Performance Test on Cryogenic Hardened Tool Steel (AISI T42)

K.B.Hariharan[1], T.Rajkumar[2], D.Ragulnath[3], P.Lakshmanan[4], M.Ranjithkumar[5], K.Saravanan[6]
Assistant Professor, Department of Mechanical Engineering,
K.Ramakrishnan College of Technology, Trichy-621112, Tamilnadu, India

***Abstract:*In this paper, the performance test on cryogenic hardened tool steel is studied. Cryogenic treatment is an appendedunadventurousmethodofhot working in cutting tool. Cryogenic treatment increases the hardness, dimensional stability and reduces residual stressesmicrostructure of metal (retained austenite to martensite). Material selected for this process is AISI T42. The performance test on cryogenic hardened tool steel such as metal removal rate (MRR) and surface finish obtained on the work piece is studied by conducting some laboratory tests. Also hardness of the material checked by Rockwell hardness method.**

Keywords: Hardening, Cryogenic treatment, Tool steel, surface roughness, metal removal rate (MRR)

I. INTRODUCTION

There are six broad classifications of tool steelssuch as cold work, shock resisting, hot work, high speed, water hardening, plastic mold and special-purpose tool steels. In thiscutting tool steels prepared by cold working are experimented here, since they are worn for various types of apparatus and usage where high resistance to wear and at reduced cost [1-3]. Tool treated steels are generally used for tool steel. Properties like toughness, wear resistance, toughness to steel are achieved by Conventional heat treatment method.Surface roughness of titanium alloy improves when drill bit is used . From steel it is impossible toeradicate all of the retained austenite (more numberofunbalanced particles of carbon carbide) even performed properly [3-6]. Thus product life reduces when the austenite retains in soft phase in steels it can be transformed into martensite. The prohibitedconversion of retained austenite into martensite is important to numerous types of component. The cold treatment is done to obtain the transformation [7-9].

The major classification of cold treatment based on “sub-zero treatment” at temperatures down to about -80o C or “deep cryogenic treatment” at liquid nitrogen temperature (-196o C). Many latest studies reveal that wear resistance is further improved by assert of treatment done by cryogenic at temperature used for liquid nitrogen. Tool steel when undergoing Cryogenic treatment the precipitation of lightlyisolated carbides in martensite and in turn converts soft unsteady austenite to martensite occurs. The properties like wear resistance, toughness, hardness, resistance to fatigue cracking, microstructure of metal (retained austenite to marten site), and dimensional stability increases using cryogenic treatment and decreases residual stresses. Mechanical properties of work can be treated cryogenically by two methods basically. The first method is credited to the transformation of retained austenite to martensite and thenextmethod is to initiate the nucleation sites for precipitating a maximum number of fine carbides in the matrix of martensite.

II. HEAT TREATMENT PROCESSES

In Conventional heat treatment process hardening and tempering are carried out, where as deep cryogenic treatment absorb an additional low temperature treatment cycle to conventional heat treatment process [10]. The conventional heat treatment involves the following process as shown in Figure 1.

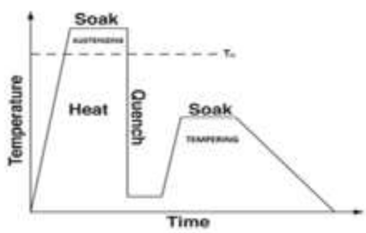

Figure.1 Conventional Heat Treatment

2.1. Austenizing process

The hardened steel has to be placed infurnace and temperature rose above its recrystallization temperature and hold for at least 2 hours.

2.2. *Quenching process*

After austenizing, the steel then dropped inside containers of water for rapid cooling to room temperature after removal from the furnace to rapidly increase the hardness of the steel.

2.3. Tempering process

The brittleness of the hardened carbon steel is removed by tempering it to 350o C.

2.4. Cryogenic Process

Cryogenic treatment involves cooling down the hardened tool steel to -185^{o} C and holds it for about 20 hours. The rate of cooling is usually 1 to 1.5o C to avoid thermal shock. The different stages in cryogenic treatment are shown in figure 2.

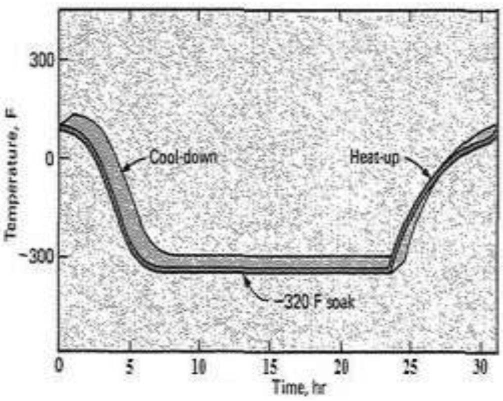

Figure.2 Stages in Cryogenic Heat Treatment

III. EXPERIMENTAL METHODOLOGY

Two samples of AISI T42 High speed steel are taken for study. One of them is conventionally heat treated tool (normal tool). The normal heat treatment involves austeninzing the steel to its re-crystallization temperature, then quenching it to room temperature and then followed by tempering process.

The other tool is not only austenized, quenched and tempered but also undergo cryogenic treatment. It is immersed in a liquid nitrogen storage tank for about 20 hours and then exposed in air for attaining room temperature. The liquid nitrogen storage tank is a multi-walled container which avoids the transition of nitrogen to gaseous state for given temperature of the room. The vacuum between the walls of container reduces the convective heat transfer and helps to store the nitrogen in liquid state. The photography of liquid nitrogen storage tanks are shown in figure 3.

Figure.3 Liquid Nitrogen Storage Tanks

The change in properties and performance of two different heat treated tools are then compared and studied. The comparative analysis on hardness of the normal tool and the cryogenic heated tool are studies based on Rockwell Hardness Test. Rockwell Hardness Test can be used for both ferrous and non-ferrous materials. Rockwell C scale is used to find the hardness of ferrous material.

The two different heat treated AISI T42 tools are grinded as a single point cutting tools in tool and cutter grinder with the following tool signature 7-7-15-15-15-15-0.1. The photography of tool and cutter grinder is shown in figure4.

Figure.4Tool and cutter grinder

The turning process is carried out on mild steel work piece using both conventional heat treated tool and cryogenic treated tool. The performances of both tools are compared by measuring the metal removal rate and surface finish obtained on the work piece [11-15]. The readings obtained during the turning operation are given in Table I for normal tool and given in Table II for cryogenic treated tool.

Table.1 Surface Finish and MRR Obtained During Turning Process Using Normal Tool

Normal Tool												
S.No	SPEED (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)	WEIGHT (g)		REDUCT-ION IN WEIGHT (g)	MACHIN-ING TIME (s)	SURFACE ROUGH-NESS (μm)	CUTTING FORCE (N)			MRR (g/s)
				BEFORE	AFTER				Fx	Fy	Fz	
1	230	1	0.2	428	427	1	38	1.46	5	11	4	0.026316
2	230	1	0.4	417	415	2	35	1.73	5	11	3	0.057143
3	230	1	0.6	424	420	4	41	1.89	5	12	4	0.097561
4	358	1	0.2	407	405	2	39	1.21	4	12	3	0.051282
5	358	1	0.4	418	414	4	44	1.34	5	11	4	0.090909
6	358	1	0.6	421	415	6	43	1.49	5	13	3	0.139535
7	544	1	0.2	422	420	2	34	0.92	4	12	4	0.058824
8	544	1	0.4	427	423	4	41	1.12	7	11	4	0.097561
9	544	1	0.6	420	415	5	32	1.26	7	12	2	0.15625
10	230	1.25	0.2	425	424	1	35	1.93	2	10	4	0.028571
11	230	1.25	0.4	425	423	2	32	2.08	4	15	4	0.0625

12	230	1.25	0.6	420	415	5	45	2.24	6	16	3	0.111111
13	358	1.25	0.2	418	416	2	37	1.35	4	13	3	0.054054
14	358	1.25	0.4	423	419	4	38	1.52	5	16	4	0.105263
15	358	1.25	0.6	418	413	5	33	1.86	8	12	2	0.151515
16	544	1.25	0.2	425	423	2	30	1.16	2	11	3	0.066667
17	544	1.25	0.4	420	416	4	35	1.47	5	14	3	0.114286
18	544	1.25	0.6	423	417	6	36	1.72	7	18	5	0.166667
19	230	1.5	0.2	420	419	1	30	2.14	4	13	3	0.033333
20	230	1.5	0.4	420	417	3	35	2.36	6	17	4	0.085714
21	230	1.5	0.6	421	416	5	37	2.57	7	15	4	0.135135
22	358	1.5	0.2	417	414	3	32	1.63	4	12	3	0.09375
23	358	1.5	0.4	426	422	4	28	1.79	5	16	4	0.142857
24	358	1.5	0.6	418	413	5	27	1.91	6	14	4	0.185185
25	544	1.5	0.2	424	421	3	29	1.22	3	11	3	0.103448
26	544	1.5	0.4	413	409	4	30	1.58	6	12	3	0.133333
27	544	1.5	0.6	419	413	6	31	1.84	5	14	4	0.193548

Table.2Surface Finish and MRR Obtained During Turning Process Using Cryogenic Tool

Cryogenic Tool												
S.No	**SPEED**	**FEED**	**DEPTH OF CUT**	**WEIGHT (g)**		**REDUCT - ION IN WEIGHT**	**MACHIN - ING TIME**	**SURFACE ROUGH- NESS**	**CUTTING FORCE (N)**			**MRR**
	(rpm)	**(mm/rev)**	**(mm)**	**BEFORE**	**AFTER**	**(g)**	**(s)**	**(μm)**	**Fx**	**Fy**	**Fz**	**(g/s)**
1	230	1	0.2	427	426	1	36	1.4	5	10	4	0.027778
2	230	1	0.4	415	413	2	32	1.69	5	11	3	0.0625
3	230	1	0.6	420	416	4	40	1.86	5	12	3	0.1
4	358	1	0.2	405	403	2	37	1.16	4	11	3	0.054054
5	358	1	0.4	414	410	4	42	1.27	4	10	3	0.095238
6	358	1	0.6	415	410	5	35	1.38	6	12	2	0.142857
7	544	1	0.2	420	418	2	32	0.84	4	11	2	0.0625
8	544	1	0.4	423	420	3	30	1.05	4	12	3	0.1
9	544	1	0.6	415	409	6	37	1.19	4	12	2	0.162162
10	230	1.25	0.2	424	423	1	32	1.83	5	10	3	0.03125
11	230	1.25	0.4	423	420	3	44	1.97	4	12	3	0.068182
12	230	1.25	0.6	415	411	4	35	2.18	6	13	2	0.114286
13	358	1.25	0.2	416	414	2	34	1.26	4	11	3	0.058824
14	358	1.25	0.4	419	415	4	36	1.43	4	13	3	0.111111
15	358	1.25	0.6	413	407	6	39	1.75	6	11	2	0.153846
16	544	1.25	0.2	423	420	3	42	1.07	3	10	2	0.071429
17	544	1.25	0.4	416	412	4	34	1.35	5	14	2	0.117647
18	544	1.25	0.6	417	411	6	35	1.67	6	15	3	0.171429
19	230	1.5	0.2	419	418	1	27	2.06	3	10	2	0.037037

20	230	1.5	0.4	417	414	3	33	2.29	6	15	3	0.090909
21	230	1.5	0.6	416	411	5	36	2.46	6	14	4	0.138889
22	358	1.5	0.2	414	411	3	31	1.55	5	12	3	0.096774
23	358	1.5	0.4	422	418	4	27	1.69	6	14	3	0.148148
24	358	1.5	0.6	413	407	6	32	1.83	7	13	4	0.1875
25	544	1.5	0.2	421	418	3	28	1.14	5	11	4	0.107143
26	544	1.5	0.4	409	404	5	36	1.48	6	13	3	0.138889
27	544	1.5	0.6	413	407	6	30	1.76	5	14	2	0.2

IV. COMPARISON OF PERFORMANCE OF NORMAL TOOL AND CRYOGENIC TOOL

4.1. Comparison of surface roughness

The surface roughness on the work piece after turning process is calculated using surface roughness tester as shown is Figure5.

Figure. 5 Surface Roughness Tester

The surface roughness on the work piece during turning process depends upon the feed rate, depth of cut, tool wear, cutting speed, etc. In cryogenic tool, the tool wear is minimum and more uniform. So the surface roughness obtained on the work piece is slightly lower than that obtained when turning in normal tool as shown in figure 6. In cryogenic tool, the decrease in the surface roughness is about 4.86%.

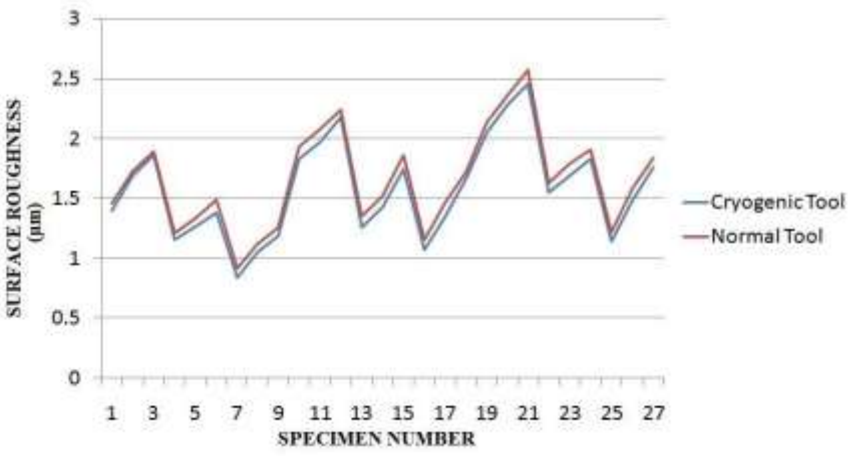

Figure.6Comparison of surface roughness

4.2. Comparison of metal removal rate

The theoretical metal removal rate may not be equal to the actual metal removal rate obtained when machining due to the resistance of work piece against the tool material. In cryogenic tool, the resistance due to the work piece is minimum due to the boost in hardness of tool steel. When turning the work piece using cryogenic hardened tool, the metal removal rate (MRR) obtained is slightly increased as shown in figure 7. In cryogenic tool, the increase in the MRR is about 3.79%.

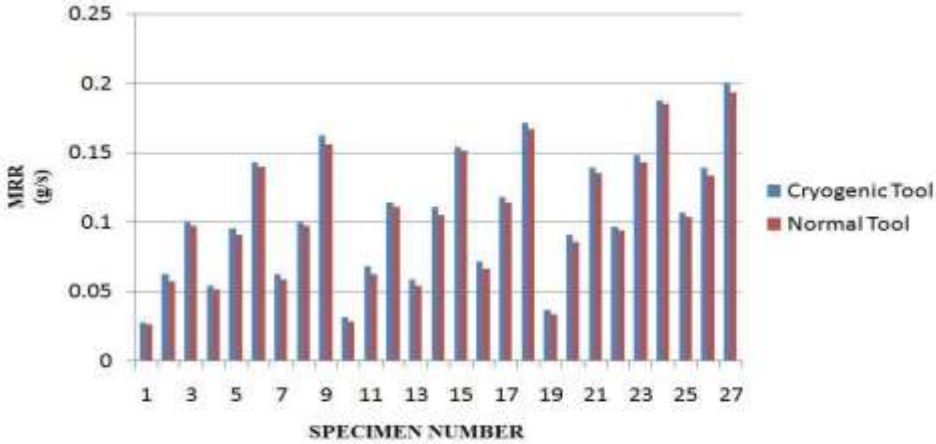

Figure.7 Comparison of metal removal rate

4.3 Comparison of hardness

Figure.8 Rockwell Hardness Tester

B scale: (1/16" diameter steel ball indenter: 100 Kg Load) is used to find the hardness of non ferrous metal.

C scale: (120º Diameter cone indenter: 150 Kg Load) is used to find the hardness of ferrous metal.

The five sets of readings are taken on both normal tool and cryogenic tool using Rockwell C scale and are given in Table 3.

Table.3Readings of Rockwell Hardness Test

TOOL	SET1	SET2	SET3	SET4	SET5	Average
Normal Tool	62	62	63	62.5	62	62.3
Cryo - Tool	65	66	65	66	64	65.2

The Rockwell hardness number of cryogenic treated tool is increased by 4.65%. The average Rockwell hardness for the tools is given in figure 9.

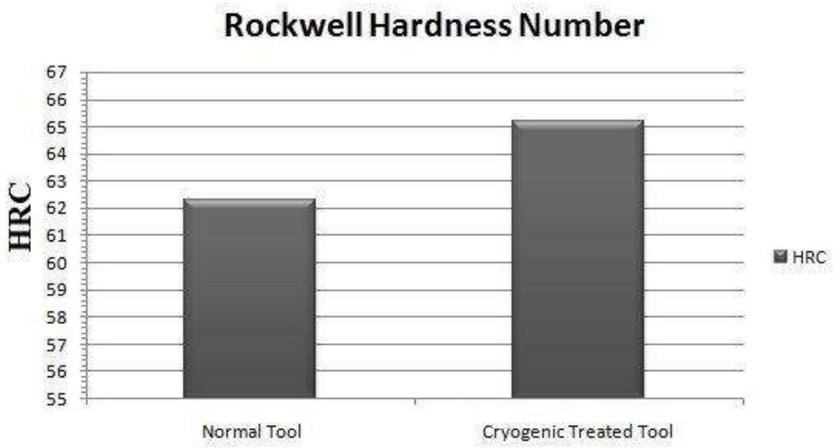

Figure.9 Comparison of hardness

V. CONCLUSIONS

The increase in hardness of about 4.65% is due to the achievement of martensite from austenite, which results in slightly increased metal removal rate of about 3.79%.

Dimensional accuracy and surface finish also substantially improved mainly due to significant reduction of wear and damage at the tool tip. The decrease in the surface roughness on work piece when turning using cryogenic tool is about 4.86%.

The increase in wear resistance has been accredited to the conversion of soft retained austenite into the harder martensite phase, and the formation of fine carbide particles in the metal structure. This results for the wear resistance improvement in tool steel.

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