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MICRO-STRUCTURAL ANALYSIS & HARDNESS TESTING OF 52100 BEARING STEEL WITH DEEP CRYOGENIC COOLING IN COMPARISON WITH CONVENTIONAL METHOD

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Abstract: Cryogenic is the study of production of behavior of material at very low temperature ranging from -80 C to -196 C. Here different cryogenics such as CO2, LN2, He, O2 etc. After a waiting period the samples are again gradually brought to room temperature. Extensive use of this cryogenic treatment method is applied to a different material used in a various field of application as it is cheaper and easier to apply as compared to other treatments mostly emphasizes the tool performance.

Cryogenic cooling with LN2 is recognized as a green solution for effective changes of hardness and micro-structural analysis and result in it may replacement of hardening process of hot working at material in to days manufacturing sectors.

Our project focus deep cryogenic cooling of AISI 52100 bearing steel. In order to study material behavior at low cryogenic temperature in comparison with convectional cold working process. Result has to obtain in terms of surface roughness and micro structural analysis. Different cooling time is provided Dewar of LN2. And respective hardness is measured and compared and after measuring and comparison of hardness, the kind of result get it is observed that hardness of material is increasing as the time interval of deep cooling is increased.

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I INTRODUCTION

Cryogenic is the science of very low temperature spanning the range between 100 K and absolute zero (0 K or -273 k). Historically The word, “Cryogenics” is taken from two Greek words – “kryos” which means ‘frost’ or freezing, and “genic” meaning to ‘produce’ or generated. Technologically, it means the study and use of materials (or other requirements) at very low temperatures However today cryogenic deals with temperatures essentially below about -150˚ C or 123 K; sometimes below -100 ˚ C or 173 K.

Cryogenics under of two process cooling process and machining process. Cryogenic treatment is the processing of materials at low temperatures ranging from -80 and -196 °C. In this treatment the samples used for cryogenics are cooled in the controlled unit using cryogens such as liquid nitrogen, liquid helium etc. Extensive use of this cryogenic treatment method is applied to a different materials used in various field of application as it is cheaper and easier to apply as compared to other treatments.[1]

Cryogenic treatment started to be utilized as a part of the late sixteenth century to upgrade the mechanical properties of material.[2]

It has several applications such as Cryo processing has emerged as a fascinating and truly spectacular means to increase the wear resistance and life of all metals and some plastics. Cryogenic processing has been proved to improve performance, reliability, and durability of racing engines, brake transmission and drive lines, suspension springs etc. Cryogenic processing of machine tools, machine parts, punching dies, and other items is known to respond well, thereby reducing the cost of production while improving the quality of the product. Cryogenic tempering transform the microstructure into a more uniform structure that is more durable, stronger, long lasting, and more dimensionally stable.

CRYOGENIC LIQUID:-

- **Liquid Nitrogen (LN2) :-**

LN2 is nitrogen in a liquid state at a very low temperature and usually stored in isolated tanks at very high pressure. When the media enters the ambient temperature and the pressure drops (1,01325 bar), the nitrogen starts boiling at -196°C.[3] It is safe non-combustible chemical and leaves no harmful residue to the environment since in becomes a part of the other 79% of nitrogen in the atmosphere.[4 5 6] However, in some cases when LN2 comes in contact with hot surfaces it starts boiling and vaporizing, an insulating film of gas forms and surrounds the part, reducing the cooling effect.

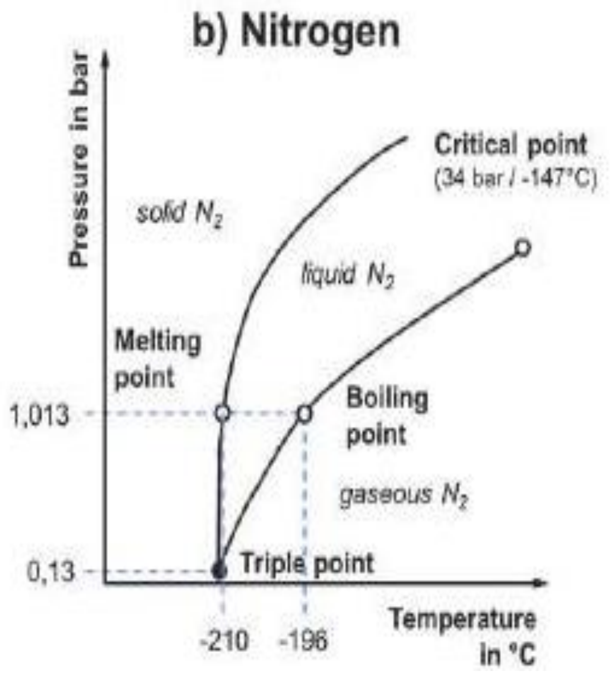


Fig 1: Liquid Nitrogen (LN2)

Carbon Dioxide (CO2):-

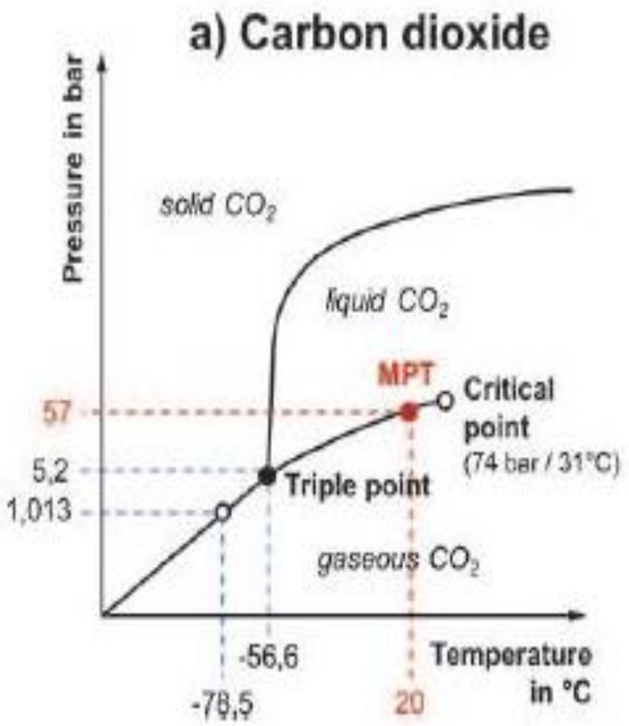


Fig 2: Carbon Dioxide (CO2)

CO2 At pressure from 0 to 5.2 bar and temperature from absolute zero (-273 °C) to -56,6°C, CO2 can only be at solid or gaseous state. In order to get it on liquid form, CO2 must be kept at pressure above 5,2 bar. Thus, CO2 is often stored in a medium pressure tank (MPT) at pressure of 57 bar in liquid form at around 20°C.When the CO2 exits the pipes and enters the atmospheric pressure, it experiences a major pressure drop, causing it to expand and cooldown due to the Joule-Thomson effect.[7]

This conversion of the physical state is called the process of sublimation.[8] The CO2 cools to -78, 5°C and transforms in 40% snow and 60% gas. The energy required for this transformation is taken from the surroundings in the form of heat.

Process of Cryo-Heat- Treatment:

The complete treatment process of the AISI 52100 Bearing steels consists of hardening that is Austenitizing and quenching, cryo-treatment or deep cryogenic treatment (DCT), and Tempering. To achieve better microstructure of the steel to get most desired properties, it is recommended by the most researchers to execute DCT after completion of quenching and before tempering in conventional heat-treatment cycle. The complete process sequentially consists of the steps austenitizing, quenching, cryo-processing and tempering

To harden AISI 52100 Bearing steels, the heat treatment process in [10] includes heating to austenitizing temperatures. The microstructure is composed of the metallurgical phase austenite plus the primary carbides. Austenitizing is followed by quenching, or rapid cooling, which transforms some or all of the austenite into the higher strength martensitic structure.

OBJECTIVE

1. Deep cryogenic cooling with LN2 is the good invention for replacement of hardening process of hot working materials in today's manufacturing sectors.
2. Comparing the microstructure of material between hacksaw cutting and grinding cutting.
3. Compare the hardness effect on material between conventional method and cryogenic cooling method.
4. To develop environmental friendly hardening method in today's manufacturing world.

II LITERATURE REVIEW

Literature review provides a correct path and background for futuristic approach in research work, following are very important review of researcher, schollers and scientist in the field of material cryogenic treatment whose thoughts and ideas gives us a constant guidance as well as motivation also whose states about increases material mechanical properties. The purpose of the application of the cryogenic liquid on material was stated as reducing temperature by cooling effect which effects on the properties of material. Generally reduction in temperature results in decrease and increase in aboration resistance, microstructure.

Vishnu Mhaske et al [2016] suggest "the cryogenic machining would improve the quality and productivity of industries. He also studied delivering of cryogenic CLF to the local cutting region of the cutting tool, which is exposed to the highest temperature during the machining process, or to the part in order to change the material characteristics and improve machining performance".

P. I. Patilet al [2012] studied the effect of cryogenic treatment on different types of steels and other materials. His paper aims at the comprehensive analysis of strategies followed in CTs and their effect on properties on different types of steels by application of appropriate types of CTs from cryogenic condition of the process. He suggest cryogenic treatment (CT) is the supplementary process to conventional heat treatment process in steels, by deep freezing materials at cryogenic temperatures to enhance the mechanical and physical properties of materials being treated.

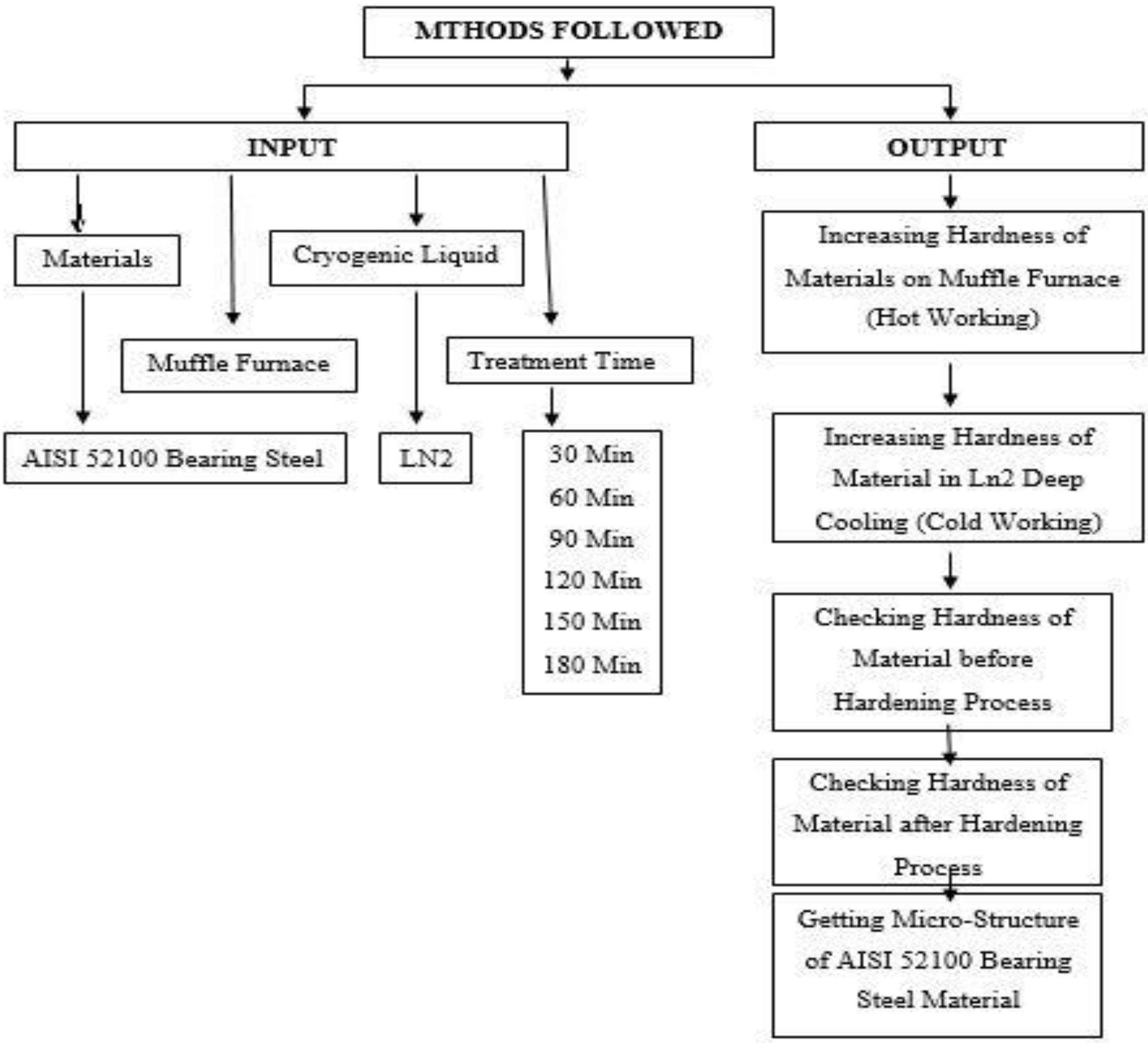
P. Prudvi Reddy, A.Ghosh et al.(2014) studied cryogenic cooling with LN2 is recognized as a green solution for effective control of machining zone temperature, thereby resulting in substantially enhanced tool life. They suggest the adverse effects could be controlled by using chilled N2 gas instead of LN2 jet however with a compromise on G-ratio.

A. Shokrani, V. Dhokia, P. Muñoz-Escalona & S.T. Newman et al. (2013)studied identify that cryo-processing can considerablyincrease cutting tool life especially for high speed steel tools.

Trausti Stefánsson et al. (2014) studied the advantage in the favour of CO2 cryogenic cooling concerning precision and surface finish but an obvious need for further optimization of the process was evident as well.

III METHODOLOGY

The process flow chart of given work is given below:-



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IV EXPERIMENTAL SETUP:-

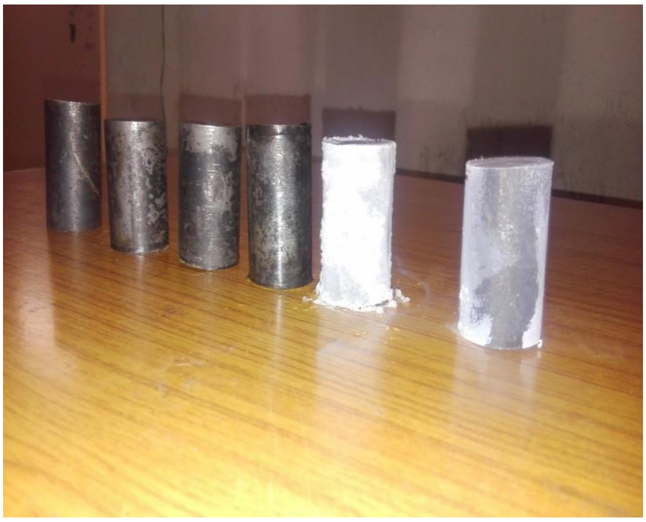


Fig.3:- AISI 52100 Bearing steel material with deep cryogenic cooling in LN2

Table 1: Liquid Nitrogen Physical and Chemical Properties Chemical Formula

Chemical Formula	N2
Molecular Weight	28.01
Boiling Point @ 1 atm	–320.5°F (–195.8°C)
Freezing Point @ 1 atm	–346.0°F (–210.0°C)
Critical Pressure	492.3 psi(33.5 atm)
Critical Temperature	–232.5°F (–146.9°C)
Density, Liquid @ BP, 1 atm	50.47 lb/scf (808.5 Kg/m3)
Density, Gas @ 68°F (20°C), 1 atm	0.0725 lb/scf (1.16 Kg/m3)
Specific Gravity, Gas (air=1) @ 68°F (20°C), 1 atm	0.967
Specific Gravity, Liquid (water=1) @ 68°F (20°C),	1 atm 0.808
Specific Volume @ 68°F (20°C),	1 atm 13.80 scf/lb (0.861 m3/kg)
Latent Heat of Vaporization	856 Btu/lb (199.1 kJ/kg)
Expansion Ratio, Liquid to Gas, BP to 68°F (20°C)	1 to 694

V RESULTS

MICRO-STRUCTUREAL ANALYSIS:-

1. Microstructure of raw material:

Figure No.4

Raw material of 52100 bearing material under the is as shown in figure. It is found that grain size are normally distributed in simple cubic structure due to which it is soft in nature and thus hardness is lower

2. Microstructure of hardened material:

Figure No.5

Fig.(6):- Hacksaw Cutting
(30 Min. Deep Cooling)

Fig.(7):- Grinding Cutting
(30Min. Deep Cooling)

While cutting the given material

Fig.(8):- Hacksaw Cutting
(1 Hr. Deep Cooling)

Fig. (9):- Grinding Cutting
(1 Hr. Deep Cooling)

Fig. (10):- Hacksaw Cutting
(1 Hr.30 Min. Deep cooling)

Fig. (11):- Grinding Cutting
(1 Hr.30 Min. Deep Cooling)

Fig. (12):- Grinding Cutting
(2 Hr. Deep Cooling)

Fig. (13):- Hacksaw Cutting
(2 Hr.30 Min. Deep Cooling)

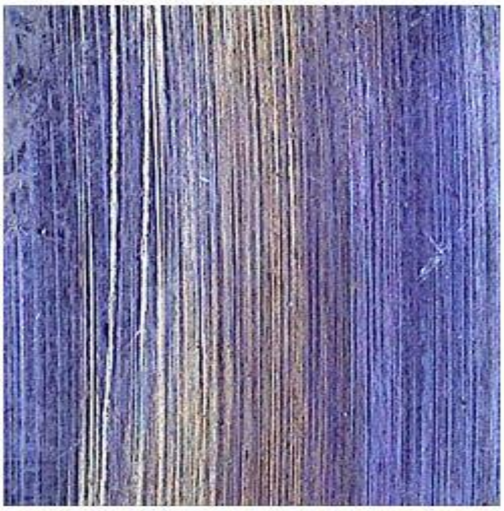


Fig. (14):-Grinding Cutting (2 Hr.30 Min. Deep Cooling)

Fig. (15):-Grinding Cutting (3 Hr. Deep Cooling)

VI RESULTS

6.1 Hardness Testing Of AISI 52100 Bearing Steel With Deep Cryogenic Cooling Steps:-

1 Selection of material (AISI 52100 Bearing Steel)

2 Hardening of material in muffle furnace(950C).

3 Checking the hardness of material.(HRC And HBR), Which is harden at muffle furnace.

4 Deep cooling of material in Liquid Nitrogen (LN2).Which stored in cryo can (Dewar)

5 Checking microstructure of harden material.

6 Again checking the hardness of materials.

6.2Hardness Testing Report:-

Your Reference:- Sample given for testing

Part Name:- AISI 52100Bearing Steel

Test Result:-

Table No.:- 3 Hardness of material before deep cooling in LN2

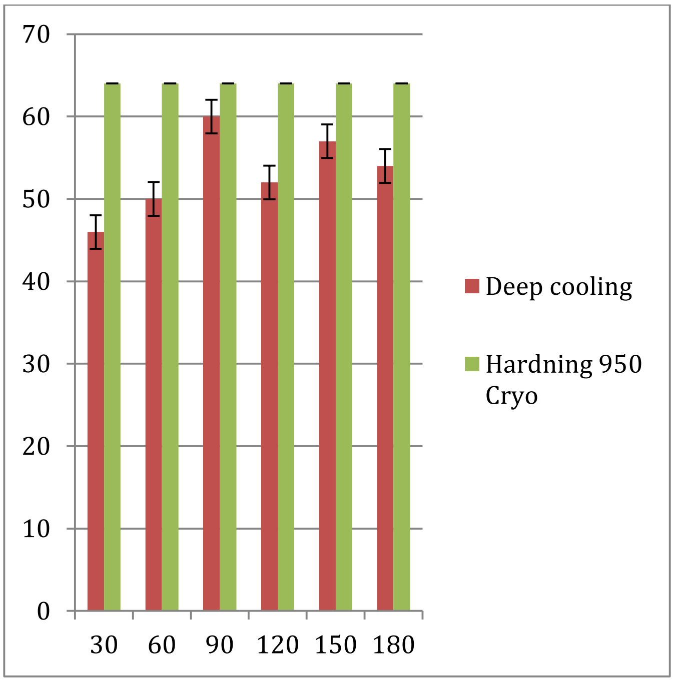
Sr. No.	Test Conducted	Observation
1.	Raw Material (Without Hardness)	187 HBN
2.	Hardening (950*C) Hardness	63-64 HRC
3.	Hardening (950*C) Hardness	62-63 HRC

Table No.:- 4 Hardness of material after deep cooling in LN2

Sr. No.	Test Conducted	Observations
1	Sample No. 1 (30 Min. Deep Cooling)	46 HRC
2	Sample No.2 (1 Hr. Deep Cooling)	50 HRC
3	Sample No.3 (1 Hr.30 Min. Deep Cooling)	60 HRC
4	Sample No.4 (2 Hr. Deep Cooling)	52 HRC
5	Sample No. 5 (2 Hr.30 Min. Deep Cooling)	57 HRC
6	Sample No.6 (3 Hr. Deep Cooling)	54 HRC

After hardening of material in muffle furnace at 950*C the hardness value of that material is 62-64 HRC. And hardening value of that material after deep cooling in LN2, the value of hardness are changes as time interval changes.

6.3Graph:-



VII ADVANTEGES AND DISADVANTEGES

7.1 Advantages of Cryogenics:-

1] Less time consuming.

2] Hardening cost should be reduced.

3] Environmental and health friendly hardening process.

4] Less space is required for the hardening process.

5] Superior hardness, 60-67 on Rockwell hardness scale at Rc.

6] High carbon, chromium alloy steel.

7] Long working life.

8] It is well established that certain materials, when subjected to extremely low temperature show signs of increased resistance to wear.

7.2 Disadvantages of Cryogenics:-

1. More precautions have to be taken.
2. Skilled labour / worker is required.

VIII CONCLUSION

The micro-structure analysis of AISI 52100 Bearing steel with deep cryogenic cooling is good invention for replacement of hardening process of hot working. Its advantage is that to reduce time of hardening process, where time is very important, as well as reduces the cost of the conventional hardening process. As well as this process recognized as a green solution for effective changes of hardness and micro-structure analysis and results. The modification of project can be done by using the Liquid Nitrogen (LN2) at the temperature of -196 c in which material is deep cooled.

1. Micro-structural changes are very rapid, when we do the cryogenics
2. Also it is environmental friendly process which will be useful for the any material which comes under very high condition.
3. Then hardness during the cryogenics machining on conversing on a raw material when we applied the hardness is increases but when we provide the hardness to the harden material at 950 and the water quench then there is decrease in the hardness so one should not be perform the deep cooling after the hardness process.

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