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Comparative Study of Wear Behaviour of Heat Treated 304 Austenitic and 410 Martensitic Stainless Steel

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Abstract

A heat treatment is the process of treating workpiece to a certain temperature (i.e., below or above recrystallization temperature), soaking for a certain time and subsequent cooling in a definite medium or rate, in order to get the improved or controlled mechanical properties, like strength, toughness, hardness, ductility, and internally developed residual stress. In addition to seeking enhanced mechanical properties, conventional heat treatment is also sought for its ability to improve corrosion resistance. To improve the service life of engineering element, the application of heat treatment has become necessary to deal with tool and die, automotive parts or aerospace parts. This paper focuses on the influences of various heat treatments in their dry sliding characteristics i.e., tribo-characteristics of two type of stainless steel 304 and ss410. Total six numbers of SS 304 and five numbers of SS 410 was taken and they have been heated to some desired temperature and then they are allowed to dwell. Then these heated specimens are cooled in some predetermined ways (air, water, oil or in furnace) to get various treatment results. A comparative study of pin against disc friction and wear for SS-304 and SS-410 was carried out in a multi tribo tester (DUCOM TR201E) against EN-24 steel disc. Corresponding micro hardness valued are also determined in HV scale in a Micro Vickers Hardness Tester (Economet VH-1 MD).

Keywords: *Friction and Wear, Heat Treatment, Micro Hardness, Tribology, Stainless Steel 304, 410*

1.0 Introduction

The study of friction and associated wear with that friction and associated lubrication in an interface in relative motion is the territory of tribology. For engineering product friction and wear plays a crucial role, so product quality and reliability depends on wear characteristics[1]. To increase functional reliability of engineering materials various type of heat treatment plays an important roles. Not only heat treatments above recrystallization temperature but also sub-zero are treatments gaining much more attractions of researchers[2-7]. And Stainless steels have huge utilisation in the modern world, although if its tonnage of use represent only about 4% of the cumulative steel production in India. In 2018 total steel produced surpassed 104 million tons in India[8]. Heat treatment is a process heating, soaking and subsequent quenching carried out, connected to a metals or metal composites in the strong state in a procedure as to create desired physical or mechanical properties. Hardening, annealing, tempering, normalizing etc. are most common heat treatment processes used to change the mechanical properties of designing materials

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especially steels Annealing is the kind of treatment most as often as possible connected so as to modify iron or steel materials and recrystallize its grain ferrite-pearlite microstructure; it is utilized where prolongations and obvious dimension of rigidity are required in engineering components[9-10]. Nowaday's of Stainless steel is essential for industry application, commercial as well as products for household application. Austenitic stainless steel, type 304 (18Cr–8Ni) is an iron-nickel-chromium alloy and can't be heat hardened further. However, annealing is possible and annealed 304 stainless steel has wide application as a structural material under the severe conditions such as the nuclear power plants and the chemical plants, refrigeration and processing plants like paper, food, beverage, cryogenics transportation, machinery parts, car headers, architecture etc. industries because of high corrosion resistance, good toughness and ductility. As earlier discussed these properties can further more enhanced by some surface treatment to increase reliability[14]. On the other hand, martensitic stainless steel grades consists of 11% – 17% Chromium (mass percent) containing carbon up to (0.15%-1.0%) proved themselves a strong contending in industry needs for their properties, such as preferable resistance to corrosion. These are usually very good inactive to high - temperature oxidation and localized corrosion, e.g., pitting and crevice corrosion, and SCC in some aggressive environment like saltwater in seas. Earlier investigations concludes that these stainless steels are inert in chemical handling rather than austenitic grades[6]. It is also extensively used in nuclear reactor due to its high strength. Efendi Mabruri *et al.* investigate various mechanical properties of martensitic stainless steel 410-1 Mo after heat treatment austenitizing temperature zone. Experiment conclude that the steels treated at 1050°C steels exhibited greater impact resistance. Whereas were pre-austenitized at 950°C and 1100°C, tempered steels that exhibits the minimum pitting potential due to presence of carbides and coarse structured martensite containing high carbon percentage.

So, many of researchers have investigated differently SS304 and SS410, but this paper will sought for a comparative study of dry sliding characteristics and Vickers micro hardness of these SS304 and SS410 steels after heat treatment.

2.0 Experimental Details

AISI 304 and AISI 410 were used for this present experimental work. Total six samples of 304 and 5 samples of 410 were made; all the samples are of diameter 6 mm and length 30 mm as per the requirement of the multi tribo-tester. The chemical compositions of the out sourced material are as given below.

2.1 Heat Treatment

Heat treatments were done in a muffle furnace with a maximum temperature capacity of 1100 degree centigrade. Chemical composition of AISI 304 and AISI 410 is detailed in Table 1 and Table 2 respectively. As earlier discussed by some researcher SS 304 cannot be hardened further but can be soften. Five different heat treatment were selected based on feasibility of achieving their process parameters, these heat treatment are discussed in following section[2,12]. For annealing one sample of SS304 is placed in the muffle furnace in ambient temperature and heated up to 950°C with a rate of 10°C per minute, then allowed to soak for 2 hours inside the furnace and then allowed to cool inside the furnace. For normalizing

Table 1. Chemical composition % by mass of AISI 304

C	Si	P	S	Mn	Ni	Cr	Fe
0.08	1.00	0.04	0.03	2.00	8.00-10.50	18.00-20.00	Balance

Table 2. Chemical composition % by mass of AISI 410

C	Si	P	S	Mn	Ni	Cr	Fe
0.08 - 0.15	1.00	0.04	0.03	1.00	0.75	11.5 - 13.5	Balance

one sample of SS304 is placed in the muffle furnace in ambient temperature and heated up to 950°C with a rate of 10°C per minute, then allowed to soak for 2 hours in the furnace and then allowed to cool in open atmosphere. For oil quenching one sample of SS304 is placed in the muffle furnace in ambient temperature and heated up to 950°C with a rate of 10°C per minute, then allowed to soak for 2 hours inside the furnace and then sudden quenching is done by dipping the specimen in cutting oil (grade 44). Two of SS304 samples are sensitized by heating them up to 660°C at a rate of 10°C per minute, then allowed to soak in furnace then cooled in open air up to atmospheric temperature. The one of sensitized samples were again heated to 1040°C with same rising rate and soaked for 30 minutes and dipped in water for solution annealing. For SS410 four samples were heat treated. Many of researcher have already been discussed different treatment procedure for martensitic steels, so based on our feasibility we have selected tempering and stress reliving followed by austenizing, annealing and process annealing[6].

So for austenizing two samples were heated to 950°C elevation at rate 10°C per minute and the allowed to soak for 30 min and then cooled in open atmosphere. Then one of sample was tempered at 320°C and another was at 650°C for 1 hours and then air cooled. Other specimen of SS 410 was annealed at temperature 850°C then allowed to cool at closed furnace for softening. One specimen of 410 was process annealed at ferrite temperature range at 660°C for 30min and then allowed to cool in air.

3.0 Results and Discussion

3.1 Micro Hardness Test Results

Table 3. Micro Hardness Test Results

Type of Stainless Steel	Heat treatment	Microhardness(HV)
Austenitic Stainless Steel AISI 304	Pure 304 Sample	312.45
	Annealing	285.53
	Solution Annealing	385.27
	Normalizing	405.53
	Oil Quenching	395.42
	sensitizing	
Martensitic Stainless Steel AISI 410	410 pure sample	573.70
	Annealing	450.42
	Austenizing followed by stress reliving	650.42
	Austenizing followed by Tempering	672.42
	Process Annealing	472.53

3.2 Wear Test Results

So from the Figures 1- 6 it can be seen that the among the 304 stainless steel samples Sensitized sample and in case

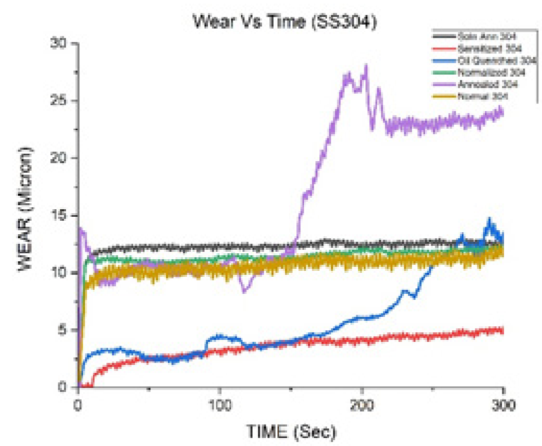

Figure 1. Wear vs. time graph for SS304.

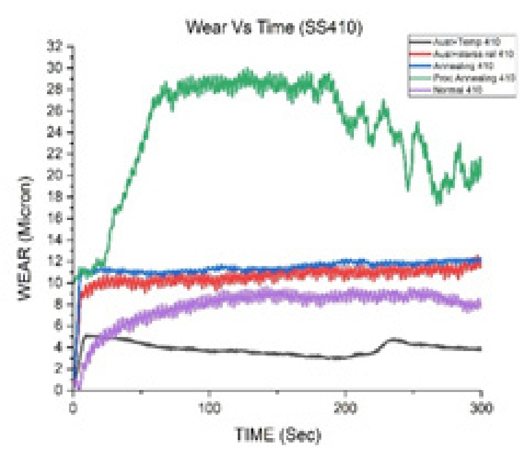

Figure 2. Wear vs. time graph for SS410.

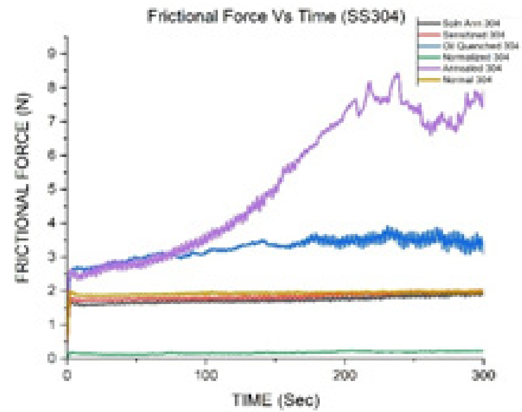

Figure 3. Friction force vs. time grpah fro SS304.

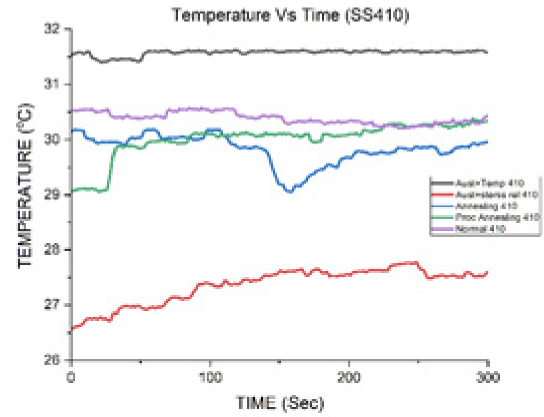

Figure 6. Temperature vs. time grpah for SS410.

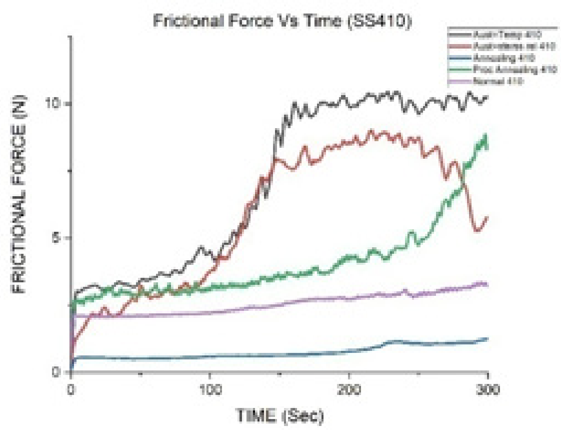

Figure 4. Friction force vs. time grpah fro SS304.

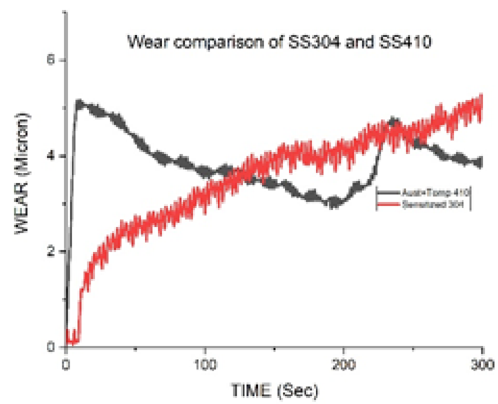

Figure 7. Wear comparison of SS304 and SS410.

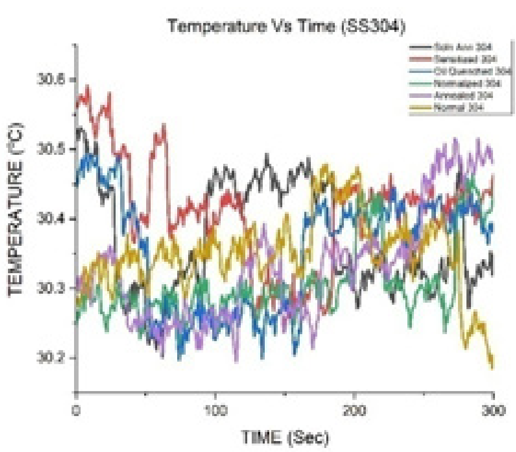

Figure 5. Temperature vs. time grpah for SS304.

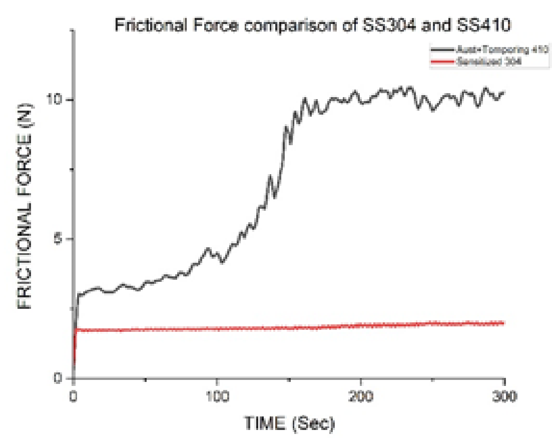

Figure 8. Frictional force comparison of SS304 and SS410.

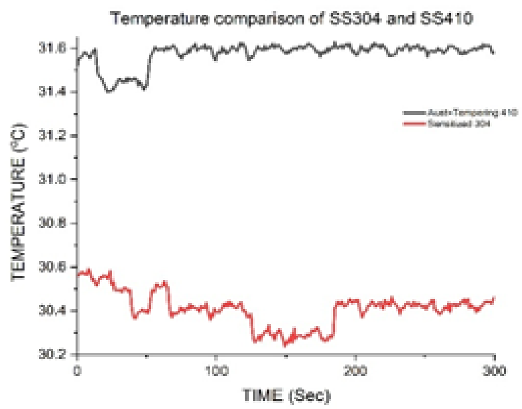

Figure 9. Temperature comparison of SS304 and SS410.

of 410 stainless steel samples austenitized sample followed by tempering have shown the best result. In Figures 7, 8, 9 respectively it can be seen that the comparative results between sensitized 304 and Austenitized 410 are followed by tempering treatment. Further, micro hardness test results are detailed in Table 3.

So from the above comparison it is clearly noticed that austenitic stainless steel AISI 304 have better tribological properties in case of dry sliding. In case of SS 304 we get better wear performance that is less wear in annealing and sensitizing samples rather than oil quenching and solution annealing specimens as the hardness of oil quenching and solution annealing specimens are not exactly too higher, annealed and sensitized examples. Ferrite and austenite stages are the dominating part of the segments of oil quenching and solution annealing examples. Where in case of SS410 the hardened steels followed by tempering at 650°C exhibits best hardness value as well as best wear resistance properties.

4.0 Conclusions

In the present work endeavors has been made for heat treatment of SS-410 and SS-304 specimens utilizing an electric Muffle Furnace. Likewise it is an undertaking of data headway in this extent of study. Common contact and related wear by relative movement characteristics depend upon the hardness, velocity, load, span for experiment and other working conditions. Thus, appraisal of such data for each individual process parameters mix is noteworthy and ought to be surveyed. This trial enlightens that the sensitization in case of SS-304 and annealed sample in case of SS-410 example is related with most minimal wear among other sort of heat-treated samples. Wear results for both the steels have been perfectly fooled their hardness properties. So, Heat treatment is an exact activity and needs much consideration and control of temperature observing. Maximum temperature of heating, soaking and subsequent cooling medium are exceptionally significant processes parameters to be considered fundamentally for the ideal result.

- The main mechanisms for wear for SS-304, are abrasion and de-lamination; where in case of SS-410 the wear mechanisms are adhesion and ploughing or abrasion.
- Air quenched or normalized SS-304 samples and in case of SS-410 annealed samples exhibits lowest frictional resistance.
- There is no such fluctuation in temperature in SS-304 but in case of SS-410 it is prominent due to difference in their hardness.
- Tempering temperature for martensitic steels have a great influence on their hardness characteristics.
- Normalized and annealed samples for SS-304 and Annealed samples show a stable trend in wear characteristics.

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