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## OPTIMIZATION OF CUTTING PARAMETERS FOR CNC TURNED PARTS USING TAGUCHI'S TECHNIQUE

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**ABSTRACT:** This paper explains the findings of the experimental results that were obtained to select appropriate cutting parameters that ensure less power consumption in high tare CNC machines. Using Taguchi's technique, experiment was conducted with an extruded aluminium shaft on a CNC lathe with cutting speed, feed rate and depth of cut as process parameters. Power consumed (energy), the output characteristic was measured with the help of a data acquisition system. The data were analyzed and appropriate process parameters were selected for minimum energy consumption.

**KEYWORDS:** Power consumption optimization, CNC, Taguchi technique, Cutting parameters

### INTRODUCTION

Metal cutting is one of the most important and widely used manufacturing processes in engineering industries and in today's manufacturing scenario, optimization of metal cutting process is essential for a manufacturing unit to respond effectively to severe competitiveness and increasing demand of quality which has to be achieved at minimal cost.

As flexibility and adaptability needs increased in the manufacturing industries, computer numerical control systems was introduced in metal cutting processes that provided automation of processes with very high accuracies and repeatability. Because of high cost of numerically controlled machine tools compared to their conventional counterparts, there is an economic need to operate these machines as effectively as possible in order to obtain the required payback. Product quality, productivity and cost became important goals in manufacturing industries.

Based on the literature review it was evident that the factors that highly influence the process efficiency and output characteristics in a CNC machine tool are tool geometry, cutting velocity, feed rate, depth of cut and cutting environment. Experimental works have been carried out on the above mentioned parameters. A significant improvement in process efficiency may be obtained by process parameter optimization that identifies and determines the regions of critical process control factors leading to desired outputs or responses with acceptable variation ensuring a lower cost of manufacturing.

Of the many goals focused in a manufacturing industry, energy consumption plays a vital and dual role. One, it cuts down the cost per product and secondly the environmental impact by reducing the amount of carbon emissions that are created in using the electrical energy.

Many have worked in optimizing the parameters of computer numerically controlled machine tools for minimum power requirement but in high tare machine tools, time dominates over power when optimizing for reduced energy. The current work considers the most commonly selected process parameters viz. cutting velocity, feed rate and depth of cut optimized for minimum energy consumption.

### TAGUCHI'S APPROACH. OVERVIEW

Quality is often approached to as conformance to specifications. However, Taguchi proposes a different view of quality as one that relates it to cost and loss in money, not just to the manufacturer at the time of production but to the consumer and to the society as a whole. According to Taguchi, "Loss is usually thought of as additional manufacturing cost incurred upto the point the product is shipped".

In case of machining, the energy consumed or the power demand varies because of noise variables which are classified as inner, outer and between product noises. To minimize the effects caused by these noise variables, some countermeasures may be considered. The most important is by design which involves 1) system design 2) parameter design and 3) tolerance design.

### PARAMETER DESIGN

This is used to reduce the influence of sources of variation. It is the most important step in developing stable and reliable products or manufacturing processes. With this technique, we find a combination of parameter levels that are capable of damping the influences of noise signals and also allow achieving the desired quality characteristics. Most important in applying design of experiments is to cite factors or to select objective quality characteristics with the intention of designing a process that

is reliable to wide range of performance conditions but at lowest price. The quality characteristics in case of machining can be surface roughness, tool wear, energy consumption, and lot more. This work focuses on energy consumed as the quality characteristic and as smaller-the-better characteristic with an ideal target being zero.

### EXPERIMENTAL SETUP AND PROCEDURE

The experimental set-up shown in fig.1 consist of a CNC turning center, an aluminum 6063 extruded shaft with diameter of 50mm and length of 75 mm. Fig. 2 shows a power cell to detect the instantaneous power, and a DAQ (Data Acquisition) system integrated with a computer system for real-time data collection and processing. The workpiece is to be reduced to the diameter of 45.0 mm. Rough turning is carried out to achieve the diameter 45.2 mm and finish turning it to be done with a depth of cut of 0.1 mm. In the case of rough turning the total depth of cut is 2.4 mm and this can be achieved by various combinations of cutting velocity, feed rate and depth of cut. Experiments have to be carried out with all possible combinations to check the effects. But to minimize cost and experiment time, Taguchi's orthogonal array technique was followed.



Figure 1. Experimental setup

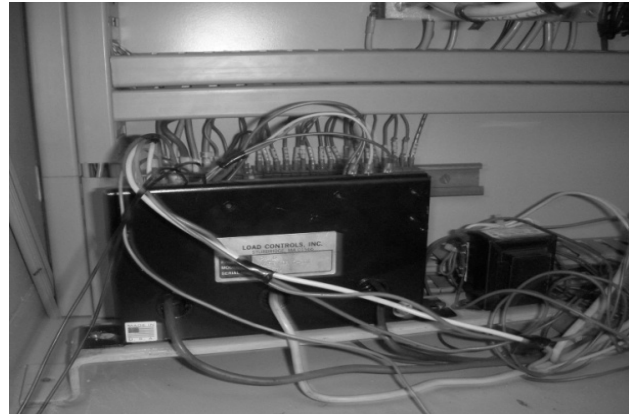


Figure 2. Power cell apparatus

The process parameters selected for the present work are tabulated in the table 1.

According to Taguchi's method, L9 orthogonal array is ideal for conducting the experiments with three control factors (cutting velocity, feed rate and depth of cut) and a variable data type output (energy consumption). An L9 orthogonal array includes 9 combinations and 4 trials (noise factors) in each combination.

Table 1. Process parameters and their levels

Factors	Process parameter	Level 1	Level 2	Level 3
A	Spindle speed(rpm)	1250	1500	1750
B	Feed rate(mm/rev)	0.1	0.2	0.3
C	Depth of cut(mm)	0.4	0.8	1.2

### DATA ANALYSIS

The experiments were carried out based on the process parameters and levels indicated in the table 1 and the output characteristic (energy) was measured and is tabulated in table 2. The power graph (time vs. power) was plotted and the area under the graph gives the total power consumed or energy utilized to machine the component. Energy consumption being a 'lower-the-better' type of quality characteristic, the S/N ratio for lower-the-better output characteristic is given by equation (1).

$$S/N \text{ ratio} = -10 \log \left[ \frac{1}{n} \sum_{i=1}^n y_i^2 \right] \quad (1)$$

where  $y_i$  is the response of the quality characteristic for a trial repeated  $n$  times.

Table 2. Experimental data of power consumption

Trial No.	Control factors			No. of passes	Energy (kW-hr)				Power demand (kW)
	Spindle Speed (rpm)	Feed rate (mm/rev)	Depth of (cut mm)		N1	N2	N3	N4	
1	1250	0.1	0.4	6	0.04513	0.05031	0.04280	0.04843	1.664108
2	1250	0.2	0.8	3	0.01257	0.01438	0.01205	0.01363	1.882270
3	1250	0.3	1.2	2	0.00629	0.00747	0.00585	0.00670	2.212450
4	1500	0.1	1.2	2	0.01452	0.01665	0.01395	0.01334	1.951679
5	1500	0.2	0.4	6	0.01998	0.02363	0.01920	0.02227	1.813330
6	1500	0.3	0.8	3	0.00786	0.00912	0.00709	0.00835	2.123730
7	1750	0.1	0.8	3	0.01825	0.02021	0.01720	0.01938	1.880995
8	1750	0.2	1.2	2	0.00640	0.00759	0.00618	0.00718	2.163320
9	1750	0.3	0.4	6	0.01103	0.01264	0.01087	0.01286	1.884566

The S/N ratio was computed for each trial and plotted for each factor as shown in the fig 3. It is seen from the plot that the variations are more for feed rate and depth of cut.

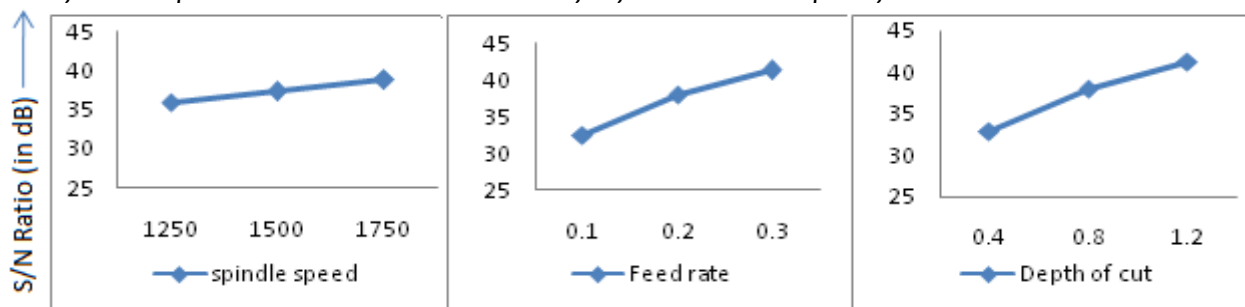


Figure 3. S/N ratios for three factors

**RESULTS**

From the experimental data, both power and energy are compared with material removal rate (MMR) which shows that, as material removal rate increases power demand increases and energy consumption decreases which is shown in fig.4. Generally, power is monitored and machining time is not taken into account but in this work, total machining time taken is also monitored, hence energy is computed and is used for analysis and the results are discussed below.

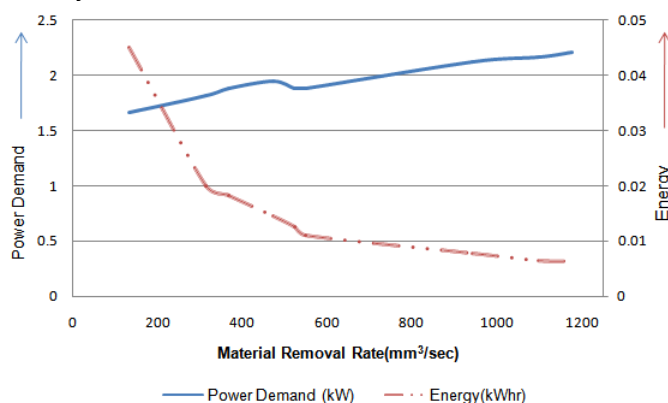


Figure 4. Power demand and energy vs. MRR

In order to quantify the influence of process parameters on the selected machining characteristic, analysis of variance was performed. The S/N pooled ANOVA data is shown in the table 3. The percent contributions of parameters are quantified. It is evident that feed rate and depth of cut are significant factors and spindle speed does not have a much pronounced effect.

Table 3. S/N pooled Anova

Source	Levels			SS	DOF	F-ratio (pooled)	% Factor Effects	Optimum level
	1	2	3					
A	35.93	37.29	38.76	12	2	39	5	1750
B	32.60	38.09	41.30	116	2	376	49	0.3
C	32.84	37.97	41.18	106	2	344	45	1.2

Tabulated F-ratio at 95% confidence level

**CONCLUSIONS**

The following are the observations from this study:

- 1) It was observed that the feed rate and the depth of cut are greatly influencing the energy consumption in high tare CNC machines.
- 2) Increasing the cutting speed by 50% decreases tool life by 80% and operating at lower cutting speed (20-40m/min) tends to cause chattering. Thus, tool life is shortened. Hence the optimum cutting speed is 200-275 m/min in case of CNC turning.
- 3) Based on theoretical relation, it is found that surface finish is dependant only on feed rate. Increasing the feed rate by 50% reduces tool life by 60%. If surface finish is not a limiting factor, then optimum feed rate is 0.3mm/rev. If surface finish is to be considered then lower feed rates can be set.
- 4) Depth of cut is chosen according to rigidity of the machine, power and tool rigidity. The workpiece was machined in a CNC machine with carbide insert (both being rigid enough) and the optimum depth of cut was found to be 1.2 mm. Changing depth of cut doesn't affect tool life greatly. When cutting uncut surfaces or cast iron surfaces, the depth of cut needs to be increased as much as the machine power allows in order avoiding cutting the impure hard layer with the tip of cutting edge and therefore prevent chipping and abnormal wear.

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