Evaluation of wear behavior on AISI 431 by vaccum annealing method for sustainable applications

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Abstract. In this research work, the vacuum annealed stainless steel samples were subjected to a constant load. The wear behavior of AISI 431 sample were examined by using pin on disc wear tester. The vacuum annealing were used to preserve the stability between ductility and brittleness. The samples were created in cylindrical shape with a length of 40 mm and diameter 8mm. For this current research, 3 samples are treated at 600°C, 660°C, 820°C temperatures and they were assigned asA1, A2 and A3 respectively. The outcome of vacuum annealing is that to reduce the hardness and increase in ductility, to overcome the material from defects and release internal stress. The hardness, wear behavior were measured for the treated and untreated samples. To evaluate the wear behavior, comparison of results, wear test studies and scanning electronic microscope analysis were done.

Keywords: Annealing, Ductility, wear, hardness, wear behavior.

1 Introduction

Martensitic stainless steels were unique among all engineering materials due to their remarkable mix of material property like high strength, acceptable ductility, toughness, and corrosion resistance. There were various heat treatment process that were underwent on the stainless steel sample like as annealing, normalizing, tempering, austempering, martempering, in order to enhance the behavior of the wear [1-3]. There were three main varieties of stainless steel austenitic, ferritic and martensitic. To achieve austenitic structure

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that were transferred from martensite stainless steel by subsequent cooling, coarsened grain size were obtained. The ferrite contents were found after quenching and austenitizing is done to allow complete carbide dissolution in martensitic phase. Austenitizing on steel were carried out at high temperature to maximize the strength, resistance to corrosion, improve the ductility and impact qualities [4-6].

A kind of heat treatment process named annealing, alters hardened material microstructure to get certain changes in mechanical properties. Annealing is a key procedure for customizing the properties of martensitic stainless steels like AISI 431, which were often employed for applications requiring corrosion resistance, reasonable strength [7-9]. Mechanical properties were varied across the annealed sample to monitor the elongation, hardness and wear behavior. Annealing demonstrates the heat treatment technique and have significantly altered the mechanical properties, improved corrosion properties in stainless steel [10-12].

These steels were usually tempered to achieve relevant engineering characteristics. The tempering temperature range for martensitic stainless steels were typically between 480^{0}C and 750^{0}C. At this range, the martensite hardness decreases with time and due to high temperature treatment of tempering stability in hardness and strength were identified [13-15]. Due to its high chromium concentration, 16Cr-2Ni steel were containing a significant quantity of δ-ferrite when it were cooled to room temperature from liquid metal where it solidifies or at high temperature processing. Because of high alloy composition and considerable quantity of carbon, alloy steels require high austenitizing temperature to allow carbides to dissolve [16-19].

2 Emperical Procedure:

2.1 Composition of material

In this study, AISI 431 stainless steel were chosen for this investigation based on its constituent makeup, that includes carbon at 0.1551%, silicon at 0.3831%, chromium at 15.7958%, manganese at 0.5378%, phosphorus at 0.0281%, sulfur at 0.0127%, nickel at 1.7111%, and the residual iron [20-23].

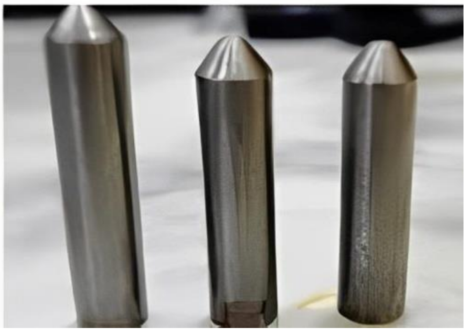

Fig.1 Samples of AISI 431 Stainless Steel

2.2 Test for Tribological Wear

In this vacuum annealing process, samples were underwent at three different temperature 600°C, 660°C and 820°C. The samples were prepared to length 40mm, diameter 8 mm.

Then both untreated, treated samples undergone for wear test and the results were compared [24-26]. Wear tests were carried out as shown in fig 2.

Fig. 2. Wear test apparatus with pin on disc

At 20N load to a speed of 1000 rpm, all samples underwent to wear test for 2 minutes duration. Later the results were compared with the untreated sample so that wear behavior of each sample will be well-known. To determine the exact wear, the sample wear has to be checked before doing the test and also after doing the wear test [27-30]. Both the results were compared and losses of weight were determined. In order to compare the findings of the wear test, microscopic inspections were done using scanning electron microscopy pictures [31-33].

3 Results & Discussion:

The sample hardness values were measured by Rockwell method at 150 kg load for 20 seconds. For untreated sample the hardness value is 39 HRC. The annealed sample were treated at the temperature of 600°C, 660°C, 820°C and the hardness value obtained were 36 HRC, 33 HRC, 29 HRC respectively[49-52]. Later the annealed samples underwent to scanning electron microscope for investigation of sample surface morphology.

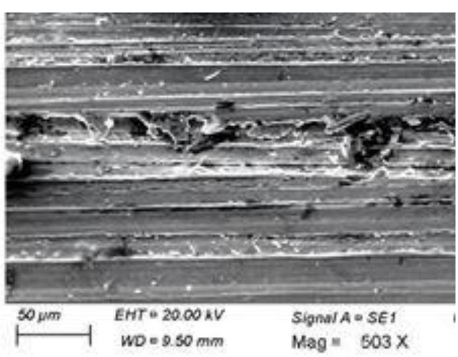

Fig. 3. AISI431UntreatedSampleMicrostructure

From the above fig 3 shows us that there was no wear loss with the untreated sample. Martensitic stainless steels were having a hardened microstructure and were made up of cementite, residual austenite. The obtained hardness was 39 HRC. Microstructure analyses were performed on AISI 431 steel specimens to investigate the surface morphology and were identified to be unchanged[33-35].

In fig 4 shows the annealed samples were treated at 600^0C temperature and so hardness were slightly minimized so that wear resistance and ductility were seen. In fig 4, some cracks on the sample were slight transformation from martensitic to austenite for getting stability in wear resistance. Ductility was increased, and fissures in the microstructure were found. The material peel was slightly improved [36-38].

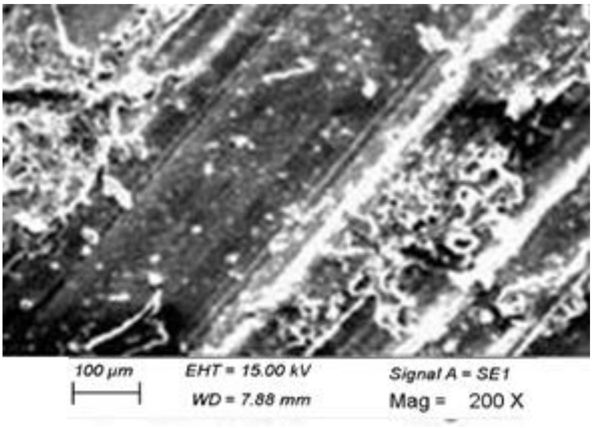

Fig. 4. A1 sample – SEM Image

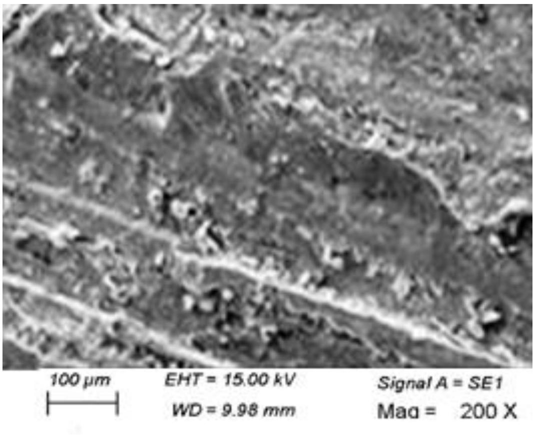

Fig. 5 A2 sample – SEM Image

In Fig 5 shows the annealed sample were treated at temperature of 660^0C. The sample were getting soften so that recrystallization occurred that were noted to be with crack propagation. So that more cracks, minute holes and more loss of material were identified. The increase in annealing time leads to change of phase from martensite to retained austenite. The cementite decomposes and formation of ferrite, free carbon were obtained which affected to the wear resistance of annealed sample [39-42].

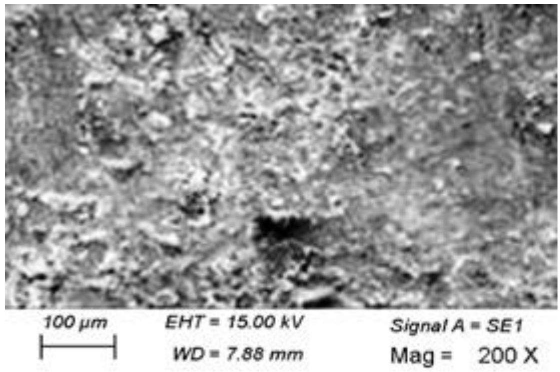

Fig.6 A3 sample – SEM Image

In this Fig 6 shows the annealed sample were treated at temperature of 820^{0}C. Due to the increase in time of treatment, cementite components decomposed and stabilization of ductility were obtained. The changes from martensite phase to austenitic transformation as shown in fig 6 and it were suppressed from the martensitic transition. There were several visible fractures in the sample, but still the hardness were maintained in AISI 431 [43-48]. The wear loss of wear were identified to be more than the other treated samples. This results from the annealing process of hard materials, which stabilizes ductility.

4 Conclusion

The primary goal of this annealing process were to examine its ductility and wear resistance stabilization on a harden material. The materials major applications were cutlery, utensils used in kitchen, equipments for surgery, dental equipments, valves and pumps, exhaust manifolds system, components of automotives, various sustainable applications like solar power plant components. Few research works were been submitted the results on AISI 431 martensitic stainless steel. Investigations were conducted on microstructures and mechanical characteristics. The conclusions were obtained

1. The volume of wear loss in annealed samples was identified as 15 mm^3, 18 mm^3 and 21 mm^3, respectively. The loss of wear in untreated samples was determined as 8 mm^3.
2. By annealing process, the samples were treated to 600^{0}C, 660^{0}C and 820^{0}C respectively. More material peel was collected from the sample that was processed at 820^{0}C. Resistances of wear for martensitic stainless steel were increased by stabilizing hardness and ductility. The fine grains in martensitic structures were transferred to coarse grain structures.
3. Prior to heat treatment process, AISI 431 specimen material had a high hardness and low ductility. The task can be modified in future by varying the load and speed for obtaining best results. Finally, it was discovered that AISI 431 were stabilized with hardness and ductility.

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