OPTIMIZATION OF CUTTING PARAMETERS OF SS316 USING DIFFERENT CUTTING TOOLS ON CNC LATHE

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ABSTRACT:-

This paper explains the findings of the experimental results that were obtained after selecting appropriate cutting parameters to ensure maximum MRR, less surface roughness and less power consumption on a CNC turning machine .Taguchi optimization methodology is applied to optimize cutting parameters in turning SS316.The turning parameters evaluated were cutting speed rpm., feed rate in mm/rev, depth of cut in mm .The analysis of results shows that with ceramic, carbide & CBN tools, significant factor for MRR is depth of cut .For surface roughness, feed rate is the most significant factor. For power consumption by cutting the material with ceramic & carbide tool the depth of cut is significant factor, whereas for CBN tool it is spindle speed.

KEYWORDS: *Taguchi Method, Turning, SS316, Ceramic, Carbide & CBN cutting tools, Minitab 14.*

I. 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. 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 speed, 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 is 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, MRR, surface finish and most important is power consumption plays a vital and dual role. Once it cuts down the power consumption, the cost per product and secondly the environmental impact also reduces (by reducing the carbon emission).

The current work considers the most commonly selected process parameters viz. cutting speed, feed rate and depth of cut optimized for minimum surface roughness, Maximum MRR and minimum power consumption.

II. TAGUCHI'S APPROACH OVERVIEW

Taguchi parameters design is an important tool for robust design. it offers a simple and systematic approach to optimize design for performance, quality and cost. Signal to noise ratio and orthogonal array are two major tools used in robust design. Signal to noise ratio, which measures quality with emphasis on variation, and orthogonal array, which accommodates many design factors simultaneously.

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 up to 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.

III. 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 MRR, Surface Roughness and Power consumption as the quality characteristic.

IV. EXPERIMENTAL SETUP AND PROCEDURE

The experimental set-up shown in fig.1 consists of a CNC turning center, an SS316 shaft with diameter of 30mm and length of 75 mm. Fig. 2 shows a Multifunction meter to detect the instantaneous power consumed, 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. 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 speed, feed rate and depth of cut). An L9 orthogonal array includes 9 combinations for each tool material used.

V. DATA ANALYSIS

The experiments were carried out based on the process parameters and levels indicated in the table 1 and the output characteristic for each tool was measured and is tabulated in table 2, 6, 10.

Table1. Process parameters and their levels

Factor/level	Notation	1	2	3
spindle speed(rpm)	**S**	**625**	**1023**	**1421**
Feed rate(mm/min)	**F**	**0.14**	**0.22**	**0.30**
Depth of cut(mm)	**C**	**0.2**	**0.6**	**1.00**

Figure1. Experimental setup

Figure2. Multifunction meter for power consumption

The tabulated data is used in Minitab14 to find the graph for MRR, Surface Roughness and Power Consumption for each tool (Ceramic, Carbide, and CBN).MRR (larger the better)

$$\frac{S}{N} = -10 \log \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_i^2}$$

Surface Roughness & Power Consumption (smaller the better)

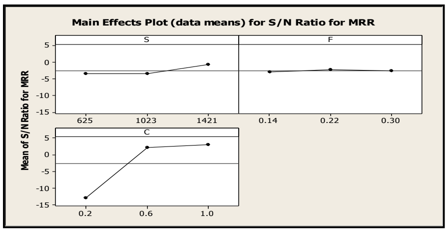
$$\frac{S}{N} = -10 \log \frac{1}{n} \left(\sum y^2 \right)$$

Experimental Results for Ceramic Tool

Sr. No.	S	F	C	MRR gm/s	Ra in µm	KW	S/N Ratio for MRR	S/N for Ra	S/N Ratio for power
1	625	0.14	0.2	0.1985	1.62	1.34	-14.0451	-4.1903	-2.5421
2	625	0.22	0.6	1.0238	2.94	1.62	1.1583	-9.3670	-4.1903
3	625	0.30	1.00	1.3026	3.22	1.91	2.2959	-10.1571	-5.6207
4	1023	0.14	1.00	1.1657	0.84	2.02	1.3318	1.5144	-6.1070
5	1023	0.22	0.2	0.2165	1.22	1.55	-13.2910	-1.7271	-3.8066
6	1023	0.30	0.6	1.1991	2.14	1.99	1.5771	-6.6083	-5.9771
7	1421	0.14	0.6	0.6435	0.72	2.05	3.8290	2.8534	-6.2351
8	1421	0.22	1.00	1.8369	1.46	2.65	5.2812	-3.2871	-8.4649
9	1421	0.30	0.2	0.2625	1.36	1.72	-11.6174	-2.6708	-4.7105

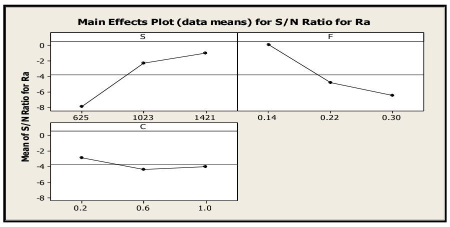
Table 2 Experimental result for MRR, Ra &Power Consumption

a) For MRR:-



Graph 1: Main effect plots for S/N ratios for MRR (larger-the-better) for Ceramic tool.

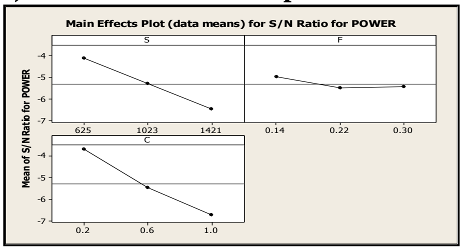
b) For Surface roughness (Ra)



LEVEL	S	F	C
1	-7.9048	0.0597	-2.8627
2	-2.2737	-4.7937	-4.3740
3	-1.0348	-6.4787	-3.9766
DELTA	-6.87	6.5384	-1.5113
RANK	2	1	3

Graph 2: Main effect plots for S/N ratios for Ra (smaller-the-better) for Ceramic tool.

c) For Power Consumption:-



Graph 3: Main effect plots for S/N ratios for Power (smaller-the-better) for Ceramic tool.

a)Response Table for S/N Ratios for MRR:-

Table 3 Response Table for S/N Ratios for MRR

LEVEL	S	F	C
1	-3.5303	-2.9614	-12.9845
2	-3.4607	-2.2838	2.1881
3	-0.8327	-2.5815	2.9696
DELTA	-2.6946	-0.6776	15.9541
RANK	2	3	1

b) Response Table for S/N Ratios for Ra:-

Table 4 Response Table for S/N Ratios for Ra

c) Response Table for S/N Ratios for Power Consumption:-

Table5 Response Table for S/N Ratios for Power Consumption

LEVEL	S	F	C
1	-4.1177	-4.9614	-3.3664
2	-5.2969	-5.4873	-5.4675
3	-6.4702	-5.4361	-6.7309
DELTA	-2.3525	-0.5259	-3.0445
RANK	2	3	1

Optimum values of the process parameters for Ceramic tool:-

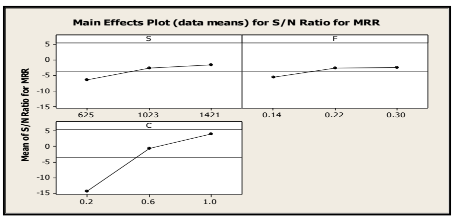
a) For MRR S=1023m/min, F=0.14mm/rev, C= 0.2mm **b) For Ra** S=1421m/min, F=0.14mm/rev, C= 0.2mm
c) For Power Consumption S=625m/min, F=0.14mm/rev, C= 0.2mm

Experimental Results for Carbide Tool

Table 6 Experimental result for MRR, Ra &Power Consumption

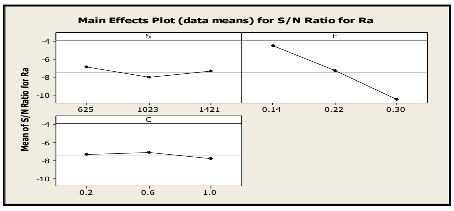
Sr. No.	S	F	C	MRR gm/s	Ra in µm	Power Demanded KW	S/N Ratio for MRR	S/N Ratio for Ra	S/N Ratio for Power
1	625	0.14	0.2	0.1250	1.52	1.31	-18.0618	-3.6369	-2.3454
2	625	0.22	0.6	0.5728	1.98	1.53	-4.8399	-5.9333	-3.6938
3	625	0.30	1.00	1.5124	3.56	1.90	3.5933	-11.0290	-5.5750
4	1023	0.14	1.00	1.0991	1.78	1.69	0.8207	-5.0084	-4.5577
5	1023	0.22	0.2	0.2686	2.66	1.52	-11.4179	-8.4976	-3.6369
6	1023	0.30	0.6	1.3301	3.34	1.92	2.4777	-10.4749	-5.6660
7	1421	0.14	0.6	0.9393	1.74	2.4	0.5439	-4.8110	-7.6064
8	1421	0.22	1.00	2.532	2.30	2.56	8.0693	-7.2346	-8.1648
9	1421	0.30	0.2	0.2124	3.10	1.78	-13.4569	-9.8272	-5.0084

a) For MRR:-



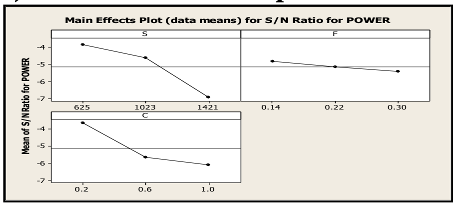
Graph 4: Main effect plots for S/N ratios for MRR (larger-the-better) for Carbide tool.

b) For Surface Roughness:-



Graph 5: Main effect plots for S/N ratios for Ra (smaller-the-better) for Carbide tool.

c) For Power Consumption:-



LEVEL	S	F	C
1	-3.8714	-4.8365	-3.6636
2	-4.6202	-5.1652	-5.6554
3	-6.9265	-5.4165	-6.0991
DELTA	-3.0548	-0.580	-2.4355
RANK	1	3	2

a) Response Table for S/N Ratios for MRR:-

Table 7 Response Table for S/N Ratios for MRR

LEVEL	S	F	C
1	-6.4361	-5.5657	-14.3122
2	-2.7065	-2.7295	-0.6061
3	-1.6146	-2.4619	4.1611
DELTA	-4.8215	-3.1038	4.1611
RANK	2	3	1

b) Response Table for S/N Ratios for Ra:-

Table 8 Response Table for S/N Ratios for Ra

LEVEL	S	F	C
1	-6.8661	-4.4851	-7.3203
2	-7.9936	-7.2218	-7.0731
3	-7.2909	-10.4437	-7.7573
DELTA	-1.1275	-5.9586	-0.6842
RANK	2	1	3

c) Response Table for S/N Ratios for Power Consumption:

Graph 6: Main effect plots for S/N ratios for Power (smaller-the-better) for Carbide tool.

The optimum values of the process parameters for carbide tool:-

a) For MRR S=625m/min, F=0.14mm/rev, C= 0.2mm **b) For Ra** S=625m/min, F=0.14mm/rev, C= 0.6mm **c) For Power Consumption** S=625m/min, F=0.14mm/rev, C= 0.2mm

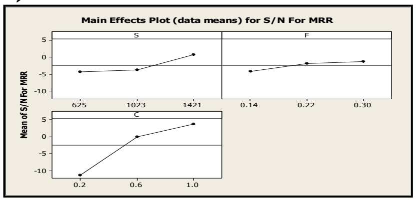
Experimental Results for CBN Tool:-

Sr. No.	S	F	C	MRR gm/s	Ra in µm	Power Demanded KW	S/N Ratio for MRR	S/N Ratio for Ra	S/N Ratio for Power
1	625	0.14	0.2	0.25441	1.02	1.35	-11.8893	0.1720	-2.6067
2	625	0.22	0.6	0.7407	1.40	2.10	-2.6072	-2.9226	-6.4444
3	625	0.30	1.00	1.155	0.48	1.61	1.2516	6.3752	-4.1365

4	1023	0.14	1.00	1.0643	1.08	1.41	-0.5412	-0.6685	-2.9844
5	1023	0.22	0.2	0.1992	1.64	1.50	-14.0142	-4.2969	-3.5218
6	1023	0.30	0.6	1.4136	1.50	2.10	3.0065	-3.5218	-6.4444
7	1421	0.14	0.6	0.9506	0.88	2.15	-0.4404	1.1103	-6.6488
8	1421	0.22	1.00	3.4501	2.38	3.1	10.7566	-7.5315	-9.8272
9	1421	0.30	0.2	0.395	2.22	1.70	-8.0681	-6.9271	-4.6090

Table 10 Experimental result for MRR, Ra &Power Consumption

a) For MRR:-

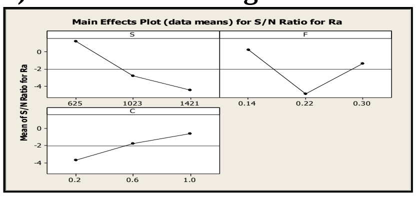


Graph 7: Main effect plots for S/N ratios for MRR (larger-the-better) for CBN tool.

a) Response Table for S/N Ratios for MRR:-

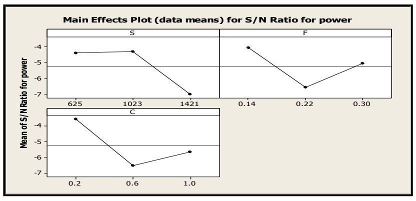
LEVEL	S	F	C
1	-4.4150	-4.2903	-11.3239
2	-3.8496	-4.8119	0.0137
3	0.7494	-1.2701	3.8223
DELTA	5.1644	-3.5418	15.1462
RANK	2	3	1

b) For Surface Roughness:-



Graph 8: Main effect plots for S/N ratios for Ra (smaller-the-better) for CBN tool.

c) For Power Consumption:-



Graph 9 : Main effect plots for S/N ratios for Power (smaller-the-better) for CBN tool.

Table11 Response Table for S/N Ratios for MRR

b) Response Table for S/N Ratios for Ra:-

LEVEL	S	F	C
1	1.2082	0.2046	-3.6840
2	-2.8291	-4.917	-1.7780
3	-4.4494	-1.3579	-0.6083
DELTA	5.6576	1.5625	-3.0757
RANK	1	2	3

c) Response Table for S/N Ratios for Power Consumption:-

Table 12 Response Table for S/N Ratios for Ra

LEVEL	S	F	C
1	-4.3959	-4.0800	-3.5792
2	-4.3169	-6.5977	-6.5125
3	-7.0283	-6.8027	-5.6494
DELTA	-2.7114	-2.7227	-2.9333
RANK	3	2	1

The optimum values of the process parameters for CBN tool: -
a) For MRR S=625m/min, F=0.14mm/rev, C= 0.2mm **b) For Ra** S=625m/min, F=0.14mm/rev, C= 1.00mm **c) For Power** Consumption S=625m/min, F=0.14mm/rev, C= 0.2mm

VI. CONCLUSION

- In the present study the work is done on optimization of the process parameters of CNC turning operation on material SS316 with three different tool materials (ceramic, carbide, & CBN).The objective function considered are the maximization of material removal rate, minimization of surface roughness & power consumption.
- For material removal rate (MRR) and Depth of cut is most dominant factor for ceramic, carbide & CBN tool.
- The Surface Roughness (Ra) mainly depends on feed rate as concluded from the delta values of S/N ratios with Ceramic, Carbide where as for CBN tool, it depend on speed.
- The power consumed for cutting the material is mainly depends on the depth of cut secondly speed & finally on feed rate, as concluded from the delta values of S/N ratios with ceramic tools.
- With carbide tool feed rate is the dominant factor for power consumption followed by depth of cut& spindle speed.
- The power consumption for cutting the material with CBN tool mainly depends on depth of cut secondly feed rate & finally cutting speed.

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