural equipment (Pustaka, 2017). Every agricultural tool definitely needs a main component for the production process, one of which is metal. In the metal industry, such as blacksmiths, the material used in the manufacturing process is used spring steel as a material in the manufacture of cutting tools (knives, machetes), agricultural tools (hoes, sickles), and building tools (crowbars, chisels). The process of heat treatment or plating used in the production process is a type of hardening heat treatment that functions as a process to harden steel materials. However, the product results can be damaged such as cracks, fractures, and so on, so the toughness of the product must be improved so that this does not happen. And the way to increase its toughness is by means of rapid cooling (quenching) (Kusuma, 2017).

There are cooling media used in the metal industry, namely water, saltwater, oil or oil, and polymer media (Kundu & Mishra, 2013). Water and oil cooling media is a medium that is often made as a medium for hardening steel because the immersion is easy and not difficult. In cooling using water faster than oil, resulting in higher cracking. Therefore, the oil medium is used more in the cooling medium (Yunaidi & Harnowo, 2015). The quenching process aims to reduce the solubility of carbon in martensite and enrich the carbon content so that it is stable when the steel is cooled rapidly. The high carbon content in martensite results in a high hardness value of steel.

2. Literature Review

According to Fawaiz (2017) Based on the results of his research, the analysis of the data that has been obtained regarding the effect of different austenitizing temperature variations on the value of material hardness, impact strength, and structure micro by heat treatment process on AISI 1050 steel, using temperatures of 800°C, 850°C, and 900°C can be concluded that: 1. The highest hardness value at austenitizing temperature was 800 ^{o}C with a hardness value of 58 HRC. Strength value highest impact at austenitizing temperature 900^{o}C with an impact strength value of 0.0643 (J/mm^2). 2. The percentage value formed is the highest martensite that exists at an austenitizing temperature of 800^{o}C with a microstructure of 87% martensite and 13% bainite (Bardelcik et al., 2018; Peng et al., 2019). The highest Grain Size Number in austenitizing temperature 800^{o}C by 11.

According Islamuddin & Soedarmadji (2020) Based on the results of his research, the discussion that has been described can be concluded that: 1. Based on the compressive test that has been carried out that the greatest pressure lies in the sawdust powder specimen with a compressive strength of 537.5 kgf because the grains inside become denser and the more parts of the cavity are filled with powder, meaning the higher the density, the higher the strength (Kempen et al., 2015). 2. Based on the density test that has been carried out, the 5-gram powder weight has the highest density value compared to the other powder weights. This means that the density of wood sawdust has not exceeded the target density value of 1 g/cm³ so that the density of wood sawdust waste produced still does not meet the standard. 3. Based on the microstructure test that has been carried out, the microstructure at the G value of the average grain size for a powder weight of 5 grams is 60 µm so that the more sawdust, the higher the density and the density of sawdust is a measure that states the weight per unit area and Density is closely related to strength.

3. Methodology

Research Material

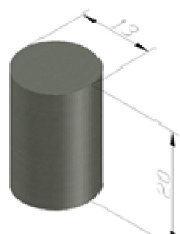
Test Material Composition and Dimension

The material used in this test is coil spring steel type SAE 9254 M, with the composition shown in the table below.

Table 1. SAE 9254 M Steel Composition

Si	P	Mn	Cr	V	C	S	Cu
1,3–1,6	≤ 0,03	0,3–0,6	0,4–0,7	0,1-0,2	0,60	≤ 0,03	≤ 0,2

Source: (Hakim et al., 2014)



Picture 1. Dimensions of the test object

In Heat treatment

This heat treatment is used to heat the workpiece. This heat treatment heats the test specimens in two temperature changes, from 815 °C to 830 °C to 850 °C, with a removal time of 30 at each temperature. (Wijaya, 2017).

Quenching Process

This cooling process is used to cool the test object quickly after being heat-treated in a heating furnace. During the roasting process, this test subject used a scalpel and oil cooling medium (SAE 20-50 W).

Microstructure Test

Microstructural testing is carried out according to ASTM E3 - 95. The steps of this test are:

a. Calculation of the percentage of each microstructure (ASTM E562)
   Performed on the basis of ASTM E562, which is the standard test for volume fraction determination by manual calculation system (point count), which calculates the content of each microstructure phase. To use ASTM E562, it is necessary to do microimaging on the test object (Fawaiz, 2017).
b. Calculation of mean particle size (ASTM E112)
   There are three methods for calculating the particle size of metallographically tested specimens according to ASTM E112. Namely, the comparative method, the intercept method (Heyne), and the plane or planimetric method (Jeffries) (Islamuddin & Soedarmadji, 2020).

Hardness Test

Hardness testing is carried out according to ASTM E18-15. The steps of this test are:

a. Rub the sample that has undergone heat treatment process and microstructure test with paper rubbing.
b. Map the surface of the sample to its middle position, and the distance between the points is 2 mm.
c. The sample is placed in a c-class Rockwell hardness tester, and the main load of the test is 150 kgf.
d. The hardness test result of the sample can be viewed on the pointer scale needle, and the test result can be recorded.

4. Results and Discussion

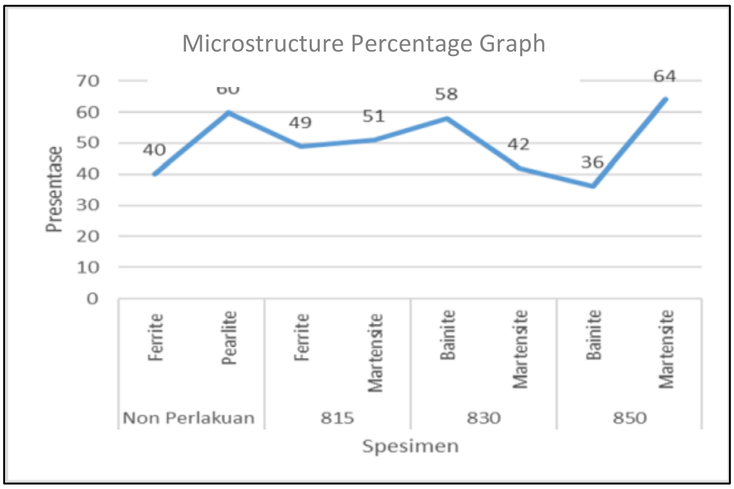
Percentage Results of Microstructures in Metallographic Tests

From the metallographic test data obtained the percentage results of the microstructure can be seen in the table and graph below.

Table 2. of Microstructure Percentage Results

Spesimen			Presentase (%)	Rata - Rata Presentase (%)
Without Heat Treatment	Ferrite		40	40
	Pearlite		60	60
815	Ferrite	Ferrite (S1)	45	49
		Ferrite (S2)	53	
	Martensite	Martensite (S1)	55	51
		Martensite (S2)	47	
830	Bainite	Bainite (S1)	61	58
		Bainite (S2)	55	
	Martensite	Martensite (S1)	39	42
		Martensite (S2)	45	

850	Bainite	Bainite (S1)	39	36
		Bainite (S2)	33	
	Martensite	Martensite (S1)	61	64
		Martensite (S2)	67	



Picture 2. Microstructure Percentage Graph

From the graph above, the results of the number of phases that occur in the test material that has been processed by hardening heat treatment with temperature variations of 815 ^{O}C, 830 ^{O}C, and 850 ^{O}C and using a temperature holding time of 30 minutes with SAE 20-50 W Mesran oil cooling media have the same results. different. It can be seen that in the results of the microstructure test the micro present value in the non-heat treated specimens of 40% ferrite and 60% pearlite were used as comparison values. And after heat treatment, it is known that the highest percentage value is specimen 2 at a temperature of 850 ^{O}C at 33% bainite and 67% martensite because at these temperatures it does not have the same microstructure as non-heat treated specimens so that there is a significant change in microstructure and there is value a high percentage of the martensite microstructure. And the lowest micro percentage value after heat treatment is specimen 2 at 815 ^{O}C temperature with a value of 53% ferrite and 47% martensite because at that temperature it has the same microstructure as non-heat-treated specimens, namely ferrite which has soft properties and the micro percentage value at ferrite exceeds the percentage value in non-heat treated specimens.

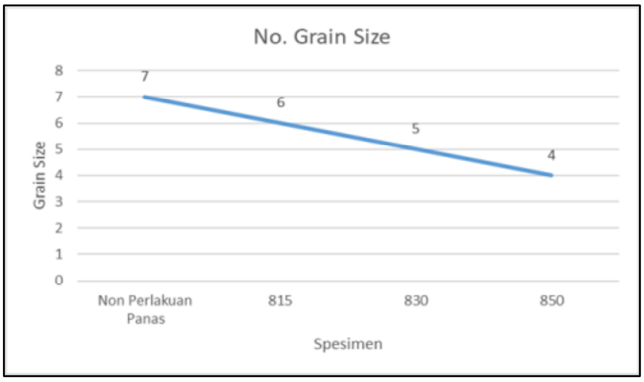
Microstructure Grain Calculation Results.

From the metallographic test data obtained in the calculation of microstructure, grains can be seen in tables and graphs.

Table 3. Microstructure Grain Calculation Results

f (mm²)	**Without Heat Treatment**		**815**				**830**				**850**			
	n1	n2	n1 (S1)	n2 (S1)	n1 (S2)	n2 (S2)	n1 (S1)	n2 (S1)	n1 (S2)	n2 (S2)	n1 (S1)	n2 (S1)	n1 (S2)	n2 (S2)
0,08	70	32	54	26	46	16	39	15	27	24	18	11	33	7
Na (Grain/mm²)	1075		837,5		675		581,25		487,5		293,75		456,25	
Rata-rata (Na)	1075		418,75				290,625				146,875			

G (Table ASTM Grain Size Number E-122)	7	6	5	4
Rata-rata Intercept (mm)	0,0283	0,0400	0,0566	0,0800
Rata-rata luas butir (mm²)	0,00101	0,00202	0,00403	0,00806
Rata-rata Diameter (mm)	0,0318	0,0449	0,0635	0,0898



Picture 3. Graph of Microstructure Grain Calculation Results

The table shows that there is a significant decrease in grain size (Grain Size Number). Starting from non-heat treated specimens to specimens that received hardening heat treatment using temperature variations. The highest grain number is found in non-heat treated specimens of 7, the average intercept is 0.0283 mm, the average grain area is 0.00101 mm^2 and the average diameter is 0.0318 mm. Then at a temperature of 815 ^{O}C it has a large grain number of 6, an average intercept of 0.0400 mm, an average grain area of 0.00202 mm^{2,} and an average diameter of 0.0449 mm. In the 3rd position, which is at a temperature of 830OC by 5, the average intercept is 0.0566 mm, the average grain area is 0.00403 mm^2 and the average diameter is 0.0635 mm. The lowest number has a large grain number with a large number of 4, an average intercept of 0.0800 mm, an average grain area of 0.00806 mm^2, and an average diameter of 0.0898 mm at a temperature of 850OC.

In the graph, it can be seen that the higher the temperature used, the lower the grain number produced by using the SAE 20-50W Mesran oil cooling medium. It can be concluded that, with variations in temperature from low temperature to high temperature, the grain number decreases. So that the data obtained results with an increase in temperature, the results of the microstructure are transformed into large ones. The smaller the grain number, the larger the microstructure, on the other hand, if the grain number is larger, the microstructure will become smaller as shown in the table data above, which is in accordance with ASTM E112 (Fawaiz, 2017). The microstructure with the largest shape is found in the 850oC temperature specimen and the microstructure with the smallest shape is found in the non-heat treated specimen.

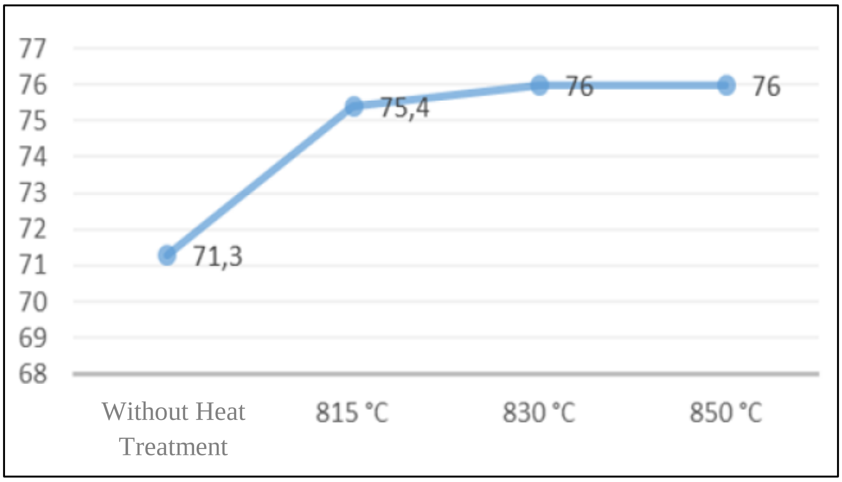
Hardness Test Results

Hardness testing was carried out using the RN-3 NRA Tokyo Testing Machine type HRC, with five points of data collection for each test material.

Picture 4. Hardness Test Material

Table 4. Total Results Average Hardness Test

Scale	Major Load (Kgf)	Indentor	Time	Hardness Test (HRc)						
				RM	**815 (S1)**	**815 (S2)**	**830 (S1)**	**830 (S2)**	**850 (S1)**	**850 (S2)**
C	150	Diamond Cone	5 Detik	68	71,5	79,5	76	73	73	80
				72,5	76	78	73	79	73	79,5
				73	77	71	77	76	77	81
				72	81	78	77,5	77	71	75
				71	71	71	77	78	76	74,5
Specimen				71,3	75,3	75,5	76,1	76,6	74	78
Average Hardness				71,3	75,4		76		76	



Picture 5. Graph of Total Results Average Hardness Test

From the data obtained after carrying out the hardness test, it can be seen in the table and figure above. By doing a hardening heat treatment then the specimen is cooled with an oil cooling medium

(SAE 20-50 W) with temperature variations of 815^{O}C, 830^{O}C, and 850^{O}C. For specimens under normal conditions, the hardness value is 71.3 HRC. For specimens after being hardened and cooled with oil cooling media, the average hardness value at a temperature of 815^{O}C obtained a hardness value of 75.4 HRC, for a temperature of 830^{O}C a hardness value of 76 HRC was obtained, for a temperature of 850^{O}C the hardness value was obtained. the hardness of 76 HRC. This is in accordance with research Saputra & Tyastomo (2016) that the results of testing specimens with oil and air quenching experienced increased hardness values in specimens with oil quenching, where cooling was carried out quickly and the oil had a good viscosity causing phase changes to transform to martensite more quickly.

5. Conclusion

From the results of the data obtained by the hardening heat treatment process at temperatures of 815°C, 830°C, and 850°C using quenching media of Mesran oil (SAE 20–50 W) it can be concluded that the highest percentage of martensite microstructure is at 850 OC temperature specimens with a value of 64% and the lowest percentage is at 830 OC temperature specimens with a value of 42%. The high percentage of bainite microstructure is at 830 OC temperature specimen with a value of 58% and the lowest percentage is at 850 OC temperature specimen with a value of 36%. Meanwhile, the highest percentage of ferrite microstructure is at 815 OC temperature specimens and the lowest percentage is in non-heat-treated specimens with a value of 40%. By comparison on non-heat treated specimens have a value of 40% ferrite and 60% pearlite.

The microstructure with the largest grain shape is found in the specimen at 850 OC with grain number 4 and the microstructure with the smallest grain shape is found in the specimen at 815 OC with grain number 6 in comparison to the non-heat treated specimen having grain number 7.

The highest average hardness value was obtained with oil cooling media on coil spring steel having a hardness value of 76.75 HRC at a temperature of 850°C. While the lowest average hardness value with oil cooling media on coil spring steel has a hardness value of 75.4 HRC, namely at a temperature of 815°C, with a hardness ratio of 71.3 HRC in the initial conditions without heat treatment.

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