

Service Life Improvement Analysis of Cryogenically Treated Blanking Punch

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Abstract

After traditional heat treatment, Cryogenic treatment is carried out as a secondary process to improve the hardness and wear resistance of tool steels. The researchers have already studied and it is well published the potential use of cryogenic treatment of AISI D2 tool steel under laboratory conditions. However, to ensure the sustainable use of this technology for industrial application, its analysis is essential. Therefore, in this work a small scale manufacturing unit having press shop was identified and impact of cryogenic treatment on AISI D2 steel blanking punch was evaluated in terms of tool life and part quality. The improved hardness and wear resistance of cryogenically treated punch resulted in approximately 60% production rise. Punch life was studied and correlated to part quality in term of dimensional accuracy of blanking punch. The AISI D2 steel samples were also prepared and subjected to laboratory tests comprising of metallographic observations and hardness. It was found that laboratory tests were not sufficient to predict improvements in service life of punch. The dimensional accuracy plays an important role in deciding the service life.

Keywords: Cryogenic, Blanking Process, Wear, Hardness, Punch life, D2 tool steel.

INTRODUCTION

With increase in industrial development and technological advancement Metal forming technique has a great importance in manufacturing precise shaped components for various applications. In sheet metal forming process, the blanking is the one of the most commonly used process because of its reliability and uniqueness. It is generally used for large scale production and has the ability to produce the components of required shape and size at cheaper price. [1, 2] studied the effect of deep cryo treatment on the microstructure, hardness and abrasive resistance of high chromium cast iron. It is observed that after subcritical treatment there is increase in hardness as well as abrasive resistance. The reason behind this is conversion of large amount of retained austenite into martensite and precipitation of secondary carbides [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 and results in increased tool life [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%. [5, 6] have mentioned that compared to conventional heat treatment the deep cryo treatment increases the hardness but reduces impact toughness of AISI D2 steel [7].

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Study on D6 tool steel shows that the cryogenic treatment increases the hardness as well as wear resistance. Whereas longer time or deep cryogenic treatment (DCT) further increase hardness [8, 9] conducted a study on the effect of cryogenic treatment on the mechanical properties and wear behaviour of M2 tool steel. It is found that during the cryo treatment hardness and wear resistance has been improved as the retained austenite is transformed into martensite along with the

precipitation of eta carbides; Lower the cryo temperature, more will be the conversion of austenite to martensite and thereby more will be induced compressive stress. This compressive stress is responsible for wear and fatigue. These things were mentioned in earlier research related to wear resistance of cryo treated En 353 steel the researchers [10–12, 16, 17] has reported that the increase in wear resistance is because of conversion of retained austenite to martensite. However it is generalized phenomena applicable to cold treatment as well as cryogenic treatment. However the actual mechanism causing increase in hardness as well as wear resistance in cryogenic treatment is not yet understood.

Many other researchers [13–15, 18, and 20] mentioned that the main reason for the increase in wear resistance by cryogenic treatment is the modification of secondary carbides. However, it needs to be supported experimentally.[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].

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 and thereby affects the lifetime of the punch [19].

Therefore, main criteria considered for large scale production for increasing the productivity of blanking process is to improve the punch and die life. The increased punch and die life reduces the idle time in terms of reduced tool changeover or sharpening time, die-punch alignment time. [1, 16], has conducted various laboratory test to study the effect of deep and shallow cryo treatment on wear behavior of AISI D2 tool steel at various cryo temperature and soaking period and observed increase in wear behavior. It has been further investigated that the enhancement in wear characteristics is due to increase in refined secondary carbide volume fraction and its uniform distribution [10], published that AISI D2 steel shows increase in wear resistance by 8.2 times as compared to its traditional treatment.[11] observed that there is reduction in toughness of AISI D2 tool steel by approximately 40% as retained austenite get transformed into martensite.

Hence, it becomes very important to investigate the impact of cryogenic treatment on AISI D2 steel in real manufacturing setup. 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, part quality was conducted at MIDC Waluj, Aurangabad.

MATERIALS AND METHODS

Material Data

The laboratory test piece samples and the blanking punch used for field test were prepared using AISI D2 tool steel. Based on previous research austenizing 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 balanced between wear resistance and toughness. For achieving the required hardness of 52 to 65 HRC one set of test specimens and punch block of AISI D 2 tool steel of 150 H × 110 W × 55 T size were heat treated as per hardening and tempering cycle as shown in the Figure 1.

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

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 (Figure 2). It was manufactured by blanking operation. Then Surface treatment of Carburizing, Hardening and Tempering with the Case Depth of 0.2–0.4 mm was carried out to obtain the Surface Hardness 550 HV AT 1 Kg min/ 48–50 HRC.

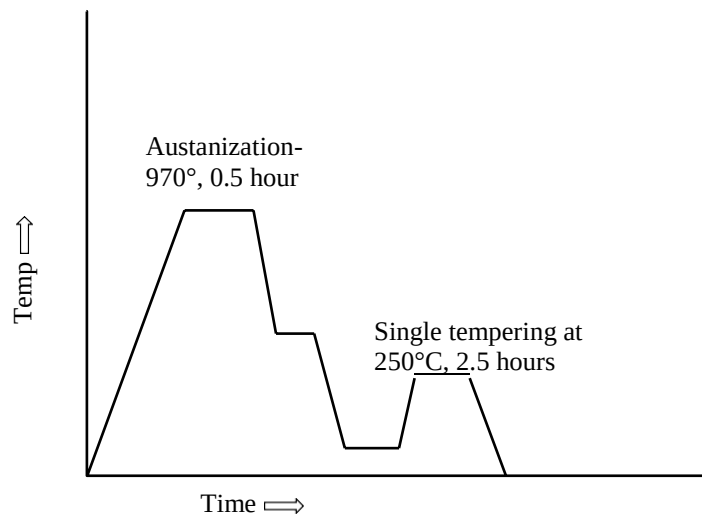


Figure 1. Traditional Heat Treatment Process employed

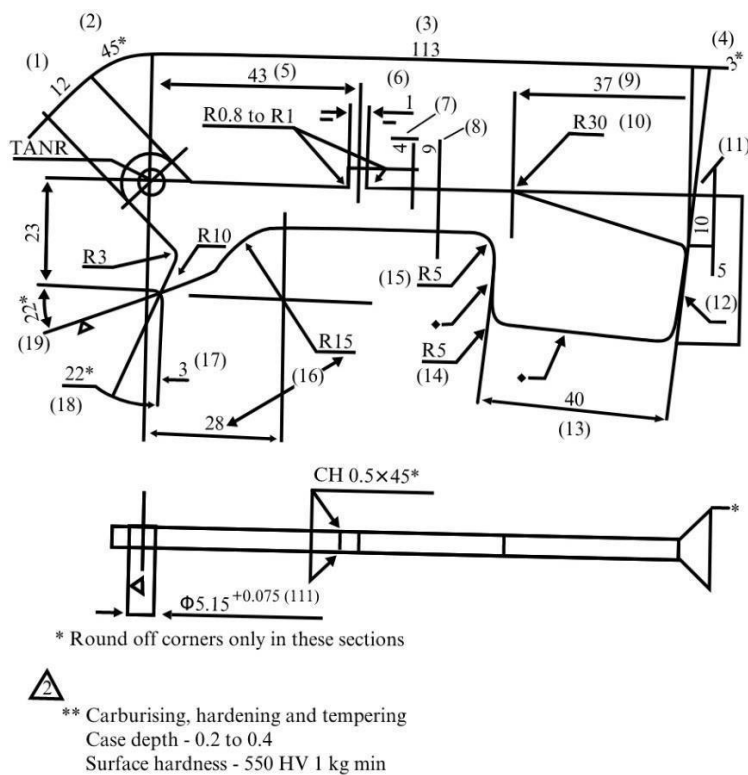


Figure 2. Schematic diagram and dimension of the control lever

Cryo treatment

Another set of test samples and punch material was heat treated as per selected traditional HT process discussed in 2.1 and immediately after reaching to room temperature dipped into cryo chamber for cryo treatment at -185°C for 36 hours as per heat treatment and cryo treatment cycle shown in the Figure 3. The effective cooling has been achieved by using computer controlled cryo chamber as shown in the Figure 4. After 36 hours the test samples and punch blocks were heated up slowly from -185°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 up to room temperature, they were kept in to furnace for single tempering at 200°C for 2 hours to relieve the thermal stresses induced during cryo treatment.

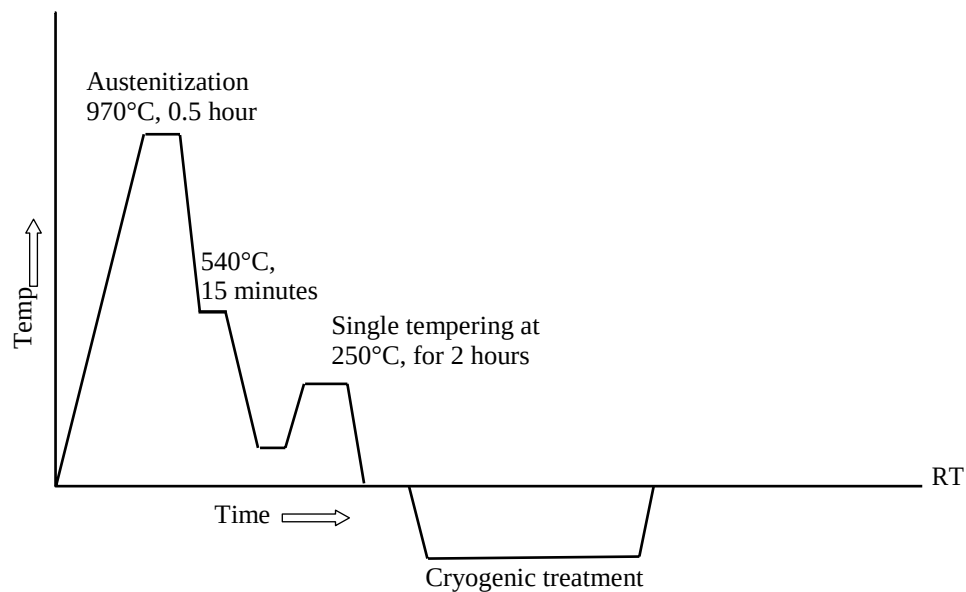


Figure 3. Modified HT and CT Process.



Figure 4. Set up for cryogenic treatment.

Metallographic Characterization

The microstructures of HT and HT CR T test piece samples exhibits carbide particles in a matrix of tampered 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, As seen from the Figure 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 Figure 5(b), shows predominant presence of small scale secondary carbides are more in number and followed a specific pattern.

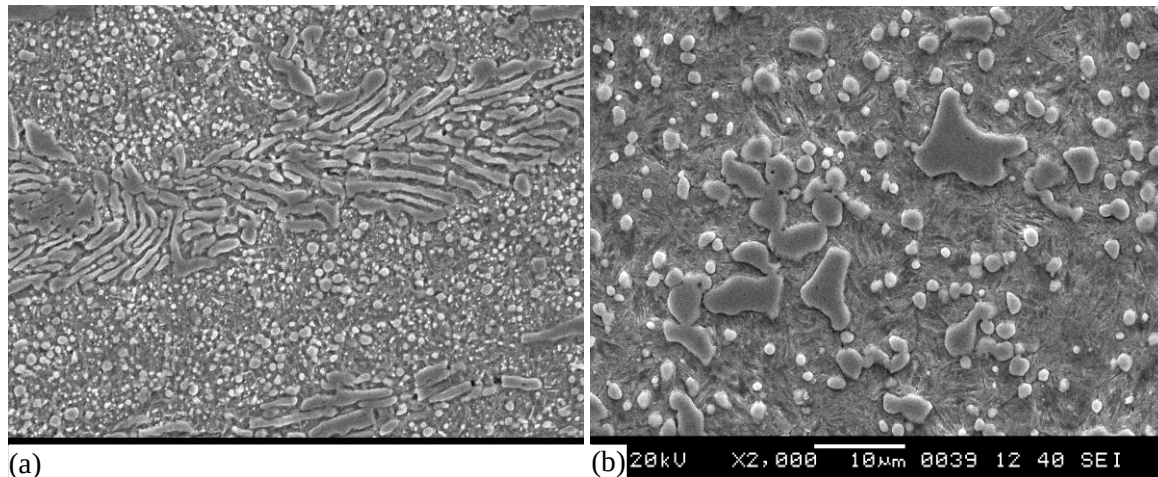


Figure 5. (a) Speciman-(H-T), (b) Speciman-(H-T-CR-T).

Table 1. Measured Hardness for HT and HTCRT test samples

S.N.	HT-HRC	HTCRT HRC	% Increase
01	54	62	13%
02	55	62	
03	54	62	
04	55	62	
05	53	63	
06	54	62	
Avg.	54.1 = 54	62.16 = 62	

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 was 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.

Shop Floor Testing

The control levers were manufactured by blanking operation with both the types of AISI D2 steel punches ((HT and HT CT) from hot rolled 4 mm thick steel sheet as per IS: 1079-1994 Grd D. The manufacturing of control lever was carried out using the mechanical press C-Type, Banson Make, India, having 100 Ton Capacity with 600 strokes/hr. To avoid the heating of punch lubricating oil was used and is spread over lever plate.

The dimensional accuracy of components manufactured and its variation from allowed range was checked by measuring its dimensions using *Coordinate Measuring Machine Mitutoyo Make (CMM)* and is tabulated in Table 2.

- The dimensions shown in blue color are important or key dimensions.
- The dimensions shown in red color are out of range dimensions.

The Table 2 shows that up to certain number of stroke each punch gives accurate dimensions. However, with increasing number of strokes of punch, some of the dimensions will be out of range. The life of the punch can be decided by the number of stroke before regrinding up to which it manufactures

Table 2. Control lever dimensions

Dim. No	Dim to be Measured	Punch Type A-HARDENED-TEMP No. of strokes X 1000				Punch Type-Bs HARD-TEMP-CRYO-TEMP No. of strokes X 1000						
		1	10	20	50	1	10	20	50	100	200	300
1	DIST 12.000	12.5421	12.5678	12.6643	12.856	12.5368	12.5576	301:12:00	301:27:50	12.5861	303:23:02	12.875
2	ANGL	45:21:43	45:32:12	45:53:09	45:59:38	45:25:54	45:23:38	45:16:49	45:22:06	45:15:36	45:24:51	45:41:15
3	DIST 113.000	113.214	113.013	113.573	113.985	113.0179	113.0372	113.0101	112.9835	112.9975	112.90867	112.9676
4	ANGL 5:00:00	4:25:31	4:54:26	4:56:13	4:59:05	4:43:54	4:45:07	4:48:21	4:41:39	4:44:42	4:44:25	4:45:24
5	DIST 43.000	43.0887	43.1853	43.3953	43.5818	42.8941	42.9124	42.8965	42.8739	42.8934	42.9412	43.5832
6	DIST 4.00	3.9918	4.019	4.195	4.254	4.259	4.259	4.25	4.2721	4.2825	4.2927	4.4956
7	DIST 4.000	3.8801	3.862	3.921	3.948	4.176	4.169	4.167	4.197	4.1727	4.1745	4.1612
8	DIST 9.000	8.9984	8.971	8.934	8.987	9.115	9.086	9.117	9.0684	9.1099	9.1386	9.1575
9	DIST 37.000	37.154	37.78	37.84	37.88	37.15	37.08	37.06	37.14	37.1516	37.2095	37.2247
10	ARC 30.0000	28.3827	28.5639	28.6371	28.7845	28.2638	28.6012	27.89	28.3011	28.3926	28.4576	27.8785
11	DIST 10.00	9.8835	9.7532	9.8512	9.9421	9.7833	9.8082	9.8324	9.7852	9.8003	9.8153	9.7679
12	DIST 31.00	31.0402	31.0536	31.1023	31.0657	31.0506	31.065	31.1051	31.06	31.0609	31.1736	30.9219
13	DIST 40.00	40.5465	40.8954	40.9917	41.3055	40.3045	40.3126	40.3056	40.3123	40.2994	40.3158	40.327
14	ARC R 5.000	5.2238	5.2357	5.2853	5.3219	5.1218	5.2151	5.1454	5.165	5.1388	5.1574	5.215
15	ARC R5.00	4.8885	4.9892	4.8541	4.9864	4.8882	4.9706	4.8647	4.8827	4.8832	4.8657	4.8735
16	DIS 28.00	28.2195	28.0848	28.4379	28.6742	27.6194	27.6694	27.6467	27.6307	27.6454	27.6823	27.6952
	ARC R 15.00	30.1355	29.6478	29.3412	29.2136	14.0663	14.1354	14.1162	14.0436	14.1765	14.1589	14.1272
17	DIS 3.000	3.1402	3.069	3.052	3.054	2.592	2.634	2.588	2.557	2.5769	2.6769	2.9958
	DIST 23.00	22.658	22.72	22.79	22.85	23.34	23.26	23.34	23.3572	23.3305	23.5713	23.8683
18	ANGL 158:00	158:23:30	158:45:30	158:52:24	158:55:20	157:30:33	157:29:09	157:25:14	157:25:41	157:24:59	158:40:34	159:30:32
19	ANGL 158:00	158:34:23	158:53:21	158:56:57	159:27:54	157:42:00	157:54:21	157:44:49	157:35:57	157:45:40	158:30:33	159:57:33

the components with correct dimensions. Because, beyond which its dimensional accuracy get disturbed and it shows burr on the component. As shown in Table 2, the dimensions in blue color are required dimensions where as measured dimensions are shown in black color and dimensions shown in red color are out of range. From industrial point of view the number of strokes before first regrinding till we get accurate dimensions on manufactured component is called as the life of that punch. Table 2 shows that the HT punch can manufacture components with accurate dimension till 50,000 component hence, its life is 50, 000 strokes. Whereas, for HT CR T punch the life is 3,00,000 strokes as it can manufacture 3,00, 000 components accurately before first regrinding.

RESULTS AND DISCUSSION

Laboratory Test

Microstructure

The metallographic study was conducted to find out the effect of cryo treatment on amount of retained austenite precipitated and distribution of secondary carbides. The microstructure images of HT and HT CRT exhibits carbide particles in a matrix of tempered martensite. It further shows that the secondary carbides precipitated on martensite matrix are of varying size. 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 round in shape as compared to dendrite structure of primary carbides. The newly precipitated secondary carbides are further differentiated as large secondary carbides (LSC) and small secondary carbides (SSC) based on their size as suggested by Das et al. [16]. As seen from the Figure 5(a), the number of secondary carbides observed are more in number, smaller in size, and round in shape in case of HT test piece samples. At the same time it has followed a specific pattern in which the secondary carbides are spread in specific pattern. The microstructure of H-T-CR-T (Figure 5(b)) strongly shows majority of uniformly distributed secondary carbides. The large secondary carbides are less in number where as small secondary carbides are large in number.

Hardness

The AISI D2 tool steel test piece samples Rockwell C (HRC) hardness values were measured at six equally spaced points along the diagonal length of each specimen. The reason behind taking more reading is to have average hardness value as there may be the possibility of varying the hardness from inner bulk of specimen to outer surface. The Table 2 shows that the HT CR T specimens are having higher hardness by 13% as compared to that of HT specimens. This increase in hardness indicates that there is a complete conversion of retained austenite to martensite and evolves uniformly spread fine carbides. Further, it is observed that there is not much variation in the hardness values obtained along the diagonal length of test piece samples. It means that the microstructural changes occurred due to cryo treatment is throughout the material.

Shop Floor Test

In order find out the life of both the punches HT and HTCRT shop floor test was conducted in actual industrial environment. This test was conducted by manufacturing control lever in blanking operation on same 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 Table 2 shows that HT punches manufacture the 50,000 components with required dimensional accuracy before first grinding. 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.

With this factual theory it is clear from Table 2 that HT punch has undergone sufficient wear after blanking 50,000 components as the some of the dimensions have crossed their range and hence are shown in red color. 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 is disturbed after 3,00,000 components. So useable life of HT CR T punch is 3,00,000 components.

CONCLUSION

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 and activates 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.
3. The use of cryo treatment of AISI D 2 tool steel blanking punch increases the service life more than 6 times as compared to that of traditionally treated punch.

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