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Strengthening the Mechanical Properties of 20MnCr5 Steel by Developing Martensite Structure through Deep Cryogenic Treatment

M. Franklin[1], P. Perumal[2], P. Keerthi Vasan[3]
[1] PG Scholar , [2] Assistant Professor, [3] Ph.D Scholar
[1, 2, 3] Department of Mechanical Engineering., ACGCET
Karaikudi-630003, Tamil Nadu, India

Abstract:- Heat treatment process is a resultant process to improve the mechanical and metallurgical properties of the material. Deep cryogenic treatment is not an alternative process to the heat treatment process it is a complimentary process to the heat treatment and it affects the entire cross section of the material. Deep cryogenic treatment is a heat treatment process where the material is subjected to comparatively extreme low temperature condition in order to enhance the mechanical and metallurgical behaviors of the material. Low alloyed case hardening steels used for manufacturing of parts which required to withstand high operating condition such as axle drives, gears & shafts. In this proposed work 20MnCr5 steel has been subjected to Deep Cryogenic Treatment at different soaking temperature and period. A comparative characterization study has to be conducted, before and after the cryogenic treatment, to investigate the behavior of materials.

***Keywords**:- Deep Cryogenic Treatment, Soaking Period, Soaking Temperature.*

I. INTRODUCTION

Deep Cryogenic treatment is a cold treatment process in which the material is subjected to subzero temperature. Because of the cold treatment the morphological structure of the material will be changed. The main objective is to change the morphological structure and also to improve the mechanical properties of the material. Initially before the cryogenic treatment the material is in an austenite structure. Retained austenite is soft and ductile, and also they are not ferromagnetic in nature. In order to change its morphological structure from retained austenite to martensite, the cooling rate has to be high. Martensite is not an equilibrium phase because it is not shown in equilibrium phase diagram. Equilibrium phases can be obtained only at the slow cooling rate. In order to achieve the high cooling rate, deep cryogenic treatment is only the suitable process. Materials after cryogenic treatment contains martensitic structure improves the hardness of the material. But it is acicular (Needle like structure) and is very brittle. It can not be used as such. That's why the materials are tempered after treatment to make it less brittle.[1]18NiCrMo5 is carburized and twenty samples are kept for tensile test and twenty samples are kept for hardness test. After carburizing all the samples are categorized into four groups. First group is only case hardened and tempered without cryogenic treatment. Second group is cryogenic treated before tempering and after the case hardening at the temperature of-185ºC for 1hr. Third group also follows the same sequence mentioned in the second group the only difference is at a soaking period of 24hrs. Sequence of the fourth group is tempering is carried out before Deep cryogenic treatment and after the carburizing at the temperature of -185ºC for 24hrs.From the above mentioned groups it is concluded by increasing the soaking time the harness of the material of the material also increased. [2]The samples are marked as 421 & 422 and they are annealed at 660ºC before the high temperature heat treatment process. After annealing high temperature carbonitriding is carried out by using carbon and nitrogen as a variable potential by varying the process parameters. The steel is carburized initially with nitrogen and finally with carbon shows a substantial development in the wear resistance. [3] Three sets of samples are used in this work first one is conventionally heat treated at 910ºC followed by quenching and the second one is cooled down to subzero temperature (-80ºC) for 5hrs and immediately exposed to the room temperature followed by tempering at 150ºC for 90mins called shallow cryogenic treatment. Third set of samples cooled down slowly at the rate of 1.26 K/min to subzero temperature (-196ºC) is kept at that temperature for 24hrs and slowly warmed up to the room temperature at the rate of 0.63 K/min followed by tempering at 150ºC for 90mins called deep cryogenic treatment. Deep cryogenic and shallow cryogenic treatment shows a better wear resistance in comparison with conventional treatment. And DCT gives 152% of wear resistance over SCT. [4] Improving the fatigue life of the transmission shafts can be obtained by double tempering to reduce the retained austenite. [5] Transformation of retained austenite to martensite results in the precipitation of eta carbides as a result it creates more denser molecular structure. [6] Three sets of M2 HSS steels are analysed and first set is used as lathe tools one is treated at -196ºC another one is untreated and second set used as twist drills and the third set used as the milling cutter. volume of the retained austenite in M2 HSS steels is calculated as 25% and the cryogenically treated steels shows 0% of retained austenite. The change in the volume of retained austenite on the untreated and treated samples gave a considerable improvement in the tool life.

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[7] AISI D6 tool steel is hardened at a temperature of 950ºC for 1hr and followed by tempering at 210ºC for 2hrs. The deep and shallow cryogenic treatment is carried out before tempering and after hardening at a temperature of -63ºC and 185ºC for a period of 20hrs and 40hrs. Based on the Design of experiments Response surface methodology it is concluded that Deep cryogenic treatment is an accompanying treatment along with conventional heat treatment and not a replacement of it. [8] Samples are treated at soaking temperature of -185°C at three different soaking period of 24,48 & 72 Hrs. DCT causes microstructural changes like fine martensitic structure, increase in carbide density and their uniform distribution which improves hardness impact toughness, wear and fatigue properties as compared to conventional harden and tempered (HT) samples. [9] Cryogenic treatment was conducted between quenching and tempering. Three cryogenic temperatures (-100°C, -150°C, -196°C) were selected, and samples were soaked at each temperature for 24 h, respectively. The cooling and heating rates at low temperature were both 2°C min. Martensitic transformation takes place because of the Ultracold treatment to enhance the mechanical properties like hardness, toughness, strength and also wear resistance by increasing hardness.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

The case hardening steel 20MnCr5 is selected for this proposed work. Below mentioned table1 provides the chemical composition of the selected material. Low alloyed case hardening steels used for manufacturing of parts which required to withstand high operating condition such as axle drives, gears & shafts. The material has been chosen for this work were prepared in the required sizes to test the mechanical properties of the material.The specimens prepared for Deep cryogenic treatment are intially machined based on the required shape and size to carry out the charterization. The entire process sequence is shown in the figure 1.

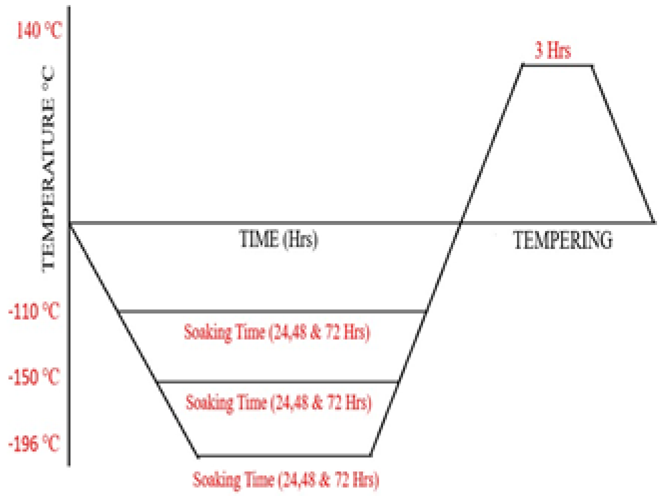

Fig 1:- Process sequence of Deep Cryogenic Treatment

These samples are classified into the three groups based on the temperature at which these specimens are kepet is called soaking temperature. Usually soaking temperature is a subzero temperature. Furthur these samples are classified into the three groups called soaking period. Intially the first sample is cooled down slowly to subzero temperature of -110ºC and it kept at that period of 24hrs. The sample S1 is warmed up to the room temperature and it is furthuer heated upto the soaking temperature of 140ºC for 3hrs. The same sequence is repeated for the remaining samples as per the process parameters given in table 2.

C	Si	Mn	S	P	Cr	Al
0.19	0.30	1.25	0.020	0.015	1.18	0.03

Table 1:- Chemical composition of the 20MnCr5 (AISI 4820) Steel,

Deep cryogenic treatment is carried out on the nine specimens by using the liquid nitrogen. Mechanical properties of the materials are studied by varying the process parameters. By varying the process parameters which parameter provides an optimized mechanical property can be found out. Hardness of the deep cryogenic treated and non-treated materials are tested by using the Vickers hardness tester by applying the load of 100grm. X-Ray Diffraction test is also carried out on the treated and non-treated materials to find out the volume fraction of the retained austenite.

Designation	Soaking Period	Soaking Temperature
R	-	-
S1	24hrs	-110ºC
S2	48hrs	-150ºC
S3	72hrs	-196ºC
S4	24hrs	-110ºC
S5	48hrs	-150ºC
S6	72hrs	-196ºC
S7	24hrs	-110ºC
S8	48hrs	-150ºC
S9	72hrs	-196ºC

Table 2:- Deep cryogenic process parameters,

III. RESULT AND DISCUSSION

➢ *Hardness Test:*

Hardness of the deep cryogenic treated specimens are measured by using the Vickers micro hardness tester. The hardness values obtained from the Vickers hardness tester are shown in the Fig2. The specimens are prepared by polishing the surfaces so that the surface hardness can be measured. Hardness is measured by calculating the diagonal lengths of the diamond indenter. From the obtained hardness values the specimen with a soaking temperature of -196°C and a soaking period of 48Hrs shows a highest harness value. Soaking Temperature and soaking period are playing an important role in enhancing the harness of the specimen.

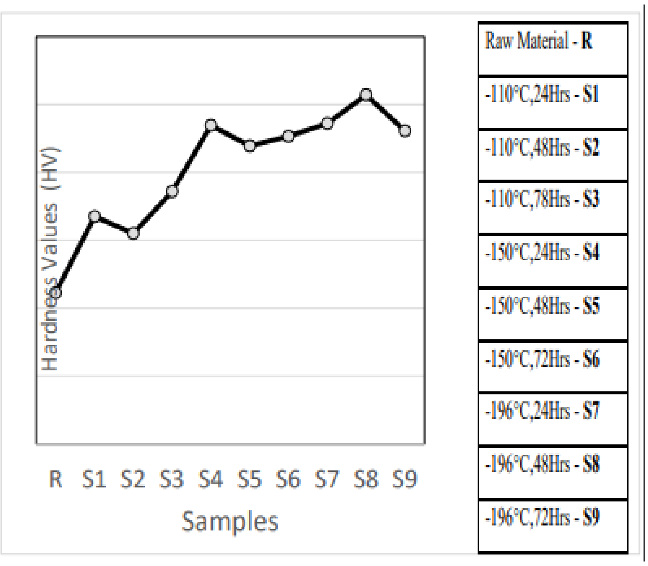

Fig 2:- Hardness values of the Deep cryogenic treated materials

➢ *XRD Analysis:*

From the XRD patterns the (hkl) value of each crystal structures for the Cryogenic treated and untreated specimens are obtained. The (hkl) value of the austenite is (2 0 0) and the (hkl) value of martensite is (1 0 1). The 2-theta values are considered between the 40o to 65o. The volume fraction of the retained austenite for the untreated specimen is 43%. The material treated with low soaking temperature and soaking period is only with the 7% volume fraction of retained austenite.

IV. CONCLUSION

Deep cryogenic treated materials with higher soaking temperature and soaking period gives a maximum hardness value. 43% Volume fraction of retained austenite in the material has been completely transformed into martensite. So that the mechanical properties of the deep cryogenic treated materials are enhanced.

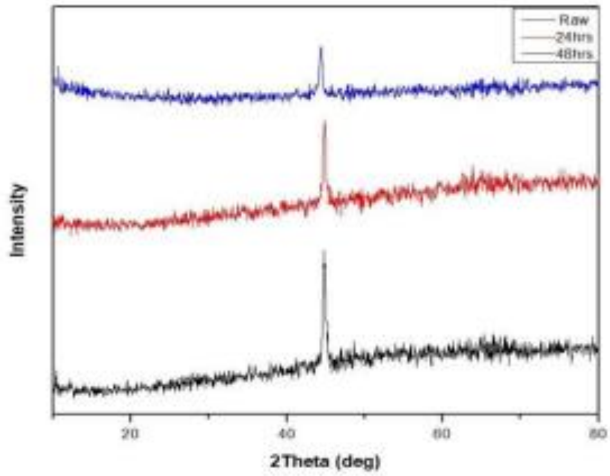

Fig 3

REFERENCES

[1]. Paolo Baldissera *, Cristiana Delprete "Effects of deep cryogenic treatment on static mechanical propertiesof 18NiCrMo5 carburized steel"2009.

[2]. Opačak I., mag.ing.mech. 1, Marić A., dipl.ing. 2, Hon.D.Sc. Dašić P. 3, Prof. dr. sc. Marušić V "The laboratory testing of steel 20MnCr5" ISSN 1313-0226.

[3]. A. Bensely *, A. Prabhakaran, D. Mohan Lal, G. Nagarajan "Enhancing the wear resistance of case carburized steel (En353) by cryogenic treatment" 2005.

[4]. Ramesh Srinivasan [a,*], S. Natarajan [a,b], V.J. Sivakumar [a,c] "Fatigue life improvement on 20MnCr5 steel through surface modification for auto transmission application" 2018.

[5]. 5.Effect of Cryogenic Treatment on Microstructure, Mechanical and Wear Behaviors of AISI H13 hot work tool steel

[6]. Fla´vio J. da Silva a, Sine´sio D. Franco b,∗, A´ lisson R. Machado c, Emmanuel O. Ezugwu d, Antˆonio M. Souza Jr. e "Performance of Cryogenically Treated HSS Tools" 2006.

[7]. Rahul H.Naravade, U.N.Gujar, R.R.Kharde "Optimization of Cryogenic Treatment on Wear Behavior of D6 Tool Steel by Using DOE/RSM" ISSN: 2249 – 8958, Volume-2, 2012.

[8]. Valmik Bhavar, Shreyans Khot, Prakash Kattire, Mohan Mehta

[9]. Dr. RKP Singh "Effect of Deep Cryogenic Treatment (DCT) on AISI H13 Tool Steel" 2015.

[10]. Kaikai Wang,* Kaixuan Gu,* R. D. K. Misra, Liubiao Chen, Xuanzhi Liu, Zeju Weng, and Junjie Wang "On the Optimization of Microstructure and Mechanical Properties of CrWMn Tool Steel by Deep Cryogenic Treatment" DOI: 10.1002/srin.201800523.