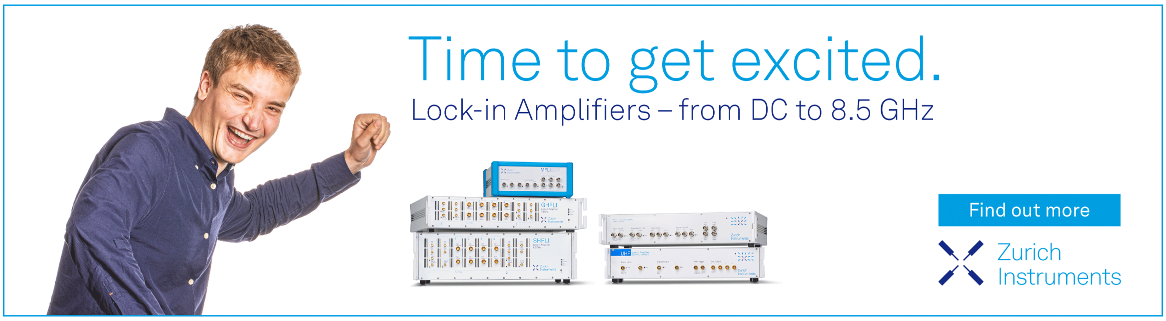
RESEARCH ARTICLE | MAY 22 2023

Effect of mechanical properties using cryogenic treatment on AISI EN 19 tool steels

S. Udaya Bhaskar ; N. Srinivasa Rajneesh; Ch. Ashok Kumar; ... et. al

AIP Conference Proceedings 2492, 020082 (2023)
https://doi.org/10.1063/5.0117543



Effect of Mechanical Properties using Cryogenic Treatment on AISI EN 19 Tool Steels

S.Udaya Bhaskar[1,a)], N. Srinivasa Rajneesh[1,b)], Ch.Ashok Kumar[1,c)], T.Venkata Deepthi[1,d)], and Subramanyam Pavuluri[1,e)]

[1]*Department of Mechanical Engineering, Malla Reddy Engineering College (Autonomous), Maisammaguda, Secundrabad, Telangana, India-500100*

[a)] Corresponding Author: udaylohith1412@gmail.com
[b)]rajneeshsrinivasa@gmail.com,
[c)]chashok027@gmail.com,
[d)]venkatadeepthi.t@gmail.com,
[e)] subramanyampavuluri@gmail.com

Abstract. Engineering materials fail below their yield strength due to the application of loads resulting in fracture. These fractures of materials are observed due to the grain structure or micro voids or discontinuities in grain structure. In order to improve the mechanical properties and modify the grain structure, investigations have been followed with different material processing operations. In this paper AISI EN 19 tool steel mechanical properties were studied. To enhance the properties of tool steel, the material have been austenized for a period of time and quenched in water. Few of the specimens have been treated with cryogenic treatment for duration of hours and later tempered. The effect of this process has made a change in the tool steel microstructure specimens and has improved their strengths.

INTRODUCTION

Tool steels have been extensively used in cutting tools industries for manufacturing of cutters, bits, reamers and punching dies. Tool steels possess hardness, toughness, and abrasive resistance properties. Some additives chromium and lead are used with tool steel for enhancing its characteristics. Chromium leads to improve the abrasive wear resistance and led leads to improve the hardness. Tool steels have wider range of applications i.e. stamping, extrusion and forming.

Conventional heat treatment process causes the micro structural change it results atoms are re-arranged and bond between atoms will increase which leads to improve the binding energy it results hardness and toughness will increase. Tool steels are heat treated followed by quenching process. In the iron-carbide diagram iron is heated above the 7230c and maximum solubility of carbon is 0.8% then austenite face will exist and it possess FCC structure, process of achieving austenite face is known as austenizing. Cryogenic are used to upgrade the properties both in relieving stress and decreasing porosity after heat treatment. Cryogenic treatment is done with different soaking periods. When cryogenic treated tool steels are compared with conventional heat treated tool steels it posses' higher toughness and hardness.

LITERATURE REVIEW

Surface roughness and tool wear of AISI D2 tool steel has been analyzed with help of cryogenic and tempering process [1]. Three different test sample are used for finding the mechanical properties of material and three different process which are convention using for conventional heat treatment, deep cryogenic treatment, Deep cryogenic treatment with tempering (DCT-T-36) using for finding the hardness and microstructure changes in AISI D2 tool steel.

Advancements in Aeromechanical Materials for Manufacturing: ICAAMM-2021
AIP Conf. Proc. 2492, 020082-1–020082-5; https://doi.org/10.1063/5.0117543
Published by AIP Publishing. 978-0-7354-4438-6/$30.00

For estimation of surface roughness artificial neutral network has been used. For finding the tool wear cutting parameter has been analyzed. [2] Cutting tool performance of AISI H11 has been estimated with cryogenic treatment. Three different methods are used which are shallow cryogenic treatment at SCT for 6hrs at -800C, DCT for 6hrs at -1960C and DCT for 24hrs at -1960C. By methods based on experimental investigation cutting tool abrasion resistance has been increases. Tool wear is analyzed by changing the different cutting parameter.

[3] Carbide precipitation of high speed steels has been analyzed. Deep cryogenic treatment has been done on three different high speeds for analyzing the deep cryogenic treatment and carbide precipitation three different methods are used which is X-ray diffraction, energy –dispersive X ray spectroscopy (EBSD), transmission electron microscopy (TEM).[4] Minimal process parameters of heat treatment and cryogenic treatment of AISI m2 steel has been analyzed for finding the process parameters steel austenized at different temperature and steels are quenched into salt bath. Because of these process abrasion resistance and toughness of steel is increased.[5] Deep cryogenic treatment of AISI M3.2 high speed steel has been done for finding the variation in mechanical properties. Different high speed steel are used for deep cryogenic treatment and DCT of different process. Out of these two methods it id conclude that some mechanical properties of material will increases because of DCT[21].

[6] During CT of AISI 52100 steel white layer is formed and formulation of white layers has been analyzed. With the help it CBN tool white layer characteristic has been analyzed. Cooling Cryogenic method is effecting reducing white layer thickness and increase hardness of steel.[7] CT on high carbon chromium tool steel has been analyzed. The purpose of cryogenic treatment on D2-steel is to improve the surface properties. High carbon chromium tool steels are widely used in punching industries. Due to continuous usage tool wear will occur. Cryogenic treatment will helps to improve wear resistance of D2-tool steel.[8] AISI bearing steel used for shallow and deep cryogenic treatment. Shallow cryogenic treatment, deep cryogenic treatment and conventional heat treatment methods are used AISI bearing steel. When compared to above three methods DCT & SCT there is small increment in hardness[22].

[9] Tungsten carbide used for cryogenic treatment soaking. Soaking period effect is analyzed for different time periods. Soaking will improve the wear resistance and hardness of tungsten carbide tool.[11] Cryogenic treatment of Ti-6Al-4v titanium alloys has been analyzed. The main aim of cryogenic treatment on titanium alloys is to improve Machinability for improving this Machinability indirect cryogenic cooling method has been use. Indirect cryogenic cooling can be done for internal and external spray system.[12] Cryogenic treatment of cast AZ91mg alloy has been done. CT is done for different time periods and analyzing microstructure. Three different methods are used after analyzing the microstructure it has been observed the due to change in the microstructure strength if mg alloys has been increased [23].

[13] AISI 52100 bearing steel has been used for cryogenic treatment CBN tool is used to perform experimental investigation of dry and cryogenic treatment on AISI 52100 bearing steel bearing steel microstructure properties has been analyzed with SEM,EDM,XRD technique. By the analysis of these techniques it is observed that surface properties are bearing steel has been increased. [17, 25] Cryogenic treatment of 1.2542 tool steel analyzed. Due to cryogenic treatment surface tropholoigical properties will increase. Microstructure changes will lead to improve the mechanical properties steel [24].

[18] Hastelloy X is used for cryogenic treatment. In this method Hastellloy X investigated at low temperature. Cryogenic treatment carried out at two different temperatures. Three different sample which at room temp(1960c 12hr),(-1960c 24hr) has been analyzed. It is observed that Hastelloy X at room temperature gives better metallurgical properties than others. [19] Different alloys are used to make special spheroidal gray cast iron. Some additives are added to improve the mechanical properties of SGI after making SGI CT has been done. It will improve the microstructure as well as metallurgical properties.

EXPERIMENTAL PROCEDURE

In this Study, AISI EN 19 tool Steel Rectangular bar of dimensions Width: 20, Depth: 15, Length: 200 mm cryogenic heat treatment. The composition of the steel is presented in Table.1.Cryogenic heat treatment process is shown in Fig.1. Specimen was subjected to Cryogenic heat treatment as per ASM standard followed by quenching and tempering. During cryogenic treatment the sample 1 were placed in 850oCand soaked for 5 hr for attaining the steady state temperature when allowed to reach to the room temperature and sample 2 were placed in 850oCand soaked for 25 hr.

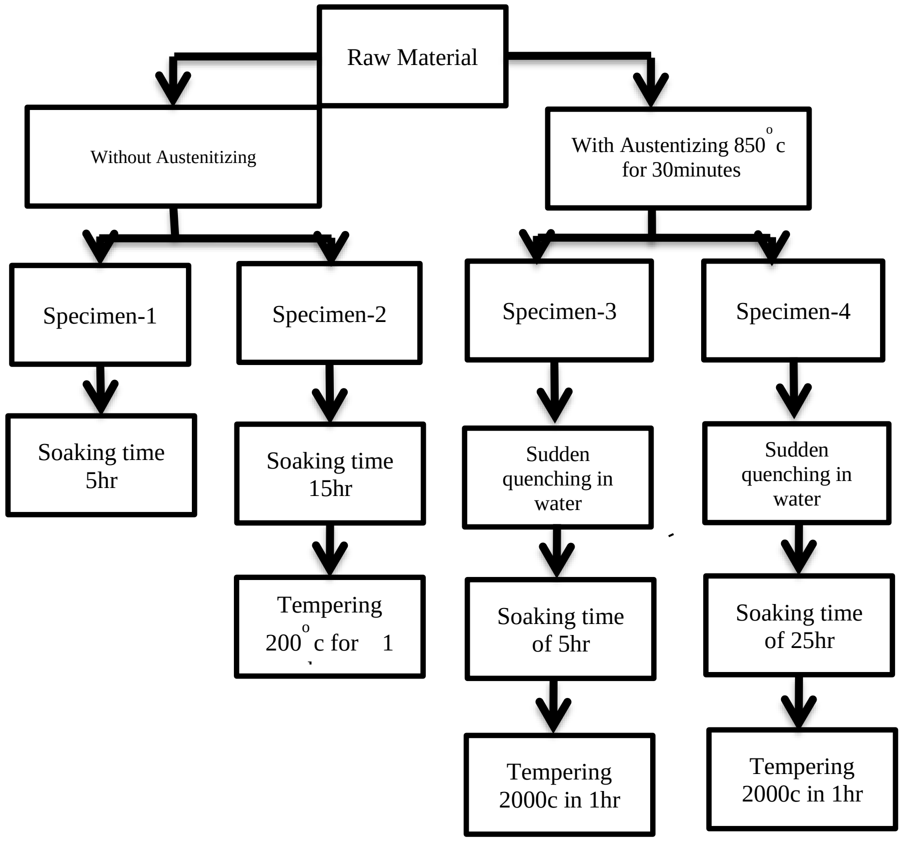


FIGURE1. Cryogenic heat treating process

TABLE.1 Chemical Analysis of AISI EN 19 Tool Steel Material

Element	C%	Cr%	Mn%	Si%	Mo%	Fe%
Wt.%	0.35-0.45	0.9-1.5	0.5-0.8	0.1-0.35	0.2-0.4	Remaining

The tool steel specimens of dimensions length 200mmhaving rectangular cross section of size 20x15 mm2 have been used in this study. Four tool steel specimens have been used in this study. Specimen 1 has been directly used for cryo-soaking for a period of 15 hrs. Specimen 2 was initially soaked in the cryogenics for a period of 15 hrs and then it was tempered at 150oC for 1 hr. Specimens 3 and 4 were first kept for austenizing at 850°C for duration of 30mins. After the austenizing process both specimens were suddenly quenched in water. Specimen 3 was left for cryogenic treatment for duration of 5 hrs. After removing from the cryogenic treatment, the specimen was tempered at 200oC for a duration of 1hr. Specimen 4 was soaked in the cryogenic for a duration of 25 hrs, After the cryogenic treatment, it was tempered at 200°C for a period of 1hr.

FIGURE 2. Specimen with austenizing process

FIGURE 3. Austenizing (850°C)

FIGURE 4. Specimen with austenizing Process

FIGURE 5. Water Quenchining

FIGURE 6. Keeping specimen in cryo-can

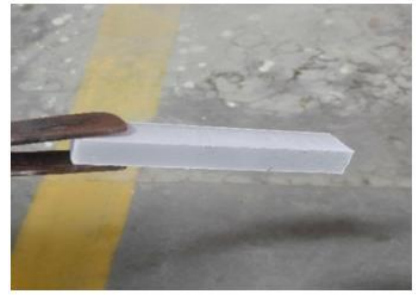


FIGURE 7. Specimen after cryo-treatment

RESULTS AND DISCUSSION

Micro structural analysis: the microstructure under optical microscope was observed after austenizing and cryogenic treatment are shown in Fig.8. The structure shows good metallurgical bonding, which improved the strength of the material. The tool steel specimens undergoing process of austenizing and cryogenic treatment is shown in Fig.9. The structures depicts of carbines in fine size in the form of matrix. It can be observed that the tempered matrensite has carbides located in a matrix structure. From the Fig.10 after increasing the soaking of the tool steel specimen in cryogenic for 25 hr, the micro structural analysis reduced the cracks and defects. Due to the micro etching, it has observed in the cross section porosity was low. After tempering carbines was reduced to fine sizes which were present in the form of matrix.

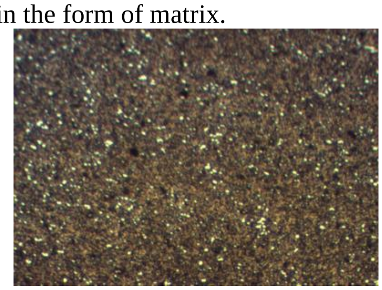


FIGURE 8. Microstructure of AISI EN 19 without treatment

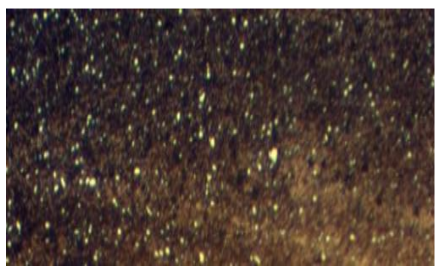


FIGURE 9. Microstructure AISI EN 19 with only cryo-treatment (5hr) and tempering (1hr)

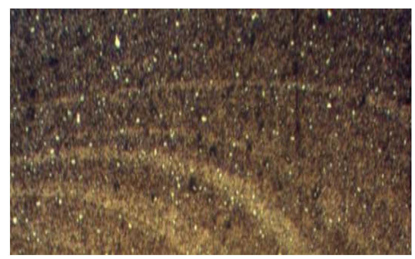


FIGURE 10. Microstructure AISI EN 19 with only cryo-treatment (25hr) and tempering (1hr)

TABLE 2. Mechanical properties of tool steel without Austenizing

Sl. No.	Type of Test	Without Treatment	Cryo-Treatment 15hr	Cryo-treatment+ Tempering 1hr
1	Brinell Hardness(HBW)	229	285	313
2	Charpy Impact (Joules)	40	8	14

TABLE 3. Mechanical properties of tool steel with Austenizing

Sl. No.	Types of Test	Cryo-treatment(5hr)+ Tempering (1hr)	Cryo-treatment(25hr)+ Tempering (1hr)
1	Brinell Hardness(HBW)	538	506
2	Charpy Impact (Joules)	10	8

From the result it is clear that conventional treatment AISI E19 tool steel has with austenizing will be having higher value than without austenizing.

CONCLUSION

From the tests we performed and by analyzing the microstructure of AISI EN 19 tool steel we observed that without austenizing 36.68% increment in the hardness and decrement in the toughness by 65% with cryogenic treatment for 15hr and tempering for 1hr. For only soaking time of 15hr hardness increased by 24.45% and toughness decreased by 80%.With austenization 134.93% increment in the hardness and 75% decrement in the toughness with 5hr of cryo soaking time and 1hr tempering and for 25hr of cryo soaking time and 1hr tempering increment in the hardness by 120.96% and decrement in the toughness by 80%.The results showing that the material after cryogenic treatment became harder and brittle and with tempering it became little softer.

REFERENCES

1. Kara, Fuat, et al., Journal of Materials Research and Technology 9.1 (2020): 969-983.
2. Fantineli, Dieison G., et al., Journal of Materials Research and Technology 9.6 (2020): 12354-12363.
3. Jovičević-Klug, Patricia, Matic Jovičević-Klug, and Bojan Podgornik., Journal of Materials Research and Technology 9.6 (2020): 13014-13026.
4. Özbek, Nursel Altan., Journal of Materials Research and Technology (2020).
5. Jovičević-Klug, Patricia, and Bojan Podgornik., Journal of Materials Research and Technology 9.6 (2020): 13118-13127.
6. Nie, Guang-Chao, et al., *Procedia CIRP* 77 (2018): 223-226.
7. Sharma, Neeraj, Ajit Singh, and Renu Sharma., *Procedia Engineering* 97 (2014): 1609-1617.
8. Idayan, A., A. Gnanavelbabu, and K. Rajkumar. *Procedia Engineering* 97 (2014): 1683-1691.
9. Dhande, S. T., et al., *Procedia Manufacturing* 20 (2018): 318-328.
10. Grandjean, Thomas RB, Jakobus Groenewald, and James Marco., *Journal of Energy Storage* 21 (2019): 202-215.
11. Suhaimi, Mohd Azlan, *Procedia Manufacturing* 17 (2018): 158-165.
12. Junwei, L. I. U., et al. *Chinese Journal of Aeronautics* 25.6 (2012): 931-936.
13. Umbrello, Domenico, Procedia Engineering 19 (2011): 371-376.
14. Meyer, D., E. Brinksmeier, and F. Hoffmann. Procedia Engineering 19 (2011): 258-263.
15. Pillai, Nandakumar, *Procedia Manufacturing* 26 (2018): 329-342.
16. Lee, Sang Won, Sang-Hoon Kim, and Sung Hyuk Park., Journal of Magnesium and Alloys (2020).
17. Vahdat, Seyed Ebrahim, Said Nategh, and Shamsoddin Mirdamadi., Procedia materials science 6 (2014): 202-207.
18. Ekambaram, Pavithra.,*Journal of Materials Research and Technology* 8.6 (2019): 6413-6419.
19. Milosan, Ioan. ,Procedia-Social and Behavioral Sciences 62 (2012): 711-715.
20. Yan, Zhijie, Kun Liu, and Jürgen Eckert., Materials Science and Engineering: A (2020): 139520.
21. Kumar, Ch Ashok, S. Udaya Bhaskar, and N. Srinivasa Rajneesh., *AIP Conference Proceedings*. Vol. 2358. No. 1. AIP Publishing LLC, 2021.
22. Rajneesh, N. Srinivasa, *AIP Conference Proceedings*. Vol. 2358. No. 1. AIP Publishing LLC, 2021.
23. Pavuluri, Subramanyam, *AIP Conference Proceedings*. Vol. 2358. No. 1. AIP Publishing LLC, 2021.
24. Rajneesh, N. Srinivasa, Ch Ashok Kumar, and S. Udaya Bhaskar. *Materials Today: Proceedings* 44 (2021): 2606-2610.
25. Subramanyam Pavuluri, B.Sidda Reddy, B.Durga Prasad, International Journal of Advanced Science and Technology, Vol. 29, No.5, pp. 2215-2226, 2020.