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# Study properties and mechanical behavior of the shaft material 16MnCr5

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ABSTRACT

A detailed study properties and behavior of the shaft material (16MnCr5) at different hardness i.e. 40 HRC, 45 HRC, 55 HRC was carried out by heat treating the shaft at 500 ℃, 450 ℃, and 250 ℃ respectively. Following this, a tensile test was carried out for the material with different hardness and hence the design stress was determined by analyzing the shaft at full load capacity. Detailed calculation involving the Factor of Safety of the shaft was done based upon the tensile stress and design stress and it was found to be Suitable material (20NiCrMo2) with a greater tensile strength and similar chemical composition is also recommended. Comparative statement has been made for obtaining maximum yield strength and hardness for a highly stressed environment parts and optimum value has been selected for 16MnCr5 material with number of heat treatment processes.



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## 1. Introduction

It is a group of industrial and metalworking process is used to alter the physical and sometimes chemical properties of a material. The most common application is metallurgical. Consequently it is found that austempering; a heat treatment process gives the maximum value of hardness, UTS and yield strength with other excellent mechanical properties [1] The traditional Hydraulic Power Assisted Steering, HPAS, system, cannot meet these new demands, due to the control unit's pure hydro- mechanical solution [2,3] The method uses static measurements as a base for calculation and optimization; the results are used in both linear and the non-linear models [4] Most common problem is wear for steels used in these engineering areas, wear resistance steels came into prominence [5,6] Table 1.1..

### 1.1. Heat treatment

Metallic materials consist of a microstructure of small crystals called "grains" or crystallites. The nature of the grains (i.e. grain size and composition) is one of the most effective factors that can determine the overall mechanical behavior of the metal. Heat treatment provides an efficient way to manipulate the properties of the metal by controlling the rate of diffusion and the rate of cooling within the microstructure. Heat-treating is often used to alter the mechanical properties of an alloy, manipulating properties such as the hardness, strength, toughness, ductility, and elasticity [7,8].

### 1.2. Annealing

Annealing consists of heating a metal to a specific temperature and then cooling at a rate that will produce a refined microstructure. The rate of cooling is generally slow. Annealing is most often used to soften a metal for cold working, to improve machinability, or to enhance properties like electrical conductivity [9].

#### 1.2.1. Tempering

Tempering is a process of heat-treating, which is used to increase the toughness of iron-based alloys. Tempering is usually performed after hardening, to reduce some of the excess hardness, and is done by heating the metal to some temperature below the critical temperature for a certain period of time, then allowed to cool in still air [10–15].

#### 1.2.2. Quenching

Quenching is a process of cooling a metal at a rapid rate. This is most often done to produce a martensite transformation. In ferrous

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**Table 1.1**
Chemical composition and properties.

| Composition (Weight %) | 16MnCr5 |
|---|---|
| Carbon | 0.14–0.19 |
| Silicon | 0.15–0.40 |
| Manganese | 1–1.3 |
| Chromium | 0.8–1.1 |
| Iron | 97.0 |
| Tensile Strength (MPa) | 660 |

alloys, this will often produce a harder metal, while non-ferrous alloys will usually become softer than normal.

## 2. Experimental procedure

### 2.1. Material composition and properties

Material used is 16MnCr5 is a low carbon alloy steel with chemical composition of, and properties of as show in table 1.1 16MnCr5 steel is widely used for manufacturing gears, pins, shafts, clutches, plates and camshafts after quenching and tempering. So the aim of the present investigation is to study the effects of tempering heat treatment temperatures on the fatigue resistance of 16MnCr5

## 3. Experimental process

### 3.1. Process required designing the shaft

#### 3.1.1. Turning

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path by moving more or less linearly while the work piece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear

#### 3.1.2. Facing

In machining facing is the act of cutting a face, which is a planar surface, onto the work-piece. Within this broadest sense there are various specific types of facing, with the two most common being facing in the course of turning and boring work (facing planes perpendicular to the rotating axis of the work-piece) and facing in the course of milling work (for example, face milling).

#### 3.1.3. Knurling

Knurling allows hands to get a better grip on the knurled object than would be provided by the originally smooth metal surface. Occasionally, the knurled pattern is a series of straight ridges or a helix of straight ridges rather than crisscross

#### 3.1.4. Grooving

Grooving is a depression on the entire circumference of a cast or machined wheel, a pulley or sheave. This depression may receive a cable, a rope or a belt.

#### 3.1.5. External thread cutting

Threading is the process of creating a screw thread. More screw threads are produced each year than any other machine element There are many methods of generating threads, including subtractive methods (many kinds of thread cutting and grinding, as detailed below); transformative methods (Refer Fig. 3.1).

### 3.2. Case hardening

Case hardening is specified by hardness and case depth. The case depth can be specified in two ways: total case depth or effective case depth. The total case depth is the true depth of the case. The effective case depth is the depth of the case that has a hardness equivalent of HRC50.

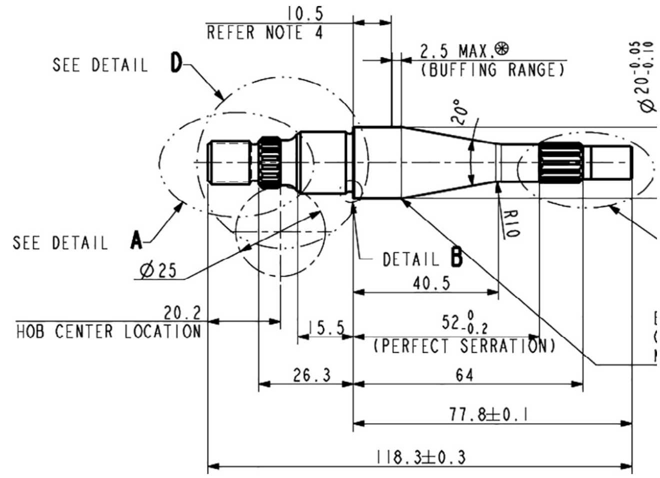


**Fig. 3.1.** Dimensions of the shaft.

### 3.3. Process

Initially raw material of 30 mm diameter was taken and subjected to skin turning for 2 mm diameter The raw material was hardened at 900 °C for 2 h, observed value was 65 HRC to 70 HRC

It was later quenched in oil for about 4–5 h. Subsequently it was tempered at 500 °C for 40 HRC, 450 °C for 45 HRC, 250 °C for 55 HRC and quenched in air for about 2 h.

The following are the microstructure images obtained at different tempering temperatures. (Refer Figs. 4.1, 4.2, 4.3, 4.4).

## 4. Results and discussions

### 4.1. Heat treatment details

Heat treatment details of the material is given in table 4.1

The following are the microstructure images obtained at different tempering temperatures. (Refer Figs. 4.1, 4.2, 4.3, 4.4)

### 4.2. Tensile strength

Tensile strength was found out for the shaft before and after heat treatment.

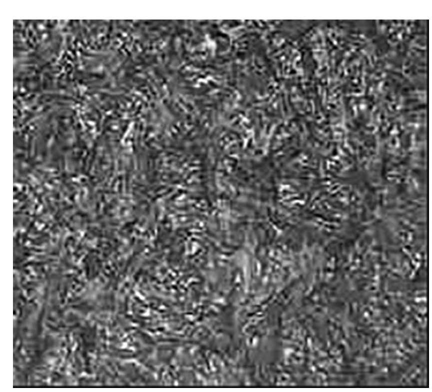

**Fig. 4.1.** Microstructure at 250 °C Tempering temperature.

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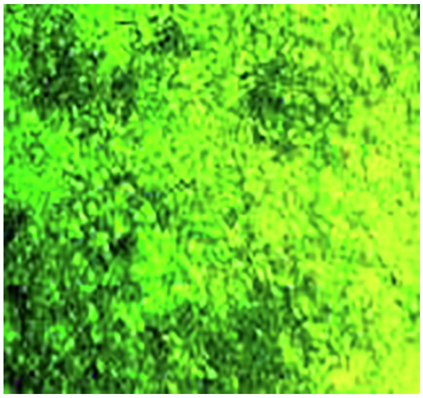

**Fig. 4.2.** Microstructure at 450 °C Tempering temperature.

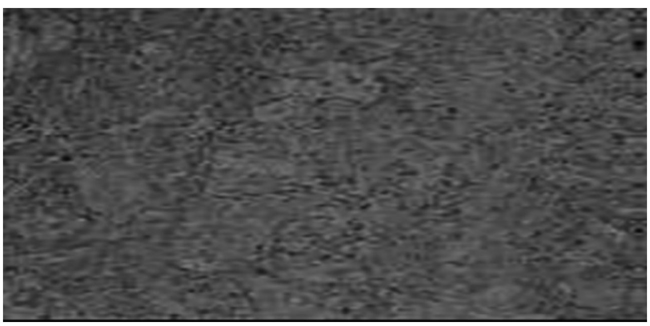

**Fig. 4.3.** Microstructure at 500 °C Tempering temperature.

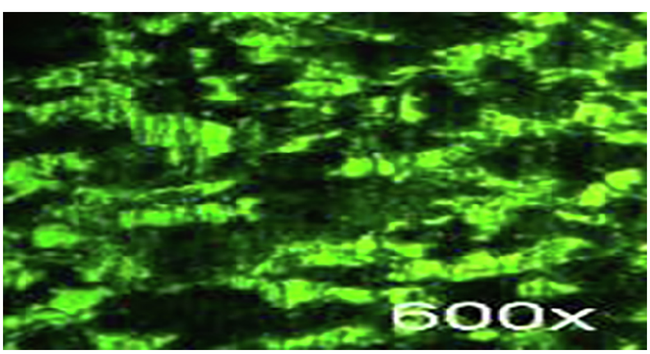


**Fig. 4.4.** Microstructure without heat-treatment.

**Table 4.1**
Tempering temperature for different hardness.

| Material Hardness(HRC) | Tempering Temperature(°C) | Cooling Time (hours) | Quenching Medium |
|---|---|---|---|
| 55 | 250 | 2 | Air |
| 45 | 450 | 2 | Air |
| 40 | 500 | 2 | Air |

Below table shows the result of tensile strength carried out for material with different hardness obtained by heat treatment (Refer table 4.2).

## 5. Conclusion

Hence depending upon the properties and applications of the work material we should select a suitable heat treatment processes

**Table 4.2**
Tensile strength value.

| Material Hardness (HRC) | Ultimate Tensile Strength (MPa) |
|---|---|
| RAW | 641.35 |
| 40 | 809.86 |
| 45 | 823.58 |
| 55 | 905.80 |

for 16MnCr5.Character steel for case hardening for parts requiring core strength of 800 to1000 N/mm$^2$ and high wear resistance. Application guiding elements, cores and machine parts with high surface hardness; Synthetic resin press moulds for processing thermoplastics and thermosetting plastics. Treatment methods: Etching, Polishing, EDM, Nitriding etc. Usually, hardened parts are not nitride due to loss of hardness. Hard chroming: recommended, increases wear and corrosion resistance. Annealing: 670 to 720 °C for about 2 to 5 h Slow controlled cooling, further cooling in air, max.206 HB Case hardening: 860 to 930 °C in powder/salt bath, cooling in oil/hot bath at 160 to 250 °C Carburizing: 900 to 950 °C. The choice of the carburizing means and carburizing temperature depends on the desired surface carbon content, the carburizing graph and the required case depth. Intermediate annealing: 630 to 660 °C, for about 2 to 4 h with slow furnace cooling. Preheating: 350 °C depending on dimension. Hardening: Curing temperature 810 to 830 °C hardens in 60 °C hot oil. Cooling: Down to about 100 °C in oil, then in air to about 50 °C.Tempering:1 h per 20 mm part thickness, min. 2 h.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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