

Effect of Heat Treatment on Hardness and Impact Strength of Stainless Steel

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ABSTRACT

Abstract: Nowadays, stainless steel is widely used in many field due to its excellent mechanical properties compare to other materials; therefore improvement on properties of stainless steel needed to respond well to current trend. Factor of safety for products can be improved by designing high durability and reliability structures in order to ensure safety to its users. This study was conducted to investigate the effect of heat treatment on impact strength, hardness and microstructure characterization of heat treated stainless steel. Stainless steel specimens will be heated in various conditions which are soaking time and temperature. Next, different quenching media were used to identify effect of it on the heat treated specimens. The alloy was treated with solution at temperature of 900°C for different time batch. Next, it was quenched using different media such as distilled water and mixed lubricant. Aging process will be conducted at temperature of 700°C which is suitable elevated temperature for aging process. Impact strength and hardness value will be obtained using Charpy impact test and Rockwell hardness tester respectively. Lastly, microstructure of the material will be observed using SEM (Scanning Electron Microscope) to determine its microstructure.

Keywords: Stainless steel, impact strength, hardness, aging.

ABSTRAK

Zaman ini, keluli tahan karat digunakan secara meluas dalam banyak bidang kerana ia mempunyai ciri-ciri mekanikal yang diperlukan berbanding dengan bahan lain; oleh itu penambahbaikan ke atas keluli tahan karat perlu dilakukan. Faktor keselamatan sesuatu produk boleh dipertingkatkan dengan mereka struktur yang mempunyai nilai ketahanan dan kebolehpercayaan yang tinggi untuk memastikan keselamatan kepada pengguna. Kajian ini dijalankan untuk menyiasat kesan pemanasan terhadap kekuatan impak, kekerasan and mikrostruktur ke atas keluli tahan karat. Keluli tahan karat akan dipanaskan dan direndamkan dalam penyejukan media yang berlainan. Aloi ini akan dipanaskan mencapai suhu 900°C mengikut masa pembakaran yang berlainan. Selepas itu, ia akan direndamkan dalam air and minyak. Proses penuaan dijalankan pada suhu 700°C yang merupakan suhu yang paling sesuai untuk proses penuaan. Kekuatan impak dan nombor kekerasan diperolehi dengan menggunakan ujian impak Charpy dan ujian kekerasan Brinell. Akhirnya, mikrostruktur spesimen akan diperhatikan menggunakan SEM untuk menentukan sifatnya.

Kata Kunci: Keluli tahan karat; kekuatan impak; kekerasan; penuaan

INTRODUCTION

Stainless steel is iron-based alloys with composition of carbon, manganese, phosphorus, sulphur, silicon, chromium, nickel and molybdenum. Stainless steel has the stainless properties due to existence of chromium inside it as one of the main composition. Chromium will form a thin layer of chromium oxide to enhance the resistance of corrosion of this material. Addition of other chemical elements can improve other properties of stainless steel and hence there is various type of it. For instant, the resistance of corrosion properties of stainless steel can be improved by increases the quantity of nickel and molybdenum inside it (Callister & Rethwisch, 2008).

In industry, stainless steel is often applied in making gas turbine, high temperature steam boilers, heat-treating furnaces, aircraft, missiles, and nuclear power generating units. It is also used in hospitals, kitchens, abattoirs and other food processing plants because it is easy to clean which fulfills strict hygiene conditions. Due to wide application of stainless steel, it is important to improve the mechanical properties of stainless steel in order to enhance properties of it. This is because heat treatment can improve durability and reliability of stainless steel. It will make a step forward in bringing more benefits to user in various application fields (Ebrahimi, Keshimiri & Momeni, 2011; Beer & Johnston, 2006). Stainless steel will faces problem under certain condition when reaction occurs with active elements. For instant, stainless steel might corrode when contacts with hydrocholic acid; intergranular corrosion when facing intense heat(900 °F to 1500°F); pitting when dirt built up on the surface to avoid oxygen from contacting the surface of the steel; and galvanic corrosion when contacting with lead, nickel, copper, copper alloys and graphite (Jester, 2012).

The objectives in the project are to determine the impact strength of stainless steel after heat treatment solution and aging process based on time batches, investigate the hardness of stainless steel after heat treatment, quenching and aging process based on time batches. Comparisons is done between the changes of mechanical properties for stainless steel after heat treatment, quenching and aging process. Besides that, this project also want to determine the relationship between the type of quenching medium and impact strength of stainless steel, and do microstructure observation on the specimens after heat treatment solution and aging process.

EXPERIMENT PROCEDURE

First, stainless steel specimens are machined into standard size for Charpy V-Notch test according to ASTM standard will be heat treated in furnace for specific time based on time batch (ASTM A370-12, 2009). After that, stainless steel will be quenched by varying the quench medium and time duration of agitation to identify the effect of these variables to the properties of heat treated stainless steel. The process flow of project is shown in Figure 1. There are five main processes in this experiment, which are heat treatment, quenching, aging, testing and microstructure observation to obtain result for this project. For heat treatment and aging process, high temperature furnace was used to heat test specimens until desired solutionizing temperature of 900°C and 700°C respectively. Once heat treatment was done, the specimens were quenched in different medium which are distilled water and mixed lubricants. On the other hand, after aging process, there will be another different quenched medium which are distilled water and mixed lubricants for comparison in result afterward (Totten, 2007).

Next, in testing stage, impact test and hardness test will be conducted to examine behavior of stainless steel after previous heating and quenching stages. Pendulum Impact Tester will be used to determine the impact strength and Rockwell Hardness Test Machine will be used to define the hardness value of the test specimens. Finally, microstructure observation will takes place. At this stage, Scanning Electron Microscope (SEM) will be used to observe the changes in stainless steel failure surface. This will help to magnifying even little transformation in the structure of stainless steel after heat treated on various time batches and quenched in different mediums.



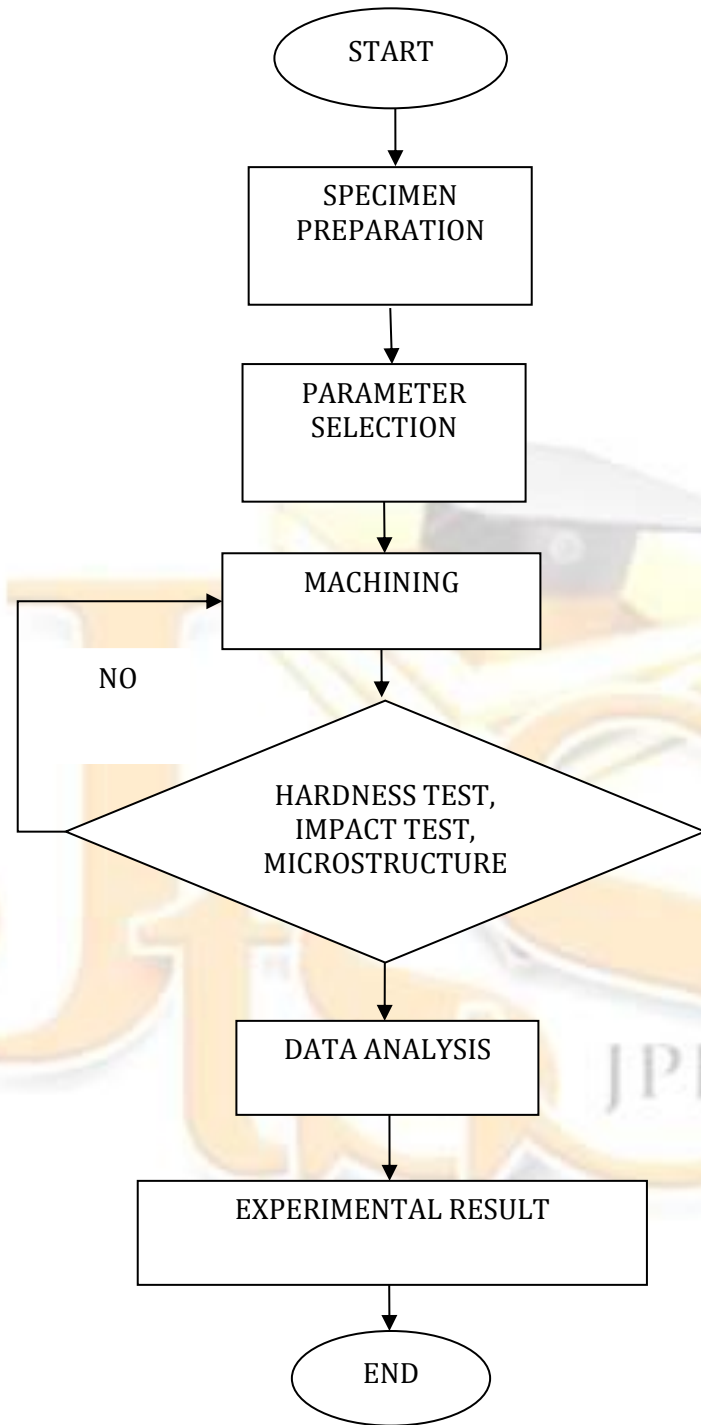


Figure 1: Flowchart Process

RESULT AND DISCUSSION

3.1 HARDNESS

Figure 2 shows specimens that quenched in distilled water have higher hardness value compared to those quenched in mixed lubricants; except for 2 hours heat treated specimen. This is the grain size in specimen of 2 hours heat treatment has not well developed within the treating time. So, when it is quenched in distilled water, the grain shrink faster than specimens that quenched in mixed lubricants. Therefore, smaller grain size of the specimens will resulted in higher hardness value compare to others specimens. The specimens of 2 hours heat treated also have higher hardness value compare to as received specimen. But, once the heat treated time increases, the hardness value for other heat treated specimens is decreases.

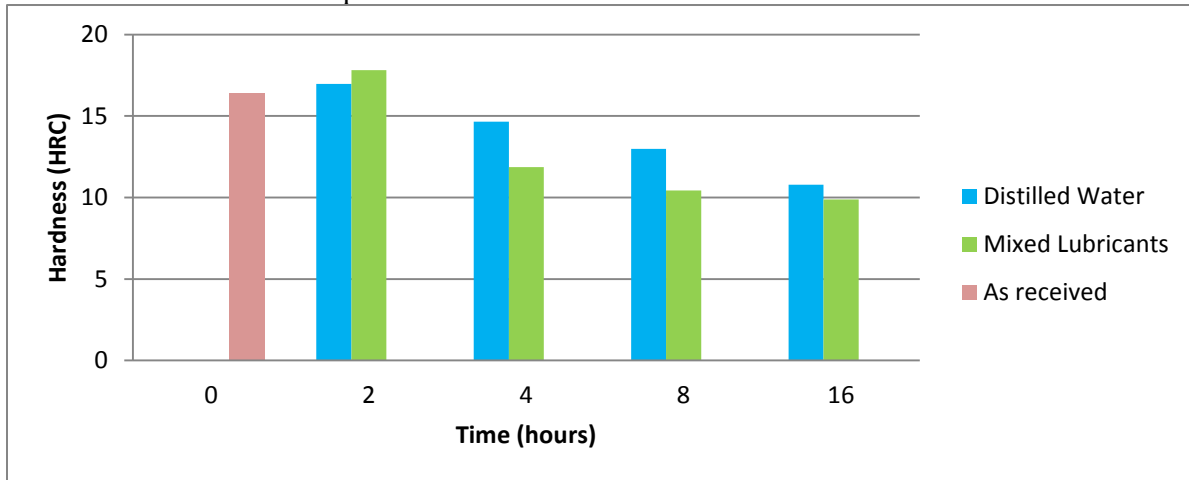


Figure 2: Hardness of Stainless Steel after Heat Treatment followed by Different Quenching Medium

Figure 3 shows that specimens that quenched in distilled water have higher hardness value compared to those quenched in mixed lubricants and as received specimens (Kopeliovich, 2013). Besides that, the trend of graph also obeys the aging curve. Specimens which are quenched in distilled water undergo rapid cooling process which will produce material with higher hardness value. This is because the grain inside the specimens will settle down faster and did not transform much during quenching process. So, once the grain size did not transform, martensite properties inside the material will influence the properties of it to become harder compared to those quenched in mixed lubricants.

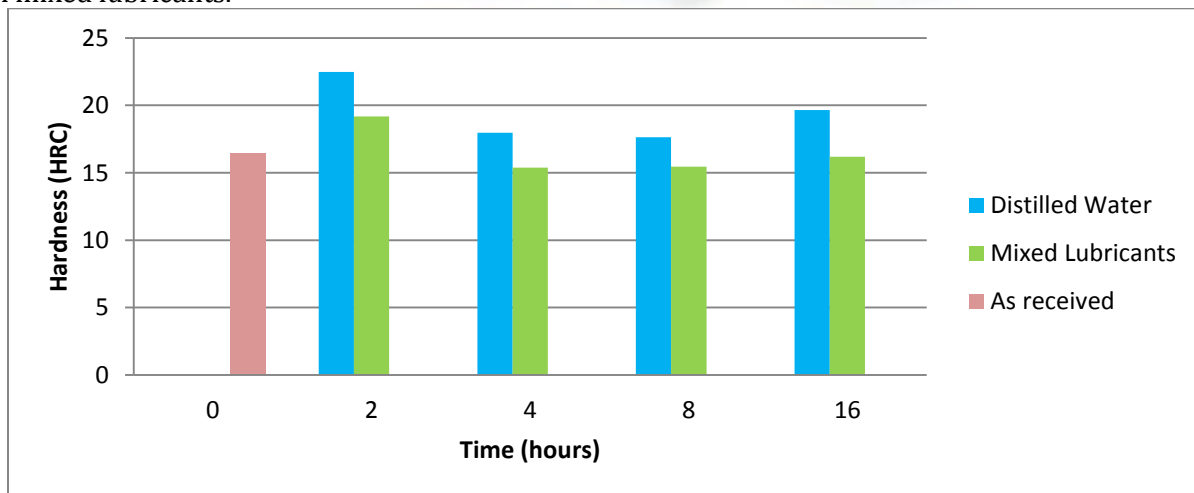


Figure 3: Hardness of Stainless Steel after Aging followed by Different Quenching Medium

3.2 IMPACT STRENGTH

Based on Figure 4, for specimens which are heat treated for 2 hours, quenching specimens in distilled water shows that they can absorb higher impact energy than mixed lubricants. Meanwhile, for the rest of the specimens, it shows a trend that mixed lubricants absorb higher impact energy than distilled water. The heat treated and quenched in distilled water for 2 hours specimens not following the trend is because of its hardness value will affect the impact energy of specimens as shown in figure 4. For the trend of higher impact energy absorbed by specimens which is quenched in mixed lubricant, it indicates that the cooling rate of mixed lubricant is lower than distilled water. Therefore, the grain inside the specimen can slowly transform into more coarser and behaves as more ductile compared to other quenching medium's specimens.

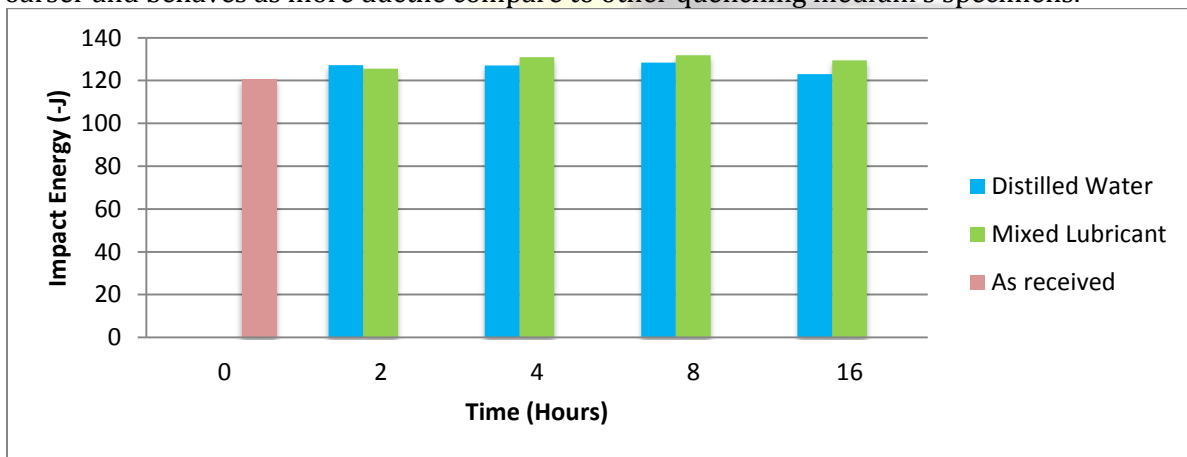


Figure 4: Impact Energy on Stainless Steel after Heat Treatment in Different Quenching Medium

Based on Figure 5, graph shows that the impact energy of aging for specimens quenched in mixed lubricant is higher than specimens quenched in condensed water. Aging process for 16 hours which quenched in distilled water has the ability to absorb highest impact energy. Based on figure 5, the trend of the curve matches with age hardening curve. Age hardening stated that once the specimens reached optimum point of aging point, the properties of material will decrease.

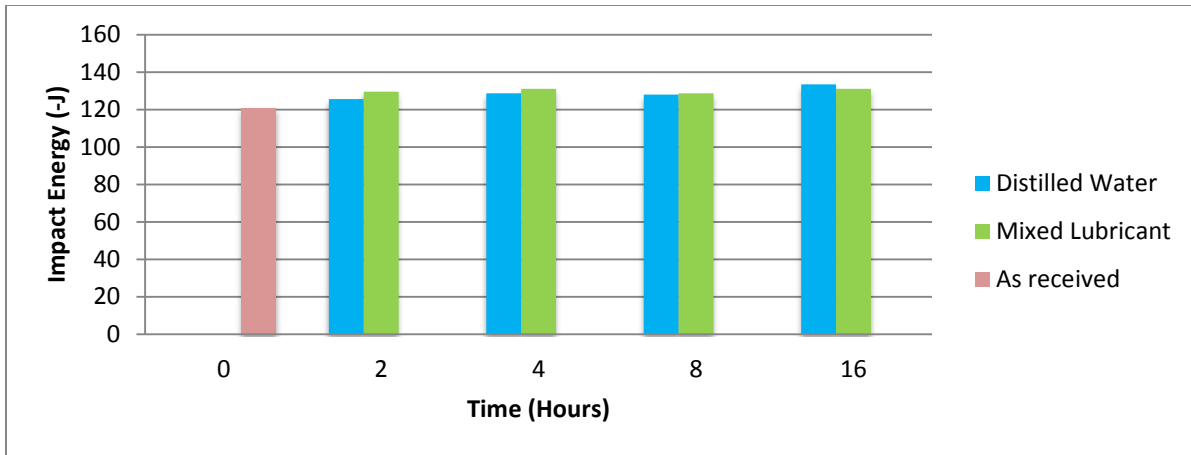


Figure 5: Impact Energy on Stainless Steel after Aging in Different Quenching Medium

In **Figure 6**, the graph shows summarize results from various processes with different heat soaking time respond to hardness properties. It shows that specimens which undergo aging and quenched in distilled water for 2 hours has the highest hardness value.

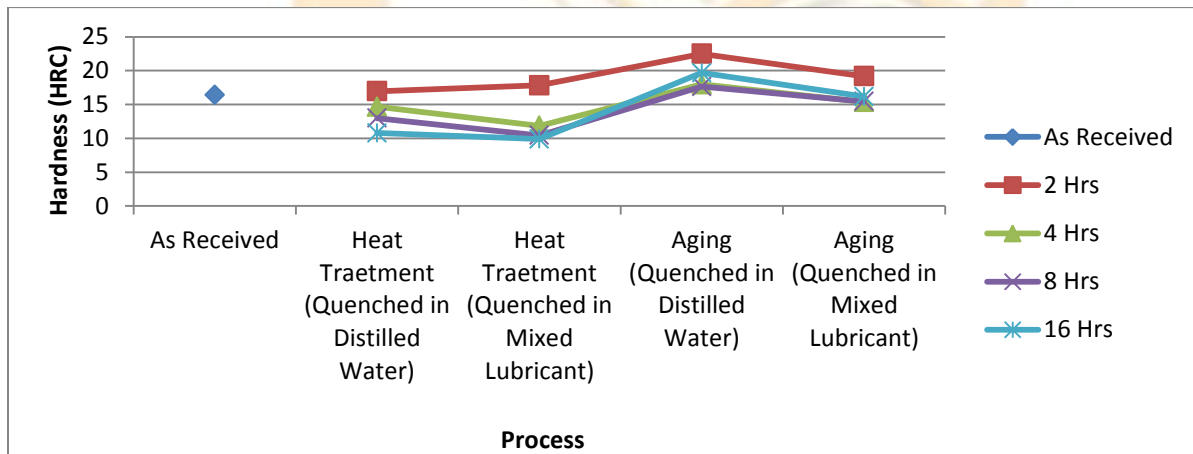


Figure 6: Graph of Hardness (HRC) versus Process

3.3 MICROSTRUCTURE OBSERVATION

From the observation using optical microscope, if compare the microstructure between heat treatment of 2 hours with as received specimen under same magnification (x500) from Figure 7(a) and Figure 7(b), the grain size has become bigger as the grain area increases. So, heat treatment process is capable to increase the grain size of the material. For aging process from Figure 7(c), it shows that precipitate occurs in the specimen. The precipitation-hardening of the specimen will impart high strength and high corrosion to it since it is stainless steel. Therefore, the precipitation-hardening of stainless steel or iron-nickel-chromium alloys mixing with others precipitation elements; for example: aluminium, titanium, copper, niobium and molybdenum (Computational Thermodynamics, 2011).

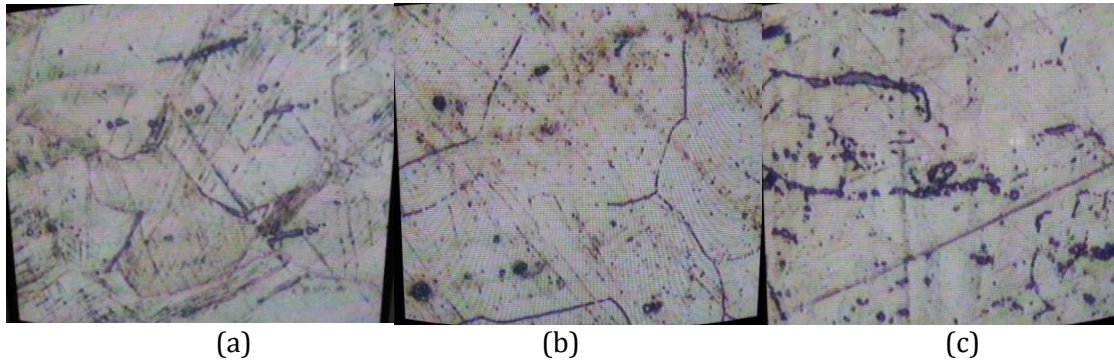


Figure 7: Stainless Steel under microscope (x500 magnification) [(a) as received, (b) heat treated with 2 hours and quenched in mixed lubricant, (c) aging with 16 hours and quenched in mixed lubricant]

CONCLUSION

As a conclusion, this research has met the objectives determined at the beginning of the experiment. Mechanical properties of stainless steel are identified after heat treatment solution and aging process based on different solution time. From the result of the experiment, it shows that smaller grain size of specimens resulted in higher hardness value compared to other specimens (Lu, Kadolkar, Ando, Blue, & Mayer, 2004; Sordi & Bueno, 2010). Higher hardness of specimens will absorb lower impact energy due to its brittle properties. So, ductility of the material is a factor that needs to be highlighted to increase their performance. Microstructure observation is completed by using an optical microscope. Yet, analysis of microstructure using specific device is helpful in determining the occurrence of elements in the specimens.

ACKNOWLEDGEMENTS

The author would like to thank to the Department of Structure and Materials, Faculty of Mechanical Engineering, University Technical Malaysia Melaka for providing financial, infrastructure and supporting for this research.

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