LOGIC
Journal of Engineering Design and Technology
Vol. 21 No. 3 November 2021; p. 225 - 231

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

EFFECT OF FORGING DEFORMATION AND COOLING ON MECHANICAL PROPERTIES OF MARTENSITIC STAINLESS STEEL

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Abstract. Stainless steel has good mechanical properties compared to other materials for strength and hardness, usually it will increase in hardness after hardening or forging. The purpose of this study was to obtain information about: The value of hardness and tensile strength of martensitic stainless steel forging with various deformations and cooling. The research method used is an experimental method, namely by forging on martensitic stainless steel with variations in deformation and cooling rate. Variations of forging deformation used are 25%, 50%, and 75%. The cooling media used are water, oil and air. The results of forgings with various cooling media were tested for tensile strength and tested for hardness using the Rockwell C (HRC) method. It was found that the higher the value of forging deformation, the higher the value of strength and hardness of martensitic stainless steel. This is because more and more martensite structures are recrystallized. In addition, it was also found that water and air cooling media gave an increase in the hardness of martensitic stainless steels. This is influenced by the cooling rate, where the higher the cooling rate, the more martensite structures formed, thus increasing the hardness value. The increase in hardness value is proportional to the increase in yield strength and tensile strength..

Keywords : martensitic stainless steel, forging deformation, cooling rate, tensile strength, hardness, yield strength, elongation.

1. INTRODUCTION

Martensitic stainless steel is widely used as a material for machine components, both transmission components and cutting tools.[1] This type of steel is a stainless steel that has good hardenability, which is easy to harden to a fairly high hardness value of 60-70 HRC.[2]

In the forging process it will go through a heating and cooling process, so that the material will undergo a heat treatment process.[3] Because the martensitic type has good hardenability, after the forging process it tends to increase in strength and hardness so that the material properties will turn out to be strong and hard.[4] With the increase of the forging pressure, the strength increased, the hardening capacity and strain hardening exponent decreased.[5] The hot forging technique was found to remove defects from the additive manufacturing material, resulting in enhanced mechanical strength, ductility, and isotropy.[6] This is necessary for engine components that require frictional resistance. Various cooling processes will have different cooling rates depending on the type of cooling medium.[7] The cooling media commonly used are: air, water, oil or other cooling media.[8] In addition to the cooling medium, different cooling methods will also produce different levels of hardness.[9] The hardness of the material increased due to combination of strain hardening and Hall-petch strengthening.[10] The good ductility benefits from the continous strain induced martensitic transformation with continous tensile deformation.[11] Maximum forging force are 100 tons, upper the value can decrease hardness.[12]

Based on this brief description, it is necessary to research the forging process on martensitic stainless steels with variations in cooling rates, so that they can determine the maximum strength and hardness properties..

2. METHODS

2.1 Research Design

In this study, 30 specimens were used of martensitic stainless steel with dimensions of 6x12x220 mm. Furthermore, martensitic stainless steel with these dimensions is forged with variations in forging deformation of 25%, 50%, and 75%. Shortly after being forged and then immersed in a different cooling medium, namely: water, air, and oil. Wait until the test specimen has cooled completely. Furthermore, the test specimens were tested for hardness on a hard test machine and also tested on a tensile machine. The aim is to obtain data on the value of hardness, elongation, tensile strength, and yield strength. Furthermore, the data is processed using a two-way analysis of variance (Two Way ANOVA) to analyze the effect of the magnitude of the deformation of the forging and the cooling medium on its mechanical properties which include hardness, elongation, tensile strength, and yield strength.

Figure 1. Martensitic Stainless Steel Specimen and test specimen

2.2 Research Flow Chart

The research design that has been described as follows:

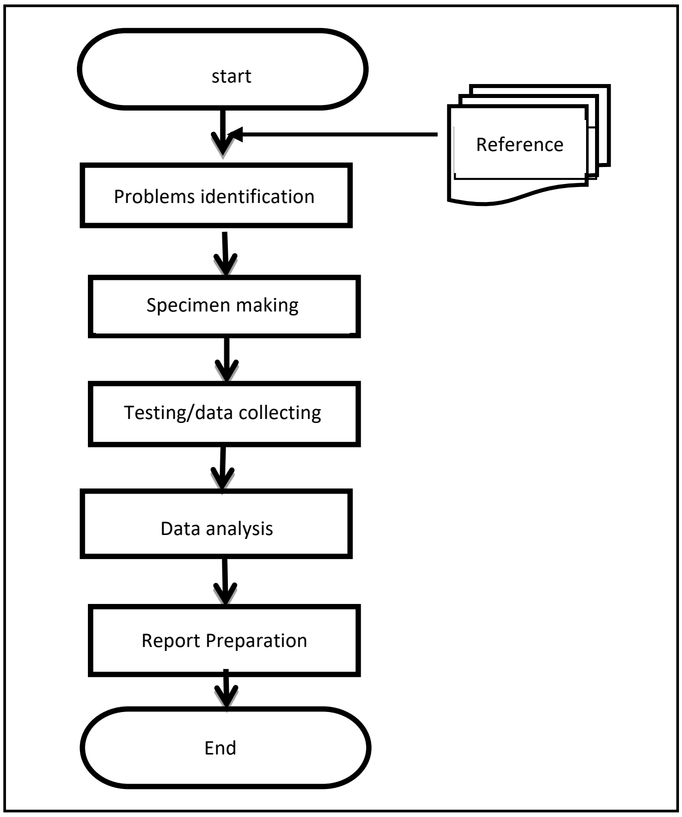

Figure 2. Design Flow Chart

3. RESULTS AND DISCUSSION

After forging with variations of forging deformation 25%, 50%, and 75% and variations of water, air, and oil cooling media. Then tested on the hard test machine and tensile testing machine. The results are as follows:

Table 1. Hardness (HRC)

Forging Deformation (%)	Cooling Media		
	Air	Oil	Water
75% (t = 1 mm)	79.8	77.6	78.3
	74.8	73.3	79.5
	74.8	75.3	79.7
Average	76.5	75.1	79.17
50% (t = 2 mm)	74.4	70.7	78.2
	74.4	69.4	78.8
	75.8	70.8	78.5
Average	74.8	70.3	78.5
25% (t = 3 mm)	74.6	65.3	78.2
	75.6	66.2	77.8
	77.3	65.7	78.2
Average	75.6	65.7	78.07

Table 2. Elongation (%)

Forging Deformation (%)	Cooling Media		
	Air	Oil	Water
75% (t = 1 mm)	20.8	20.8	16.7
	22.9	21.8	19.8
	20.8	22.9	20.8
Average	21.5	21.1	19.1
50% (t = 2 mm)	22.9	23	20.8
	22.9	22.9	20.8
	23	23	23
Average	22.93	22.96	21.53
25% (t = 3 mm)	24.3	24.3	22.8
	24.3	25	22.8
	23	23	23
Average	23.87	24.1	22.87

Table 3. Tensile Strength (Kg/mm^2)

Forging Deformation (%)	Cooling Media		
	Air	Oil	Water
75% (t = 1 mm)	93.4	84.4	91.3
	90.6	91.3	92.6
	90.2	86.2	93.3
Average	91.4	87.9	92.4
50% (t = 2 mm)	82.8	76.5	90.6
	80.3	78.4	88.5
	81.1	80.3	88.1
Average	81.4	78.4	89.1
25% (t = 3 mm)	76.3	68.6	79
	77.4	69.3	82.1
	78.2	70.3	79.8
Average	77.3	69.4	80.3

Table 4. Yield Strength (Kg/mm^2)

Forging Deformation (%)	Cooling Media		
	Air	Oil	Water
75% (t = 1 mm)	78.4	74.6	79.3
	74.2	73.5	78.4
	73.9	74.2	74.5
Average	75.5	74.1	77.4
50% (t = 2 mm)	71.5	65.5	68.6
	70.4	67	72.3
	69.3	70.4	70.9
Average	70.4	67.6	70.6
25% (t = 3 mm)	59.8	58.5	68.6
	58.2	60.6	69.3
	74.8	62.4	67.3
Average	64.2	60.5	68.4

3.1 Effect of Cooling Media Variation and Forging Deformation on Hardness

The interaction of cooling medium variation and forging deformation on hardness is shown in Figure 3. It was found that the 25%, 50%, and 75% forging deformations had the same characteristics of hardness values. The highest hardness values were equally obtained in water cooling media, followed by air cooling media, and the lowest hardness values were equally obtained in oil cooling media. This is influenced by the higher the cooling rate, the higher the hardness value. However, the oil cooling medium may react with the martensitic stainless steel structure, thereby eroding the carbon element in the martensitic stainless steel which causes the lowest hardness value compared to air and water cooling media. Furthermore, it was found that the higher the value of forging deformation, the higher the hardness value because the more martensitic stainless steel structures increased in hardness due to recrystallization. Lower processing temperatures increased strength, decreased ductility but decreased within-part property variation [13].

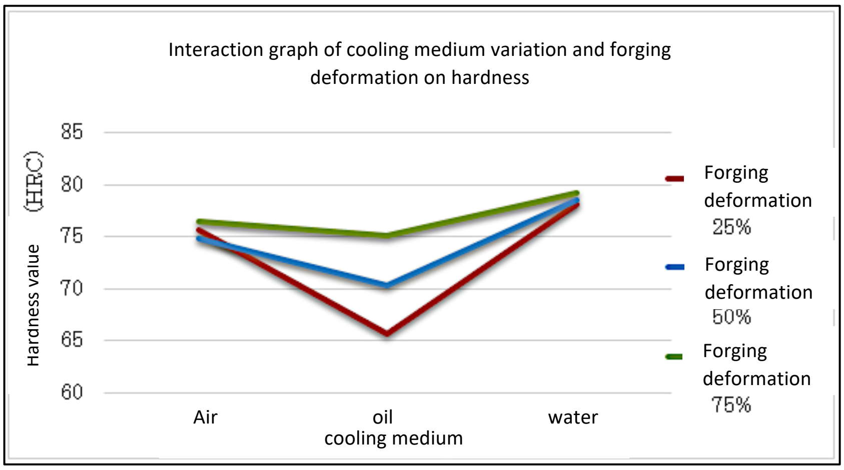

Figure 3. Interaction of Cooling Medium Variation And Forging Deformation On Hardness

3.2 Effect of Cooling Media Variation and Forging Deformation on Elongation

The elongation of forged steel with variations in cooling medium and forging deformation is shown in Figure 4. The highest elongation value is for forged steel with a forged deformation value of 25%, followed by forged steel with a forged deformation value of 50%, and the lowest deformation value is steel. forging with 75% forging deformation. At 25% forging deformation, the mechanical properties of martensitic stainless steel still have elastic or ductile properties. When the forging deformation is increased to 50%, the mechanical properties of the martensitic stainless steel change to become more plastic, until the 75% forging deformation results in the martensitic stainless steel having the dominant property of being plastic.

Variations in cooling media have a significant effect on water cooling media. Where the steel forged with water cooling media experienced a drastic decrease in the elongation value at 75% forging deformation. It is different with 25% and 50% forging deformation which has the highest elongation value in the oil cooling medium, 75% forging deformation has the highest elongation value in the air cooling medium. This indicates that the higher the value of forging deformation will have a significant impact on the effect of the cooling medium used in relation to the increase in the hardness of martensitic stainless steel.

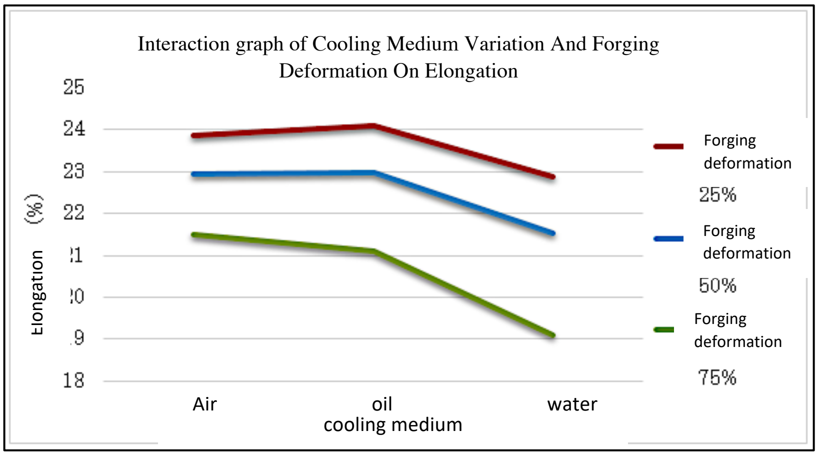

Figure 4. Interaction of Cooling Medium Variation And Forging Deformation On Elongation

3.3 Effect of Variation of Cooling Media and Forging Deformation on Tensile Strength Max.

Interaction of cooling medium variation and forging deformation on the max. shown in Figure 5. It was found that the forging deformations of 25%, 50%, and 75% had a characteristic tensile strength value of max. the same one. The value of tensile strength max. The highest values were found in the water cooling medium, followed by the air cooling medium, and the tensile strength value of max. The lowest values were equally found in the oil cooling medium. This is influenced by the higher the cooling rate, the higher the tensile strength value. also getting higher. However, the oil cooling medium may react with the martensitic stainless steel structure, thereby eroding the carbon element in the martensitic stainless steel which causes the maximum tensile strength value. lowest compared to air and water cooling media. Furthermore, it was found that the higher the value of forging deformation, the higher the hardness value because more and more of the martensitic stainless steel structure recrystallized and increased the value of the tensile strength max. Otherwise, the grain size does not increase with increasing the forging temperature, which results from the occurence of dynamic recrystallization caused by deformation.[14]

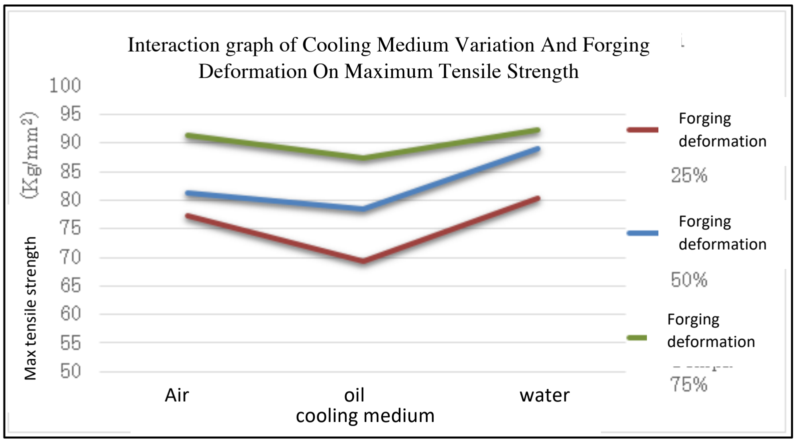

Figure 5. Interaction of Cooling Medium Variation And Forging Deformation On Maximum Tensile Strength

3.4 Effect of Cooling Median Variation and Forging Deformation on Yield Strength

The interaction of cooling medium variation and forging deformation on yield strength values is shown in Figure 6. It was found that the 25%, 50%, and 75% forging deformations had the same characteristic yield strength values. The highest yield strength values were equally obtained in water cooling media, followed by air cooling media, and the lowest yield strength values were equally obtained in oil cooling media. This is influenced by the higher the cooling rate, the higher the yield strength value. However, the oil cooling medium may react with the martensitic stainless steel structure[15], thereby eroding the carbon element in the martensitic stainless steel which causes the lowest yield strength value compared to air and water cooling media. Furthermore, it was found that the higher the value of forging deformation, the higher the hardness value because more and more martensitic stainless steel structures recrystallized and increased the yield strength value.

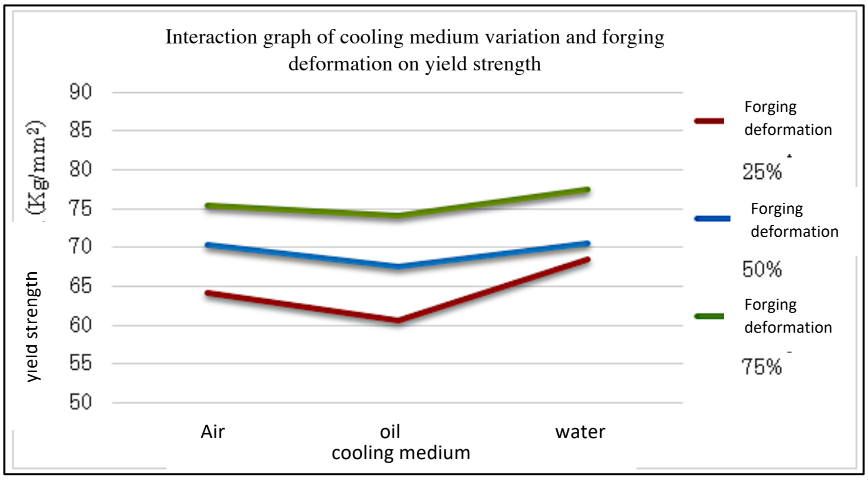

Figure 6. Interaction of cooling medium variation and forging deformation on yield strength

4. CONCLUSION

Based on this discussion, it can be concluded that the higher the value of forging deformation, the higher the value of strength and hardness of martensitic stainless steel. This is because more and more martensite structures are recrystallized. In addition, it was also found that water and air cooling media gave an increase in the hardness of martensitic stainless steels. This is influenced by the cooling rate, where the higher the cooling rate, the more martensite structures formed, thus increasing the hardness value. The increase in hardness value is proportional to the increase in yield strength and tensile strength.

5. ACKNOWLEDGEMENT

The author would like to thank all those who have helped financially or morally so that the researcher can complete this research article. The author hopes that the results of this research can contribute to the development of science and technology and can be applied to industries engaged in the material sector.

6. REFERENCES

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