DESIGN AND THERMAL ANALYSIS OF SUB ZERO PROCESS

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ABSTRACT

The project relates to theoretical and practical thermal analysis of subzero process in D2 steel. It is a latest process which increase surface hardness, wear and corrosion resistance, anti-galling properties and improved fatigue strength and we had a comparison of D2 steel by these two process it shows the difference between subzero and without subzero process Sub zero process relates to a heat treatment method of steel for improving dimensional stability, wear resistance and mechanical properties. Steel is generally subjected to a quenching to improve its hardness. Due to the quenching, the structure of the steel is transformed from austenite into martensite, to be hardened in order to complete the transformation of retained austenite to martensite after hardening and earlier than tempering. Firstly steel is heated at certain temperature and suddenly it drops to cryogenic stage or freezing temperature then it changes the grain size and microstructure. It is mainly applied to high carbon, excessive alloy steels similar to tool steels but is extra-commonly utilized by using aerospace companies

It also deals with analytical solutions of unsteady transient heat convection problems. It improved on different parameters of temperatures variations and heat flux at different time period in certain boundary conditions

1.0 INTRODUCTION

Sub zero process relates to a heat treatment method of steel for improving dimensional stability, wear resistance and mechanical properties. Steel is generally subjected to a quenching to improve its hardness. Due to the quenching, the structure of the steel is transformed from austenite into martensite, to be hardened. It has also been known that the quenched steel having less retained austenite is more excellent in dimensional stability, mechanical properties and wear resistance (fatigue resistance). Hereinafter, the term "steel having excellent mechanical properties" means steel that is less broken and cracked. In order to further decrease the retained austenite, the quenched steel can be subsequently subjected to a tempering or sub-zero treatment. The tempering uses the nature of the retained austenite that it is easily transformed into martensite through a high temperature treatment. Accordingly, the retained austenite starts decreasing when the steel is heated to a satisfactorily high temperature due to the tempering. For example, in case of SKH51 steel according to Japanese Industrial Standard, the retained austenite starts decreasing when the steel temperature reaches 500 °C or higher.However, in case that the quenched steel is tempered at too high tempering temperature, there is a problem of lowering the steel hardness, thereby decreasing the wear resistance. Alternatively, the subzero treatment can be performed after the quenching as described above. In the subzero treatment, the quenched steel is rapidly cooled to a temperature of lower than 0 °C, also makes it possible to reduce the retained austenite in the steel, thereby giving an extremely enhanced hardness, wear resistance and dimensional stability (i.e., decreased age deformation) to the steel. As described above, the steel is conventionally subjected to the subzero treatment, which may be followed by the tempering, to decrease the retained austenite amount. However, the decrease is not sufficient for obtaining such a high performance steel that has excellent properties. Thus, steel having a further decreased amount of the retained austenite has been desired. In addition, the conventional method of the subzero treatment has a problem that the steel to be treated is likely to be broken or cracked during the treatment.

Heat Treatment

Cycles of heating process

In this heating process there are commonly 3 stages.

Heating

A form of energy associated with the movement of atoms and molecules in any material. The higher the temperature of a material, the faster the atoms are moving, and hence the greater the amount of energy present as *heat* Steel is heated to pre-determined temperature above top crucial temperature [austenitizing temperature].

Socking

Metallic is held in particular time to obtain homogeneous all through the move section.

Cooling

Cooling is the transfer of thermal energy via thermal radiation, heat conduction or convection of warmth treatment via which the structure and metallic from austenite shape is cooled to room temperature relies upon the homes required tiers the homes of steel can be modified.

2.0 LITERATURE SURVEY

D. Das, K. K. Ray, A. K. Dutta Their study examined the effect of the temperature of the treatment on the wear behavior of AISI D2 steel. Samples were subjected to conventional treatment (CONT), Cold Treatment (CT), Shallow Cryogenic Treatment (SCT) and Deep Cryogenic Processing (DCT) in separate batches. CONT consists of hardening and tempering; while in CT, SCT and DCT, an additional step of controlled sub-zero treatment with the lowest quenching temperature under 198, 148 and 77 K respectively, was incorporated into the curing and quenching treatments. Microstructural examinations were performed using optics and SEM. The hardness was measured by a Vickers hardness tester. They concluded that All types of sub-zero treatments appreciably improve the wear resistance of the die steels compared to the CONT ones. Improvement in wear resistance by SCT and DCT is significantly higher than that achieved by CT, and the maximum improvement is obtained by DCT. The obtained hardness of AISI D2 steel for CONT and DCT are 759 and 791 VHN, respectively and typical values of their specific wear rate are 1.03×10^{-6} and 8.26×10^{-9} mm3 N−1mm−1. The obtained results lead to the conclusion that lower the temperature of sub-zero treatment higher is the improvement in wear resistance.

A Joseph Vimal, A Bensely, D. Mohanlal They studied the behavior of Deep Cryogenic Treatment (DCT) on EN31 steel sample work piece used for bearing to improve its wear resistance. The austenitizing temperature in this study is 1039 K (819 °C) after that quenching was done at 40 °C and tempering at 140 °C. They observed wear resistance by pinon-disc test, microstructure by SEM and hardness test by VHN. They came to conclude that DCT gives rise to hardness with or without tempering. Also, the stated that wear resistance increases as hardness increases. It was observed that by cryogenic treatment, wear can be decreased by a maximum of 75% depending on the service conditions. A. Akhbarizadeh , A. Shafyei, M. A. Golozar They studied the effects of cryogenic treatment on the wear behavior of D6 tool steel. For this, two temperatures were used: -63 °C as SCT and -185 °C as DCT. The effects of cryogenic temperature (Shallow and Deep), cryogenic time and stabilization temperature on the wear behavior of D6 tool steel were studied. Hardness and wear test were carried out. Results showed that the cryogenic treatment increases hardness. The samples which were cryogenically treated for a longer time or deep cryogenically treated showed further increase in hardness. The Higher hardness of the shallow cryogenically treated samples was due to the decrease of the retained austenite. It was observed that the cryogenically treated samples have higher wear resistance compared with the conventionally heat-treated samples; this improvement was 5–11% in SCT and 39–68% in the DCT samples.

D Senthil Kumar, I Rajendran Effect of cryogenic treatment on the wear resistance property of En 19 steel was studied. Also, an analysis on the effect of DCT (-196 °C , 24 h), SCT (-80 °C, 5 h) and CHT was done by dry sliding wear test. Dry sliding wear test for low loading and high loading was observed. The microstructures of CHT, SCT and DCT samples were studied by SEM. They have concluded that both DCT and SCT promote the transformation of retained austenite to martensite, thereby causing a significant increase in wear resistance. Wear resistance was increased by 118.38% for SCT samples and 214.94% for DCT when compared to CHT samples. In addition, the increase in wear resistance of DCT samples is 44.39% with respect to SCT samples. The lowest coefficient of friction is obtained in DCT samples treated at - 196 °C for 24 hr V Firouzdor, E. Nejati, F. Khomamizadeh The effect of deep cryogenic treatment on wear resistance and tool life of M2 HSS drill was studied in their research work. The austenite temperature was 1100 °C and gas quenching was done in nitrogen gas and consequent tempering was done at 600 °C for 2h. Deep cryogenic treatment consisted of slowly cooling drills to approximately −196 °C and holding at this low-temperature for 24h and gradually bringing the specimens back to room temperature. They concluded that Cryogenic treatment profoundly improved the wear resistance of M2 HSS drills in the configuration of high-speed dry drilling of steels. Low-temperature tempering (200 °C) after cryogenic treatment was also found to be highly beneficial. It has been deduced that fine carbide precipitation during cryogenic treatment is the main reason for wear resistance improvement. Transformation of retained austenite to martensite could also contribute to wear resistance improvement, i.e. enhanced hardness value. Cryogenic treatment could not only facilitate the carbide formation and increase the carbide population in martensite matrix, but also make the carbide distribution more homogeneous.

Ilyas et al., effect of CT on the corrosion of AISI D3 Steel was studied. The alloy AISI D3 is a high carbon, high-chromium steel developed for various applications which require high resistance to wear, severe pressure and abrasion. Four types of uncoated AISI D3 steel used in the study were conventionally heat treated, 24 h cryogenically treated, 36 h cryogenically treated and 36 h cryogenically treated and then 2 h tempered at 150 °C. Due to a more uniform carbide distribution in association with a higher carbide percentage, the corrosion behavior of deep cryogenically treated samples had been enhanced, for the longer holding durations (e.g., 36 h), the corrosion resistance has been improved as a result of the increase in the carbide percentage by 3% and a more uniform carbide distribution. Cryogenic treatment causes the formation of martensite, which can improve the mechanical properties, but unfortunately can also reduce the good resistance to corrosion. In steels, martensite is more susceptible to corrosion than austenite.

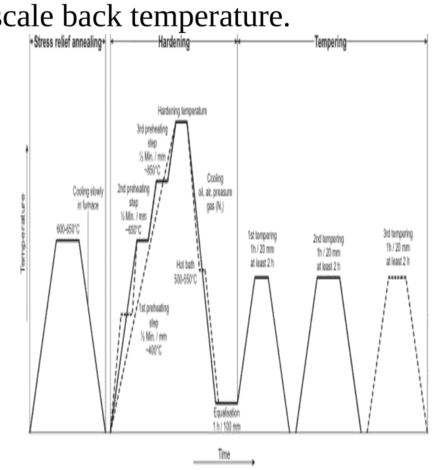
Arvind et al the, effect of CT on AISI-D2 Tool steel is studied. The samples were cryo treated at -196oc for 24 hours. After the CT it showed that the carbon bonding the carbon atoms are very closed to iron atoms thus they give strong Bonding characteristics to the steel, austenite phase is gradually reduced to martensite phase and the hardness is improved

3.0 SUB ZERO PROCESS

Subzero process is holding steel components at a temperature below zero degrees Centigrade to obtain the required structure. The temperature used is on the whole between -70ºC and -196ºC and the system is invariably adopted by using tempering.

Sub-zero healing is carried out in order to complete the transformation of retained austenite to martensite after hardening and earlier than tempering. It's mainly applied to high carbon, excessive alloy steels similar to tool steels but is extra-commonly utilized by using aerospace companies to assurance entire transformation.

Inthe early days of sub-zero treating, when huge, low-temperature fridges weren't on hand, the trouble used to be the way to get reproducible low temperature processing equipment. The reply used to be to add dry ice to a bath containing a compatible liquid equivalent to industrial alcohol or trichloroethylene. With sufficient dry ice, the temperature of the liquid might be maintained at a temperature of -78.5ºC. As a result, most necessities require a temperature between -70ºC and -80ºC. These days, with the in a position availability of liquid nitrogen' at -196ºC, many corporations have centered their sub-zero treating standards on that scale back temperature.



Subzero process

PURPOSE OF SUB-ZERO PROCESS

- Dissolved in the austenite. Moreover, it forms the potential for the secondary hardening of the ledeburitic steels during the tempering.
- To achieve the dimensional stability of the material.
- The offsetting and balancing of the internal stresses due to the metal history and its martensite formation.
- After the quenching, the steels contain martensite, retained austenite and un dissolved carbides. In some cases, also a certain steels are, due to their high wear resistance, hardness and compressive strength, used in variety of industrial operations. To ensure a sufficient service time of the tools, the materials have to withstand the compressive stresses, abrasive and/or adhesive wear, total tool collapse.
- To meet these demands, the materials must be subjected to proper heat treatment. Generally, the heat treatment of steels consists of the austenitizing, quenching and several times tempering. During the austenitizing, eutectoidal and a part of secondary carbides are portion of bainite was detected, but without a significant reduction of hardness. Subsequent tempering induces a transformation of retained austenite into the martensite both phenomena result in so-called secondary hardening effect.

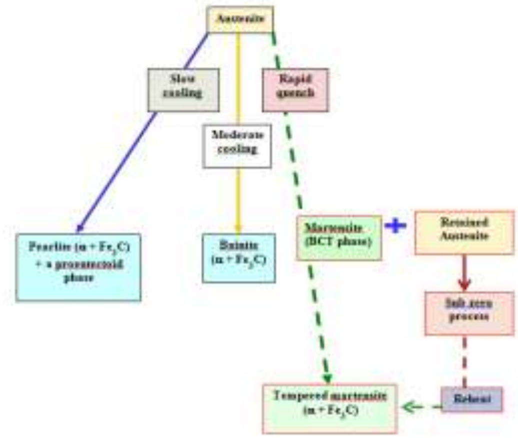
Furnace method

Dry Ice Method

SUBZERO PROCESS AND WITHOUT SUB ZERO PROCESS

CASE STUDIES ON SUBZERO

- The subzero process is carried out in HCHCR steel (High carbon high chromium steel material).
- The material is loaded into the hardening furnace in which the hardening process will takes place in four different temperatures with various soaking timings.
- Initially the material is heated to 650˚C and soaked for 60 min and raised the temperature to 850˚C with 45 min further it is heated to 1040˚C with the soaking time period of 30 min.
- The material is then quenched 60 min so that the austenite is converted into the martensite Now the material is loaded into the tempering furnace at 180˚ C for 240 min such that it results in the stress relieving in the material and some retain austenite is converted to martensite this process is called as first tempering
- The tempered material is then loaded in the sub-zero furnace which is maintained at -72˚C FOR 240 min so that the retained austenite is completely converted into the martensite and it results in the increase of hardness about 5-6 HRC.
- After the sub-zero process again we go for the sec tempering which is carried for 4hrs to 510C that makes the material to maintain its hardness and helps in reliving the stress.
- The third tempering is carried at 510C for increasing the life span of a material.



CHEMICAL COMPOSITION:

JYOTHI SPECTRO ANALYSIS

TEST REPORT FOR CHEMICAL TESTING

Work Order No: JSA/16/03558 Work Order Date:

Test Report No: C - 14598 Test Report Date:

Customer Name & Address: Sample Received Date:

LAKSHMI VACUUM HEAT TREATERS PVT LTD Tested Date:

Sample Stamped As:

Ref. No: Ref. Date:

Equipment Used: Sample Received As:

CHEMICAL ANALYSIS (%)

Specification: Test Procedure:

S.No	Material Identification		C	Si	Mn	P	S	Cr	Mo	V
1	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Specified Values:		Min:	1.4	0.1	0.1	-	-	11	0.7	0.5
		Max:	1.6	0.6	0.6	0.03	0.03	13	1.2	1.1

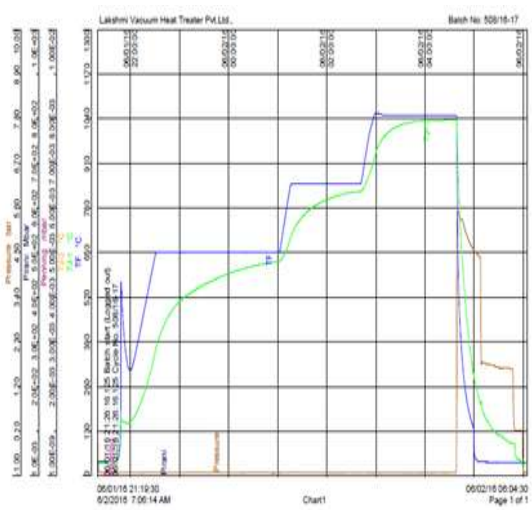
Result: The Elements Tested are within limits of the above specification.

Remarks:

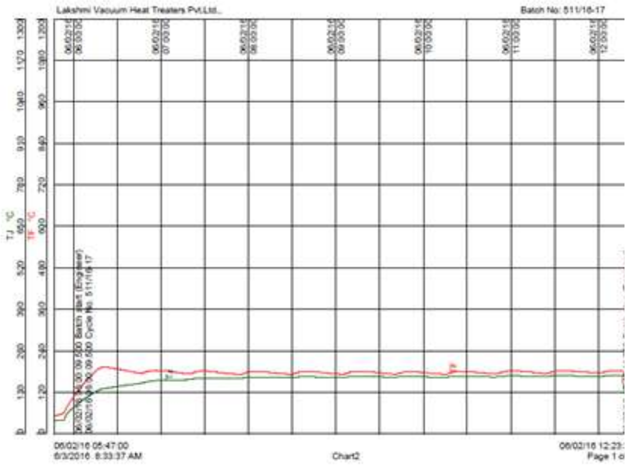
Verified By: Witnessed By: For JYOTHI SPECTRO ANALYSIS PVT LTD.

Authorised Signatory

HEAT TREATMENT GRAPH:



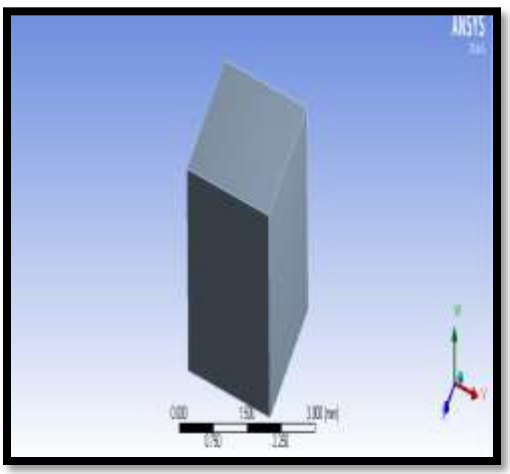
Heat treatment process graph



D2 Hardening process graph

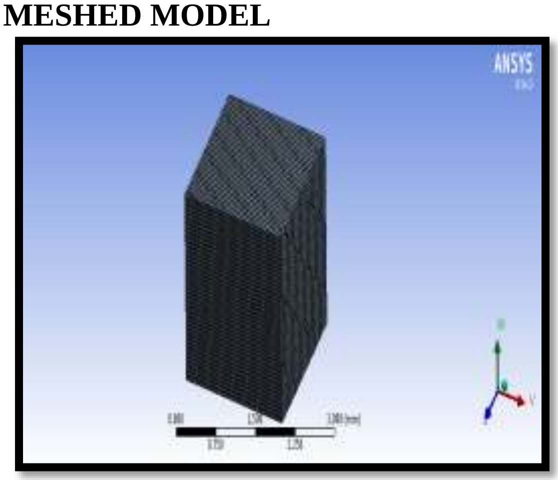
4.0 Material-En8 Steel

IMPORTED MODEL



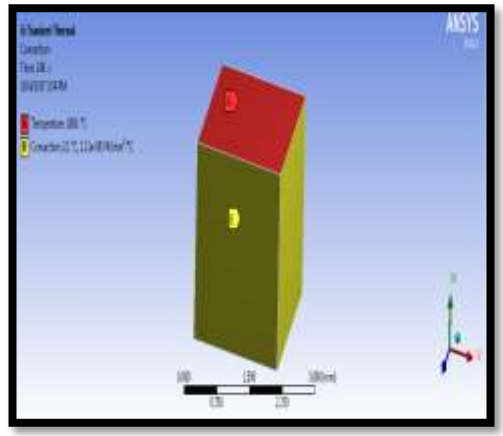
Imported Model of En8 Steel

MESHED MODEL



Meshed Model of En8 Material

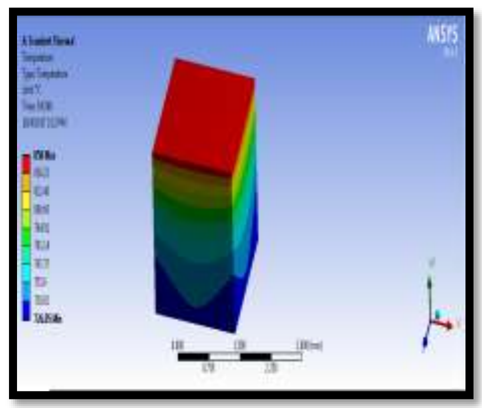
BOUNDARY CONDITIONS



Boundary Conditions

TIME 60 SECONDS

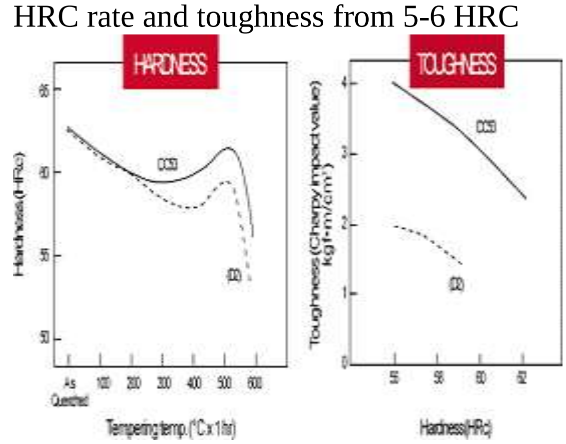
TEMPERATURE 850C



5.0 RESULTS AND DISCUSSIONS

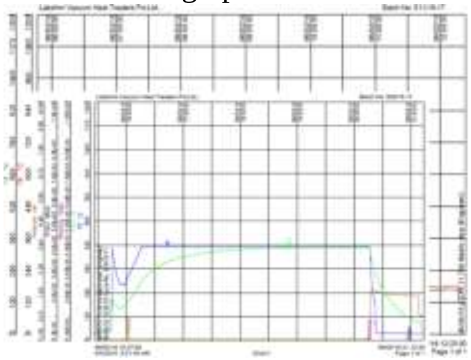
THEORETICAL ANALYSIS

In this we have taken D2 material and we had a comparison with material like En8 tool steel both the steels has good HRC(hardness) rate but by cryogenic(subzero process) it improved the HRC rate and toughness from 5-6 HRC



HDS material kept in the furnace for 9 hours at 1000 degree C by these it changes the material grain size and microstructure of D2 material.

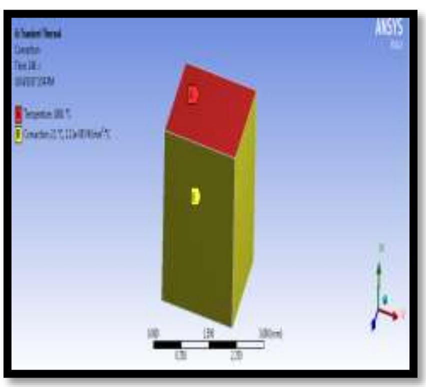
HDS Steel (D2) material is kept for 3 hours in the low pressure vacuum tempering furnace on 1st Tempering process and get the below results graph.



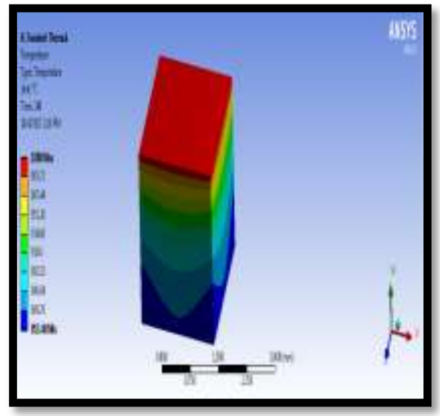
HDS Steel (D2) material is kept for 3 hours in the low pressure vacuum tempering furnace on 2nd Tempering process and get the below results graph.

ANSYS ANALYSIS

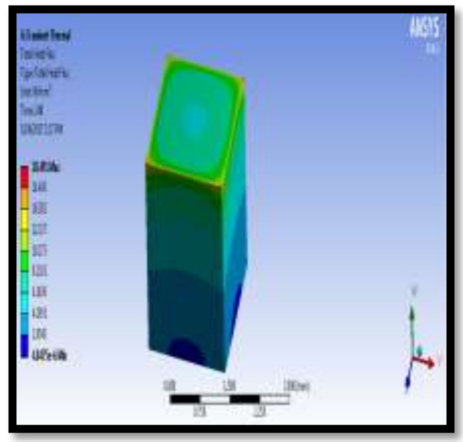
Based on thermal analysis heat distribution and heat flux at different temperatures i.e 1000, 850,-72 degree Celsius of both materials D2 and En8 boundary conditions also.



Boundary conditions



Temperature 1000 degree Celsius at 240 seconds



Heat flux at 240 seconds

The above figure shows that D2 material press tool die which can give more output then other materials and as well as increases the wear resistance, life span and decreases the stresses of the die material.

6.0 CONCLUSION

For this project on sub-zero we found ourselves very curious throughout the process. We felt we engaged really well with the subject. In this project on sub-zero we have learned about the total heat treatment based on surface and through hardening. Sub-zero is very interesting as it is done in the negative atmosphere. In this report starting with introduction process, selection of material and advantages over the other process are clearly explained. In this project we found more advantages of sub-zero by referring different research papers, text books, journals, chemical report and micro structure.

This study will definitely improves the material hardness, converts the retain austenite into martensite and will increases the life span of the material. Which will decreases the rejection cases of the material in different field regarding the different applications.

REFERENCES

- *Heat Transfer Text Book by Sachdeva*
- *P. Suchmann, J. Niznanska. (2015) "Deep cryogenic treatment of H11 hot working tool steel" Journal of Achievements in Materials and Manufacturing Engineering 73/1 21-26*
- *"Influence of Cryogenic Treatment on Microstructure and Properties Improvement of Die Steel". Journal of Materials Science and Chemical Engineering, 3, 37-46.*
- *S. Zhirafar, A.Rezaeian, M. Pugh. (2007) "Effect of cryogenic treatment on the mechanical properties of 4340 steel" Journal of Materials Processing Technology 186 298–303.*
- *R.H.Naravade, S.B.Belkar, R.R.Kharde. Effects of Cryogenic Treatment, Hardening and Multiple Tempering On Wear Behavior of D6 Tool Steel. The International Journal Of Engineering And Science*
- *AjitBehera, S. C. Mishra, "Comparative Study of Cryo -Treated Steel", international journal of scientific & technology research*