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INFLUENCE OF CRYOGENIC TREATMENT ON TOUGHNESS (CVN) AND HARDNESS OF HOT DIE STEEL (AISI-H11)

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Abstract: This study present the effect of cryogenic treatment on the AISI H11 steel. Cryogenic treatment performed at -154°C for 6, 21, and 36 hours. The toughness and hardness obtained after Cryogenic treatment have been evaluated along with its effect on microstructure. It was observed that ATC1 (21) T treated samples have 2.8% higher hardness than A3T samples while ATC1 (36) T have 7, 38 and 57% higher toughness than ATC1 (21), ATC1 (6) T, and A3T respectively.

Keywords: Hot die steel, Cryogenics treatment, Carbides, Retained austenite

1. INTRODUCTION

Heat treatment of hot die steel carried out to enhance its mechanical properties and refine its morphology of microstructure. AISI H11 is chromium base hot die steel which is commonly used in the industries for tools and dies. This grade faces strong challenges such as wear resistance along-with toughness [1-2]. Nowadays deep cryogenic treatment is applied on to tools and dies to enhance the materials mechanical properties, and this treatment exhibits the encouraging effects on various tools and die materials. Cryogenic treatment affects the bulk properties as well as surface properties of the materials and hence its effects are permanent [1]. Many investigators have reported the importance of cryogenic treatment on the modification of the morphology of microstructure, mechanical property and homogeneity of crystal structure of materials [1, 3-4]. Cryogenic treatment improves the micro hardness value, increase the number of secondary carbides and improves dry sliding wear behaviour in comparison to vacuum treated samples of hot die steel grade AISI H13 [5].Modification of microstructure and improvement in the mechanical properties of AISI H13 hot die steel has been reported by the cryogenic treatment [6].The aim of present experimental work is to study the effect of cryogenic treatment on the hardness, toughness and microstructure of Hot Die Steel AISI-H11.

2. EXPERIMENTAL DETAIL

2.1. Materials

Annealed AISI- H11; chosen for the investigation. The chemical composition of selected ascertain with optical spark emission Spectrometer following ASTM E 415-2014 standards [7]. The chemical composition as follows (wt.%): 0.37, C; 0.91, Si; 0.31, Mn; 5.32, Cr; 1.31, Mo; 0.34, V; 0.014, P; 0.007 S; balance –Fe. Material chemical composition conforms to HDS AISI- H11.

2.2. Sample preparation

Rectangular specimens of dimensions 10 ×10 × 55mm were machined from steel for Charpy impact testing as per ASTM E23-07 [8]. Sample surface roughness and V-notch dimension were kept precisely as per standard E23 and verified using Surface Roughness tester, (Model:SJ201P), Profile Projector and V-notch template. Hardness and metallographic study were also performed on the same samples.

2.3. Treatment

Specimens were vacuum heat treated electrical heated vacuum furnace, vacuum maintained at the level of 10^{-2} mbar and hardening temperature: 1040°C, with hold time at austenization temperature was 30minutes. Quenching of specimens after hardening was done with Nitrogen gas at a pressure of 5bar. Than samples were divided in two groups namely A3T: vacuum heat treated and three times tempered for 2 hours, C1: vacuum heat treated plus cryogenic treated at -154°C for varied soak time 6, 21, and 36 hours and tempered for 2hours. A3T group samples of HDS H11 were tempered at 550, 570 and 600°C respectively for 2 hours, coded as A3T, C1group samples were deep cryogenic treated at -154 for varied soak time 6, 21and 36 hours with post tempering at 600°C temperature. Table 1 provides the details of sample treatment conditions.

Table 1
Heat Treatment Sequence Followed For HDS H11

Nomenclature	*Depiction of treatment*
A 3T	VFA = 1040° C, ST = 30 Minute, Nitrogen gas quench, quench pressure = 5bar, Three T = 550°C, 570°C, 600°C respectively for 2 hours .
A T C1(6)T	VFA = 1040°C, ST = 30 Minute, Nitrogen gas quench, Quench pressure = 5bar, T = 550°C for 2 hours, C1, ST = 6 hours, T = 600°C for 2 hours.
AT C1(21)T	VFA = 1040°C, ST = 30 Minute, Nitrogen gas quench, Quench pressure = 5bar, T = 550°C for 2 hours, C1, ST = 21 hours, T = 600°C for 2 hours.
AT C1(36)T	VFA = 1040°C, ST = 30 Minute, Nitrogen gas quench, Quench pressure = 5bar, T=550°C for 2 hours, C1, ST = 36 hours, T= 600°C for 2 hours.

Number in parentheses shows the soaking times in hours at cryogenic temperature.

2.4. Micro hardness

The apparent hardness of specimens determined with the Micro Vicker hardness tester, model: MVK-H2, by following ASTM standards E384-08a [9]. Indentation load applied in hardness test was 1000gf (9.8N) with dwell time of 15 second. Five hardness readings were taken at different points to estimate the average value of hardness for each sample.

2.5. Toughness

Toughness of specimens was evaluated with the Charpy V-notch impact test and was performed on calibrated Impact test machine, least count: 2J, as per ASTM standards designation E23-07a [8] at ambient conditions temperature: 24.5°C and relative humidity RH 54%. The value of Charpy impact strength was measured using three Charpy impact tests for conventional and varied cryogenic treatment samples.

2.6. Microstructure

To prepare micro structural analysis samples ASTM standard, E3-01(Reapproved 2007) followed [10]. Micro etching of polished specimens was done with 3% Nital solution and dried in hot air. Micro structural features of both group samples were studied under the field emission scanning electron microscope model: Quanta FEG450.

3. RESULT AND DISCUSSION

3.1. Hardness

The Micro hardness value obtained for the A3T and C1 group samples as a function of treatment condition given in table 2. ATC1(21)T treated sample have significantly higher micro- hardness, which is around 2.8% higher than the A3T sample and also highest in the C1. The apparent hardness value for treatment C1 increases up to 21 hour soaking time and then shows decrease in micro-hardness with further increase in soaks time at DCT i.e. 36 hours soaking.

Table 2
Micro-hardness of Conventionally and Varied Cryogenic Treated Samples

Treatment Condition	*Mean Micro-hardness (HV_1)*	*SE of Mean*
A3T	446	1.974
ATC1(6)T	456.2	1.280
ATC1(21)T	458.6	2.4
ATC1(36)T	436	2

Koneshlou et al. [6], Das et al. [11], Gill et al. [12], and Amini et al. [13] concluded that increase in the micro-hardness is due to the elimination of retained austenite, more homogeneous carbide distribution and higher degree of carbide distribution. Amini et al. [13] also showed the

decrease in hardness of 80CrMo12 5 cold work tool steel and predicted that 48 hours holding time is optimum to have best hardness value in this tool steel grade.

3.2. Toughness

Toughness (CVN) for A3T and cryogenically treated sample of AISI H-11 are shown in Table 3 which depicts the results of mean value of three samples for each treatment group along-with standard error of mean.

Table 3
Toughness of Conventionally and Varied Cryogenic Treated Samples of HDS AISI H11

Treatment Condition	*Mean Charpy Impact strength (J)*	*SE of Mean*
A3T	18.6	0.66
ATC1(6)T	27.3	0.66
ATC1(21)T	21.3	0.66
ATC1(36)T	29.3	1.33

ATC1 (36) T treated samples have significantly higher toughness, which is around 57% higher than the A3T sample and also highest in the C1 sample. Enhancement in toughness observed in case of ATC1 (36) T is around 7 and 38% higher than the other DCT samples viz. ATC1 (6) T and ATC1 (36) T respectively. Cryogenically treated sample shows the remarkable improvement in the toughness over the A3T sample and enhancement is approximately 46, 14 and 32% for the treatment group viz. ATC1 (6) T, ATC1 (21) T and ATC2 (36) T respectively. This result is in line with earlier findings of Li et al. [14] that shows DCT treated cold work tool steel Cr8Mo2SiV have the higher toughness due to the modification of microstructure with DCT.

3.3. Microstructure

Cryogenic treated FESEM microstructure images of C1 and A3T group sample shown in Fig. 1 and Fig. 2. Cryogenic treated FESEM Micrograph shown in Fig. 1 indicates more density and even distribution of precipitated secondary carbides in comparison to A3T sample as shown in Fig.1 Number of secondary carbides increases after the cryogenic treatment and morphology of secondary carbide in A3T and C1 group samples are noticeably different. Results of this study are in concurrence with previous studies [1, 3, 4, 12-14],

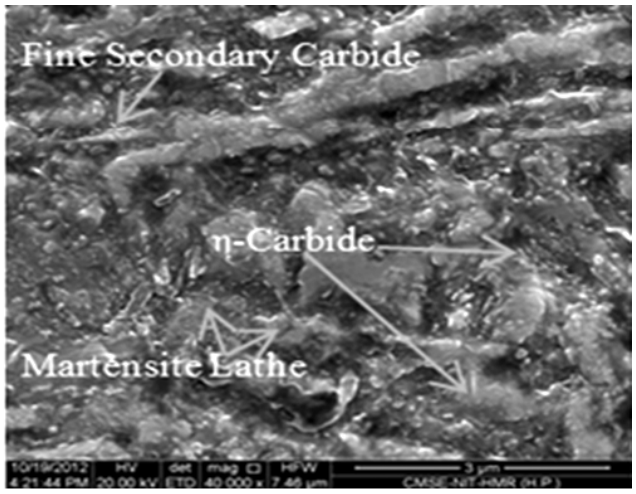

Figure 1: FESEM Image of Cryogenic treated (C1) sample

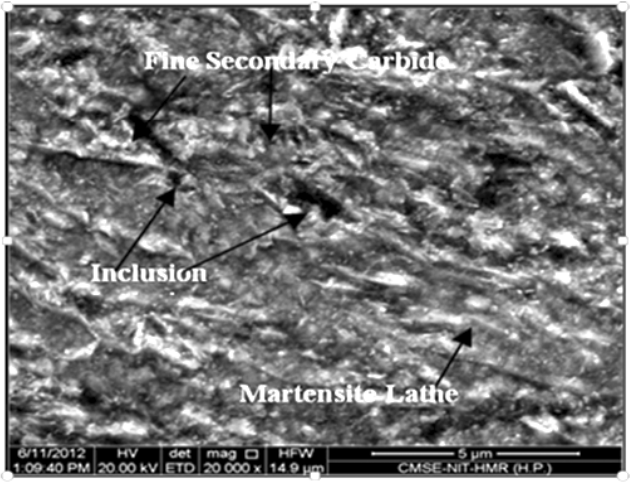

Figure 2: FESEM Image of A3T sample

that reported the enhancement of number of secondary carbides, which is responsible for the strengthening of matrix and load bearing capacity of tools and dies.

4. CONCLUSIONS

The major conclusions of this research study are:

- Micro Vickers hardness of cryogenically treated samples increases up to 21 hour soak time and then decreases with further increase in duration of soaks time at cryogenic treatment.
- Toughness increases in DCT with longer soak time. There is 57% higher Toughness (CVN) in case of ATC1 (36) T sample than the A3T sample and is also highest in the C1 group sample.

- 21 hours soaking times at DCT (-154°C), enhances the number of carbides precipitations and formation of very fine needle type carbides.

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