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Cryo-Treated Blanking Punch Life Improvement Analysis

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ABSTRACT

Cryogenic treatment is a secondary process to traditional heat treatment used for improving the hardness and wear resistance of tool steels. Though the potential use of cryogenic treatment on AISI D2 tool steel under laboratory conditions has been well established by the researchers, it is essential to do the analysis to ensure its sustainable use for industrial application. Therefore, impact of cryogenic treatment on AISI D2 steel blanking punch was evaluated in terms of increase in production rate and its life. The cryogenically treated D2 tool steel punches were used and subjected to manufacture the control levers using blanking operations. The improved wear resistance of cryogenically treated punch resulted in increase in production and punch life more than 200%. Punch life was studied and correlated to increase in production & wear behavior of blanking punch. The AISI D2 steel samples were prepared and subjected to laboratory tests comprising of metallographic observations and hardness. It was found that laboratory tests were not enough to predict improvements in mechanical properties. The mechanism responsible for augmented wear resistance by cryogenic treatment was the conversion of retained austenite to martensite and precipitation of new secondary carbides.

Keywords— Cryogenic, Blanking Process, Punch Life, D2 Tool Steel

I. INTRODUCTION

With increase in industrial development and technological advancement metal forming process has a great importance in sheet-metal industry to manufacture precise shaped components in various applications. In sheet metal forming process, the blanking is the one of the most commonly used process because of its reliability & uniqueness. It is generally used for large scale production & has the ability to produce the components of required shape & size at cheaper price.

The blanking process produces the components by shearing the metallic sheet varying the thickness from 0.15 to 25 mm by means of mechanical / hydraulic presses as per requirement of the component. The versatility of the process is that it can be used for producing the variety of components used in engineering applications such as automobile parts & general machine and supporting components of electrical / electronic equipments / instruments.

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Subramonian S.[1], Hao –huai Liu et al [2] studied the effect of deep cryo treatment on the microstructure, hardness and abrasive resistance of high chromium cast iron . It was observed that after subcritical treatment there was increase in hardness as well as abrasive resistance. The reason behind this was conversion of large amount of retained austenite into martensite and precipitation of secondary carbides.

Kalsi et al [3] studied the fatigue behavior due to fluctuating stresses and thermal loads during the service life. Cryo treatment prevents the dislocation of martensite at higher fatigue loads & results in increased tool life. Bensely et al [4] also studied and mentioned that the cold treatment of steel increases the fatigue life by 71 % where as the deep cryo treatment decreases it by 26 %.

Rhyim et al. [5] and Wierszyłłowski et al. [6] mentioned that compared to conventional heat treatment the deep cryo treatment increases the hardness but reduces impact toughness of AISI D2 steel.

Akhbarizadeh et. al. [7] studied on D6 tool steel shows that the cryogenic treatment increases the hardness as well as wear resistance and deep cryogenic treatment (DCT) further increase hardness.

R. Mahmudi and co-workers [8] conducted a study on the effect of cryogenic treatment on the mechanical properties and wear behaviour of M2 tool steel. It was found that during the cryo treatment hardness and wear resistance has been improved as the retained austenite get transformed into martensite along with the precipitation of eta carbides.

Lower the cryo temperature, more will be the conversion of austenite to martensite & thereby more will be induced compressive stress. This compressive stress is responsible for wear and fatigue. These things were

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mentioned in earlier research related to wear resistance of cryo treated En 353 steel by Bensely A. et al [9]

Many researchers have already pinpointed that cryogenic treatment is useful for increasing the wear resistance of tool steels. [10,11,12,13,14,15]. However the actual mechanism causing increase in hardness as well as wear resistance in cryogenic treatment is not yet understood.

The researchers [10, 11] has reported that the increase in wear resistance was because of conversion of retained austenite to martensite. However, it is generalized phenomena applicable to cold treatment as well as cryogenic treatment. Hence, it cannot be claimed that the main reason for increase in wear resistance is reduction of retained austenite [10, 11, 12].

Mohan lal et al [13] reported that cold treatment of T1, M2 and D3 steels increases the wear resistance compared to traditional heat treatment from 108 % as mentioned by Collins and Dormer [11] to 817 % as reported by Barron [10].

Wilson [23] reported that cryo treated slitter knives in paper mills increases the lifetime by more than 500%. The improvement in wear life is due to complete transformation of the retained austenite to martensite at cryogenic temperatures; the amount of retained austenite in typical steel is reduced by a factor of three by the cryogenic treatment. This leads to a small increase in the size of the component, and enhanced stability of the component.

Mohan Lal et. Al. [13] studied the effect of different cryogenic process parameters on the enhancement of wear resistance & its importance in D3, M2 and T1 tool & die steel under different situations. At the end of the study it was observed that the cryo process improves the tool life approximately by 110 %. It has been mentioned that the deep cryo treatment shows highest increase in wear resistance because of fine distributed and precipitated carbide particles.

J. Y. Huang et al [21] presented the microstructure variations observed by conducting the study before and after the cryo treatment by soaking the samples for 1 week in liquid nitrogen. The result shows that the cryo treatment helps in forming the carbon cluster by increasing the carbon density in the next treatment, and thereby increasing the wear resistance of steels.

During Blanking process, as the punch moves in the die deforms the sheet metal plastically until a crack is initiated on both sides of the work piece. As the punch moves further in die makes the crack to propagate and leads to final rupture. Therefore the blanking process is a shearing operation with plastic deformation and ductile failure of the component. Since the punch moves in and out of die continuously it is a cyclic process imparting the dynamic loads on punching tools during operation & thereby affects the lifetime of the punch Pleterski et al., [24].

Further to improve the efficiency of blanking operation it is necessary to keep in control the punch and die wear. Most of the times the punch wear before the die wear. Comparing all these technologies, cryo treatment is more suitable & easy to implement as a additional step after traditional hardening and tempering process.

The mechanical and metallurgical behavior of AISI D2 tool steel under cryo treatment has been studied by various researchers and is well published in many journal. Das et al [16], has conducted various laboratory test to study the effect of deep & shallow cryo treatment on wear behavior of AISI D2 tool steel at various cryo temperature and soaking period & observed increase in wear behavior. It has been further investigated that this enhancement in wear characteristics is due to increase in refined secondary carbide volume fraction and its uniform distribution.

Collins & Dormer [11] observed that there is reduction in toughness of AISI D2 tool steel by approximately 40% as retained austenite get transformed into martensite.

Pleterski et al [24] has mentioned that the most of the researchers has carried their research work related to cryo treatment of AISI D2 tool steel in some or other laboratories. However, the metallurgical behavior of shearing/wearing during sheet metal forming process is totally different during industrial applications.

Hence, it becomes very important to investigate the impact of cryogenic treatment on AISI D2 steel in real manufacturing setup. Also, to make the process of cryogenic treatment a practically feasible option, economic analysis is required to be done in terms of production cost and output. In view of this, the present research work has been planned and executed. The actual shop floor testing of AISI D2 steel blanking punch and analyzing its tool life, productivity and cost saving was conducted at M/s Shree Saigan Industries, MIDC Waluj, Aurangabad.

II. METHODOLOGY

2.a. Material Data

The laboratory test piece samples & the blanking punch used for field test were prepared using AISI D2 tool steel.

Based on previous research hardening and tempering cycle was selected so that the hardness of blanking punch will be achieved in the range of 52 to 65 HRC to maintain the required balance between wear resistance and toughness.

For achieving the required hardness of 52 to 65 HRC one set of test specimens and punch block of

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AISI D 2 tool steel of 150 H X 110 W X 55 T size were heat treated as per hardening and tempering cycle as shown in the fig.1.

The test samples & punch material were austenitized at 970 ^{o} C for half an hour, then quenched at 540 ^{o} C in a oil bath for 15 minutes and then air cooled to room temperature. The tempering was carried out at 250 ^{o} C for 2 hours in the furnace.

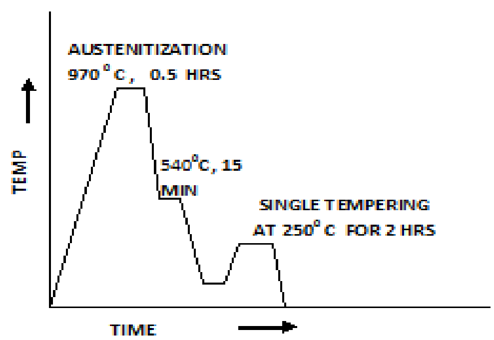

Fig. 1. Traditional HT Process

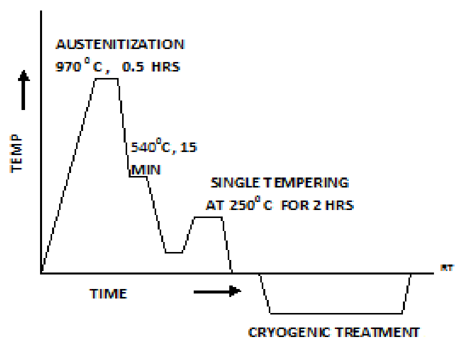

Fig. 2. Modified HT & CT Process

2.b. Cryo Treatment

Another set of test samples and punch material of AISI D 2 tool steel were heat treated as per selected traditional HT process as discussed above and immediately after reaching to room temperature dipped into cryo chamber for cryo treatment at -185 ^{0} C for 36 hours as per heat treatment and cro treatment cycle shown in the fig. 2.

All the test samples and punch block placed in cryo chamber were not directly cooled to -185 ^{0} C, however its temperature has been gradually reduced with an average cooling and heating rate of 0.5 ^{0} C /min to avoid thermal shocks of rapid cooling. The effective cooling has been achieved by using computer controlled cryo chamber as shown in the fig. 3. After 36 hours the test samples and punch blocks were heated slowly from -185 ^{0}C to room temperature within 24 hours to avoid thermal shocks by computerized controlled heating system.

After cryo treatment once the test samples and punch material were heated to room temperature, they were kept in a furnace for single tempering at 200 ^{0} C for 2 hours to relieve the thermal stresses induced during cryo treatment.

Fig. 3. Cryogenic treatment set up

2.c. Metallographic Characterization

In order to conduct the metallographic observations two sets of test piece samples of L 10 X W 10 X 2 mm thick were cut on wire electro discharge machine. One set of traditional heat treated and other set of cryo treated. The test piece samples were placed in Bakelite mould using specimen mounting press. The samples were polished using emery paper of grade 80, 120, 200, 600, 800, 1000, further polishing with diamond paste on rotating linen disc and finally polished on velvet cloth in the presence of white kerosene as liquid medium. The test samples were etched using 2 % nital solution (Nitric acid and ethanol) and kept in open air for drying. The etched samples were examined using SEM. The microstructure shows carbide particles in a matrix of tempered martensite. The carbide particles were identified as primary carbides, small secondary carbides and large secondary carbides presented in Das et al [16]. XRD Analysis was done using X-ray Diffractometer. The ASTM standard E 975-00 was used to measure volume fraction of retained austenite considering the diffraction peaks.

The microstructures of HT & HT CRT test piece samples exhibits carbide particles in a matrix of tempered martensite. The carbide particles have been classified as primary (coarse) and secondary carbides (fine). The secondary carbides can be distinguished from primary carbides as they are approximately round shape compared as compared to dendrite shape of primary carbides

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As seen from the fig. 5 a , the number of secondary carbides observed are more in number, smaller in size, and round in shape in case of hardened and single tempered test piece as compared with other sample. At the same time in case of HTCRT sample fig. 5 b, shows predominant presence of small scale secondary carbides more in number with specific pattern.

Table 1: Measured Hardness for hardened & single tempered (HT) & hardened- tempered –cryo - tempered (HTCRT) test samples **:-**

SR, NO	HT test piece HRC	HTCRT test piece HRC	% Increase
01	54	62	
02	55	62	
03	54	62	
04	55	62	13 %
05	53	63	
06	54	62	
Avg.	54.1= 54	62.16= 62	

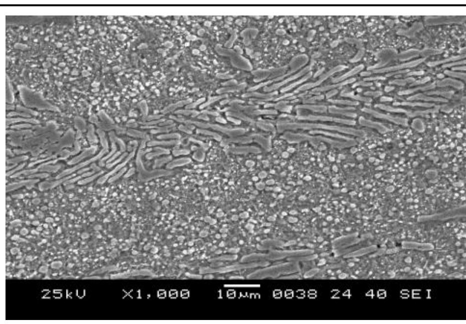

Fig. 5 a. SPECIMAN-(H-T)

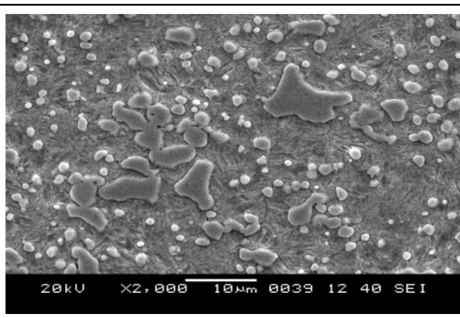

Fig. 5 b. SPECIMAN-(H-T-CR-T)

2.d. Hardness Measurement

Though, the hardness measurement is not directly reflecting performance, it relates to strength, wear resistance and other mechanical properties. Hence, hardness of both the type of test specimens were measured using digital Rockwell C hardness tester. Initially, for setting the specimen the minor load of 98 N was applied then the major load of 1470 N applied for HRC scale for 30 seconds. The readings were taken at five different locations evenly scattered diagonally for each specimen so that average reading can be obtained. The hardness values measured are tabulated in the table 1

III. SHOP FLOOR TESTING

The component selected for shop floor test was control lever having material specification as Hot rolled steel sheet as per IS: 1079-1994 Grade D, with 4 mm thickness (Fig. 7). It was manufactured by blanking operation. Then Surface treatment of Carburizing, Hardening & Tempering with the

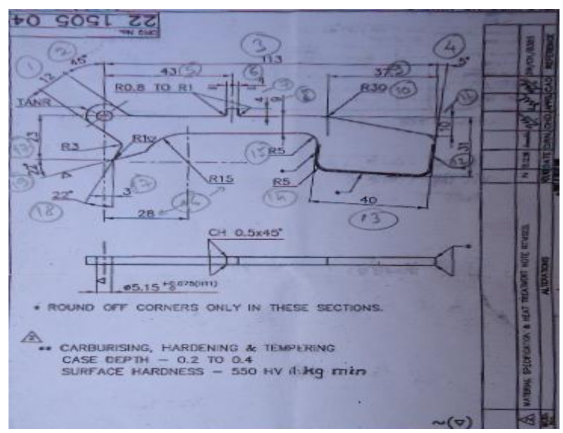

Fig. 7. Control lever

specimens. This increase in hardness indicates that there is a complete conversion of retained austenite to martensite and evolves uniformly distributed fine carbides. Further, it is observed that the hardness values obtained along the diagonal length of test piece samples are nearly same. It means that the microstructural changes occurred due to cryo treatment are same throughout the material.

In order find out the life of both the punches HT & HTCRT shop floor test were conducted in actual industrial environment. This test was conducted by manufacturing control lever on same blanking press to avoid machine related defects if any. The blanked control levers were separated after every 1000 strokes and its dimensional accuracy was measured on CMM. The HT punch manufacture 50,000 components with

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required dimensional accuracy before first regrinding. Confirming 50,000 strokes as the life of traditionally heat treated punch. Whereas, the HTCRT punch manufactures 3,00,000 components with accurate dimensions before first grinding of punch. Thereby, confirming the life of cryo treated punch as 3,00,000 strokes.

Thus, it is clear that sufficient punch wear has been occurred till manufacturing 50,000 components and hence, useable cutting life of HT punch is 50,000 components. Whereas in case of HT CR T punch, due to wear during manufacturing, the dimensional accuracy can be obtained till 3,00,000 components, So useable life of HTCRT punch is 3,00,000 components.

IV. CONCLUSIONS

Based on the present study the important inferences / conclusions drawn are:-

1. The cryo treatment of AISI D2 tool steel decreases the % volume of retained austenite & activate the precipitation and uniform distribution of secondary fine carbides in whole of the cross section of the material.
2. The hardness and wear resistance of AISI D2 steel punch increases drastically by cryo treatment as compared to that of traditionally treated punch which ultimately results in increasing the tool life by 5 times.
3. The cryo treatment is having very bright future in blanking as well as in punching operations. It can be further anticipated that the blanking as well as punching industry will include cryo treatment of AISI D2 tool steel as an additional heat treatment process after traditional heating process.

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