Investigation of tempered AISI 420 SS under dry slided conditions for sustainable applications

S.N.S. Santhosh Kumar[1], *R*. Vinoth[2], *Rajesh* Kumar[3], *M*. Jeevan Kumar[3], *DVSSSV*. Prasad[4], *S*. Prabhu[5], *S*. Ram[6*]

[1]Mechanical Engineering Department, Hyderabad Institute of Technology and Management, Hyderabad, Telangana
[2] Mechatronics Engineering Department, Sona College of Technology, Salem, Tamilnadu
[3] Mechanical Engineering Department, CVR College of Engineering, Hyderabad, Telangana
[4]Mechanical Engineering Department, Aditya Engineering College Surampalem, Andhrapradesh
[5]Mechanical Engineering Department, Kumaraguru College of Technology, Coimbatore, Tamilnadu
[6]Mechanical Engineering Department, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad, Telangana

Abstract. Martensitic stainless steel exhibits a lower corrosion resistance, higher hardness, wear resistance, and strength, but no ductility. As a result, tempering techniques have been used to stabilise the ductility. AISI 420 stainless were chosen and prepared in cylindrical shape for a dimension of 35 mm length, 10 mm diameter. The specimens were tempered to 245°C, 345°C, 445°C temperatures respectively and termed as T1, T2 and T3. The material which is not treated is kept on the other side for results comparison. Testing of hardness was taken up by Rockwell method. Wear tests were carried out for all the specimens using pin-on disc wear analyser. The changes in microstructure were distinguished with all the samples and were captured by electron microscopic techniques. The goal of the test is to determine, the best treated specimen suited for a particular application. It was noted that, phase change from martensite stage to residual austenite is determined.

Keywords: Tempering process, phase change, hardness, Wear tests.

1 Introduction

Stainless steel is widely utilised in a wide range of applications, which includes hydraulic rams, pump parts, medical equipment, automotive parts, building materials and for various sustainable applications like solar power plant components. Stainless steels are well-known for its strength, durability, and corrosion resistance [1-3]. There are several varieties of stainless steel, each having distinct features and characteristics. Austenitic, duplex type,

* Corresponding Author: ram4msrm@gmail.com

ferritic, precipitation hardened type, martensitic are few of the stainless steel types. Tempering was carried out on AISI 420 for improving the strength, corrosion, stabilization of property like brittleness, hardness and ductility [4-6].

Tempering is a method of improving the mechanical characteristics of martensitic stainless steels. It involves heating the steel at a specified temperature and then carefully cooling it to get the necessary characteristics [7-9]. The various parameters like hardness tests, wear tests and microstructural analysis are used to evaluate the behaviour of wear in stainless steel. The treated AISI 420 martensitic stainless steel is subjected to controlled friction, abrasion during the wear test [10-14]. Wear testing methods such as pin-on-disc, ball-on-disc, and scratch testing are available. Wear testing findings can reveal information about the steel's wear resistance and capacity to tolerate abrasive. The wear qualities of treated martensitic stainless steel is evaluated through microstructural investigation. Optical and electron microscopy can be used to investigate the steel's microstructure [15-18]. Microstructural examination can reveal information regarding phase distribution, grain size, shape, and the existence of any flaws or inclusions. This information can help to explain the steel's mechanical qualities and wear resistance [19-22].

To summarise, hardness testing, wear testing, and microstructural analysis may be utilised to evaluate the wear parameters of treated AISI 420 martensitic stainless steel after tempering. These procedures can give useful information on the mechanical characteristics of the steel as well as its resistance to wear and tear [23-26]. Tempering is used to enhance the hardness and brittleness of a material that has been hardened using methods such as quenching. The procedure is adopted by treating the material to hardening temperature and then progressively cooling it down [27-30].Tempering is often performed in a furnace. The material is heated to the desired temperature. The temperature is kept for a set duration of time, which varies the desired qualities. After holding the material at the tempering temperature for the prescribed period, it is progressively cooled in air, water, or oil. The precise temperature and time necessary for tempering are determined by the material being tempered [31-34]. Higher tempering temperatures produce a softer, more ductile material, whereas lower tempering temperatures produce a harder, more brittle material. Tempering is a common procedure used in the production of tools, machine parts, and structural components.

2 Experiment adopted

2.1 Specification of Material

The composition of AISI420 stainless steel used for this investigation is given: chromium 12.66%, phosphorous0.0018%, sulphur 0.024%, nickel 0.56%, manganese 0.78%, carbon 0.25%, silicon 0.44%, iron as base metal as displayed in Fig 1. The specimens were produced to dimensions mentioned: 35 mm length and 10 mm diameter respectively as shown in Fig 1.

Fig. 1. AISI 420 Stainless steel samples

2.2. Experimental Investigation

The specimens were tempered at temperatures of 245°C, 345°C, 445°C and a sample which is not subjected to tempering is placed another side for comparing the micro-structural results from hardness tests, Scanning electron microscopy tests. All specimens were submitted to wear testing on a pin on disc setup, as illustrated in Fig 2, and the specimens were analysed to determine wear loss [35-38].

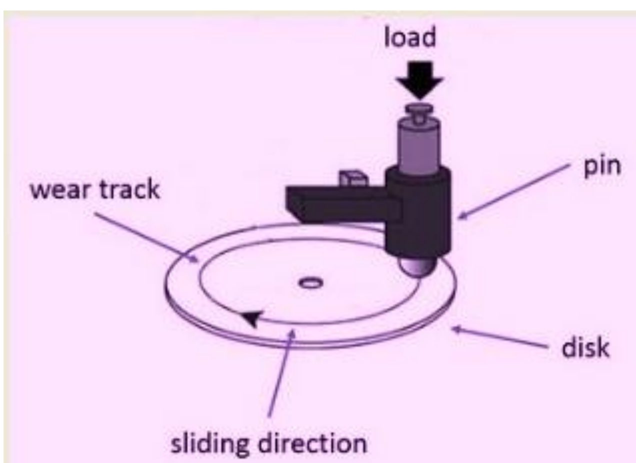

Fig. 2. Schematic Diagram of Wear test

The pin-on disc tribometer works with a lever armed disc, sensors, a pin holder, a dead weight and a sliding distance scale. The wear loss was derived from the quantity of material lost. The loads, rotation speed of disc were held constant. After rotating the disc at 1000 rpm for two minutes with a load of 20 N, wear loss was determined. Prior to wear test, the samples are carefully cleaned with sulphuric acid, and the disc is hardened on the surface [39-42]. The hardness of the shortest tempered sample got increased, while the hardness and ductility of the longest processed sample decreased significantly.

3 Results and discussion

3.1 Hardness Measurements

Hardness test is performed to determine the steel's resistance to deformation. A Rockwell machine is used to determine the hardness for this research work. The hardness of AISI 420 stainless steel was measured as 34 HRC, while the tempered samples have hardness of 30 HRC, 25 HRC, 21 HRC. The wear loss of samples tested at 245°C, 345°C and 445°C were identified as 1.85 grams, 2.28 grams, 3.14 grams. As the temperature increases, the wear loss decreases [43-46]. This suggests that at higher temperatures, the material stabilized with ductility and obtained the ability to manage wear and tear.

3.2 Scanning electron Microscope microstructures

Few researches on tempered AISI 420 material have yielded results as shown in Fig 3. The microstructures were recorded using a scanning electron microscope. The surface of untempered sample was polished and observed. The cementite presence has made the material extremely hard [47-49]. The peel of the material was less, resulting a volume wear loss of 17.1 mm^3. In the case of martensitic phase transition, the hardness can change depending on the conditions under which the transformation occurs.

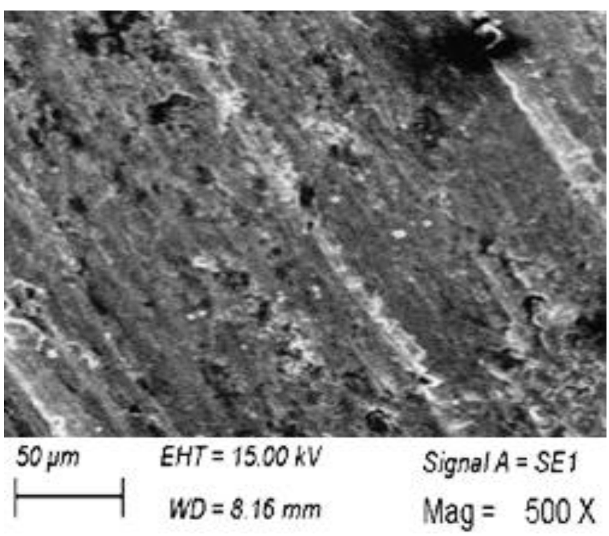

Fig. 3. Untreated AISI 420 Microstructure

The microstructure of the tempering sample at 245°C is depicted. Mild peel of material was produced and the microstructure remained the same as of like untreated tempered sample. The hardness of material slightly decreased causing volume loss of 16.2 mm^3 during the wear characterization. The cementite doesn’t decomposed and the phase transition remained same as shown in Fig 4. This suggests that the material maintained its properties despite the wear test. There were no changes in compositions, which further supports the notion that the material maintained its properties and the grain structure remained to be fine with slight decrease in hardness.

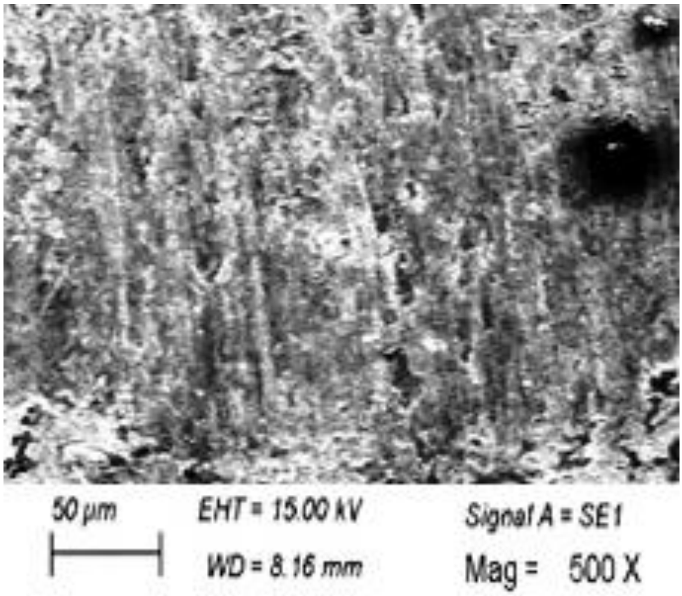

Fig 4. Tempered specimen microstructure for 245°C

The time of tempering was increased as shown in Fig 5, which leads to the decomposition of cementite into a pearlite structure. This contributes to an increase in ductility of material. The material hardness got decreased further and the material able to resist wear and deformation [50-53]. The volume wear loss during the wear test was 15.62 mm^3.The material peel during the wear test was high, that the material may have undergone some form of grain growth during the tempering process.

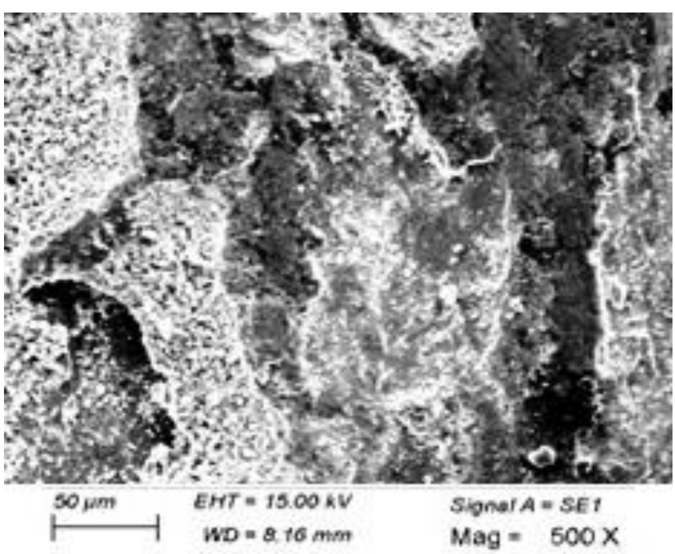

Fig 5. Tempered specimen microstructure for 345°C

 https://doi.org/10.1051/e3sconf/202455201007

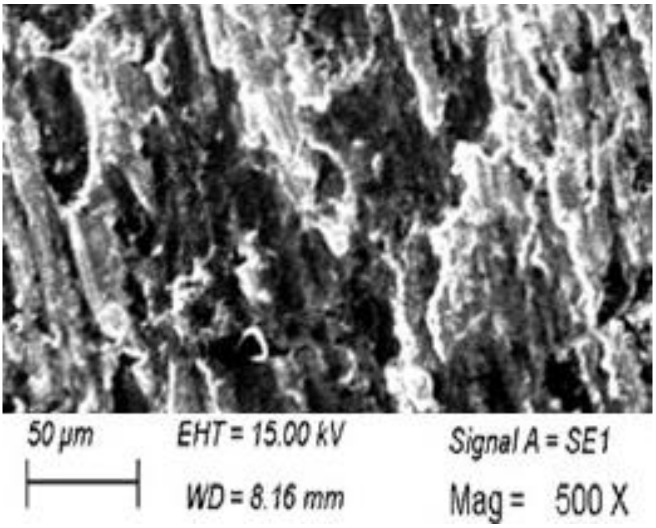

Fig 6. Tempered specimen microstructure for 445°C

As a result of the structural change, pearlite structures in coarse form were seen in the microstructure. This indicates that the material's microstructure has undergone austenite transformation, which can have an impact on its properties. Despite the structural changes, the hardness were minimized, promoting ductility of the material generating a volume wear loss of 13.88 mm^3. The tempered martensite formed by the mixture of carbide and ferrite increased the machinability, ductility of stainless steel. This reduces material wear by increasing the ductility of the martensitic steel.

4 Conclusion

The influence of the tempering process on AISI 420 martensitic steel was investigated utilising a pin-on-disc device, followed by a series of metallographic tests. Few experimental works were carried out and the ductility was enhanced through tempering process. The following are this project major findings:

1. The treated specimen's hardness was determined to be 34 HRC, while the tempered samples have hardness of 30 HRC, 25 HRC, 21 HRC. This revealed that the untreated material was relatively hard and it will be difficult to machine without specialized tools.
2. The wear loss of the material tempered at 245°C, 345°C and 445°C were 1.85 gms, 2.28 gms, 3.14 gms and the volume wear loss obtained was 16.2 mm^3, 15.62 mm^3, 13.88 mm^3. It was confirmed that the wear resistance of the material decreases as the temperature of the heat treatment increases.
3. It appears that the wear resistance of the tempered specimen is lower than that of the untreated specimen. However, tempering improves material ductility, which may lead to a greater decrease of wear volume over time. This was achieved by the wear obtained in wear test, which suggests that tempered samples display a greater decrease of wear volume compared to untreated samples. It is important to note that wear resistance and ductility are two different material properties and improving one may lead to a decrease in the other. Therefore, it is necessary to carefully balance the above properties depending on the intended application of martensited steel.

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