International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

Analysis and Improvement of Distortion of Lathe Machine Main Spindle

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***Abstract**: In lathe machine, main spindle is an important component which is generally made with En353steel. It undergoes distortion or bending due to high stresses and is controlled by the heat treatment process called carburizing. It is the process where the component is heated to a specified temperature, generally above the critical temperature and cooled for long period of time such that the microstructure of the material gets changed from austenite to martensite. Retained austenite reduces the hardness, wear resistance and thermal conductivity of steel and makes its dimensions unstable. A sub-zero treatment has been devised to reduce the retained austenite in hardened steel which is done by cooling the metal to sub-zero temperature. This treatment is suitable only when the temperature at which the martensite transformation is completed is below zero. Due to this change in material from austenite to martensite, the material improves in its properties like change in microstructure, hardness, carbon percentage and composition of the material. Here, in this paper an attempt is made to apply a heat treatment called sub-zero treatment to check the changes in the material and results are compared with conventional properties of specimen material En353.*

Key Words: lathe, main spindle, distortion, heat treatment, sub-zero treatment, Austenite, Martensite , hardness

1. INTRODUCTION

Lathe main spindle undergoes various types of stresses, and bending stress is one of them. It is made up of En353 material. It is made by following some sequence of operations. Cryogenically treated high speed steel tools which shows micro structural changes in the material that can influence tool life and productivity. It shows the improvements when using the cryogenically treated HSS tools in industry [1], and a cooler fan drive gears used in the MGB to cool the oil in the ALH Helicopters. By the implementation of the fixture at time of heat treatment and tested to see that distortion could be reduced [2] and an example calculations using DANTE software shows, it has very advanced features, and its predictions were shown to agree in a relative sense (within about 15%) with measurements reported on heat treatment distortion on Navy-C rings made from 4140 and 8620 steel quenched in water and in oil [3], and the optimum process parameter for XW-5 and XW-42 were determined where XW-5 is recommended for applications demanding maximum wear resistance and XW-42 is a versatile tool steel used for cold work applications like blanking and other processes [4]. A low pressure carburizing (LPC) and high pressure gas quenching (HPGQ) heat treatment processes reduces distortion significantly and HPGQ provides a very uniform heat transfer coefficient [5]. The ultimate tensile strength and the yield strength decrease while the elongation increases with an increase in tempering temperature and tempering time of different tempered specimen, when specimen of quenched, hardened AISI1040 steel was tempered at temperature (650, 450 & 250^0 C) for 60, 90 & 120 minutes to modify desired properties [6] and the effects of cooling rate on the microstructure and mechanical properties of AISI 1050 steel, was studied and find out that it varies by using various quenching medium on the hardness of AISI 1050 Carbon steel [7], various types of heat treatment on fracture toughness and hardness is analysed using UTM with the help of sample specimens of low carbon steels and Stainless Steels[8], and quenching produces a martensitic microstructure characterized by significant increase in material's hardness and a significant decrease in its impact energy when E110 case hardening steel is subjected to different heat treatment processes[9] and the cutting parameters that have the highest influence on the dimensional changes are the feed rate and the depth of cut. Residual stresses induced by soft-machining lead to an increase of the ring diameter, depending on the machining parameters [10].

2. DISTORTION

Distortion is defined as an irreversible and usually unpredictable dimensional change in the component during processing by heat treatment due to temperature variations in the material. The term dimensional change is used to denote changes in both size and shape. The heat-treatment distortion is therefore a term often used by engineers to describe an uncontrolled movement that has occurred in a component as a result of heat-treatment operation. This can be classified into two categories namely it is apparent here that some steels such as case hardening steels appreciable increase in size of about 0.2% after hardening and tempering between 840 and 870°C and 180 - 200°C. This is sometimes called straightness or angularity change. It is found particularly in non-symmetrical components during heat treatment. From the practical viewpoints, warpage in water- or oil-hardening steels is normally of greater in magnitude than in size distortion. Sub - zero literally means "beneath zero" as such, it is usually used for negative numbers, especially with regards to temperature. It also known as cryogenic treatment, utilizes ultra-cold temperatures to modify the micro-structure of metals and other materials. It is part of heat treating operations in manufacturing processes. This process requires temperatures of at least -85°C to begin. For deep sub-zero treatment the parts must be cooled to -185°C where they are held for relatively long periods of time and then slowly warmed back up. This type of heat-treating production has been widely accepted as a cost reduction process and performance enhancing technology.

The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The basic Vickers Test principle with details of indenter is shown in Fig 2.1

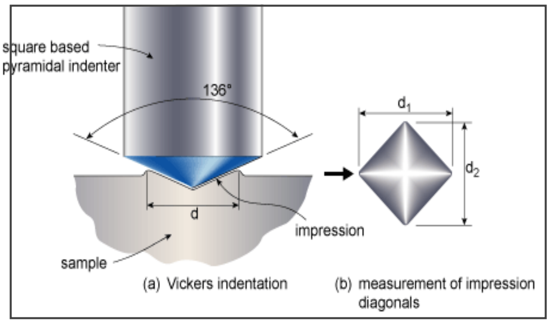


Fig 2.1 Vickers Hardness Test nomenclature

3. METHODOLOGY

The general conventional procedure is applied to make the main spindle of lathe machine is as follows:

- Selecting the material and cutting it to desired size of length
- Forging
- Pre Turning
- Normalising
- Carburising and Annealing to 1.2-1.5 mm case hardening
- Machining after heat treatment
- Hardening and Tempering.

In this analysis, two En 353 steel specimens are made by conventional procedure mentioned above, which has a carbon content of 0.171%. The samples of specimens are shown in Figure 3.1(a), (b),(c) & (d) used for analysis. These specimens has undergone different heat treatment processes like Case carburizing, Hardening & tempering.

(a) Specimen before case carburizing

(b) Specimen after case carburizing

(c) After Hardening process

(d) After tempering process

and the composition of material for En 353 which are taken for analysis are mentioned in Table 3.1

Table 3.1 Properties of Material

Elements	Materials present in %
Carbon	0.171 %
Manganese	0.56 %
Silicon	0.3 %
Sulphur	0.13 %,
Phosphorus	0.012 %
Chromium	0.953 %
Nickel	0.989 %
Molybdenum	0.16 %

By considering two samples of the material En353 of sample size 60 mm each and one sample is processed according to the conventional procedure. The second sample is also made with same process but processed with a heat treatment called sub-zero treatment. Later the samples are tested with a hardness tester (Vickers's Hardness test) and microstructures are tested for both the samples and are compared.

4. RESULTS AND DISCUSSION

4.1 Results: The comparison of material composition is shown in Table 4.1(a) and it shows that the Carbon content increased from 1.171% to 1.20 %, and Manganese increased from 0.56 to 0.70% but the Sulphur, Chromium gets decreased. Nickel material also increased from 0.99% to 1.15%, Silicon increased from 0.30% to 0.34 %, Phosphorus was increased to 0.01% to 0.03% in the material. Due to these variations the hardness and strength were increased.

Table: 4.1.(a) Comparison results of material composition

Elements	Present in %	After carburizing Process in %
Carbon	0.171%	1.20%
Manganese	0.56%	0.70%
Silicon	0.30%	0.34%
Sulphur	0.13 %,	0.02%
Phosphorus	0.01%	0.03%
Chromium	0.95%	0.90%
Nickel	0.99%	1.15%
Molybdenum	0.16%	0.14%

4.2 Comparison of Microstructures: First the specimen En353 steel is undergone a heat treatment process of carburizing and it is annealed, hardened and the un tempered martensite ranges between 15-20% and the hardness lies in between 59-60HRC which is shown in Fig 4.2.a.

Fig:4.2.a Specimen microstructure with un tempered Martensite

Next another specimen of the same material En353 steel is Case-carburized, 1.9 Hardened at 840^{0}C and tempered at 180 ^{0} C and the tempered martensite can be seen with 15-20% retained martensite and the hardness lies in between Case 59-60HRC and core has hardness of 30 HRC which is shown in Fig 4.2.b.

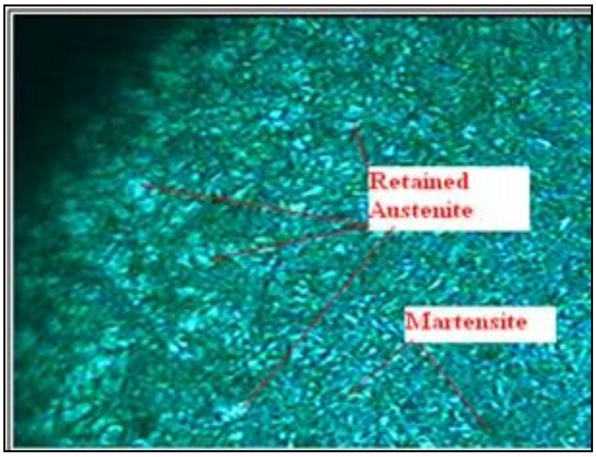


Fig 4.2.b. Specimen with case carburising and Hardened with tempered Martensite

Another sample specimen of En353 steel is carburized, Annealed and hardened followed by a heat treatment process of sub-zero treatment and the un tempered martensite is seen and the hardness increased to 62 HRC and the temperature is taken as 930^0 C where the image is shown in Fig 4.2.c

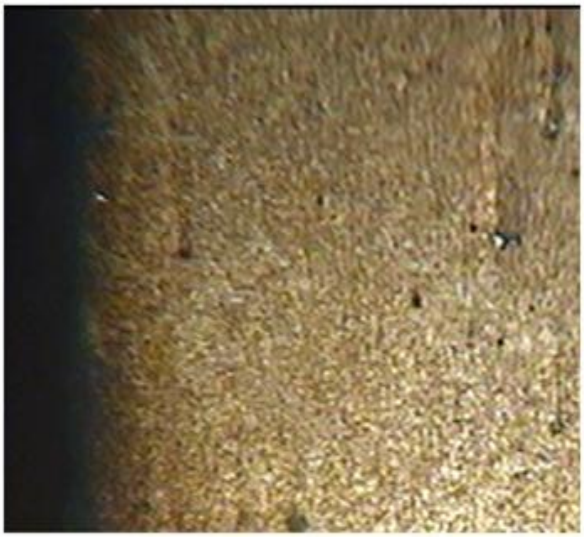


Fig 4.2.c Specimen microstructurewith subzero treatment and un tempered Martensite

For sub-zero treatment another specimen of the same material En353 steel is Case-carburized to 1.8 mm followed by sub-zero treatment, Hardened at 840^{0}C and tempered at - 80 ^{0} C and the tempered martensite can be seen with 2-3% with retained Austenite and the hardness lies in between core 61-62 HRC and core has hardness of 31 HRC which is shown in below Fig 4.2.d

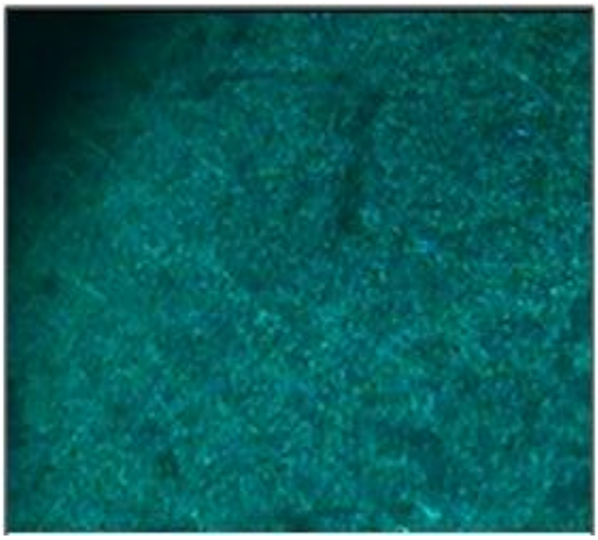


Fig:4.2.d Specimen with case carburising and Hardened with subzero treatment

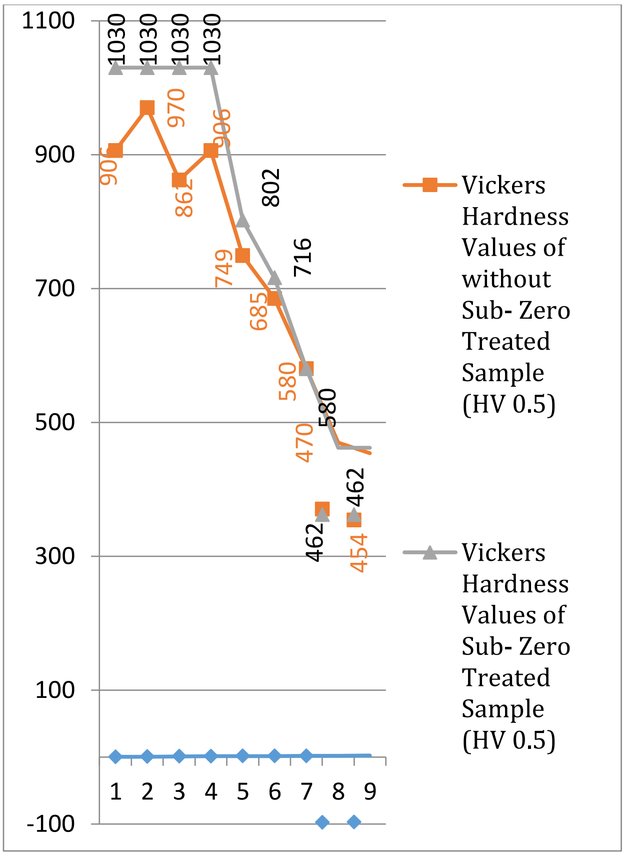
After the sub-zero treatment conduced to the sample , it shows lower hardness value which is 906 at 0.3 mm, 970 at 0.6mm and 862 at 1.1 mm etc., and the results obtained from various points at surface level of material are tabulated in the table : 4.2

Table 4.2 Comparison of Hardness of samples by Vickers Method

Distance on surface level (in mm)	Vickers Hardness Values of without Sub-Zero Treated Sample (HV 0.5)	Vickers Hardness Values of Sub-Zero Treated Sample (HV 0.5)
0.3	906	1030
0.6	970	1030
1.1	862	1030
1.3	906	1030
1.5	749	802
1.7	685	716
1.9	580	580
2.2	470	462
2.5	454	462

4.3 Graphical Comparison: The hardness values of both specimens are compared in graph and shown in Graph 5.2(a) below.

Graph 4.3(a) Graphical Comparison



4.4 CONCLUSIONS:

- Carbon potential is high 1.201 against 0.8 to 0.9 % Max. hence formation of Retained Austenite has increased.
- Effect of Hardening temperature can be reduced to 820°C to reduce Retained Austenite
- From above results it is been observed that retained austenite of 15 -20 % is effecting dimensional instability up to 30 to 50 microns for the component of without sub-zero treated.
- It has been observed that retained austenite of 1 -2 % is improved dimensional stability up to 5 microns for the component with sub-zero treatment.
- The Hardness of the specimen is decreased by Sub Zero Treatment. The hardness value varied from distance of 0.3 to 1.7mm at surface of the material.
- The hardness value remains same at distance of 1.9 mm from the surface.

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