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Heat Treatment Process Parameter optimization for HSS 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, drill bit, Taguchi Orthogonal Array, Hardness, Heat treatment, hardness.

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 at elevated temperature. Traditional tool materials such as HSS continue to experience considerable improvement in their properties through suitable alterations in their composition by optimizing the processing method as well as incorporating various surface treatments. As a result of

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these technological developments HSS are still in use having surviving rivalry from carbides and ceramics.Carbide because of the ability to hold its strength and hardness at very high temperatures, to withstand cutting speeds 6 or more than 6 times advanced than tools of HSS and the cost-effective price has become a logical choice of many cutting industries. However with the combination of suitable surface treatments, its service life as well as its properties can be enhanced even more.

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 optimize heat treatment process parameter that will give desired temperature time relation.

III. LITERATURE REVIEW

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. The micro structural changes results in improvement of properties of HSS, (T-15) tool material.

O.O. Joseph, R.O. Leramo [4] has studied The effect of heat treatment at 850oCon the microstructure and mechanical properties of SAE 1025 carbon steel has been studied. Annealing, normalizing and age-hardening heat- treatments at 850oC were used for the experimental work. Hardness tests, tensile tests and metallography were done on the heat-treated and controlled samples. The results were additionally analysed using the one-way ANOVA test. Results obtained showed significant differences in the microstructure and mechanical properties of the different heat- treated samples. And observed that higher tensile strength was observed for the annealed samples than for the control, normalized and age-hardened samples. A microstructure of improved quality was obtained with normalizing heat treatment whereas a lesser quality was obtained by age-hardening.

Dennis W. Hetzner, William Van Geertruyden [5] studied crystallography and metallography of carbides in high alloy steels. The carbides in high carbon, high chromium bearing steels, high chromium carburizing steels, newly settled easily carburizable low carbon, low chromium high speed steels and M62 high speed steel fabricated by powder metal processing were studied. The particular steels assessed include 440C, BG42.M50-Nil, CHS1, M2, CHS50, and M62. The morphology and structure of the carbides were evaluated by means of metallography, X-ray diffraction and electron beam backscattered diffraction. The combination of these three techniques has provided new insight into how different carbide morphologies form throughout processing and the carbide structures that can be expected to be present in components fabricated from these steels by various types of heat treating.The literature survey concludes optimization of heat treatment plays a vital role in the consistent performance of cutting tools. Hardening and Tempering cycle need to be optimally managed for getting required toughness in order to absorb shocks during application. The present paper discusses the optimization of Hardening & Tempering process of Taper Shank Drills manufactured to improve the performance, hole quality thereby reducing CPC (cost per component)

IV. MATERIAL

HSS M2 Material- commonly used tool material. M recognizes molybdenum content. Its bending strength can reach 4700 MPa.

Table 1: Composition of alloying element

Alloying element	(By % wt.)
C	0.95
Cr	4
Mo	5
W	2

V. METHODOLOGY

The objective of this project is to improve quality & consistency in the performance of Taper Shank Drills. For this project, DMAIC methodology is followed:

5.1 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.

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 2: Define Phase

5.2 Measure (Benchmarking)

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

- Column Drilling M/C
- Cutting Speed- 500 RPM
- Cutting Feed- 100 mm/min
- Depth of Hole- 48 mm
- Test Specimen- EN9 (C: 0.45%-0.65%
- Testing Block Hardness- 229 BHN

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 3: Performance Test Results

5.3 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

Table 4

VI. IMPROVEMENT AREAS

When a system is subjected to free vibration and the system is considered as continuous system in which the beam mass is considered as distributed along with the stiffness of the shaft. In such case the equation of motion of a cantilever beam is given as (Meirovitch, 1967)

6.1 Problems Identified in Existing Heat Treatment Practice

1. Inconsistent soaking time
2. Variation in hardness
3. Poor control over grain sizes
4. Over heating: It results in excessive distortion, irregular grain growth, loss of ductility and low strength
5. under heating: It results in low hardness and low wear resistance

6.2 Improvement in Existing Heat Treatment Process

Hardening and tempering process is to be optimized for the different diameters of Taper Shank Drills: 14mm, 16mm, and 26mm.

For this purpose, Taguchi design (DOE) (L9) will be used by three deferent levels of Soaking Temperature, Soaking Time, tempering temperature & tempering time to arrive at the optimum Hardness with the approach of "Larger the better" The effect of these parameters (between low, medium and high) on hardness is to be measured.

Symbol	Factor	Unit	Range
A	Soaking Temperature	°C	1190 – 1220
B	Soaking Time	Seconds	220–280
C	Tempering temperature	°C	540–590
D	Tempering time	min	75–120

Table 5: Fermentation factor

6.3 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 (34) for factors are listed for this cases and shown in the following table. The experiments are performed for the various heat treatment cycles 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.

Sr. No	Soaking temp	Soaking time	Tempering temp	Tempering Time	hardness
1	1190	205	545	90	690
2	1190	225	560	105	710
3	1190	245	575	120	720
4	1205	205	575	105	810
5	1205	225	545	120	829
6	1205	245	560	90	842
7	1210	180	560	120	790
8	1210	210	575	90	823
9	1210	245	545	105	836

Table 6: Experimental Details For 16 mm Subgroup, Taper Shank Drills

VII. RESULT AND DISCUSSION

Hardness: The experiments were performed by varying the heat treatment parameters and the average response of the factors is measured. with three deferent levels of Soaking Temperature, Soaking Time, tempering temperature & tempering time to arrive at the optimum Hardness with the approach of "larger the better." This will give desired temperature time relation. Similarly for other drill the experiments were performed. Table shows the optimized hardness with best temp time relation

Sr. No.	Drill Size	Hardness(VHN)
1	14	849
2	16	845
3	26	835

Table 7: Result table with optimized temperature time Relation

Size (mm)	Performance (No. of Holes)		
	Existing Performance	Competitor I	Competitor II
14	52	59	63
16	49	50	53
26	32	30	32

Table 8: Performance test with optimized temperature time Relation

VIII. CONCLUSION

- Experiments have to be performed for optimization of Heat Treatment of Taper Shank Drills. The hardness & performance has to evaluate. Significant improvement expected in the performance of Taper Shank Drills. Including following points.
- Maximum Hardness should be achieved which get up to 849 VHN.
- Performance of Taper Shank Drills is improved to in comparison with other competitors.
- Optimization of heat treatment significantly improves the performance of tool.

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