Assessment of Wear Properties on Treated AISI 410 Martensitic Stainless Steel by Annealing Process

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Abstract. Martensitic stainless steels find less application in commercial products as they have high hardness, strength, and wear resistance. It lacks in ductility and exhibits moderate corrosion resistance compared to other stainless steels. As a result, annealing process were been used to strengthen the ductility and maintain stability in hardness of martensitic stainless steel material. AISI 410 was chosen for this research work and the samples were made to cylindrical shape for the following dimensions: 50 mm length and 08 mm diameter. The specimens were annealed at temperatures of 730°C, 830°C, and 930°C. The untreated material is kept aside for results comparison. All specimens were subjected to wear test using a pin on disc wear test apparatus. All the specimens were examined using a scanning electron microscope for the surface morphological changes. The outcomes were compared and the best specimen for the required application was chosen. It was discovered that there was a phase change from the martensite stage to the residual austenite stage.[**]

1 Introduction

Stainless steel is known for its corrosion-resistant properties, due to the presence of chromium in the steel. The chromium in the air combines with the oxygen to generate a thin coating of oxide on the stainless steels surface, which helps to protect it from further corrosion [1-4]. In addition to its corrosion resistance, stainless steel is durable and strong, making it a popular material for a wide range of applications. Martensitic stainless steel is well-known for its hardness and strength [5-8]. The ductility of the material is found to be poor. AISI410 is a specific grade of martensitic stainless steel, which is known for its high strength, hardness and wear resistance. The carbon content makes cementite in combined

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*Corresponding author: ram4msrm@gmail.com form and provides a martensitic structure [9-13]. Martensitic stainless steel can be further hardened by surface treatment process to further increase its strength and wear resistance. By heat treatment process, the strength, hardness can be stabilized by promoting ductility. The addition of other elements like nickel and molybdenum helps to improve its corrosion resistance, although it is not as corrosion-resistant like austenitic stainless steels. AISI 410 is widely utilized in a wide range of applications, including cutlery, surgical instruments and valve parts [14-17].

Annealing is a heat treatment technique that includes heating a material, keeping it at a given temperature for a certain period of time, and then gently cooling it to change its characteristics. In the case of martensitic stainless steel AISI410, annealing can help to improve its machinability and ductility, reduce internal stresses and improve its resistance to cracking during processing [18-22]. The annealing process for AISI 410 typically involves heating the steel to a temperature between 723°C to 950°C, depending on the desired properties, and holding it at that temperature for a period of time, typically between 45 minutes to 3 hours. The steel is then cooled slowly in the furnace to reduce the risk of cracking or warping [23-27].

The annealing process and conditions for AISI 410 may vary depending on the desired properties and the specific application. Full anneal may be used to achieve maximum softness and ductility, while a partial anneal may be used to achieve a balance of strength and hardness [28-31]. It is important to note that annealing can also reduce the hardness and strength of the stainless steel. As a result, the process must be closely monitored to ensure that the necessary qualities are obtained without affecting the overall performance of the stainless steel [32-35].

2 Experimental Procedures

2.1 Materials specification

The elemental composition of the stainless steel used in this investigation was determined to be chromium 12.28%, sulphur 0.045%, phosphorous 0.0027%, nickel 0.50%, silicon 0.41%, carbon 0.21%, manganese 0.74% and balance iron. As indicated in Fig.1, the specimens were produced to the following dimensions: 50 mm length and 8 mm diameter.

Fig.1. AISI410 Stainless steel samples

2.2 Material processing and testing

AISI 410 stainless steels were annealed at temperatures of 730°C, 830°C, and 930°C respectively as the annealing process emerges from 723^{0}C and an untreated sample was held aside to analyze the microstructural results from Scanning electron microscopy and hardness tests. Before the test, the specimens were completely cleaned using acetone, and the disc material was surface hardened to saturated level. All the samples were undergone through a wear test with pin on disc machine and the wear loss was calculated. The pin on disc test is a widely used tribological test that involves placing a small cylindrical sample known as the "pin" against a flat rotating disc under 10N load with a speed of 750 rpm [31-35]. The test helps to evaluate the friction and wear behavior of materials in various industrial applications, providing valuable information on their wear resistance, coefficient of friction and surface damage under different conditions.

The wear loss increases as the temperature rises. The wear losses for the sample treated at 730 °C, 830 °C, 930 °C were identified to be as 11.42 mm^3, 14.28 mm^3, 25.71 mm3, respectively. This implies that the material is more resistant to wear and tear at greater temperatures promoting the material with ductility and stabilized with hardness.

3 Results and discussion

3.1Hardness Measurements

The hardness of untreated and annealed AISI 410 stainless steel was measured. The untreated AISI 410 stainless steel has a hardness value of 40HRC, whereas the annealed samples subjected to 730°C, 830°C, 930°C were identified to be with 33 HRC, 29 HRC, and 25 HRC respectively.

3.2 Scanning Electron Microscope Microstructure

Scanning electron microscope is a valuable tool for wide range of scientific and industrial applications. It is used to obtain high-resolution images of the surface of a sample, but they can also be used for other types of imaging and analysis, such as backscattered electron imaging and energy-dispersive X-ray spectroscopy. These techniques can provide information about the composition, structure, and surface morphology of the material [28-30].

Several studies have offered findings on the AISI 410 martensitic stainless-steel material. All the sample microstructures were recorded using a scanning electron microscope. It was noted that the surface of an untreated sample was found to be smooth as seen in Fig. 2. It is due to the presence of cementite, which is extremely hard. As a result, the peeling of the material was found to be less, resulting in a volume wear loss of 8.42 mm^3. The martensitic phase change remains constant; the hardness remains constant as 40 HRC.

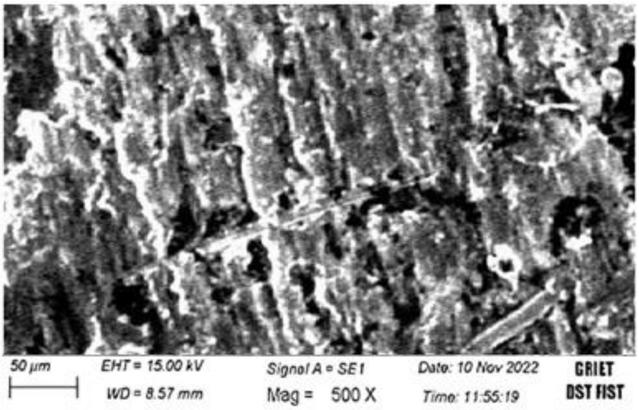

Fig.2. AISI410 Untreated Sample Microstructure

Fig.3 depicts the microstructure of an annealed sample at 730°C. It was observed that a very fine peel of material was obtained. This is due to the load acting on the specimen. Because of the high hardness, less material peeled off during the wear test. The cementite content is not degraded, and the martensitic phase change remains constant. The ferrite and carbide compositions remained unchanged, and the wear loss was determined to be 11.42 mm^3. With slight decrease in hardness, the grain structure was found to be fine grains.

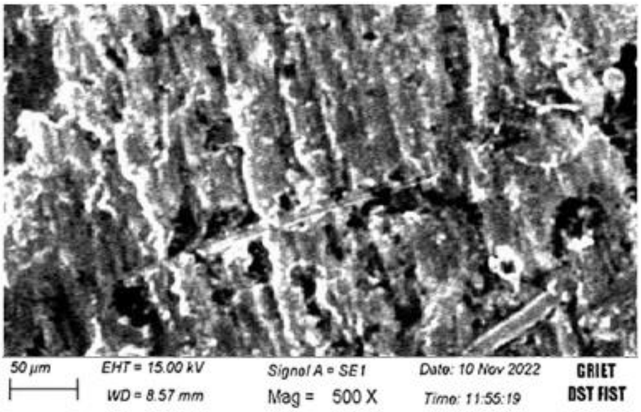

Fig.3. Microstructure of Annealed specimen at 730°C

Fig.4 depicts the microstructure of sample that has been annealed to 830°C. The softness of the metal increases as the duration of treatment increases. As the cooling process is longer, cementite decomposes to pearlite structure, increasing the material's ductility. The material's hardness stability is maintained, resulting in a volume wear loss of 14.28 mm^3. During the wear test, it was discovered that the material peel was high, resulting in a medium coarse grain structure.

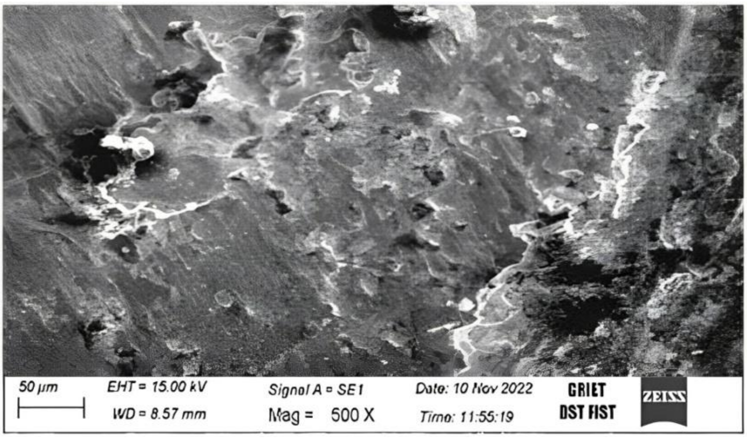

Fig.4. Microstructure of Annealed specimen at 830°C

Fig.5 depicts the microstructure of annealed sample treated to 930°C. The ductility of the specimen increases and the wear property begins to increase. As the duration of cooling process increases ,the cementite components entirely decomposes and the phase structure shifts from martensite to retained austenite. As a result, coarse pearlite structure is generated in the microstructure, resulting the hardness and ductility of the material to be in stable condition.

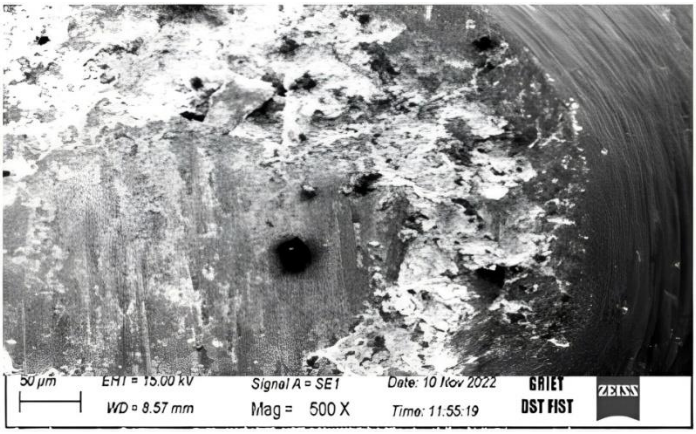

Fig.5. Microstructure of Annealed specimen at 930°C

4 Conclusions

Very few research works were carried out on AISI 410 stainless steel material over annealing process. After annealing, the applications finds on cutlery and kitchenware, surgical instruments, dental tools, pumps, valves, and pipes, production of exhaust systems, manifolds, and other automotive components. The following results were obtained from the above experimental work.

1. The wear loss for the samples annealed to 730°C, 830°C, 930°C were found to be as 11.42mm^3, 14.28mm^3 and 25.71 mm^3 respectively. Whereas the wear

loss in untreated specimen was found to be with 8.42 mm^3. The annealed sample treated to 930^0 C had more material peeling than the untreated sample.

2. As the heat treatment temperature range increases, the wear resistances of stainless steel material were improved with ductility and stability in hardness.

3. Through annealing process, the wear resistance of a martensitic material is improved. The ductility, hardness are well stabilized and the material is applicable for commercial manufacturing of products. It is important to note that these results were obtained by maintaining the speed and load constant. The work can be extended to future by varying the speed and load to produce better results.

References

1. Y Zhao, B Yu, L Dong, J Xiao, Surf Coat Tech. J. E, 210, 90 (2012).
2. M Laleh, F Kargar, M Velashjerdi, Mater Eng Perform. J. E, 22, (2013)
3. Tong, Z Han, LM Wang, J Lu, K Lu. Surf Coat Technol. J. E, 202, 3947 (2008).
4. D Majumdar, J. Alphonsa, A. Basu, Wear. J, E 62, 3117 (2008)
5. P. Tschiptschina, A. S. Nishikawaa, Luis Bernardo Varelaa, Thin Solid Films. J. E, 644 96 (2017).
6. T. BlesslinSheeba, A. AlbertRaj, D. Ravikumar, S. SheebaRani, P. Vijayakumar, Ram Subbiah, Materials Today: Proceedings, 45, 2440-2443 (2021).
7. A. Jayapradha, G. JimsJohnWessley, G. Vimalarani, P. RameshKumar, Ram Subb iah, S. Maniraj, Materials Today: Proceedings, 45, 2121-2124 (2021).
8. Veernapati Gitanjali, Panati Nithya, P. Pandiarajan, Nunna Dhruthi, TappaVineeth Raj, Ram Subbiah, Materials Today: Proceedings, 45, 2479-2481 (2021).
9. M. Makesh, G. Sivaraman, N. Saravanan, S. Prashanth, Ram Subbiah, K. Anand, Materials Today: Proceedings, 45, 2498-2500 (2021).
10. N. Ravikumar, P. Sharmila, S.P. Premnath, Rajakumar S. Rai, J. Mohammed Feros Khan, Ram Subbiah, Materials Today: Proceedings, 45, 2581-2583 (2021).
11. R. Ganesh, Ram Subbiah, K. Chandrasekaran, Materials Today: Proceedings, 2, 1441-1449(2015).
12. S. Surendarnath, Ram. Subbiah, K. Sankaranarayanasamy, B. Ravisankar, Materia ls Today: Proceedings, 4, 2544-2553(2017).
13. Ram Subbiah, Md. Rahel, A Sravika, R. Ambika, A. Srujana, E. Navya,Materials Today: Proceedings, 18, 2265-2269 (2019).
14. B.Chaitanyakumar, P. SriCharan, Kanishkar Jayakumar, D.Alankrutha, G.Sindhu, Ram Subbiah, Materials Today: Proceedings, 27, 1541-1544 (2020).
15. T. Lakshmi Deepak, G. Ananda Mithra, K. Lokesh, B. Sai Chandra, Ram Subbiah, Materials Today: Proceedings, 27, 1681-1684 (2020).
16. A. Rohit Sai Krishna, B. Vamshi Krishna, T. Sashank, D. Harshith, Ram Subbiah, Materials Today: Proceedings, 27, 1555-1558 (2020).
17. J. Anix Joel Singh, T. Vishnu Vardhan, J. Vairamuthu, B. Stalin, Ram Subbiah, Materials Today: Proceedings, 33, 4893-4896 (2020).
18. K. ManjithSrinivas, S. Bharath, P.N.V. KrishnaChaitanya, M. Pramod, Ram Subbi ah, Materials Today: Proceedings, 27, 1575-1578 (2020).
19. S. Sathish, K. Kesavaraj, L. Girisha, A. DanielDas, Pradeep Johnson, Ram Subbia h, Materials Today: Proceedings, 47, 4235-4238 (2021).
20. M.Mamatha Gandhi, Animesh Bain, P Rohith, R. Srilatha, Ram Subbiah, E3S Web of Conferences, 184, 01002, (2020)

21. K. Ramya Sree, G. Keerthi Reddy, K. Aishwarya, E. Nirmala Devi, Ram. Subbiah, E3S Web of Conferences 184, 01003 (2020)
22. A Rohit Sai Krishna, B Vamshi Krishna, D Harshith, T Sashank, Ram Subbiah, E3S Web of Conferences 184, 01018 (2020)
23. Shivani Koppula, Aakula Rajkumar, Siram Hari Krishna, Reddi Sai Prudhvi, S. Aparna,Ram Subbiah, E3S Web of Conferences 184, 01019 (2020)
24. Lakshmi Deepak Tadepalli, Ananda Mithra Gosala, Lokesh Kondamuru, Sai Chandra Bairi, A. Anitha Lakshmi, Ram Subbiah, E3S Web of Conferences 184, 01020 (2020)
25. Gandla Lakshmi Prasanna, G. Keerthi Reddy, Ram Subbiah, E3S Web of Conferences 184, 01021 (2020)
26. Gandla Lakshmi Prasanna, J Saranya, Ram Subbiah, E3S Web of Conferences 184, 01022 (2020)
27. Manne Vamshi, J. Saranya, Ram Subbiah, E3S Web of Conferences 184, 01023 (2020)
28. ManneVamshi, AnimeshBain, M. Sreekanth, Ram Subbiah, E3S Web of Conferences 184, 01024 (2020)
29. M. Mamatha Gandhi, J. Saranya, G. Keerthi Reddy, S. Srikanth, Ch. Keshav, M. Niranjan, S. Someshwar Rao, Ram Subbiah, E3S Web of Conferences, 309, 01066 (2021).
30. D.Prathusha, J.Venkatesh, K.K.Arun, KulkarniSanjay Kumar, S. Prabhu, Ram Subbiah, Materials Today: Proceedings, 47, 4312-4315 (2021).
31. Animesh Bain, B.RamakrishnaReddy, PrasadRamchandra,Baviskar, M Patil Milind, J. Saranya, P. Geethasree, R. Shruthi, Ram Subbiah, E3S Web of Conferences, 309, 01125 (2021).
32. K. Ramya Sree, D. Raguraman, J. Saranya, Animesh Bain, V.SrinivasViswanth, S. Aparna, Ch. Dhanush, Ram Subbiah, E3S Web of Conferences, 309, 01181 (2021).
33. B Divyasri, Ch.PhaniRamaKrishna, Pradeep Jayappa, G. Keerthi Reddy, V. Vinay Kumar, B. Shankarachary, M. Surya and Ram Subbiah, E3S Web of Conferences, 309, 01182, (2021).
34. Ram Subbiah, V. Vinod Kumar, G. Lakshmi Prasanna, Materials Today: Proceedings, 26, 2946-2952 (2020).
35. Ram Subbiah, Anand Poras, K. Ratna Babu, M. Mamatha Gandhi, K. Ramya sree, Ch. Naveen, Materials Today: Proceedings, 26, 2977-2982 (2020).