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Experimental Study on the effect of Cooling Media on Impact Strength in the Heat Treatment Process of Medium Carbon Steel S45C

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***Abstract*—Steel possesses mechanical properties that can enhance the hardness and microstructure of its surface, and heat treatment is one way to achieve these properties. This study aimed to investigate the impact of different cooling media on the heat treatment process and the resulting impact strength of S45C medium carbon steel. The steel specimens were heated at various temperatures (800ºC, 850ºC, and 900ºC) in a furnace and then cooled using three different media: water, oil, and air. The study concluded that for all three temperatures, the specimens cooled with oil had the highest impact value. Furthermore, oil and air immersion resulted in ductile fractures, while water immersion caused brittle fractures.**

***Keywords*—cooling media; impact strength; heat treatment, medium carbon steel**

I. Introduction

Steel has a weak resistance to wear and friction, and improving the mechanical properties of its surface is necessary to increase the resistance. The hardness and microstructure of the surface play a significant role in improving these properties [1,2]. One way to achieve the desired properties is through a heat treatment process, which involves heating and cooling the material to obtain specific properties. Heat treatment is essential to achieve desirable mechanical properties such as hardness, strength, ductility, and stress reduction [3,4]. Hardening, annealing, and tempering are common heat treatment methods, and the hardening method is used in this study. Hardening is a process that strengthens the material by phase separation, which results in fine dispersion of a hard phase in a ductile matrix [5]. Hardening improves surface hardness, strength, and wear resistance of steel. Several factors affect the heat treatment process, including carbon content, temperature, cooling medium, and holding time. The carbon content helps in determining the critical temperature in the hardening process, while temperature aids in dissolving carbon.

The mechanical properties required by a various material, including hardness, ductility, strength, toughness, stiffness, fatigue [6,7]. With different material properties, there are many methods that can be used to test the mechanical properties of a material. One of the tests on a material is the impact test, which is a method that can be used to determine the strength, toughness and ductility of a material. To assess the resistance of a material to brittle fracture, it is necessary to test and consider dynamic factors that can affect brittle fracture, including impactor velocity, notches, plate thickness, impactor mass, and others. Toughness (impact) is the resistance of a material to shock loads. This distinguishes impact testing from tensile and hardness tests which are carried out slowly. Impact testing is an attempt to simulate the operating conditions of materials that are often encountered in transportation or construction equipment where the load does not always occur slowly but comes suddenly.

Manufacturers place a high value on quality materials to maintain the standard of their products in the market [8,9]. They need to carefully consider the location and function of the materials they use, taking into account factors such as temperature, dynamic load, and friction, among others. This helps them select the appropriate material with good impact strength. Thus, the production

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process involves determining the composition of the material, as well as heat treatment or other processes that can enhance the material's impact strength.

The aim of this research was to examine how the cooling medium used during the heat treatment process affects the impact strength of S45C medium carbon steel.

II. Research Methodology

A. Location and Method

From May to September 2022, An experiment was carried out at the Mechanical Engineering Laboratory of the State Polytechnic of Ujung Pandang (PNUP) to investigate the impact of cooling medium on the impact strength of S45C medium carbon steel. The study utilized a quantitative method involving experimental testing, data collection, and analysis. The hardening process was carried out by heating the steel specimens in a furnace at different temperatures (Annealing) (800ºC, 850ºC, 900ºC), followed by cooling with different media, including water, oil, and air.

B. Tools and Materials

This study utilized specific tools to gather data, including a shop hardening system with a maximum temperature of 1200 degrees and a Charpy-type impact testing equipment. The test material used was a medium carbon steel with a 0.48% carbon content, specifically the Bohler EMS 45 AMUTIT product. The sample was in the form of a steel box with dimensions of 10 x 10 mm and a length of 55 mm.

III. Results and Discussion

A. Results

The data on the results of the hardening process and impact strength tests can be seen in table 1.

Table 1. Data Impact test results and calculation results using Charpy method

Temp. (ºC)	Cooling Media	α°	β°	Cos α	Cos β	W_1 (kgm)	W_2 (kgm)	W (kgm)	K			Fault Condition
									kgm/mm²	Nm/mm²	kJ/m	
800	Air	120	109	-0,500	-0,326	19,050	16,835	2,215	0,028	0,272	2,716	ductile
800	Air	120	97	-0,500	-0,122	19,050	14,248	4,802	0,060	0,589	5,889	ductile
800	Oil	120	99	-0,500	-0,156	19,050	14,687	4,363	0,055	0,535	5,350	ductile
800	Oil	120	104	-0,500	-0,242	19,050	15,772	3,278	0,041	0,402	4,019	ductile
800	Water	120	118	-0,500	-0,469	19,050	18,662	0,388	0,005	0,048	0,475	brittle
800	Water	120	116	-0,500	-0,438	19,050	18,267	0,783	0,010	0,096	0,960	brittle
850	Air	120	105	-0,500	-0,259	19,050	15,987	3,063	0,038	0,376	3,756	ductile
850	Air	120	107	-0,500	-0,292	19,050	16,413	2,637	0,033	0,323	3,233	ductile
850	Oil	120	101	-0,500	-0,191	19,050	15,123	3,927	0,049	0,482	4,815	ductile
850	Oil	120	101	-0,500	-0,191	19,050	15,123	3,927	0,049	0,482	4,815	ductile
850	Water	120	118	-0,500	-0,469	19,050	18,662	0,388	0,005	0,048	0,475	brittle
850	Water	120	119	-0,500	-0,485	19,050	18,857	0,193	0,002	0,024	0,237	brittle
900	Air	120	104	-0,500	-0,242	19,050	15,772	3,278	0,041	0,402	4,019	ductile
900	Air	120	107	-0,500	-0,292	19,050	16,413	2,637	0,033	0,323	3,233	ductile
900	Oil	120	101	-0,500	-0,191	19,050	15,123	3,927	0,049	0,482	4,815	ductile
900	Oil	120	101	-0,500	-0,191	19,050	15,123	3,927	0,049	0,482	4,815	ductile
900	Water	120	117	-0,500	-0,454	19,050	18,466	0,584	0,007	0,072	0,717	brittle
900	Water	120	119	-0,500	-0,485	19,050	18,857	0,193	0,002	0,024	0,237	brittle
850	Oil	120	93	-0,500	-0,052	19,050	13,365	5,685	0,071	0,697	6,972	ductile
850	Oil	120	94	-0,500	-0,070	19,050	13,586	5,464	0,068	0,670	6,700	ductile

Where αº is starting angle of hammer position, βº is starting angle of hammer position, G is pendulum weight (12,7 kg), λ is swing arm distance (1.0 m), W is the effort required to break (kg m), W_1 = efforts made (kgm), W_2 is residual effort after breaking (kgm), K is impact value (kg m/mm2)

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B. Discussion

Table 1 presents the results of impact tests conducted at a temperature of 800°C, showing the average impact values obtained at each surface position of the test sample. The test sample that was immersed in oil had the highest impact value of 4.685 kJ/m, while the ones immersed in air had an impact value of 4.303 kJ/m. Conversely, the test sample immersed in water had the lowest impact value of 0.718 kJ/m. Notably, oil and air immersion media resulted in ductile fractures, whereas water immersion produced brittle fractures due to the different cooling rates.

At a temperature of 850ºC, the impact test data from Table 1 shows that the average impact value was obtained for each position of the surface of each test sample. The test specimen immersed in oil had the highest impact value of 4.815 kJ/m, while the test specimen with air immersion produced an impact value of 3.495 kJ/m. On the other hand, the test specimen with water immersion had the lowest impact value of 0.356 kJ/m. As in the previous case, oil and air immersion media resulted in ductile fractures, while water immersion produced brittle fractures due to different cooling rates.

At a temperature of 900ºC, a similar trend was observed where the average impact value was obtained at each position of the surface of each test sample. The test specimen with oil immersion media had the highest impact value of 4.815 kJ/m. The test specimen with air media resulted in an impact value of 3,626 kJ/m. While the test specimens with water media produced the lowest impact value, namely 0.477 kJ/m. Among these three specimens, oil and air immersion media produced ductile fractures, whereas water immersion produced brittle fractures. This can be attributed to the varying cooling rates of the different media. It was found that increasing the temperature of the cooling medium (water) leads to a decrease in the impact strength of steel, and that quenching with salt water results in smaller impact strength than quenching with regular water. Moreover, the impact strength of S45C steel was found to be higher when cooled with oil compared to when cooled with water [10], [11].

IV. Conclusion

In conclusion, based on the experiments and data analysis conducted, the following observations can be made:

- At all temperatures tested (800°C, 850°C, and 900°C), the test specimen immersed in oil had the highest impact value.
- Oil and air immersion resulted in ductile fractures, while water immersion resulted in brittle fractures.

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References

[1] T. Kovács and E. Bitay, “The hardness control in the coated surface layer,” in *Materials Science Forum*, 2013, vol. 729, pp. 415–418.

[2] Z. H. Stachurski, “Testing materials’ hardness science, technology & application,” in *Mater Forum*, 2006, vol. 30, pp. 118–125.

[3] G. E. Totten, *Steel heat treatment: equipment and process design*. CRC Press, 2006.

[4] M. Domanski and J. Webb, “A review of heat treatment research,” *Lithic Technol.*, vol. 32, no. 2, pp. 153–194, 2007.

[5] S. Y. Sirin, K. Sirin, and E. Kaluc, “Effect of the ion nitriding surface hardening process on fatigue behavior of AISI 4340 steel,” *Mater. Charact.*, vol. 59, no. 4, pp. 351–358, 2008.

[6] S. S. Murugan, “Mechanical properties of materials: definition, testing and application,” *Int. J. Mod. Stud. Mech. Eng.*, vol. 6, no. 2, pp. 28–38, 2020.

[7] A. Lavakumar, “Mechanical properties of materials,” *Concepts Phys. Metall.*, pp. 1–5, 2017.

[8] J. T. Black and R. A. Kohser, *DeGarmo’s materials and processes in manufacturing*. John Wiley & Sons, 2017.

[9] R. Singh, *Introduction to basic manufacturing processes and workshop technology*. New Age International, 2006.

[10] M. B. Widodo and A. M. Sakti, “Analisa perbedaan kekerasan dan ketangguhan baja S45C bila di di quench dan di temper pada media pendingin udara bertekanan, air dan oli untuk aplikasi poros motor roda tiga,” *J. Tek. Mesin*, vol. 9, no. 03, pp. 105–112, 2021.

[11] M. S. A. Nurdiansyah and A. M. Sakti, “Analisa pengaruh hardening terhadap kekerasan dan ketangguhan baja S45C dengan media pendingin air garam dan oli untuk aplikasi poros motor roda tiga,” *J. Tek. Mesin*, vol. 10, no. 01, pp. 123–128, 2022.

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