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Experimental Investigations & Analysis of Process parameters during End Milling process for AISI Steel.

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Abstract. The research work mainly deals with doing experiments on the End milling process using the experimental data set developed using Design of experiments. After doing experimentation the responses R1 & R2 i.e Material Removal rate & Tool wear were measured and recorded. Later Analysis is done on the experimental data by drawing graphs between the input variables and the output responses. By using the graphs plotted using the experimental data, the detailed analysis is done by deriving the conclusions. After then the optimal process parameters can be found out using any one of the Evolutionary algorithms. The optimized values can be used for automating the process.

***Keywords*— End Milling Process, DOE, Central Composite Design, AISI S2.**

1. INTRODUCTION

The End mill is an indispensable tool in the milling operations. During operation, when the End Mill rotates it makes a plane material in the Left -and-right direction or a plane of a bottom side of the end mill. Using End mills various shapes can be made. As the edge is weak, proper care should be taken while it makes contact with the material to be removed. A large variety of cutter materials has been developed to meet the required conditions in milling operation the common materials used for making of milling cutters are carbon steel, high speed steel, sintered carbides, ceramics and satellites.

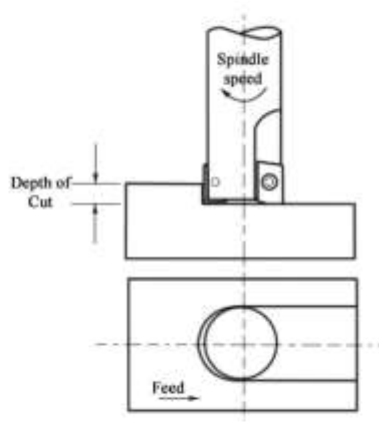

Fig. 1. End Milling process

The mechanism which involves with surface roughness formation is dynamic, complicated and is also process dependent. In a CNC End mill there are several factors which influences the surface roughness and the factors which can be controlled are (spindle speed, feed rate and depth of cut) and uncontrollable factors (tool geometry and material properties of both tool and work piece) [2]. Milling is treated as one of the common process in manufacturing and is very much applied for Metal removal operations in numerical control machines. Oktem and Erzurumlu [3] observed closeness in the results between experimental and predicted values in end milling process. They used neural network and genetic algorithm. Experimental optimization of end milling is a difficult task. It depends on mainly the experience of the operator. But as end milling contains more number of parameters to be controlled, it is needed to develop a method for the optimal selection. The present work involves the conduction of experiments by varying the input parameters speed, feed and depth of cut. Later the detailed analysis is done with the help of plots drawn using statistical tools.

2. EXPERIMENTAL WORK

The experiments are done by using 3-axis CNC vertical machining center as shown in Fig. 3. AISI S2 is taken as the work piece material for investigation. It is a Shock-Resisting Steel grade *Tool Steel*. It is composed of (in weight percentage) 0.40-0.55% Carbon (C), 0.30-0.50%, 0.30-0.60% Manganese (Mn), 0.90-1.20% Silicon (Si), 0.30% Nickel (Ni), Molybdenum (Mo), 0.50% Vanadium (V), 0.25% Copper (Cu), 0.03% Phosphorus (P), 0.03% Sulfur (S), and the base metal Iron (Fe). It has excellent fine wear resistance and toughness will find various applications in cutting tools for heavy plate, shear blades, cold punching and upsetting and used in various cutting tools.

The specimen is prepared with the dimensions of 150mm x 250mm x 20mm and ceramic insert is used for experimentation. It was found from the experiments and literature survey that the process parameters such as spindle speed ($x1$), feed ($x2$), and axial depth of cut ($x3$) is the decision (control) variables and the MRR, Tool wear both as output responses. The ranges of the process control variables are given in table 1. The output responses were measured and recorded and is shown in the Table 2 for the experiments conducted as per the DOE.

Table 1. Cutting parameter Ranges

Input Variables	**Units**	**Notation**	**Feasible range**	
			Lower Limit	**Upper Limit**
Cutting Speed	Rpm	x_1	900	1500
Feed	mm/min	x_2	30	60
Depth of Cut	mm/min	x_3	0.4	0.6

Table 2. Experimental dataset

S.No	**SPEED (X1)**	**FEED (X2)**	**DEPTH OF CUT (X3)**	**M.R.R**	**WEAR**

1	1500	30	0.6	5.587	0.163
2	900	30	0.4	3.487	0.09
3	1500	60	0.5	8.294	0.209
4	1200	45	0.6	7.59	0.199
5	1200	30	0.5	4.888	0.13
6	900	30	0.6	5.587	0.139
7	1500	30	0.4	3.492	0.115
8	1200	60	0.4	5.924	0.145
9	900	45	0.4	4.744	0.145
10	1200	45	0.5	6.641	0.174
11	900	45	0.5	6.641	0.149
12	1200	30	0.4	3.497	0.115
13	1200	45	0.4	4.744	0.148
14	1500	45	0.6	7.605	0.207
15	1500	60	0.6	9.479	0.225
16	900	45	0.6	7.59	0.175
17	1500	45	0.4	4.744	0.11
18	900	60	0.6	9.479	0.225
19	900	30	0.5	4.888	0.13
20	1500	30	0.5	4.888	0.116
21	900	60	0.5	8.294	0.189
22	1500	60	0.4	5.924	0.175
23	1200	60	0.5	8.294	0.202
24	1500	45	0.5	6.654	0.188
25	1200	60	0.6	9.479	0.235
26	900	60	0.4	5.924	0.173
27	1200	30	0.6	5.594	0.143

3. ANALSIS OF PROCESS PARAMETERS

The effects of End milling process parameters i.e Feed, Depth of cut & Cutting Speed and on the output responses i.e Tool Wear resistance and Material Removal Rate were plotted using Minitab14 and analyzed. The plot of factors effects on material removal rate is as shown in the Fig. 2.

This plot can be used to graphically assess the effects of factors on response. It can be seen from the figures.

- The Increase in cutting speed results in a very small increase in the MRR.
- The increase of feed increases the tool wear as shown in Fig. 3.
- MRR initially increases with increase in depth of cut and later on decreasing trend of MRR.

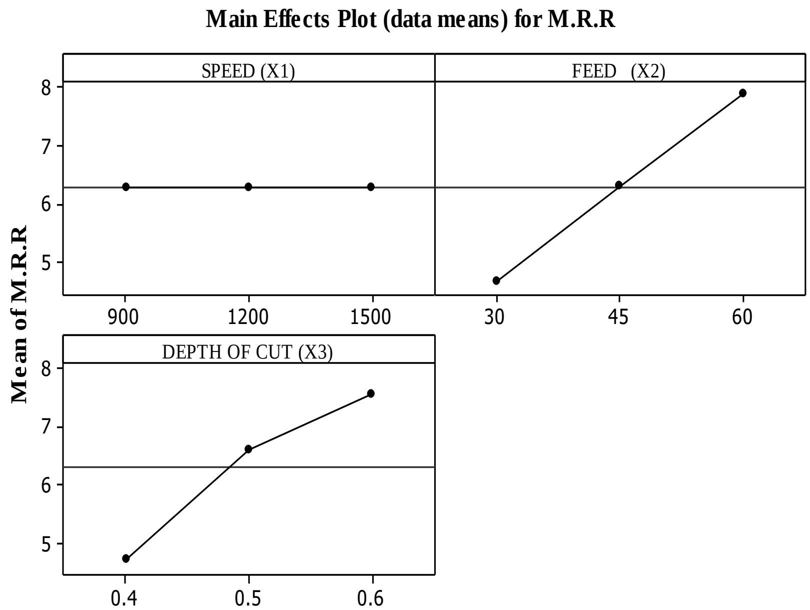

Fig. 2. Factors plot for predicted MRR

Fig. 9 is the plot of factors effect on tool wear. From this plot, it can be observed that

- A very slight increase in wear can be observed with the increase in cutting speed.
- Increase in feed initially increases MRR and later on a little decrement of MRR is observed.
- The increase of depth of cut increases the tool wear.

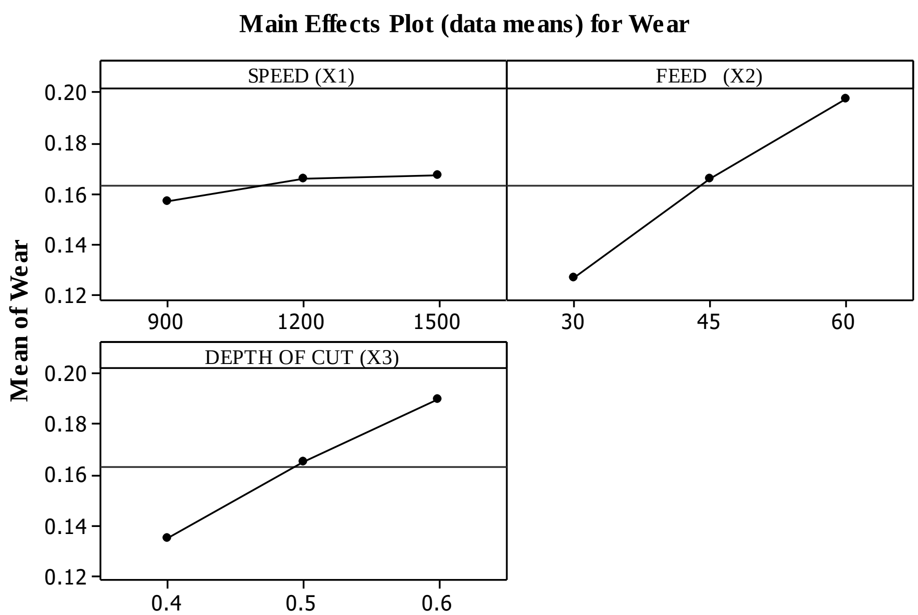

Fig. 3. Factors plot for Predicted tool wear

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The predicted values and experimental values of MRR and Tool Wear both training and testing are shown in the Fig.s 4 & 5. From the above said figures it is evident that network responded well for the testing data as well.

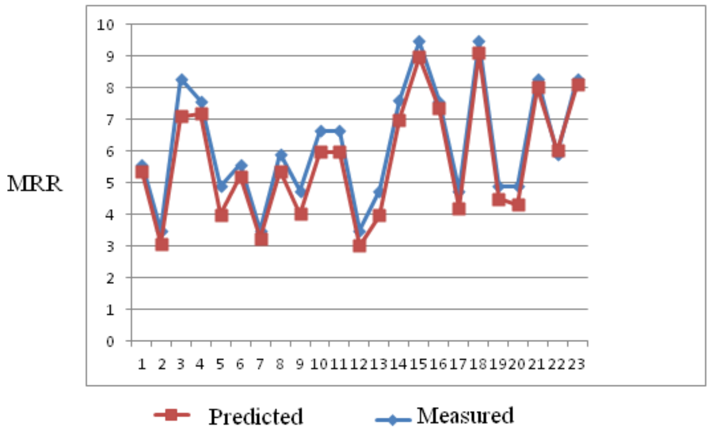

Fig. 4: Experimental & Predicted MRR values

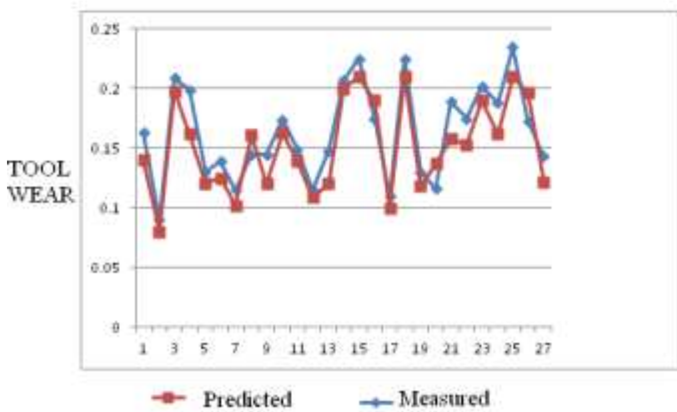

Fig.5: Experimental & Predicted Tool Wear values

CONCLUSIONS

The present research experimentation is done on 3-axis CNC vertical machining center, employing a variable continuously spindle speed up to a maximum of 6000 rpm and maximum spindle power of 5.5kW. The research was carried out on AISI steel The feed rates is set to a maximum of 10m/min. Experiments are done as per DOE. Depth of cut, Cutting speed and Feed is taken as process parameters and the output responses are Material removal rate and Tool wear resistance. The graphs were plotted between the measured values and the ANN predicted results. It is shown that the ANN predicted results show good agreement with the Experimental results, Hence ANN proved its efficiency in optimizing the End Milling process parameters. Later the experimental results can be used to predict the models using any one of the evolutionary algorithms. Also for Optimizing the End milling process parameters, the present method can be integrated with GA.

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