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# Study on the Effect of Cryogenic Treatment of T1, T4 and M42 High-Speed Steels

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## Abstract

**Objectives**: Deep cryogenic treatment is a one-time, permanent treatment affecting the entire part and not just the surface alone. Cryo treatment changes metals as a result of the martensitic transformation of retained austenite. **Methods/ Statistical Analysis**: Conventional Heat treatment and Cryo treatment are selected. The cryogenic fluid used here is nitrogen. An attempt is made to study the property changes mainly dwelling on the hardness of the high-speed steels before and after the Cryo treatment. Comparative studies made by modifying the quenching media oil, water and cryogenic media. **Findings:** The Cryo treatment using liquid nitrogen has shown the profound increase in the hardness of the tool steel materials. Moreover, by use of cryogenic treatment, multi-tempering could be avoided. From the optical microscopy studies, the actual component responsible hardness i.e. martensite is seen clearly in all the three samples but differs in the percentage of martensite content. **Application/Improvements:** Life of the cutting tools in the lathe, the milling and drilling will be enhanced.

**Keywords:** Cryogenic Treatment, Hardness, High-Speed Steels, Tempering, Tool Steels

## 1. Introduction

Barron investigated 12 tool steel, three stainless steel and four other steel, was subjected to cryogenic treatments to determine the difference between an 189 K soak and a −77 K soak in improving the abrasive wear resistance. The tool steels exhibited a significant increase in wear resistance after the soak at 77 K and a less dramatic increase in 189 K by in[1].

In[2] indicated that the removal of retained austenite combined with fine dispersed-carbide precipitations has been widely observed and their effects on mechanical properties measured in cryogenic treatment.

In[3] investigated that the Deep Cryogenic Treatment after quenching and before tempering was confirmed to be crucial to maximizing the hardness of the steel.

In[4] examined the effects of Cryogenic treatment on the mechanical properties and microstructures of AISI 4340 steel. Mechanical properties, including rotating fatigue, impact and hardness carried out, after many treating conditions and the results compared[4].

In[5] studied the effect of deep Cryogenic treatment (−196°C) on the properties of some tool steels using both field tests and laboratory tests. The execution of the deep Cryogenic treatment on quenched and tempered high-speed steel tools, increase hardness, reduce tool consumption and downtime for the equipment set up, thus leading to cost reductions of about 50%.

Hence, T1, T4 and M42 high-speed steels are treated with Cryogenic treatment to improve their properties.

## 2. Experimental

Carbon and alloy steels having a high hardness, strength and wear resistance are used to make cutting and measuring tools and dies of various kinds. High-speed steels constitute a group of tool steels. The carbon content of tool steels ranges from 0.7 to 1.5 %. After being hardened and tempered at a low temperature, cutting tools (twist drills, reamers, single point tools, milling cutters, etc.) should have a cutting edge of hardness (60-65 RC) considerably. The tools should also have a high wear resistance, so that

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the size and shape of the cutting edge are preserved as long as possible in machining and strength and toughness sufficient to avoid tool breakage in operation.

For the present study, two tungsten based high-speed steel and one molybdenum based high-speed steel were selected for carrying out the treatment: Their chemical composition given in Table 1.

The two tungsten based high-speed steel is:

- T1 High-speed steel.
- T4 High-speed steel.

The molybdenum based high-speed steel is:

- M42 High-speed steel.

After selecting the high-speed tool steel materials, the specimens or samples were prepared and shown in Table 2. The preheating stages carried out as represented in Figure 1 for a time interval of 30 minutes. After attaining the austenitizing temperature, they were left for one hour for homogeneous austenitization to take place. Quenching was carried out in the three different media; oil, water and liquid nitrogen. Water quenching at room temperature experienced. The oil quenching was carried out with quenching oil No. 2 whose specification given in Table 3. Cryogenic quenching at $77^0$ K with the controlled rate of $0.86^0$ K/min and for the oil and water quenched sample, double tempering was done at $570^0$C for one hour time duration each as shown in Figure 1. For the cryogenically quenched samples at the specified temperature for one-hour single tempering is done.

## 3. Results and Discussion

The purpose of the Cryo treatment is to increase the hardness of the materials which is more than other conventional treatment processes. The increase of hardness is due to the conversion of the major portion of austenite to martensite, more the amount of martensite transformation more in the hardness. This transformation of austenite to martensite for different treatments can be seen effectively from the microstructure photographs. Figure 2 clearly shows the needle-like lamellar structures are the tempered martensite and the white spaces are the retained austenite. Figure 3 indicates the microstructures of water quenched samples; there are fewer amounts of tempered martensite and more amount of retained austenite. Figure 4 shows the microstructures of oil quenching samples; the martensite content is more compared to water quenching. The retained austenite is comparatively lower than water

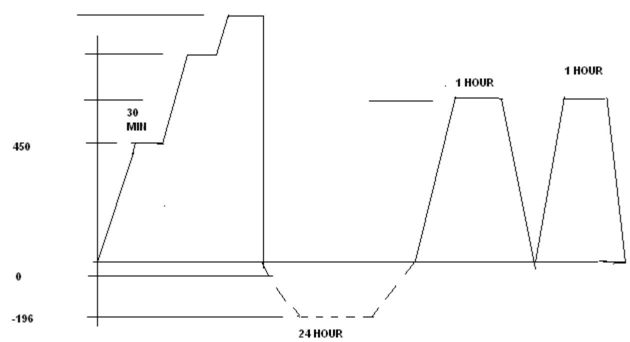


**Figure 1.** Heat treatment cycle between temperature and time.

**Table 1.** Chemical composition of materials

| Specimen | C | Si | Mn | Cr | Mo | V | W | Co | Ni |
|---|---|---|---|---|---|---|---|---|---|
| **T1** | 0.65-0.75 | 0.1-0.35 | 0.2-0.4 | 4.0-4.5 | 0.6 Max | 1.0-1.5 | 17.5-19.0 | - | - |
| **T4** | 0.7-0.8 | 0.1-0.35 | 0.2-0.4 | 4.0-4.5 | 0.5-1.0 | 1.0-1.5 | 17.5-19.0 | 5.0-6.0 | - |
| **M42** | 1.05-1.15 | 0.15-0.4 | 0.15-0.65 | 3.5-4.25 | 9-10 | 0.95-1.55 | 1.15-1.85 | 7.75-8.75 | 0.3-Max |

**Table 2.** Samples prepared for the various treatments

| Material Type | Size of the Specimen (mm) | No. of Specimen |
|---|---|---|
| **T1** | 20 x 20<br>15 x 15 | 4<br>2 |
| **T4** | 15 x 15 | 6 |
| **M42** | 20 x 20<br>15 x 15 | 4<br>2 |

**Table 3**. Physical characteristics of quenching oil no. 2

| Appearance | Clear homogeneous liquid free from suspended in purities and dust |
|---|---|
| Flash pail closed (Pensky of Martons) | Above $160^0$C |
| Kinematic viscosity | Between 20 and 38 @ $37.8^0$C centistokes |
| Pour point | About $8^0$C |
| Specific heat $^0$C | 0.46 |
| Specific gravity | 0.892 |
| Thermal conductivity | |

quenching samples. In Cryogenic treatment, the tempered martensite spread over almost the whole area except some spots where retained austenite is present. Figure 4 shows the more amount of tempered austenite transformed.

From the microstructural studies, it inferred that:

- More amount of martensite formed compared to water, oil quenching.
- Increased hardness and wear resistance considerably.
- The toughness and strength had also increased by this treatment.

The hardness values obtained are higher than the values obtained from other conventional treatment processes which had shown in Figure 5 to Figure 7.

**Figure 2a.** Water quenched.

**Figure 2b.** Oil quenched.

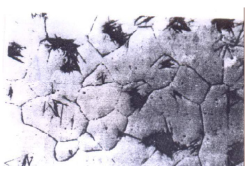

**Figure 2c.** Cryo quenched.

**Figure 2.** Microstructure of T1 metals.

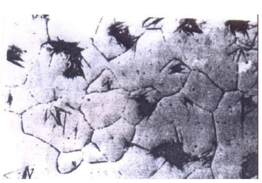

**Figure 3a.** Water quenched.

**Figure 3b.** Oil quenched.

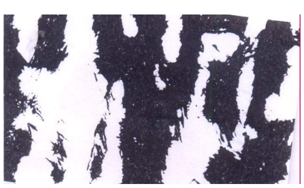

**Figure 3c.** Cryo quenched.

**Figure 3.** Microstructure of T4 metals.

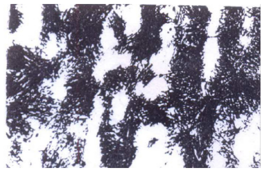

**Figure 4a.** Water quenched.

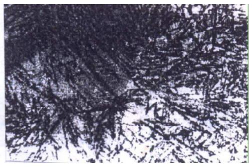

**Figure 4b.** Oil quenched.

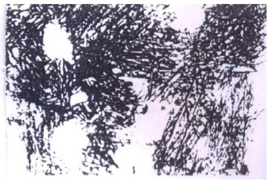

**Figure 4c.** Cryo quenched.

**Figure 4.** Microstructure of M42 metals.

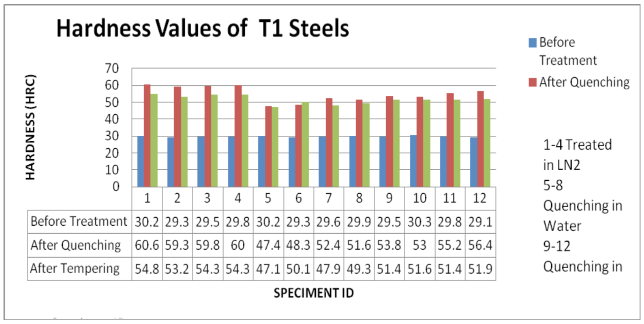


**Figure 5.** Hardness values of T1 steels.

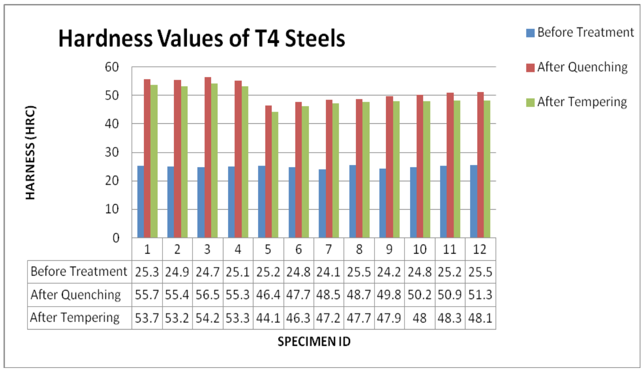


**Figure 6.** Hardness values of T4 steels.

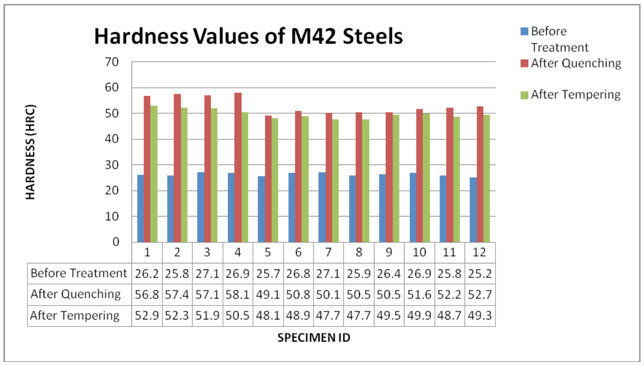


**Figure 7.** Hardness of values of M42 steels.

## 4. Conclusion

The Cryo treatment using liquid nitrogen has shown a profound increase in the hardness of the tool steel materials. Moreover, by the Cryogenic treatment, multi-tempering is avoided. From the optical microscopy studies, the actual component responsible hardness i.e. martensite is seen clearly in all the three samples but differs in the percentage of martensite content. Thus the property changes due to Cryo treatment in the high-speed tool steel materials and the reasons behind these changes are inferred and their superiority over the other conventional treatment is justified to an extent.

## 5. Reference:

1. Barron RF. Cryogenic treatment of metals to improve wear resistance. Cryogenics. 1982 Aug; 22(8):409–13.
2. Baldissera P, Delprete C. Deep Cryogenic treatment: A bibliographic review. The Open Mechanical Engineering Journal. 2008; 2:1–11.
3. El Mehtedi M, Ricci P, Drudi L, El Mohtadi S, Cabibbo M, Spigarcelli S. Analysis of the effect of Cryogenic treatment on the hardness and microstructure of X30 CrMoN 15 1 steel. Journal Materials and Design. 2012 Jan; 33:136–44.
4. Zhirafar S, Rezaeian A, Pugha M. Effect of Cryogenic treatment on the mechanical properties of 4340 steel. Journal of Materials Processing Technology. 2007 May; 186(1-3):298–303.
5. Molinari A, Pellizzari M, Gialanella S, Straffelini G, Stiasny KH. Effect of deep Cryogenic treatment on the mechanical properties of tool steels. Journal of Materials Processing Technology. 2001 Dec; 118(1-3):350–5.