A STUDY ON IMPROVEMENT OF TOOL LIFE THROUGH MODIFICATION OF CENTER DRILL

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ABSTRACT

The main objective is to review various modifications done on various Drill parameters such as helix angle, web thickness, and rack angle to obtain maximum tool life. The research contributions are classified into methodology for investigation and analysis, input processing conditions and response variables. A number of drilling experiments were conduct on a CNC drilling machine to increase tool life as trial and error methods. The experiments are performed on C45 material mostly. Analysis of variance was employed in general to determine the most significant control factors affecting the tool life. After the number of experimental trials, one can try to find the most significant factor for the tool life increment.

Keyword: - *Drilling, geometry, tool life, tool wear*.

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1. INTRODUCTION

Drills are used for create a hole which operate under difficult conditions resulting from the constant availability of the stock around the tool, the hampered removal of the chips and the rather difficult application of coolants to the cutting edges. The tool life and machining properties of drills are to a large extent influenced by the shape of the cutting element; the size, angle of inclination and shape of the flutes; the materials of which the drill is made, and partly also by the coating of its machining part and the quality of production of the drill.
It was the aim of these investigations to determine the geometry of the drill and to increase the tool life of drill, so that it might be applied in the machining of C45.

1.1 Tool life

The amount of satisfactory performance by fresh tool till it declared failed.

2. LITERATURE SURVEY

A.R.C. Sharman, 2008 [1] analyzed the general machinability of Inconel 718 a series of experiments examining the tool life/wear of various commercially available drills, recommended for use on nickel-based super alloys is used. Drills with a curved cutting edge and radius on the periphery were shown to have superior performance when drilling Inconel 718 compared to drills with an either a straight or concave cutting edge and sharp periphery. Drills with a curved cutting edge and radius on the periphery were shown to have superior performance when drilling Inconel 718 compared to drills with either a straight or concave cutting edge and sharp periphery (up to three times the number holes drilled).

A.R. Zareena and S.C. Veldhuis, 2012 [2] works on tool wear mechanism and tool life enhancement in ultra precision machining of titanium. In this case the PFPE coating was found to act as an effective barrier delaying the onset of graphitization of the tool and thus allowing the tool to retain its sharp edge longer. This delayed the generation of conditions causing rapid adhesion of titanium to the tool which in turn extended the functional life of the tool and so allowing for a larger final part to be produced with a single tool.

B. Denkena and D. Biermann, 2009 [3] describe the Cutting edge geometries**.** Tool life and performance are decisively determined by cutting edge geometry. An appropriate shape of the cutting edge improves wear resistance, tool life and process reliability. Paper reviews major developments in cutting edge preparation technologies and methods of cutting edge characterization. Moreover, the influences of cutting edge geometry on chip formation, material flow, as well as mechanical and thermal loads on the tool are discussed. The essential modeling and simulation approaches are presented. Effects on surface integrity are described. Finally, an overview of important perceptions for prospective research and development field is provided.

D. Biermann, 2009 [4] optimized the process adapted structure of deep hole drilling tools. Problems when drilling ductile materials, the removal of cooling lubricant and chips can be hindered by long chips which block the inside of the chip mouth. In order to increase the volume flow rate of the cooling lubricant and chips, the chip mouth cross-section of a commercially available state-of-the art boring tool was analyzed. Therefore, a structured approach with model experiments, FEM analysis and structure topology optimization was conducted. Moreover, the performance tests show that with the optimized drill head a significant improvement is achievable. This is because of enlarging the chip mouth cross sections.

J. Kosmol, 2015 [5] optimized the drills for the machining of austenitic steel. It deals with the results of investigations on the design of a twist drill for the machining of austenitic steel. The wear of the drill points as well as the roughness and erroneous shape of the bore-holes have been measured. The results of experimental investigations indicate that drills with a cross-section achieved by means of optimization, making use of FEM, are characterized by good cutting properties. We can only say that the optimized drills are better than the standards.

J. Wang and Q. Zhang, 2008 [6] studied on a modified drill point design with plane rake faces for drilling high-tensile steels. A geometrical analysis has shown that the modified drill point design yields positive normal rake angle on the entire lips and point relieving in the vicinity of the chisel edge. This drill geometry can be expected to reduce the cutting forces and torque, and hence reduce the possible drill breakages when drilling high-tensile steels. Drill-life tests have also been carried out. In some cases, the conventional drills were broken inside the workpiece, while the modified drills performed very well under the same cutting conditions.

Erkki Jantunen, 2002 [7] has presented a summary of method applied to tool condition monitoring in drilling. The monitoring method, signal analysis and diagnostic techniques for tool wear and failure monitoring in drilling that have been tested and reported in the literature. The paper covers only indirect monitoring methods such as force, vibration and current measurements Signal analysis techniques cover all the methods that have been used with indirect measurements including e.g. statistical parameters and Fast Fourier and Wavelet Transform. Only a limited number of automatic diagnostic tools have been developed for diagnosis of the condition of the tool in drilling. In the reported material there are both success stories and also those that have not been so successful.

S. Gerardis, 2009 [8] presents the effect of micro-blasting conditions such as pressure and duration on film mechanical properties, cutting edge geometry and thus on tool life is introduced. FEM supported method is used to obtain tool wear result. Micro-blasting pressure and duration increases lead to high coating material deformation. In this way a cutting performance increase up to 50% can be achieved. Tool life increase up to a pressure of 0.2 MPa is induced by the superficial hardness increase.

M. Henerichs Et al, 2014 [9] focuses on required drilling tool characteristics for a large tool life time of diamond coated carbide tools. The machining tests are being conducted at different feed rates and cutting velocities. Two different nano-crystalline diamond coatings are being evaluated regarding wear resistance depending on the drill geometry and tool diameter. A change in wear resistance depending on the tool geometry is not unique for different diamond coatings. A rake angle of 25°, as used for geometry Model shows better machining quality and lower feed forces**.**

M. V. Kowstubhan and P. K Philip, 1991 [10] generated the tool-life equation for Tools of TiN-coated high speed steel. Efforts are made to understand the behaviour of TiN coats 5 micron thick on the performance of turning tool. Two types of cutting tools were used to turn Cl5 low carbon steel workpieces. They are conventional M42 HSS and the other TiN coated M42 HSS tools. A conventional HSS tool was used as a benchmark. A stepwise multiple regression analysis was used to investigate the combined effect of speed and feed on tool-life. This is found to have more effect on the tool-life equation of TiN-coated HSS tools. The tool-life of TiN-coated tools was found to be from 3 to 10 times higher than the conventional HSS tool under all cutting conditions. The maximum tool-life for both coated and uncoated tools was found to be at a cutting speed of 20 m/min TiN-coated tools perform better even at high cutting speeds and feeds where conventional tools fail.

3. DESIGN OF EXPERIMENT

3.1 General factorial designs

In statistics, a full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible combinations of these levels across all such factors. A full factorial design may also be called a fully crossed design. Such an experiment allows the investigator to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable.
If the number of combinations in a full factorial design is too high to be logistically feasible, a fractional factorial design may be done, in which some of the possible combinations (usually at least half) are omitted

3.2 Taguchi method

Taguchi's philosophy is an efficient tool for the design of high quality manufacturing system. Dr. Genichi Taguchi, a Japanese quality management consultant, has developed a method based on orthogonal array experiments, which provides much-reduced variance for the experiment with optimum setting of process control parameters. Thus the integration of design of experiments (DOE) with parametric optimization of process to obtain desired results is achieved in the Taguchi method. Orthogonal array (OA) provides a set of well balanced (minimum experimental runs) experiments and Taguchi's signal-to-noise ratios (S/N), which is logarithmic functions of desired output serve as objective functions for optimization. You can also add a signal factor to the Taguchi design in order to create a dynamic response experiment. A dynamic response experiment is used to improve the functional relationship between a signal and an output response.

Table 1: Parameters considered for modified design

Parameters	Level 1	Level 2	Level 3
Helix angle	27°	30°	33°
Web taper (mm)	0.8	1	1.2
Web thickness (mm)	0.8	0.9	1

4. METHODOLOGY

4.1 Work piece material

EN-24 is used for applications in which high strength, hardness and wear resistance are necessary. The common applications of EN-24 are air craft, heavy vehical crank shaft, connecting rods, gear shaft, clutches, propeller shaft, cam shafts, spindle and boring bars etc. By using drilling operation surface finished parts made from EN where finished product is very hard and wear resistance.

The work material selected for experimental work was EN-24.
Flat plate dimension for material:
Dimension: 100×100×50

Table 2: Chemical Composition of EN-24

Product	C	Si	Mn	Cr	Mo	Ni	Others
Percentage(%)	0.44	Max 0.35	Max 0.70	Max 1.40	Max 0.35	Max 1.70	Max 0.75

Table 3: Mechanical Properties

Properties	Metric
Tensile strength	850 N/ mm^2
Yield stress	680 min N/ mm^2
Hardness	248 HB
Rockwell hardness	28-32 HRC

Figure 1 Workpiece EN-24

4.2 Tool Detail

Miranda center drills are made from M2 grade of HSS. Miranda center drills are manufactured with ground flutes. Center drills are available in bright finish or with coating TiN , TiCN , TiAlN.

Table 4: M2 HSS Chemical Composition in %

C	Si	Cr	V	W	Mo	
0.83	0.33	4.13	1.98	6.13	5	Normal C
1	0.33	4.13	1.98	6.13	5	High C

Table 5: M2 HSS Physical Properties

Properties	Metric
Density	0.295 lb/ cu. In
Melting Point	2600 deg F
Specific Gravity	8.16
Tempering temperature	1025˚ f

Table 6: Geometry Parameters of Center Drill

Center drill parameters	Type A 3.15×8 IS
Pilot diameter	3.15 mm
Shank diameter	8 mm
Overall length	50 mm
Pilot length	4.90 mm
Web thickness	0.9 mm
Point leap relief	15˚
Lead	38.61 mm
Helix angle	27˚
Pilot relief	0.24 mm
Countersink relief	8˚
Web taper	1.2 mm

Application: The center drills are designed with spiral flutes for producing high quality center hole with 60˚ countersinks.

Table 7: Compare study Parameters

Parameters	Existing Tool	New Tool
Helix angle	27˚±3˚	30˚±3˚
Web thickness (mm)	0.75 mm	0.8±0.1 mm
Web taper (mm)	0.70 mm	1±0.2 mm

4.3 Mazak Milling Machine Specifications:

Table 8: Mazak Center Smart 430AS CNC Machine Specification

Model	VERTICAL CENTER SMART 430A
Table size	900×430
Travel (X/Y/Z)	560/430/510 mm
Rapid traverse rate(X,Y,Z)	42000 mm/min
Spindle (5min. rating)	12000 rpm, 18.5 Kw (25HP)
Tool shank	MAS BT-40, CAT-40
Tool storage capacity	30
Floor space requirement	2080 × 2624 mm
Factory location	JAPAN

Figure 1: Vertical Center Smart 430AS

5 RESULTS AND ANALYSIS

5.1 Result of Tool Life Test

The tool life test of machined plates is completed on mazak VMC. The tool life test of each tool held according to orthogonal array is shown in Table 9.

Table 9: Results of Tool Life Test

Tool no	Helix angle	Web taper(mm)	Web thickness(mm)	Tool life(no)
1	27˚	0.8	0.8	182
2	27˚	1.0	0.9	153
3	27˚	1.2	1.0	15

4	30˚	0.8	0.9	247
5	30˚	1.0	1.0	194
6	30˚	1.2	0.8	102
7	33˚	0.8	1.0	298
8	33˚	1.0	0.8	378
9	33˚	1.2	0.9	69

5.2 Calculation of S/N Ratio for Tool Life

For calculating S/N ratio for this case of higher the better Taguchi has outlined an equation. The equation to obtain the values of S/N ratio is shown below:
S/N = -10log10 (MSD)

Table 10: S/N Ratio for Each Tool for Tool Life

Tool No.	Helix angle	Web taper(mm)	Web thickness(mm)	Tool life(NOS)	S/N Ratio (dB)
1	27˚	0.8	0.8	182	45.2014
2	27˚	1.0	0.9	153	43.6938
3	27˚	1.2	1.0	15	23.5218
4	30˚	0.8	0.9	247	47.8539
5	30˚	1.0	1.0	194	45.7560
6	30˚	1.2	0.8	102	40.1720
7	33˚	0.8	1.0	298	49.4843
8	33˚	1.0	0.8	378	51.5498
9	33˚	1.2	0.9	69	36.7770

In Taguchi method the most essential criterion for analyzing experimental data is signal-to-noise ratio. According to this method, the S/N ratio should have a maximum value to obtain optimum design conditions. Thus, the optimum condition was found as 51.5498 S/N ratios for tool life in L9 orthogonal array in table 4.2. The optimum cutting conditions, which were the helix angle of 33˚, the web taper of 1 mm, and the web thickness of 0.8 mm (3 2 1 orthogonal array) were obtained for the best tool life values. According to the Taguchi design, the level values of the factors obtained for tool life and their interpretations may be made according to the level values of A, B and C factors are given in Table Fig. shows the optimum cutting conditions of experiments to be conducted under the same conditions.

Table 11: Response Table for Signal to Noise Ratios

Larger is better

Level	Helix angle	Web taper	Web thickness
1	37.47	47.51	45.64
2	44.94	47.00	42.77
3	45.94	33.49	39.59
Delta	8.46	14.02	6.05
Rank	2	1	3

The optimal level for each control factor was calculated based on highest S/N and shown in Table.4.3 for tool life. According to this, the factors giving the maximum tool life was specified as helix angle (A3, S/N = 45.94), web taper (B1, S/N = 47.51) web thickness (C1, S/N = 45.64). In another way, a good tool life value was obtained with a helix angle 33˚, at web taper 0.8mm and at a web thickness 0.8 mm.

5.3 Main Effect Plots for S/N Ratio

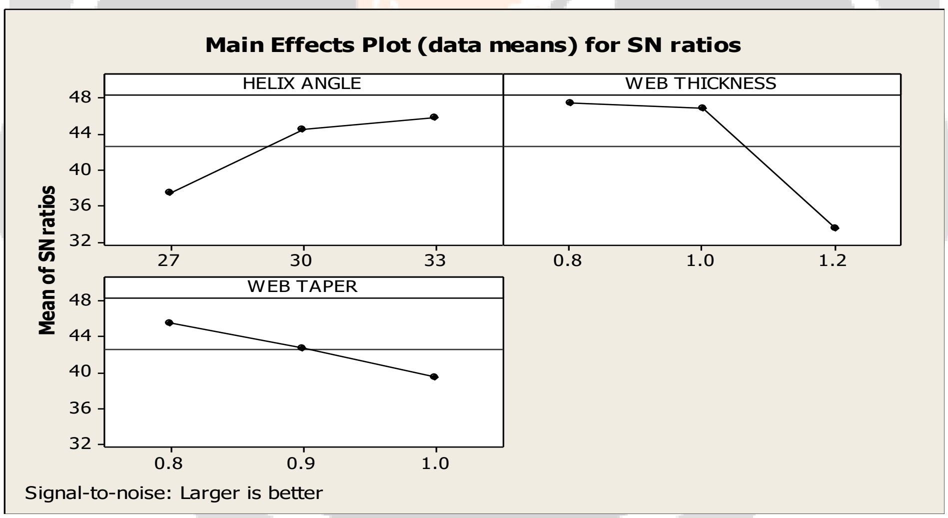

Figure 2: Main Effect Plot for S/N Ratio

Increase in helix angle, tool life increases. Helix angle increases from 27˚ to 30˚ the tool life increase.

5.4 Analysis of Variance for tool life model

Table 12: ANNOVA Table for Tool Life

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	77995	25998	5.10	0.056
Helix angle	1	26004	26004	5.10	0.073
Web taper	1	47883	47883	9.40	0.028

Web thickness	1	4108	4108	0.81	0.410
Error	5	25476	5095		
Total	8	103471			

In ANOVA, the F values of each control factor were compared to determine the significance each control factors. The higher F contribution, the higher the influence a factor has on the result. F ratio is the ratio between mean square and the mean square of the experimental error.

5.5 Residuals Plots for Tool Life

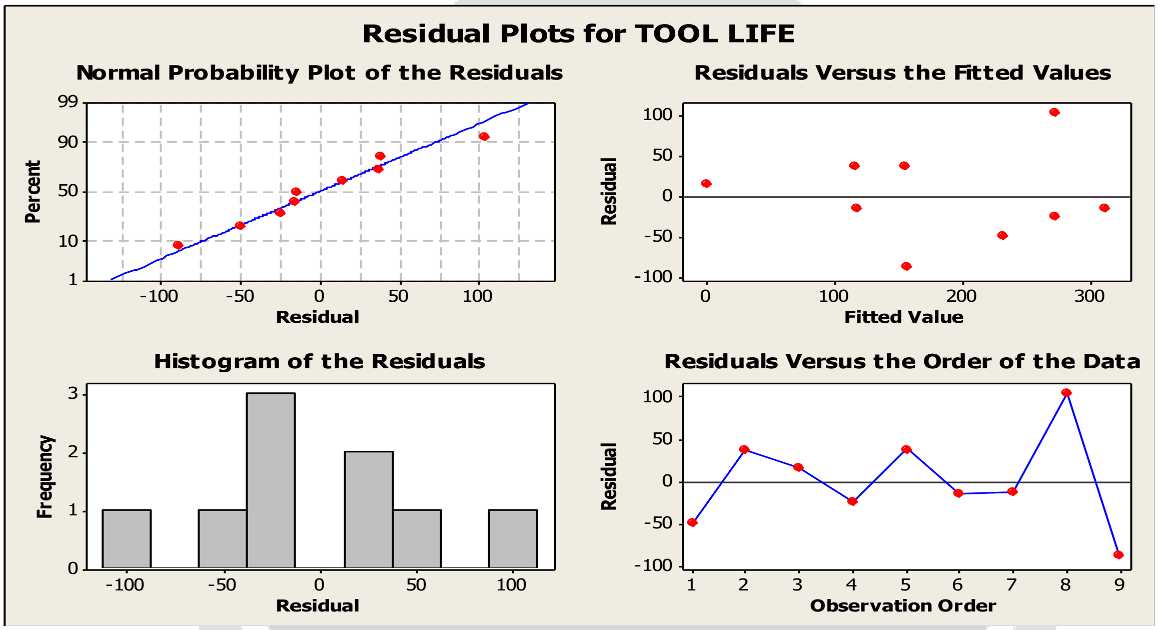

Figure 3: Residuals Plots for Tool Life

The normal probability plots of the response; tool life is depicted in Fig. 4.2. The graph shows that the data closely follow the straight lines, denoting a normal distribution.

5 CONCLUSION

The geometric parameters are studied in order to optimize tool life to the greater extent by understanding the concepts of establishing the values of geometric parameters. By using the suitable optimization procedure following conclusion has made,

- Tool life with helix angle 33˚, web taper 1mm and web thickness 0.8mm yield the optimal quality characteristics and increase tool life.
- Tool life was found 378 NOS holes at optimal setting from optimization model.
- The highest SN ratio in predicted results indicates that the optimization model is adequate.
- It was observed from S/N ratio plots that as helix angle increases the tool life decreases.
- Analysis of variance demonstrates that the web taper have the highest influence on the tool life.

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