Experimental Analysis of CNC Turning using Taguchi Method

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ABSTRACT:

The objective of this research is to utilize Taguchi methods to optimize material removal rate (MRR) during machining operation on CNC turning of aluminium samples. The material removal rate has been identified as the quality traits and assumed to be directly linked to productivity. There are three important cutting parameters namely, cutting speed, feed rates and depth of cut, which has been considered during the turning operation. An Orthogonal array has been constructed to determined the signal-to-noise (S/N) ratio. According to experimental results, depth of cut is determined to be the most important factor on material removal rate during turning operations.

INTRODUCTION:

The high speed machining (HSM) and modern machining technologies has been used to machine the parts that need significant amount of material removal. Turning is one of the most important machining process in which a single point cutting tool removes unwanted material from the surface of a rotating cylindrical work piece [1]. The process parameters like cutting speed, feed rate, depth of cut, coolant condition and tool geometry affects the material removal rate in turning. The proper selection of process parameters is essential to optimize the metal removal rate. The objective of this paper is to investigate process parameters for a turning aluminium work piece on EMCO CNC turning machine. In this study, three levels of speed, feed and depth of cut are evaluated for high material removal rate (MRR). There are many cutting parameters like cutting speed, feed rate and depth of cut has been selected to optimize the economics of machining operations, as assessed by productivity, total manufacturing cost per part or some other criterion

Regardless of the early works on setting up optimum cutting speeds in Computerized Numerical Controlled (CNC) machining, the recent research [2, 3, 4] have mentioned that the process parameters need to be optimized during CNC machining is an essential and costly process for small and medium type manufacturing industries. The common tendency of process is to reduce the machining cost and time and increasing the accuracy of the product. Taguchi method is statistical method developed by Professor Genichi Taguchi of Nippon Telephones and Telegraph Company Japan for the production of robust products. According to Taguchi, quality of a manufactured product has total loss generated by that product to society from the time has shipped. Taguchi developed a method based on orthogonal array experiments, which reduced "variance" for the experiment with "optimum settings" of control parameters. Thus the combination of Design of Experiments (DOE) with

optimization of control parameters to obtain best results have achieved in the Taguchi Method. Signal to noise (S/N), ratio and orthogonal array are two major tools used in robust
design. Signal to noise ratio, which are log functions of desired output measures quality with emphasis on variation, and orthogonal arrays, provide a set of well balanced experiments to accommodates many design factors

EXPERIMENTATION:

In this paper, there are three cutting parameters: cutting speed, feed rate and depth of cut has been considered for three levels. Three variables are studied for three levels and hence nine experiments were designed and conducted based

The experiments were conducted on EMCO CNC turning machine, which is highly versatile with the latest CNC technology ,driven by latest CNC control system Figure 1 the configuration of the machine as listed. Industrial design: 2 axes slant bed lathe,
Tool Turret: 12 station VDI automatic tool changer optional 6 driven tool, Max turning diameter: 85 mm, Distance between centre 405 mm, Travel X Z: 100*250 mm, Spindle speed: 60 – 6300 rpm, Max bar stock diameter: 25.5 mm, Feed force: 0-3 N and Display: 12" LCD

Figure 1EMCO CONCEPT TURN 250

The component has drawn in AutoCAD 11 and shown in the Figure 2. Experiments have been designed and carried out using Taguchi's L9 Orthogonal Array (OA). The objective
of this research to obtain a mathematical model that relates the material removal rate to three cutting parameters in CNC turning process. In this research, a 3 factor three level factorial
technique has been implemented for the development of design matrix to conduct the experiments and construction of the orthogonal array for this experiment.

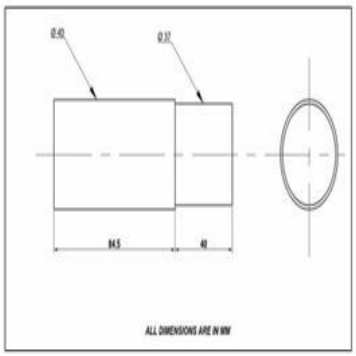

Figure 2

Methodology:

There are various methodologies by which CNC machining operation can be optimized to improve the quality of a product or process. The "Build-test-fix" is the primal approach to conduct the process according to the resources available, rather than optimize it. On the other hand, the objective of "One-factor-at-a-time" approach is to optimize the process by running an experiment at one particular condition and repeating the same experiment by changing one factor till the effect ofall the factors are known.The process parameters taken for the design of experimentation study follows table 3:

Table 3: Process parameters				
Parameter	Unit	level 1	level2	level 3
Cutting speed (RPM)	RPM	600	800	1000
feed (f)	mm/rev	0.10	0.15	0.20
Depth of cut (mm)	mm	0.5	1.0	1.5

A. Design of Experiments

The Design of Experiments (DOE) is the most powerful statistical technique in product\process development. The general quantitative approach which is more logical has been selected for designing the experiments to achieve a predictive knowledge of a complex, multi-variable process with the fewest trials possible. In this research, a 3 factor three level factorial technique has been employed for the development of design matrix to conduct the experiments. A full factorial design may also be called a fully crossed design. If there are k factors, each at 2 levels; a full factorial design has 2^k runs.

TAGUCHI METHOD

In Taguchi method, the main parameters have influence on process results, which are positioned at different rows in a designed orthogonal array. The difference between the functional value and objective value is recognized as the loss function that can be expressed y signal-to-noise (S/N) ratio. The category the larger-to-the-better was used to calculate S/N ratio for material removal rate, according to the equation :

$$S/N(\eta) = -10 \times \log (i/n \, \Sigma_{i=1} * yi^2)$$

The DOF valued at six defining the L-9 trail conditions of Taguchi's Orthogonal array method studying the main effects than interactions.

Traditional experimental design methods are very complicated and difficult to implement, as it require a large number of experiments by increasing the process parameters . To minimize the number of tests, Taguchi developed a particular design of orthogonal arrays to study the entire parameter space with small number of experiments.

Experimentation and observation table

Exp No.	Speed Rpm	Feed m/min	Depth of cut	Cutting speed (m/min)	Weight of material removed (gms)	Cycles time to remove material (sec)	MRR (gm/min	MRR (mm^3/min)	S/N Ratio (µm)
1	600	0.10	0.5	75.398	19.5956	300	3.91912	1451.52	63.236
2	600	0.15	1.0	75.398	19.5934	115	12.6409	4681.819	73.408
3	600	0.2	1.5	75.398	19.5942	75	17.0384	6310.531	76.001
4	800	0.10	1.0	100.530	19.591	133	9.19765	3406.537	70.646
5	800	0.15	1.5	100.530	19.5928	110	13.06186	4837.728	73.693
6	800	0.2	0.5	100.530	16.1971	120	8.4855	3142.777	69.946
7	1000	0.10	1.5	125.663	19.591	60	19.519	7255.925	77.214
8	1000	0.15	0.5	125.663	19.594	120	9.797	3628.518	71.195
9	1000	0.2	1.0	125.663	19.5941	54	36.2853	13439.06	82.567

The process parametric conditions taken at orthogonal array L-9 taguchi techniques results in response variables of MRR and surface roughness for best optimization results of turning operating in EMCO TURN 250

Result Analysis:

The response table, which contains the sums of the S/N ratios for each level and for each factor has been shown in the following below table

Factors	Depth of Cut	Feed	Cutting Speed
Level 1	204.377	211.096	212.645
Level 2	226.622	218.295	214.285
Level 3	226.908	228.515	230.976
Difference	22.531	17.419	18.330
Total	657.906	657.906	657.906

In practice MRR should be high, thus Taguchi method refers to select the process parameter having more S/N ratio. From above Table all level totals has been compared and combination yielding the highest combined S/N ratio has selected for maximum metal removal rate. In this experiment, S3-F3-D3 combination yields the maximum metal
removal rate. This is the optimal levels combination of factors for turning operation in CNC for aluminium material.

Conclusion:

The paper has demonstrated an application of the Taguchi method for investing the effects of cutting parameters on material removal rate in turning aluminium metal. L9 orthogonal array has been constructed for three different levels of cutting parameters, which are speed ,feed and depth of cut. The results of the experiments have performed according to L9 orthogonal array, S/N ratio by using bigger is better S/N ratio equation. According to maximum S/N ratio, the optimum cutting parameter for material removal rate having highest significant factor is depth of cut and the next significant factor is speed and least is feed.

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