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EFFECT OF HEAT TREATMENT ON THE STRENGTH OF AUSTENITIC STAINLESS STEEL SS304

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ABSTRACT

EFFECT OF HEAT TREATMENT ON THE STRENGTH OF AUSTENITIC STAINLESS STEEL SS304. Stainless steel is used in the nuclear industry and nuclear power plants because it has good corrosion resistance. In its usage, occasional heating process results a sensitization. Past research shows that it is possible to restore the microstructure of austenitic stainless steels that have undergone a process of sensitization to the initial conditions. To see the possibility of it then do some heat treatment processes on stainless steel SS304 in the hope it can also improve its mechanical properties. The samples are heated at a temperature varies from 500^{O}C to 1100^{O}C. The heating time varies and so does the cooling process. The repair process is done at a temperature of 1100^{O}C in the furnace with cooling variation. The process of heating also made with LPG flame to the melting point and followed by cooling using ice water. Metal strength represented by the hardness testing that have a direct correlation to the tensile strength of the metals. From the research that has been done, it can be concluded that it is not possible to upgrade the hardness of SS304 with heat treatment process. Each heating process followed by varies cooling of SS304 produce the hardness in the same or decreased. The results can also be used to conclude that the welding process on the SS304 will always result in a decrease in the strength of the metal parts that are affected by the welding heat.

Keywords: heat treatment, improved strength, SS304.

ABSTRAK

PENGARUH PERLAKUAN PANAS TERHADAP KEKUATAN BAJA TAHAN KARAT AUSTENITIK SS304. *Baja tahan karat digunakan dalam industri nuklir dan PLTN karena mempunyai ketahanan terhadap korosi yang baik. Dalam penggunaannya, kadangkala terjadi proses pemanasan yang mengakibatkan terjadinya sensitisasi. Riset terdahulu memperlihatkan bahwa dimungkinkan untuk mengembalikan struktur mikro baja tahan karat austenitik yang telah mengalami proses sensitisasi ke kondisi awalnya. Untuk melihat kemungkinan itu maka dilakukan beberapa proses perlakuan panas pada baja tahan karat SS304 dengan harapan juga dapat memperbaiki sifat mekaniknya. Sampel dipanaskan pada temperatur bervariasi dari 500^{O}C hingga 1100^{O}C. Waktu pemanasan juga dibuat bervariasi dan begitu juga dengan proses pendinginan. Proses perbaikan dilakukan pada temperatur 1100^{O}C di dalam tungku dengan pendinginan yang bervariasi. Juga dilakukan proses pemanasan dengan api LPG hingga titik leleh dan dilanjutkan dengan pendinginan menggunakan air es. Kekuatan logam diwakili dengan pengujian kekerasan yang mempunyai korelasi langsung terhadap kekuatan tarik logam. Dari penelitian yang telah dilakukan dapat disimpulkan bahwa tidaklah mungkin melakukan peningkatan kekerasan SS304 dengan proses perlakukan panas. Setiap proses pemanasan SS304 yang diikuti dengan pendinginan yang bervariasi hanya menghasilkan kekerasan yang sama atau menurun. Hasil yang ada ini juga dapat digunakan untuk menyimpulkan bahwa proses pengelasan pada SS304 akan selalu mengakibatkan penurunan kekuatan pada bagian logam yang terpengaruh oleh panas pengelasan.*

Kata kunci : Perlakuan panas, perbaikan kekuatan, SS304.

INTRODUCTION

Austenitic stainless steel is used in an industry including the nuclear industry. It steel has better corrosion resistance than carbon steel. However, the enrichment of $Cr_{23}C_6$ in SS304 was increased due to the increasing time of sensitization. This enrichment caused the reduction in nobility and nucleation pitting corrosion resistance behavior of SS 304 [1].

Sensitization of austenitic stainless steels will decrease tensile strength. SS304 austenitic stainless steel is used as a coating of the nuclear reactor vessel. This steel occasionally undergoes uncontrolled heating process resulting in chrome assembling as one of the passive layer forming elements in the grain boundary [2]. If that condition occurs, then the tensile strength of the stainless steel will decrease [3]. The purpose of this study is to determine effectively improvement the strength of austenitic stainless steels that have been damaged by heating. One possible way is to reconstitute the elements that have been assembled at the grain boundaries by heating and continuing with rapid cooling. To carry out the research in question, it will be used heating furnaces or LPG flames to heat test and cooling samples at different speeds. The tensile strength of the metal is measured by a hardness test representative having direct correlation to metal tensile strength [4].

One reason of using austenitic stainless steels is to coat the pressure vessel to increase its corrosion resistance. The austenitic stainless steel will experience sensitization when subjected to warming in the range 500^{O}C-850^{O}C [5]. Sensitization will reduce or losing the integrity of an alloy. The cause of sensitization is reduction or depletion of chromium due to the formation of chromatic carbides that are settled at the grain boundaries. The presence of this sensitization is thought to decrease the strength of the alloy. Components that have experienced a decrease in strength will certainly decrease its function. In large enough components, it is very difficult to replace it. There must be a way that can be done to increase the strength of the alloy that has been decreased. The purpose of this study was to find a way to increase the strength of SS304 austenitic stainless steel alloys that have experienced a decrease in strength due to sensitization. How to increase the strength of austenitic stainless steels will be sought by heating and cooling at a certain rate. In the presence of warming it is desirable that chrome carbide can be separated. By doing a rapid cooling it is expected that carbides will not be formed or at least less formed.

METHODOLOGY

The way to be selected for this research is to make a sample made of SS304 austenitic stainless steel of the same shape. In this case is in the form of coins. Later, the sample can also be used in corrosion rate testing. The first step is to test the SS304 austenitic stainless steel alloy in fresh condition. The tests include microstructure test and hardness test. The microstructure test is performed to see the grain shape before experiencing the destruction / alteration. Hardness test is performed instead of tensile test because of the direct correlation between hardness and tensile strength of metal.

Fresh test specimens of SS304 are then damaged / altered by heating the test samples in a furnace at 500^{O}C - 1100^{O}C and followed by different cooling rate, in the furnace and at the air. Then the microstructure and hardness were tested. The test results were used to look for possible improvements to the damaged alloy.

The sample that has been damaged is then given heat treatments by heating in a heating furnace or heated with an arc of acetylene welding. After heating, the test specimens are cooled with different cooling rates. To illustrate different cooling rates, it will be cooled in the open air, in engine oil, in water at room temperature and in ice water. After cooling at different rates, the test sample is reexamined in hardness as well as its microstructure.

RESULTS AND DISCUSSION

The hardness values of the heat treatment process in the sample are shown in Table1.

Table 1. Hardness values of the heat treatment process in the sample

No	Heating Temperature	Holding Time	Treatment	Hardness Value
1	600^{O}C	1 hour	Cooled in furnace	223HV30
2	800^{O}C	2 hours	Cooled in furnace	171HV30
3	800^{O}C	2 hours	Cooled in a	Once process 178HV30 and two

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No	Heating Temperature	Holding Time	Treatment	Hardness Value
		45min	furnace	times process 145HV30
4	800^{O}C	2 hours	Cooled in the furnace, followed by heating 850^{O}C 5 hours and cooled in air, water, ice water, and engine oil	No hardness test results indicate rising value
5	800^{O}C	2 hours	Cooled in the furnace, followed by heating 1100^{O}C 1 hour and cooled in water and air	150HV30
6	1100^{O}C	1 hour	Cooled in water	140HV30
7	1100^{O}C	gradually in the furnace and held for 1 hour	Cooled in water	150HV30
8	1100^{O}C	5, 10, 20, and 30 minutes	Cooled in air	140-150HV30
9	1100^{O}C	5, 10, 20, and 30 minutes	Cooled in air, continued with heating of 800^{O}C 36 hours of cooling in the furnace	140-150HV30
10	500^O, 600^O, 700^O, 800^O and 900^{O}C	5 hours	Cooled in furnace	Obtained by sequential hardness of 223HV30, 223HV30, 206HV30, 184HV30, 171HV30
11	500^O, 600^O, 700^O, 800^O and 900^{O}C	5 hours	Cooled in air	Obtained by sequential hardness of 223HV30, 223HV30, 191HV30, 184HV30, 171HV30
12	500^O, 600^O, 700^O, 800^O and 900^{O}C	5 hours	Cooled in furnace and continued by heating with LPG flame until	Obtained by sequential hardness of 171HV30, 165HV30,

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No	Heating Temperature	Holding Time	Treatment	Hardness Value
			the surface of the sample melted and cooled with ice water	155HV30, 171HV30, 155HV30
13	1100^{O}C	5, 10, 20, and 30 minutes	Cooled in air, continued by heating 800^{O}C 36 hours of cooling in the furnace and then heated by LPG flame and cooled with ice water	155HV30

After heating the fresh samples at 800^{O}C for 7 hours 45 minutes and continuing with cooling in the furnace, the sample is then be grinding followed by polishing. Etching was performed on a smooth surface using aqueous aqua regia and observed its microstructure using a microscope at 1000X lens enlargement. In the un-etched section, hardness testing is performed. A similar process was performed on samples undergoing heating and annealing twice. The microstructure obtained is compared to the microstructure of fresh samples and is given in figures 1 to 3.

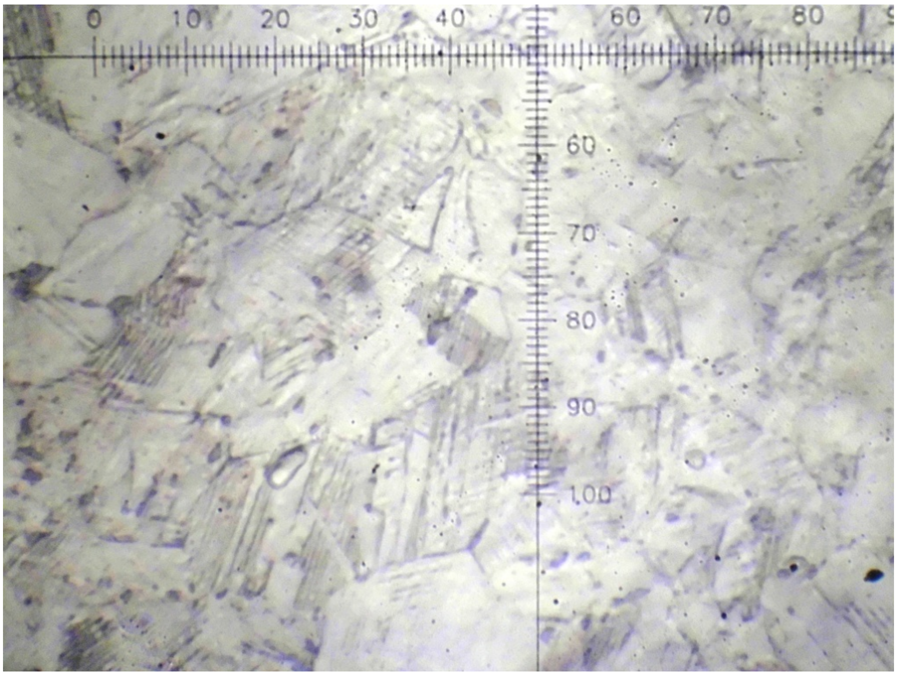

Figure 1. SS304 microstructure in fresh condition, (magnification 1000X), hardness 252HV30.

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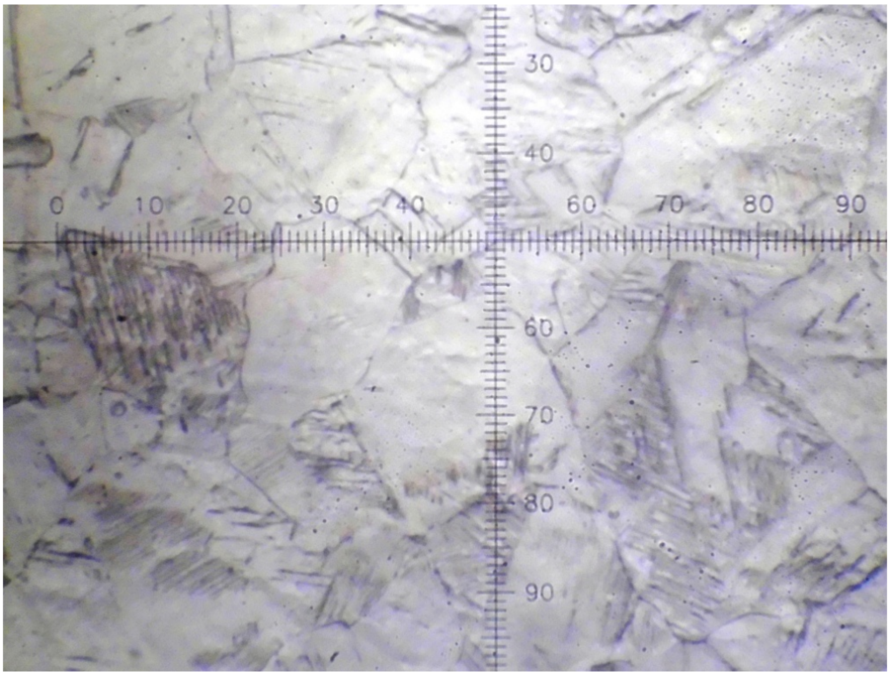

Figure 2. SS304 microstructure after heating and cooling in the furnace (magnification1000X), hardness 178HV30.

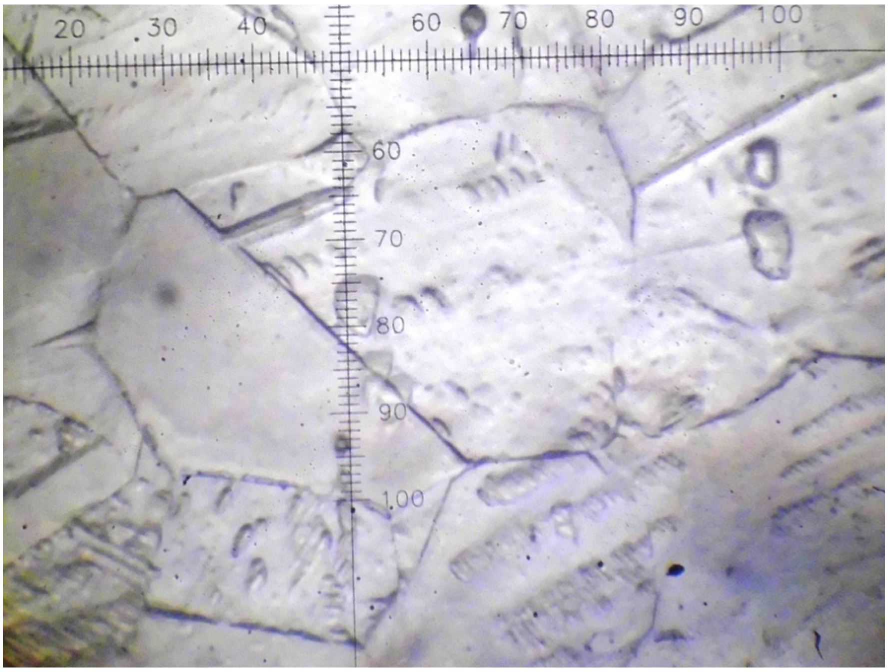

Figure 3. SS304 microstructure after two heating and cooling in the furnace (1000X magnification), hardness 145HV30.

Microstructure showed that the specimens which had once experienced heating and cooling in the furnace experienced grain enlargement and grain boundary thickening / widening. The results of the hardness test showed that the sample had a considerable decrease in hardness. In samples undergoing two similar heat treatment processes exhibit microstructure with increasingly enlarged grains and grain boundaries that are thickened while the hardness decreases but not as much as the first heat treatment process.

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The process for reducing the strength of SS304 as a simulation of the sensitization is done by heating the test samples in a furnace at 800^{O}C and followed by cooling in the furnace. After process, there were decreases in hardness from 250HV30 to about 170HV30. The descending sample was heat treated by heating at the furnace up to 850^{O}C for about 5 hours and cooled in four ways: cooled in the open air, cooled in water at room temperature, cooled in ice water, and cooled in oil. Hardness tests of samples that have been experienced with various media to illustrate different cooling rates show that no single specimen has increased hardness. Temporary suspicion does not occur solid dissolution at 850^{O}C. For that the process is repeated by heating specimens that have decreased strength at 1100^{O}C. It turns out that the violence actually decreased dramatically at 150HV30.

Because the increase in hardness is not obtained then heated fresh specimens at 1100^{O}C for one hour and continued with cooling in water. Also heated the specimens in the furnace gradually up to 1100^{O}C and held for one hour and continued by cooling in water. From the hardness test to the last two specimens obtained almost the same hardness that is about 140-150HV30. It was then attempted to heat the specimen that had undergone heat treatment and also on fresh specimens at 1100^{O}C for 5, 10, 20, and 30 minutes and cooled in air. It turns out the violence gained around 140-150 HV30 as well. From the results, it is temporarily concluded that the value of 140-150HV30 is SS304 hardness during the manufacturing process prior to cold work.

Specimens that have experienced a decrease in hardness of up to 140-150 HV30 due to heating at 1100^{O}C and cooling in air are heated repeatedly at 800^{O}C for 6 hours and cooled in the furnace 6 times. After a total of 36 hours of warming at 800^{O}C and cooled in the furnace, the research activity continued by heating the sample using LPG heater up to 25 seconds and continued with cooling with ice water drenched. Hardness testing results show a value of 155HV30, this means that the process of increasing the hardness failed to be obtained.

Figure 4 shows that the hardness of austenitic stainless steels prior to cold working has a hardness of about 160 HV. This value is close to the value obtained from hardness testing in the sample used in this study.

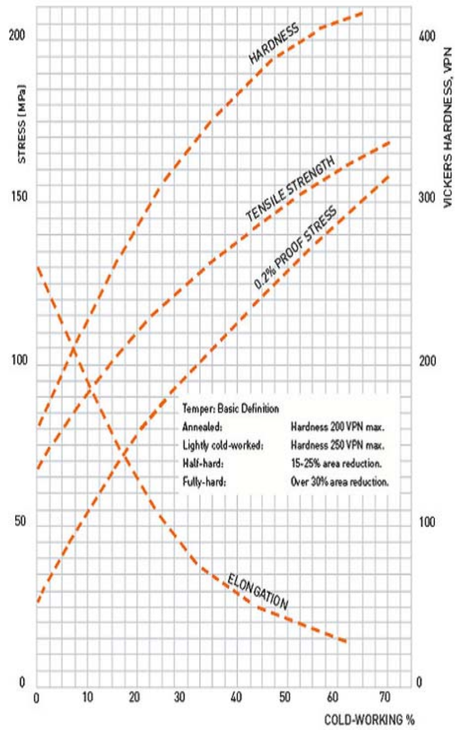

Figure 4. Effect of Cold Working on Mechanical Properties of Austenitic Stainless Steel [6].

To obtain a more structured result, the study continued by heating each of the two fresh samples at temperatures of 500^{O}C, 600^{O}C, 700^{O}C, 800^{O}C, and 900^{O}C for 5 hours and cooled in the furnace. Also done the same heating each one fresh sample, but cooled in air.

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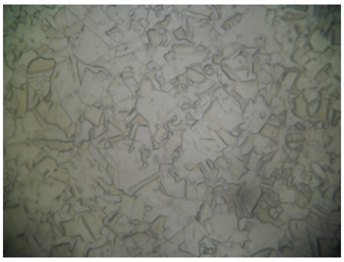
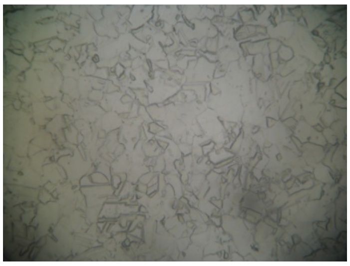
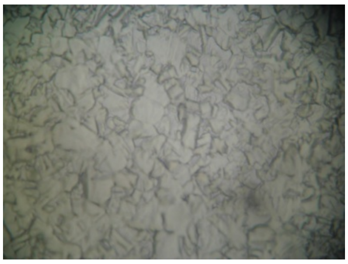


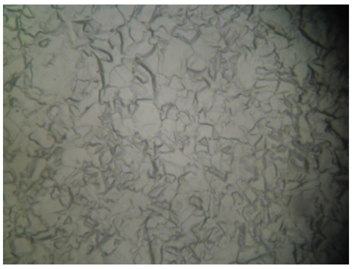
Sample A, 500X magnification.



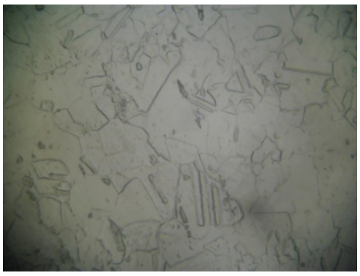
Sample B, 500X magnification.



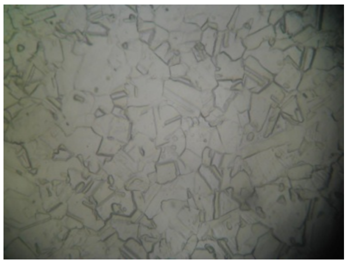
Sample C, 500X magnification.



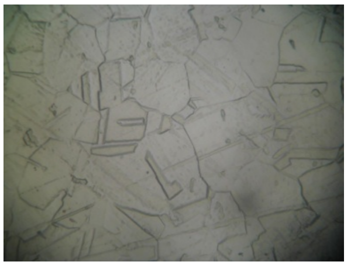
Sample D, 500X magnification.



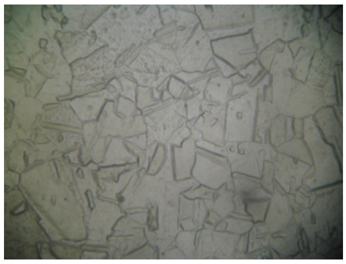
Sample E, 500X magnification.



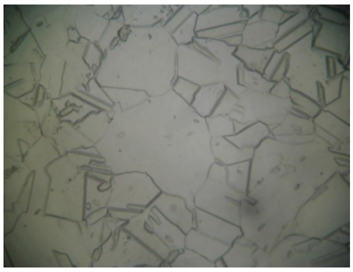
Sample F, 500X magnification.



Sample G, 500X magnification.



Sample H, 500X magnification.



Sample I I, 500X magnification.

Sample J, 100X magnification.

Figure 5. Microstructure of A-J Samples

The next heat treatment is to heat the specimen using a LPG heater up to 25 seconds (noticeable start of sample melting) and continued with cooling with ice water drenched.

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The heating results of each of the two fresh samples at a temperature of 500^{O}C, 600^{O}C, 700^{O}C, 800^{O}C, and 900^{O}C for 5 hours and cooled in the furnace were found to be 223HV30, 223HV30, 206HV30, 184HV30, 171HV30, respectively. While from the same heating of each sample, but cooled in the air (named samples A, B, C, D, and E) obtained 223HV30, 223HV30, 191HV30, 184HV30, 171HV30 respectively.

From the results it is seen that the cooling process in the furnace or in the air that has a different cooling rate, was not enough to affect the hardness.

The sequential hardness obtained from heating by LPG flame for 25 seconds and cooled with ice water, in each of the samples subjected to cooling in the furnace (named samples F, G, H, I, and J), is 171HV30, 165HV30, 155HV30, 171HV30, 155HV30. The sample hardness value after heating up to its melting point and cooled with ice water, was only very slightly above the sample which heated to 1100^{O}C and cooled with various cooling rates that were between 140-155HV30. In the scale of the indenter diagonal gauge trace hardness test, the value is only different 1-2 smallest scale.

The microstructure of sample A to sample J is given in Figure 5. By comparing the existing images between samples A and F, B and G, C and H, D and I, E and J, it is clear that there is an enlargement of the grain size caused by the heating samples to their melting point.

CONCLUSION

From the research that has been done, it can be concluded that the increase of SS304 hardness cannot be done with heat treatment process. Any SS304 heating process followed by varying cooling will result in only the same or decreased hardness. These existing results can also be used to infer that the welding process in SS304 will always result in a decrease in strength on the heat affected zone.

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