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# A Review on Optimization of Heat Treatment Process Parameter for High Speed Steel Taper Shank Drill

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**Abstract**: *Drilling is a cutting process that uses a drill bit to make or widen a hole of circular cross section in solid material. The Bit is pressed against the work piece and rotates at high speed, Due to the increasing competitiveness in the market, the performance of drill bit must be increased. There are various methods to improve the performance of Tool Steel like Surface coating, cryogenic treatment, and optimization of heat treatment process parameter to obtain best possible metallurgical properties. By comparing with other competitor it is revealed that there is gap in performance of Taper Shank Drill. This project based on Optimization of Heat Treatment Process Parameter to improve performance with reduction in cost per component. High Speed Steel M2 material is used as drill material for experimentation. There are four parameter in heat treatment process i.e. soaking temperature, soaking time, tempering temperature and tempering time. Different experiments are performed, for that Taguchi orthogonal array (L9) is used with three levels of heat treatment process parameter. From the response of design of experiments the desired heat treatment cycle is selected. The performance of Taper shank drills in terms of number of holes drilled between two re-sharpening has to be measured. And it is expected from project that the performance of drill in terms of number of drill to be improved with a best possible temp-time relation.*

**Keywords**: HSS M2, Taguchi Orthogonal Array, Hardness, Heat treatment.

## I. INTRODUCTION

Metal cutting process forms the foundation of the engineering industry and is involved either directly or indirectly in the manufacture of nearly every manufactured goods of our modern civilization. The cutting tool is one of the important elements in realizing the full budding out of any metal cutting operation. Over the years the burdens of economic competition have motivated a lot of research in the arena of metal cutting leading to the development of new tool materials of remarkable performance and vast potential for a remarkable increase in productivity. Changes in work piece materials, manufacturing processes and even government guidelines catalyse parallel advances in metal cutting tooling technology.

As manufacturers continually seek and apply new engineering materials that are lighter and tougher and therefore more fuel efficient it follows that cutting tools must be so established that can machine new materials at the highest possible productivity. The most important basics in the design of cutting tools is the material construction and there judicious selection The properties that a tool material must possess are as follows:

1. Capacity to hold firm stability at elevated temperatures during high cutting speeds.
2. Cost and easiness of fabrication.
3. Resistance to thermal and mechanical shock.
4. Highly resistance to brittle fracture.

Developmental activities in the area of cutting tool materials are guided by the knowledge of the extreme circumstances of stress and temperature produced at the tool-work piece interface. Tool wear happens by one or more complex mechanisms which comprises abrasive wear, chipping at the cutting edge, thermal cracking etc. Since most of these processes are significantly accelerated by increased temperatures, the more obvious requirements for tool materials are enhancements in physical, mechanical and chemical properties.

## II. Objective

1. To improve the Performance of drill in terms of number of holes to be drilled.
2. To obtain better hardness of the tool material.
3. To obtain better microstructure with uniform distribution of carbides.
4. To optimize heat treatment process parameter that will give desired temperature time relation.

## III. Literature Review

A comprehensive literature review summarizing the previous published work relevant to research work in improving the performance of high speed tool material and the influence of the various heat treatment process on their mechanical properties.

**V.K. Murugan, P. Koshy[1]** Mathewshas discussed in his paper an optimal setting of carburizing process parameters (carburizing temperature, soaking time, gas diffusion effect ,furnace air circulation ) causing in optimal values of the correct depth of the case in the surface of the components. Taguchi method is a influential design of the experiment (DOE) tool for engineering optimization of a process and they concluded that The Taguchi method efficiently, obtains optimal heat treatment parameters for the plain low carbon steel, reduces the number of experiments, and analyzers the effect of each heat treatment parameter on the experiment results and the contribution of individual parameters.

**S.Z. Qamar [2]** has analysed results of mechanical testing performed on variously heat treated H11 steel samples, to arrive at an optimum heat treatment strategy for hot work applications. The tensile and impact test specimens were fabricated using precision milling and EDM. These samples were exposed to various heat treatment arrangements, consisting of annealing, hardening, air and oil quenching, and tempering at different temperatures. Heat treated samples then mechanically tested for hardness (Rockwell), impact toughness (Charpy), and tensile properties (yield strength, ultimate strength, ductility). The paper concludes that mechanical testing of H11 samples revealed that with increasing temper temperatures hardness first increases to a maximum and then gradually decreases; impact toughness first decreases to a minimum and then increases.

**Harvinder Singh, Aneesh Goyal [3]** found out that the Cryogenic treatment process uses sub-zero temperatures down to -184°C to modify the micro-structure and properties of material. This process is an extension of heat treatment which further improves the properties of material. This paper focuses on the effect of cryogenic treatment on High Speed Steel (T-15) tool material. Cryogenic treatment at -184°C is conducted in this research and its properties compared with untreated material. It has been found that as the temperature is decreased, microstructure of material is refined and more number of carbide precipitates appeared on the surface after the treatment. Interestingly to note that the retained austenite is completely converted into marten site after subjecting the T42 HSS specimen to cryogenic treatment.

## IV. Problem Definition

The productivity, cost and quality are the main factors which have to be optimally managed in order to sustain in today's competitive world. Existing performance of Taper Shank Drills is lesser than TS Drills manufactured by other Competitor. Due to less performance, Taper Shank Drills manufactured are costlier than other competitor Drills in terms of CPC (cost per component).

## V. Methodology

Heat treatment can be defined as a sequence of heating & cooling designed to get desired combination of properties in the steel. The deviations in the properties of steel after heat treatment are due to phase transformation and structural changes that happen during the heat treatment. The factors which determine & control these structural changes are called as principles of heat treatment. These principles are as follows:

1. Phase transformations during heating
2. Effect of cooling rate on structural changes during cooling
3. Effect of carbon content & alloying elements

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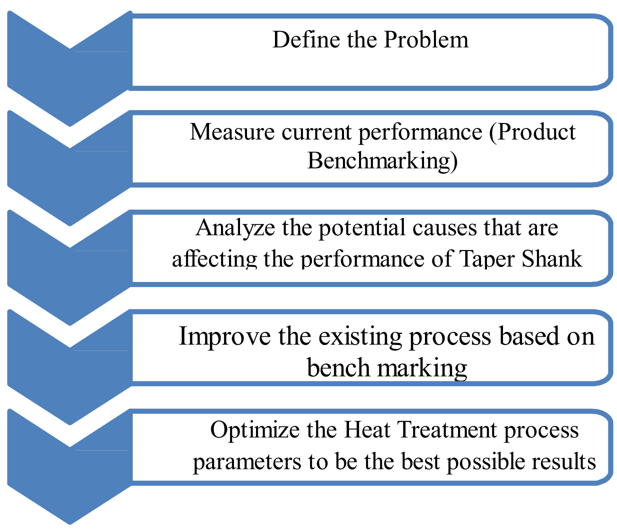
The heat treatment process can be divided into four main areas, preheating, austenizing, quenching and tempering.

1. **Preheating-**from a metallurgical view, it plays vital role as it reduces thermal shock, which always result when a cold tool is placed into warm or hot furnace. It also reduces stresses developed during machining or forming.
2. **Austenitizing (hardening)** is a time/temperature dependent reaction. High speed tool steels depend upon the melting of various complex alloy carbides during austenizing to develop their properties.These alloy carbides do not melt to any appreciable level unless the steel is heated to a temperature within 28 to 56 °C of their melting point. This temperature is reliant on upon the particular high-speed tool steel being heated and is in the range of 1150 to 1290 °C.The generally suggested hold time for high-speed tool steel is approximately 2 to 6 min, depending upon high-speed tool steel type, tool shape, and cross-sectional size. Lowering the hardening temperature (under hardening) generally improves the impact toughness while dropping the hot hardness. Rising the hardening temperature rises heat-treated room-temperature hardness and also increases the hot hardness.
3. **Quenching**- The quenching or cooling of the work piece from the austenitizing temperature is considered to transform the austenite that forms at the high temperature to a solid martensitic structure. The rate of cooling, which must be well-ordered, is dictated by the analysis of the particular steel. Occasionally high-speed steels are quenched in two steps, initially in a molten salt bath maintained at approximately 540 to 595 °C or an oil quench, and after that by air cooling to near ambient temperature. The minimum drastic form of quenching is cooling in air, though only in the smaller or thinner cross sections would high-speed tool steels air quench quickly enough to transform the majority of the structure into the desirable martensitic condition.
4. **Tempering -** After austenitizing and quenching, the steel is in a highly stressed state and therefore is very vulnerable to cracking. Tempering (or drawing) rises the toughness of the steel and also provides secondary hardness, Tempering includes reheating the steel to an intermediate temperature range (always below the critical transformation Temperature), soaking, and air cooling.Tempering assists to stress relieve and to transform retained austenite from the quenching step to new martensite. Some precipitation of complex carbide also occurs, further enhancing secondary hardness. It is this procedure of transforming retained austenite and tempering of newly formed martensite that dictates a numerous tempering procedure.




**A. Define Phase**

Define phase is the first & most important activity in quality improvement activity. Define phase involves problem details, identifying of the process to be improved, objectives of the project etc**.**

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| Sr. No. | Parameter | Details |
|---|---|---|
| 1 | Problem Statement | Less Performance |
| 2 | Part number selected for study | 14mm, 16mm, 26mm dia. |
| 3 | Suspected manufacturing process | Heat Treatment |
| 4 | Process stages where the problem is inspected | Endurance Testing |
| 5 | Objective of the project | To improve the performance of Taper Shank Drills |

**Table 1:** Define Phase

**B. Measure (Benchmarking)**

Product Benchmarking was carried out with the leading competitors: Following are the performance test parameters:

1. Column Drilling M/C
2. Cutting Speed- 500 RPM
3. Cutting Feed- 100 mm/min
4. Depth of Hole- 48 mm
5. Test Specimen- EN9 (C: 0.45%-0.65%
6. Testing Block Hardness- 229 BHN
7. No. of Holes after Two Regrinding

**Performance Test Results**

| Size (mm) | Performance (No. of Holes) | | |
|---|---|---|---|
| | Existing Performance | Competitor I | Competitor II |
| 14 | 37 | 59 | 63 |
| 16 | 35 | 50 | 53 |
| 26 | 19 | 30 | 32 |

**Table 2:** Performance Test Results

**C. Analyze**

**a. Analysis of Hardness**

After Analysis of Hardness, it is observed that the hardness of Taper Shank Drills manufactured, is lesser than those which are manufactured by Competitor I and Competitor II. The performance of Taper Shanks Drills primarily depends on the hardness. Hardness is most important stipulated property that any cutting tool must have.

| Size (mm) | Hardness (VHN) | | |
|---|---|---|---|
| | Existing hardness | Competitor I | Competitor II |
| 14 mm | 798 | 849 | 856 |
| 16 mm | 792 | 856 | 869 |
| 26 mm | 804 | 856 | 869 |

**b. Analysis of Microstructure**

The microstructure of competitor II Taper Shank Drills has high volume of fraction of Carbides with uniform distribution. The microstructure of Taper Shank Drills manufactured shows uneven carbide distribution and carbide segregation. It affects the performance of Drills.

**Figure 4:** Microstructure of Hardened & Tempered Drills Samples (HSS M2 at x50)

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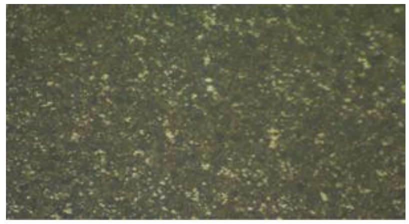

**Figure 5:** Microstructure of Hardened & Tempered Drills Samples of Competitor I (HSS M2 at x50)

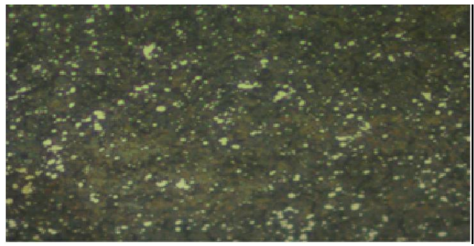

**Figure 6:** Microstructure of Hardened & Tempered Drills Samples of Competitor II (HSS M2 at x50)

## VI. Experimental Details

Design of experiment is powerful tools for analyzing the influence of the process variables covers some specific variable, which is a unknown function of these process variable. The major step in the taguchi method is the selection of the factors affecting the performance measures. The table shows the parameters and the corresponding levels chosen for the investigations. The multiple response characteristics including four heat treatment parameters are chosen on the output parameter to validate the effectiveness.

The standard experiment layout 3 level OA L9 ($3^4$) for factors are listed for this cases and shown in the following table. The experiments are performed for the various heat treatment cycle as per the layout. And the response or hardness will be measured for various experiments. At the optimum Hardness with the approach of "Larger the better". The cycle will select which will be the optimal solution for existing problem.

## VII. Expected Outcome

1. Experiments have to be performed for optimization of Heat Treatment of Taper Shank Drills. The hardness, microstructure (grain size & carbide distribution) & performance has to evaluate.
2. Max Hardness should be achieved which at par with the desired level.
3. More Uniform distribution of fine carbide.
4. Performance of Taper Shank Drills has to be improved in comparison with other competitor in terms of number of holes to be drilled.
5. A Significant Reduction in cost per component is expected with more improved performance.

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