

Drilling Process Parameter Optimization by DOE

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ABSTRACT

In automotive sector, process reliability is of prime importance. The CNC machines have to provide ample power and to be sturdier in construction, especially if work-hardening materials are to be drilled. The each machine center has to give optimum output with maximum efficiency. The major goal of DOE application on deep hole CNC drilling machine is to obtain minimized product and process variation and robust process development by optimum setting to reduce noise factor effect.

Keywords: Deep hole, CNC machining, Set-up-time.

1. INTRODUCTION

In automotive sector for drilling holes with a diameter of 15 mm and above, the automatic CNC machine principle of like BTA deep hole machining is usually employed. The precision hole producing requires four to five operations like drilling, boring, rough and finish reaming, honing [7]. Machining of bore holes with a high length to diameter ratio necessitates slender tool/boring-bar assemblies [5]. These components therefore have low dynamic stiffness properties which in turn can be the cause of dynamic disturbances such as chatter vibration and spiraling. Chatter occurs in the shape of self excited tensional vibrations of the tool and mainly leads to increased tool wear along with marks on the generally discarded bottom of the bore hole [4].

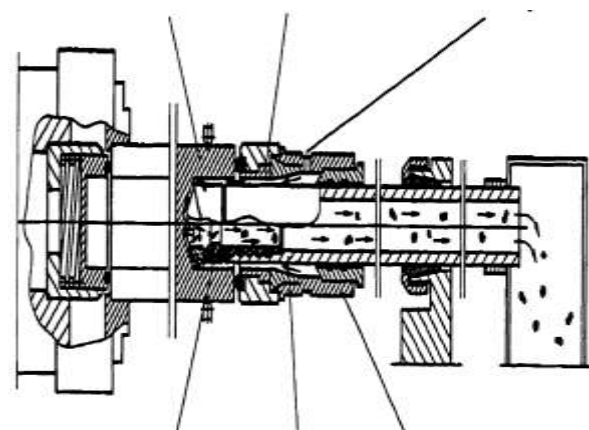
The deep hole drilling process is often used during the last production phases of expensive work pieces, process reliability is of prime importance. Prediction and prevention of this dynamic disturbance are therefore highly desirable. [2] To maintain optimum machining rates and to get the best out of a relatively expensive machining operation, the machines have to provide a close control of cutting conditions. The highest capacity in production is obtained, by manufacturing the required quantity of the product, of required quality, at required time, by the best and cheapest method. IN experiments, it was observed that surface quality increased by with

increasing cutting speed and decreased with increasing feed rate [3].

2. CNC MACHINE FEATURES

The tool is designed to balance the resultant cutting force by the counter-acting reactions on the two support pads [2]. Another special feature of these machine tools is a cutting fluid recirculation system incorporating both filtration and cooling facilities. The pump unit is separate from the machine and connected to the pressure head assembly by a flexible line to prevent the transfer of vibrations to the drill itself [1]. Pumps have to be capable of delivering pressures as high as 7-8 MPa for small diameter tools and longer holes, as well as flow rates as high as 200 l/min when drilling bigger diameters [4].

Work piece Guide bushing Inlet for cutting fluid



Drill head Bore shaft Pressure head

Fig.1: Setup of BTA drilling Process

3. SEQUENTIAL DOE

Competitiveness is one of the strategic goals for all companies. In manufacturing area employee satisfaction is disregarded while all the attention is given to production but it should not be forgotten that without considering employee satisfaction it is not easy to gather a good result or useful solution to enhance production like reducing the production time [10].

Design of experiment is a powerful statistical technique for determining the optimal factors setting of the process and thereby achieving improved process performance, reduced process variability and improved manufacturability of products and processes [9]. Design of experiment, DOE is an efficient procedure for planning experiment so that the data can be analyzed to yield valid and objective conclusion. Taguchi postulates that loss occurs increasingly as products deviate from target values [6].

To minimize the loss, products should be produced with minimal variations in their functional characteristics. The factors that affect functional characteristics of products are either by design compensation, saving is substantial, controllable or uncontrollable; the latter being called noise. Noise factors are difficult, impossible, or expensive to control [10]. The aim is to apply Taguchi method systematically for process optimization to control deep hole CNC drilling process and to get optimum design parameters in an economical process, as change in process parameters at manufacturing stage is very costly but at design stage its cost only 20% of manufacturing stage change cost.

The loss function is defined as “loss imparted by the product to the society, from the time the product is shipped” [8]. Taguchi views that the customer becomes increasingly dissatisfied as performance of the product or process moves away from the target. Further, Taguchi parameter design can improve the performance through the setting of process parameters [2].

4. METHODOLOGY

In any machine shop heavy investment is involved in special automatic high precision machinery for mass flow type operation. Any loss of manufacturing cycle time result into product high manufacturing cost due to ideal time in production process. In machine shop of current study different batches of products are processes on different machine center as per manufacturing cycle. Five control factors with two levels are decided as in table-1 and roundness error is measured at four different depths in each job.

Table-1. Control factors and levels

Symb.	Control factor	Level 1	Level 2
A	Tool diameter, d (mm)	18.90	26.50
B	Shaft length, l (mm)	1200	1600
C	Feed rate, f (mm/rev)	0.05	0.12
D	Cutting speed, v (m/min)	390	860
P	Cutting fluid pump used	P ₁	P ₂

The work piece material was AISI 1045 steel with dimension of Ø 50x300mm. The work piece was drilled to a depth of 200mm and cut into four equal pieces

(about 50mm long) after the drilling test. Smaller the best type S/N ratio is calculated as in Fig. no. 2.

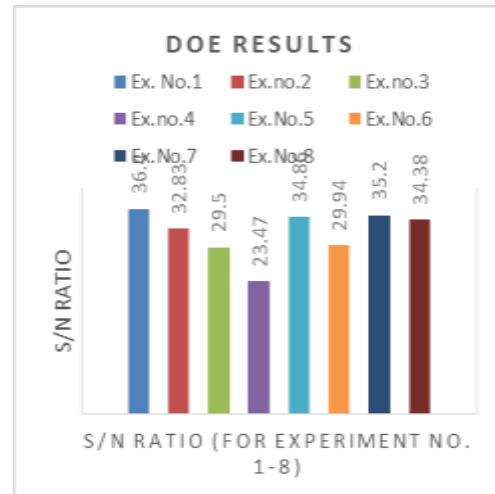


Fig.2. Roundness error for different experiments

The main losses area is the machine center of maximum load in comparison to other centers. It causes unbalanced capacity utilization on different machine center. The maximum load in this study is on CNC drilling machine, so if the drilling process optimize then the complete manufacturing cycle is properly balanced and losses will be also reduced. Design of experiments is planned for minimum drilling operation performance variations. The goal of this work was to obtain minimum roundness error in the deep-hole drilling. The instrument for measuring the roundness is bore gauge dial. The S/N ratio is used as a performance measurement instrument to develop the products and process insensitive to noise factors. Process parameter setting with the highest S/N ratio always yields the optimum quality with minimum variance. Consequently, the level that has a higher value determines the optimum level of each factor. The optimum setting obtained is shown in table-2 and

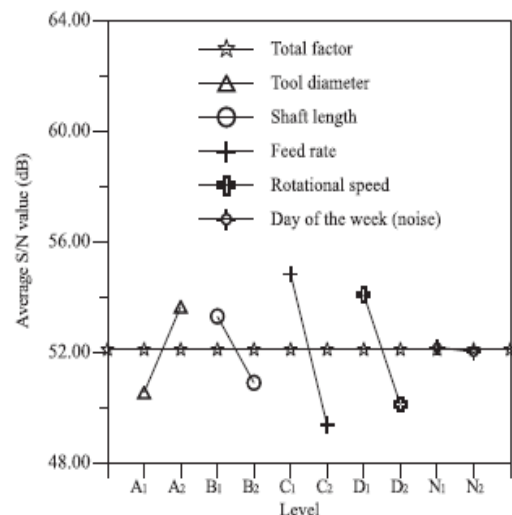


Fig-3.Optimal Control factors

Fig-3 represented the confirmatory test.

Table-2.Optimal setting of Control factors:

Control factors	Notations	Setting
Tool diameter, d (mm)	A ₂	26.50
Shaft length, l (mm)	B ₁	1200
Feed rate, f (mm/rev)	C ₁	0.05
Cutting speed, N (rpm)	D ₁	390
Cutting fluid pump used	p ₁	Pump 1

5. RANKING OF PROCESS PARAMETERS

Following ranking was found after the experiment:

Table-3 Optimum Ranking of Parameters

S. N.	Control factors	Contribution %age	Rank	Influence
1	Feed rate	45.46	I	Very strong
2	Cutting speed	23.05	II	Strong
3	Tool diameter	14.58	III	Moderate
4	Shaft length	12.94	IV	Low

The quality of surface generated depends on these factors combination; the desired result by help of Taguchi DOE method are obtained, to get optimum and high surface finish and correct dimension may be obtained with these parameters.

On applying design parameter on the CNC machine the spare time availability is increased by 20%, i.e. now utilization of 98% is reduced to 81% and by increase in utilization of these machines increases the chances of improving unused capacity of whole plant so plant capacity utilization is also increased by about 20%, but we have to apply this methods to other machines also to get optimum set parameters for their unused capacity. After getting optimal parameters for deep hole drilling machine set up time is reduced by about 30%, so more spare time will be available on machine centers.

6. CONFIRMATORY TEST

A confirmatory test was performed after the optimal control factor settings were determined. Two trials at the optimal control factor settings were made in the confirmation test. The results of the confirmatory test are presented in Table-4. The hole profile was measured by dial type bore gauge.

Table-4 Confirmatory test result:

Trial no.	Roundness error, r (mm)				Average roundness error, R _{VER}
	50 mm	100m m	150m m	200m m	
1	0.0015	0.0014	0.0012	0.0014	0.0014
2	0.0014	0.0013	0.0012	0.0013	0.0013

The table shows the average roundness errors of 0.0014 and 0.0013 mm, respectively. Up to 95% the data obtained are correct and optimal control factor within the operational constraints were obtained. Because of optimal parameters setting the rejection percentage will also expected to be reduced by about 20%. In Fig.-4 bore inspection by bore gauge is shown.

**Fig-4. Bore gauge dial measurement**

7. RESULTS & DISCUSSION

The unused capacity of the machine center may be considered and indicating indirectly the area of the losses. The availability of spare time on key machine of production line may be considered as improvement to whole production line and proper line balancing. The maximum capacity utilization of the different machine indicates the more profits to the company. The less machining capacity utilization indicates that less profitability to the company. Hence the proper capacity utilization increases the overall profitability of the Company also. The ANOVA table not only determine the significant of control factor but also studies their interaction on hole profile or roundness.

The object of the optimal design parameters for CNC drilling machine is obtained with minimum production cost and time per piece. The optimization process will continue till all machine may obtained the optimal process parameters. The effect of the pump unit cannot be avoided as it is useful to control vibration for chip easily removal, surface finish and large depth conditions. The long shaft length will create problem due to deflection so 1200mm shaft is much stiffer in compare to 1600mm shaft.

8. CONCLUSION

By Taguchi loss function concept, area of weakness was selected as the CNC main BTA machine e.g. deep hole drill machine which affects the productivity of the whole organization. By reducing it set up time by optimal parameter setting, the spare available time on this machine was increased and productivity of the organization will be automatically improved. It is the losses over one machine center. In the same way, all machining losses will be optimized with help of Taguchi

method of DOE. With the help of this methodology we can optimize the overall cost as well as utilization of material also. The optimization process will continue till all machine may obtained the optimal process parameters.

9. ACKNOWLEDGMENTS

We are thankful to M/S AVTEC Ltd, Pithampur, Dhar, which is a part of "C.K.Birla Group of companies" for their support for research work.

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