International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Effect of Temperature Variations and Cooling Media on S355J2 and SS400 Steel Materials in the Reforming Process

Indarto Yuwono[1], Alfi Tranggono Agus Salim[2], Kholis Nur Faizin[3], Tania Setya Ningsih[4], Nabila Wienda Wahyudi[5], Alfin Nur Adinda[6], Pitaloka Nurhalizah[7], Shella Cory Indila Putri[8], Tomi Alfian Ogik Awan[9]
[1,2,4,5,6,7,8,9]Rollingstock Engineering, Department of Engineering, Madiun State Polytechnic, Madiun City, East Java, Indonesia
[3]Automotive Engineering Technology, Department of Engineering, Madiun State Polytechnic, Madiun City, East Java, Indonesia

Abstract— *In the train underframe fabrication process at PT INKA (Persero), there is a mismatch in shape according to the dimensions that have been determined on the material. In overcoming this problem, the reforming process is carried out by engineering heat treatment and cooling using the appropriate parameters, because this affects the mechanical properties of the material. This research aims to determine the temperature parameters and cooling media in the reforming process at PT INKA (Persero). This research method is a reforming process using a brander with temperature variations of 500°C, 600°C, 700°C, and variations in water and air cooling media on the train underframe with S355J2 and SS400 steel materials. This research produces data from the value of tensile test, hardness rockwell test, micro examination, and compared with the results of test specimens before and after the reforming process. The results of this study are the material reforming process at 500oC, producing higher values of tensile strength, hardness, and microstructure than the 600°C and 700°C temperature variations. The conclusion of this research is that the higher the reforming temperature, the mechanical properties of the material decrease, and the material using air cooling media is superior in mechanical properties compared to water cooling media.*

Keywords— *SS355, SS400 Steel, Cooling Media, Reforming, Mechanical Properties, Temperature.*

I. INTRODUCTION

The development of the manufacturing industry encourages the improvement of product quality. PT INKA (Persero) as a train manufacturing industry, contributes to the manufacture of trains. This project was carried out in the context of rejuvenating trains in Indonesia, by procuring 612 trains [1]. In working on the project, PT INKA (Persero) used S355J2 and SS400 steel materials [2]. S355J2 and SS400 steel with low carbon content below 0.3% [3]. Low carbon steel has high ductility and toughness. In the railroad manufacturing industry, this steel functions as a material in the construction of train underframes [4]. From the results of observations made at PT INKA (Persero), the problem of deformation of the material was found [5]. In reducing this, a reforming process is needed to restore the shape according to the specified dimensions and restore the physical properties of the material [6]. The reforming process is engineering and a combination of heat treatment and cooling with certain parameters for materials to produce certain properties [7]. From the results of the analysis, the urgency of this research is due to dimensional deviations exceeding the specified tolerance limits resulting in obstruction of the fabrication, assembly, and increased costs in the train underframe production process [8]. In previous research conducted on steel using the furnace method with temperature variations to analyze its effect on the mechanical properties of S355J2 and SS400 steel [9].

This research aims to analyze the mechanical properties (tensile strength, hardness, and microstructure values) of S355J2 and SS400 steel after the reforming process [10], with the target of identifying suitable temperatures and cooling media to meet the needs of the industry with the benefits resulting from this research are to solve problems in the railway industry, improve the quality of products produced from industrial development, and increase knowledge.

The results of this study are research data including tensile strength values (ultimate tensile strength (MPa), yield strength (MPa), and elongation (%)), hardness (rockwell hardness (HRC), and microstructure (grain type and percentage (%)) to show the temperature parameters and cooling media in accordance with the Process Instruction (PI) of the reforming process of S355J2 and SS400 steel in the train underframe [11]. The findings targeted in this study show that increasing the temperature in the reforming process results in a decrease in the mechanical properties of the material, and materials that use water cooling media produce higher mechanical properties compared to air cooling media [12]. Contribution to science and technology to add insight and knowledge in the field of engineering applied to the railway industry through related courses on engineering drawings, applied physics, manufacturing processes, and materials science. Novelty in this research is the reforming process of S355J2 and SS400 steel materials in the train underframe.

II. METHOD

This research uses a quantitative experimental method. The initial stage begins with cutting the S355J2 and SS400 steel materials with a thickness of 12 mm according to the predetermined dimensions of 300 mm x 250 mm using a CNC Plasma Cutting machine. The reforming process is carried out using a brander to reach the specified temperature measured

Indarto Yuwono, Alfi Tranggono Agus Salim, Kholis Nur Faizin, Tania Setya Ningsih, Nabila Wienda Wahyudi, Alfin Nur Adinda, Pitaloka Nurhalizah, Shella Cory Indila Putri, Tomi Alfian Ogik Awan, "Effect of Temperature Variations and Cooling Media on S355J2 and SS400 Steel Materials in the Reforming Process," *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 4, pp. 153-158, 2024.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

using a thermogun. Determination of the reforming area using marking in the center of the material with a size of 50 mm. The use of the brander is carried out in a swinging manner in the specified area until it reaches a temperature variation of 500°C, 600°C, and 700°C as shown in Figure 1.


Figure 1. Material reforming process

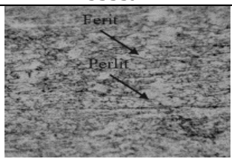
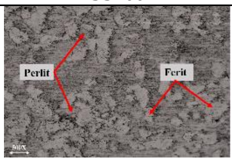
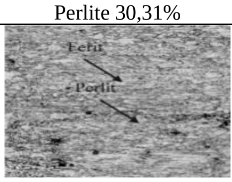
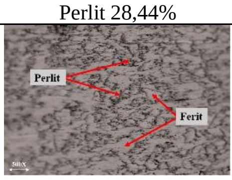
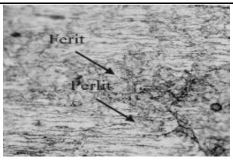
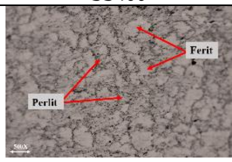
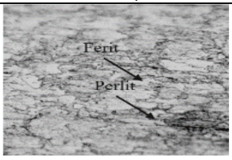
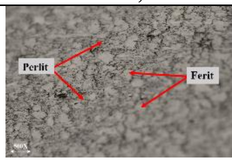
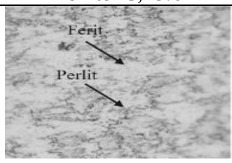
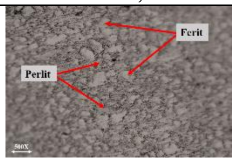
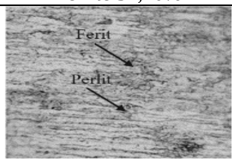
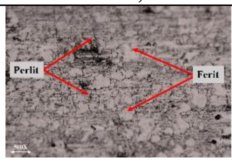
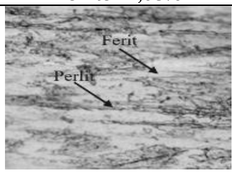
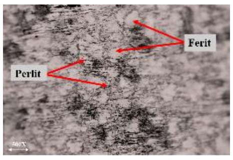
The cooling process after the reforming process is carried out by flowing water and pressurized air until it reaches a temperature of 35°C [13]. Cutting the material according to the specified cutting plan using a cutting grinding machine and continuing with the formation of specimens for testing using in accordance with the standards used.

Flattening and smoothing of the test specimen is done on a grid of 80 to 5000. Followed by polishing to produce a shiny test specimen surface using a polishing cloth with the help of autosol. Test specimens that are ready for testing are carried out at the Madiun State Polytechnic Campus 2 Material Test Laboratory. The test aims to analyze the effect of temperature variations and cooling media on raw materials and reforming process specimens on the mechanical properties of S355J2 and SS400 steel materials. The tests carried out were tensile test, hardness rockwell test, and micro examination [14].

III. Results and Discussion

Micro examination using ASTM E3 standard [15]. The microstructure with a magnification scale of 500X using a microscope is analyzed for the type of phase to determine the mechanical properties of the material, the results of the micro examination of the reforming process test specimens at temperatures of 500°C, 600°C, and 700°C with water and air cooling media are shown in Table 1.

TABLE 1. Micro Examination Results

Specimen	S355J2	SS400
Raw Materials	 Ferrite 69,69% Perlite 30,31%	 Ferit 71,56% Perlit 28,44%
500°C (Water Cooling Media)	 Ferrite 68,26% Perlite 31,74%	 Ferrite 70,29% Perlite 29,71%
600°C (Water Cooling Media)	 Ferrite 71,75% Perlite 28,25%	 Ferrite 74,01% Perlite 25,99%
700°C (Water Cooling Media)	 Ferrite 74,22% Perlite 25,78%	 Ferrite 77,38% Perlite 22,62%
500°C (Air Cooling Media)	 Ferrite 68,30% Perlite 31,70%	 Ferrite 70,39% Perlite 29,61%
600°C (Air Cooling Media)	 Ferrite 72,92% Perlite 27,08%	 Ferrite 75,85% Perlite 24,15%
700°C (Air Cooling Media)	 Ferrite 74,36% Perlite 25,64%	 Ferrite 77,56% Perlite 22,44%

It can be seen that there is an increase in the percentage of pearlite phase and a decrease in the percentage of ferrite phase in the reforming process test specimens with water cooling media compared to the raw material. The higher the temperature the ferrite phase increases and the pearlite phase decreases [16], this affects the mechanical properties of the material and decreases.

Due to the results of the analysis of the temperature and the cooling environment, the grain size in the steel is related to the microstructure of the SS400 steel material. In general, the reforming process at higher temperatures causes greater grain growth. The change in grain size affects the mechanical properties of steel such as strength and ductility [17]. During the reforming process the phase structure changes, these changes can reduce the hardness, composition, and percentage of phases in the overall microstructure [18]. Lower reforming temperatures tend to produce harder and stronger microstructures, while higher reforming temperatures produce softer and more resistant microstructures [19].

The hardness test of fine rock using the ASTM E18 standard and the applied load is 150 kg/ft [20]. The specimen was indented as many as 13 points with a distance of 2.5 mm.

Indarto Yuwono, Alfi Tranggono Agus Salim, Kholis Nur Faizin, Tania Setya Ningsih, Nabila Wienda Wahyudi, Alfin Nur Adinda, Pitaloka Nurhalizah, Shella Cory Indila Putri, Tomi Alfian Ogik Awan, "Effect of Temperature Variations and Cooling Media on S355J2 and SS400 Steel Materials in the Reforming Process," *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 4, pp. 153-158, 2024.

given a point to mark the distance between indents. A Rockwell hardness tester uses a diamond-shaped indenter and creates an indentation in the sample as a result of the indentation, resulting in a hardness value in units of Rockwell hardness (HRC).

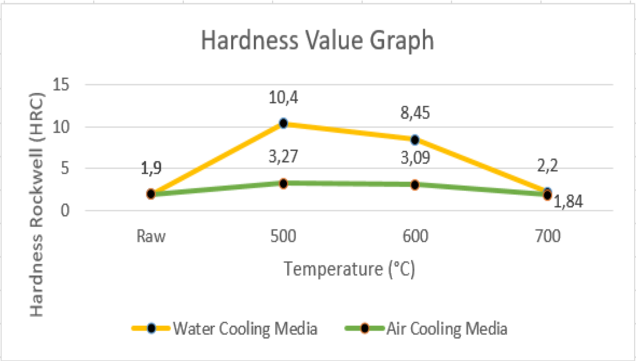


Figure 2. Hardness Value Graph of S355J2

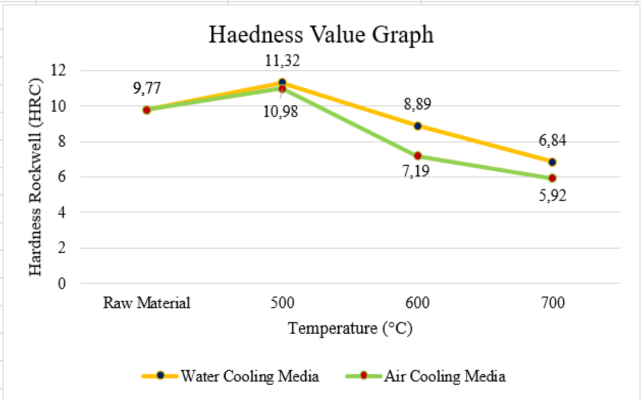
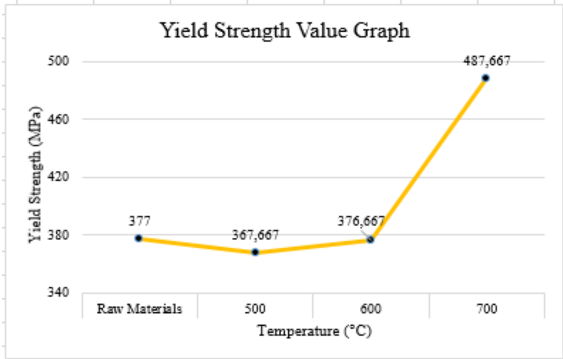


Figure 3. Hardness Value Graph of SS400

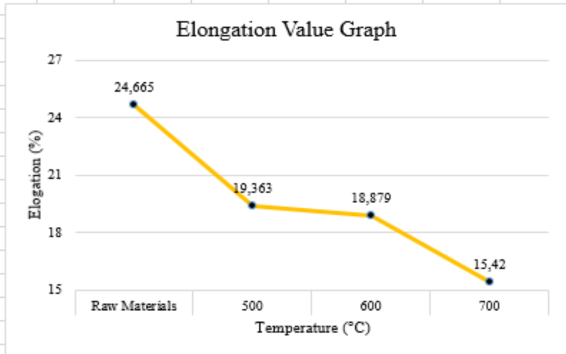
Figure 2 and Figure 3 show the increase in the hardness value of the 500 temperature-change samples compared to the samples of the raw materials, indicating that they become harder and more brittle. It can be seen that the higher the temperature used in the repair process, the lower the hardness value. This is due to the heat treatment, which leads to the softening of the material [17].

Cooling media affects the cooling speed, air cooling media tends to have a slower cooling speed and can affect the hardness and strength of the material [21]. The cooling environment and the temperature in the modification cycle affect the material's strength, hardness and flexibility. Higher reforming temperatures tend to produce a more significant decrease in hardness, the higher the reforming temperature, the greater the decrease in hardness that occurs and causes a decrease in hardness which results in decreased material strength [19].

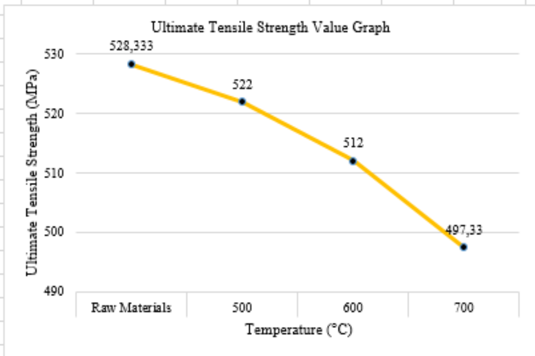
Tensile tests are performed using the tensile strength to determine the strength of the material, the level of elasticity and elongation with the standard used ASTM E8M using the unit 300 kN UTM [22]. The test produces hardness values including yield strength, elongation, and ultimate tensile strength as shown in Figure 3, Figure 4, Figure 5, and Figure 6.



(a)

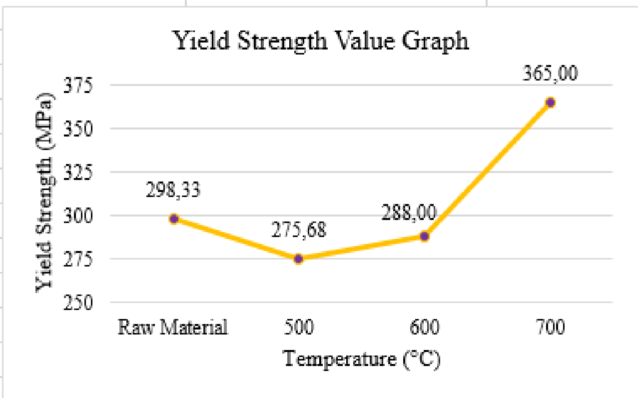


(b)

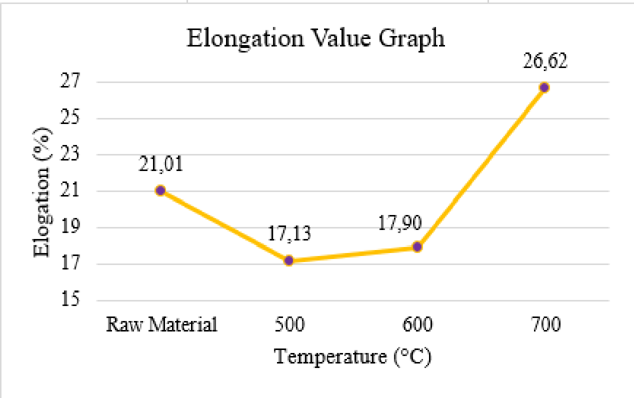


(c)

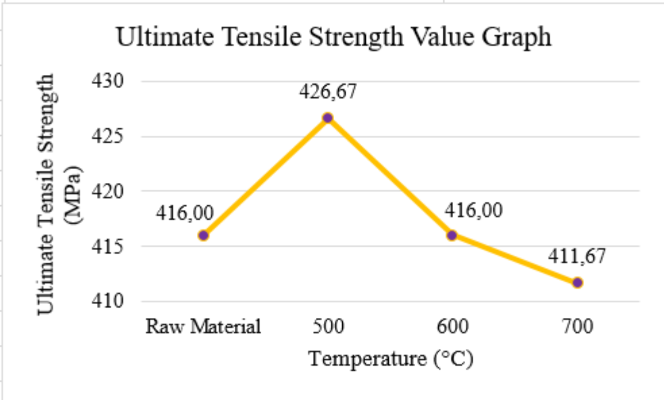
Figure 4. Graph of Tensile Strength Values of Materials with Water Cooling Media (a) Yield Strength (b) Elongation, (c) Ultimate Tensile Strength of S355J2 Steel



(a)



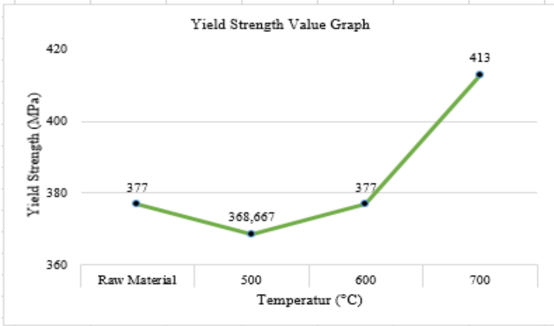
(b)



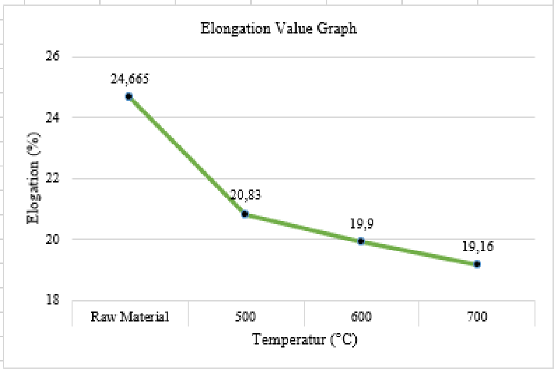
(c)

Figure 5. Graph of Tensile Strength Values of Materials with Water Cooling Media (a) Yield Strength (b) Elongation, (c) Ultimate Tensile Strength of SS400 Steel

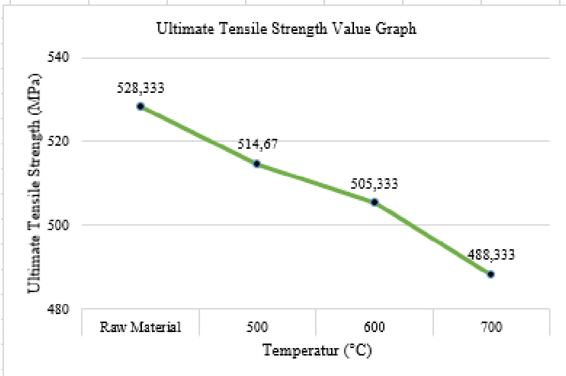
The modification process results in a change in the strength and hardness of the material, which is indicated by a change in the yield strength value. It can be seen that the value of the place of delivery or the place of delivery of goods after the test has increased continuously by crossing the place of delivery. In this design, the yield strength value of the raw material is 298.33 MPa. This value affects the increase in elongation and the resulting final tensile strength [23]. The elongation of a material refers to how long the material lasts until it breaks during the test. The elongation of the material is related to the yield strength value, the lower the yield strength value, the shorter the length of the material because the material is more prone to entrainment and breakdown [24]. The Ultimate Tensile Strength (UTS) graph shows different values at each reforming temperature, the results of the UTS value of the material using water media reforming temperatures of 500°C, 600°C and 700°C decreased. The results of the UTS value are inversely proportional to the results of the elongation value and the yield strength value [25].



(a)

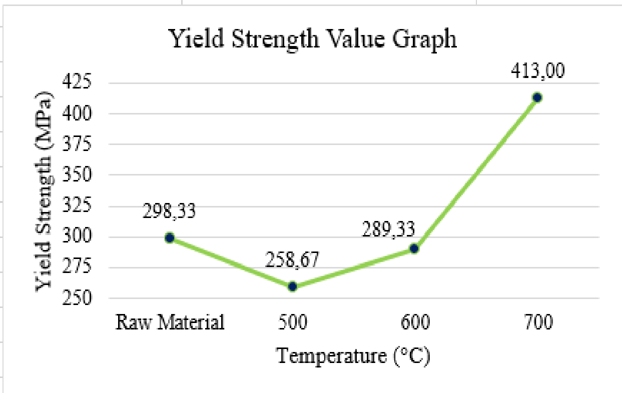


(b)



(c)

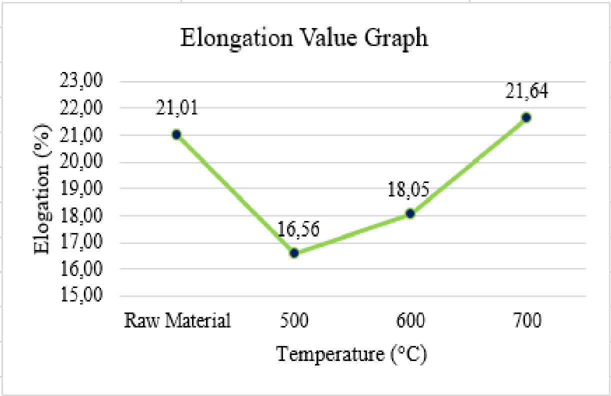
Figure 6. Graph of Tensile Strength Values of Materials with Air Cooling Media (a) Yield Strength (b) Elongation, (c) Ultimate Tensile Strength of S355J2 Steel



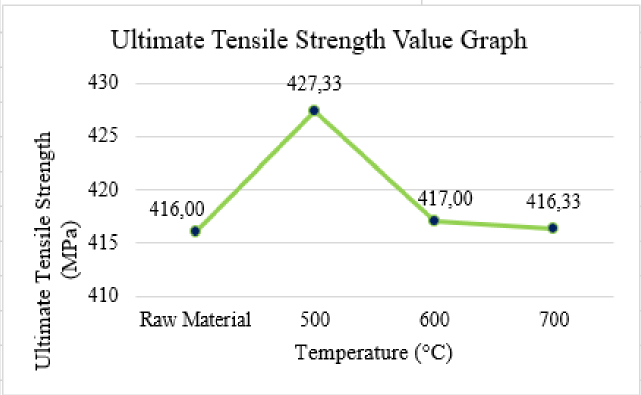
(a)

Indarto Yuwono, Alfi Tranggono Agus Salim, Kholis Nur Faizin, Tania Setya Ningsih, Nabila Wienda Wahyudi, Alfin Nur Adinda, Pitaloka Nurhalizah, Shella Cory Indila Putri, Tomi Alfian Ogik Awan, "Effect of Temperature Variations and Cooling Media on S355J2 and SS400 Steel Materials in the Reforming Process," *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 4, pp. 153-158, 2024.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024



(b)



(c)

Figure 7. Graph of Tensile Strength Values of Materials with Air Cooling Media (a) Yield Strength (b) Elongation, (c) Ultimate Tensile Strength of SS400 Steel

Cooling media affects the cooling speed, air cooling media tends to have a slower cooling speed so that it can affect the value of tensile strength and material strength [21]. The cooling media and temperature in the reforming process can affect the results of the tensile strength and ductility of the material, higher reforming temperatures tend to produce a more significant increase in tensile strength values, the higher the reforming temperature, the greater the increase in tensile strength that occurs [17].

IV. CONCLUSION

In this study, the microstructure formed in raw materials and test specimens of the reforming process with air and water cooling media produces ferrite and pearlite phases. The highest percentage value of pearlite phase at the lowest temperature variation of 500°C is higher than the raw material, and the higher the temperature of the reforming process affects the grain size of pearlite and ferrite phases which are getting bigger, which has an impact on the value of hardness and tensile strength which is decreasing. The highest hardness value in the 500°C temperature variation is higher than that of the raw material, and the higher the temperature of the reforming process results in a lower hardness value, and specimens with water cooling media have higher hardness values than those with air cooling media, resulting in materials with harder and brittle properties. The highest tensile strength value in the 700°C temperature variation is higher than that of the raw material, and the higher the reforming process temperature, the higher the tensile strength value, and the specimen with air cooling media has a higher tensile strength value than that with water cooling media, resulting in a material with softer and more ductile properties.

ACKNOWLEDGMENTS

We would like to thank the funders in the Internal Competitive Research activity, namely the DIPA Fund Number: 023.18.2.677632/2024 Madiun State Polytechnic (Politeknik Negeri Madiun), and thank the institution, namely the Madiun State Polytechnic and the Bench Work and Welding Workshop for helping the sustainability of our event both morally and materially.

REFERENCES

[1] Sulistyo, R., 2019, Pengaruh Temperatur Annealing Terhadap Kekuatan Mekanis Pada Daerah HAZ Pengelasan GMAW Semi Otomatis Baja SS 400 Pada Bogie Kereta Api. Jurnal Teknik Mesin 7(1), 111–116.
[2] Prayogi, A., 2019, Analisa Pengaruh Variasi Media Pendingin Pada Perlakuan Panas Terhadap Kekerasan dan Struktur Mikro Baja Karbon Rendah. Jurnal Polimesin 17(2), 29–36.
[3] Pratama, M.Y., Budiarto, U., Jokosisworo, S., Soedarto, J., 2019, Analisa Perbandingan Kekuatan Tarik, Tekuk, dan Mikrografi Pada Sambungan Las Baja SS 400 Akibat Pengelasan FCAW (Flux- Cored Arc Welding) dengan Variasi Jenis Kampuh dan Posisi Pengelasan. Jurnal Teknik Perkapalan 7(4), 203–214.
[4] JIS G3101, 2015, Rolled Steel for General Structure, 1st ed. Japanese Industrial Standards Commitee, Japan.
[5] Prabawanto, B., Rasyid, A.H.A., 2018, Pengaruh Annealing Terhadap Sifat Mekanis Daerah HAZ Pengelasan GMAW Baja SM490 Normalizing dan Tanpa Normalizing Pada Bogie Kereta Api Di PT. INKA Madiun. Jurnal Teknik Mesin 6(1), 75–82.
[6] Seno, H.R., 2022, Analisis Pengelasan GMAW Pada Pelat Baja SS400 Untuk Mengurangi Distorsi Studi Kasus Sheeting Roof E-Inobus. Prosiding Semnas Mesin PNJ, 46–55.
[7] Wijaya, T.A., 2017, Analisa Pengaruh Variasi Temperatur Reforming Terhadap Struktur Mikro dan Kekuatan Tarik Pada Baja SS400. Teknik. Institut Teknologi Sepuluh November.
[8] Satrijo, D., Prahasto, T., 2007, Analisis Kekuatan Underframe Kereta Barang Menggunakan Metode Elemen Hingga. ROTASI 9(3), 1–5.
[9] Bisri, H., 2022, Pengaruh Media Pendinginan Pada Proses Pengelasan SMAW Material Baja SS400 Terhadap Kekuatan Tarik dan Struktur Mikro. JTM 10, 55–60.
[10] Jordi, M., Yudo, H., Jokosisworo, S., 2017, Analisa Pengaruh Proses Quenching Dengan Media Berbeda Terhadap Kekuatan Tarik dan Kekerasan Baja ST 36 Dengan Pengelasan SMAW. Jurnal Teknik Perkapalan 5(1), 272–281.
[11] Hadi, S., 2016, Teknologi Bahan, 1st ed. CV. Andi Offset, Yogyakarta, Indonesia.
[12] Syahroni, N., Hidayat, M., 2012, 3D Finite Element Simulation of T-Joint Fillet Weld: Effect of Various Welding Sequences on the Residual Stresses and Distortions. https://doi.org/10.5772/50015
[13] Ferdiansyah, E., 2013, Ilmu Bahan Teknik. Kementerian Pendidikan dan Kebudayaan, Jakarta, Indonesia.
[14] Karno, 2023, Komunikasi Pribadi. Observasi PT INKA (Persero).
[15] ASTM E3, 2017, Standard Guide for Preparation of Metallographic Specimens. ASTM International. United States of America, 2–6.
[16] Zayadi, A., 2022, Pengaruh Waktu Tempering terhadap Karakter Baja S45C Pasca Quenching pada 950oC dan Tempering 500oC. Teknik. Universitas Nasional Jakarta.
[17] Zamazari, S.M., 2023, Studi Eksperimen Rekayasa Sifat Mekanik Baja S45C Dengan Menggunakan Heat Treatment. Teknik. Politeknik Negeri Madiun.
[18] Asmeanti, Y., 2014, Pengaruh Perlakuan Panas Terhadap Kekerasan Baja Karbon Tinggi Bohler K460. SINERGI 2, 124–138.

[19] Sardi, V.B., Jokosisworo, S., Yudo, H., 2018, Pengaruh Normalizing dengan Variasi Waktu Penahanan Panas (Holding Time) Baja ST 46 terhadap Uji Kekerasan, Uji Tarik, dan Uji Mikrografi. Jurnal Teknik Perkapalan 6, 142–149.
[20] ASTM E18, 2022, Standard Test Methods for Rockwell Hardness of Metallic Materials. ASTM International. United States of America, 3–11.
[21] Nasir, M., 2014, Pengaruh Media Pendingin Pada Proses Hardening Terhadap Peningkatan Kekerasan Baja Karbon Sedang. Teknik. Universitas Negeri Padang.
[22] ASTM E8/E8M, 2022, Standard Test Methods for Tension Testing of Metallic Materials. ASTM International. United States of America, 3–12.
[23] Julian, N., Budiarto, U., Arswendo, B., Soedarto, J., 2019, Analisa Perbandingan Kekuatan Tarik pada Sambungan Las Baja SS400 Pengelasan MAG Dengan Variasi Arus Pengelasan dan Media Pendingin Sebagai Material Lambung Kapal. Jurnal Teknik Perkapalan 7(1), 277–285.
[24] Sofyan, B.T., 2021, Pengantar Material Teknik, 2nd ed. UNHAN RI PRESS, Jawa Barat, Indonesia.
[25] Salindeho, R.D., Soukota, J., Poeng, R., 2013, Pemodelan Pengujian Tarik Untuk Menganalisis Sifat Mekanik Material. Jurnal Poros Teknik Mesin Unsrat 2(2), 1–11.