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Approach to identify influences of process parameters in terms of ranking using DOE and Fuzzy logic during Hard Turning

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ABSTRACT:
The basic objective in this stage of work is to know about the effects of machining parameters on machining responses for the considered type of hardened steels. As an initial task from this stage of work, experimental data were collected for source literatures and those data were subsequently analyzed following different methodologies.
The work was carried out to identify influences of process parameters in terms of ranking. Optimization method was also implemented for optimal solution of machining parameters on machining responses.

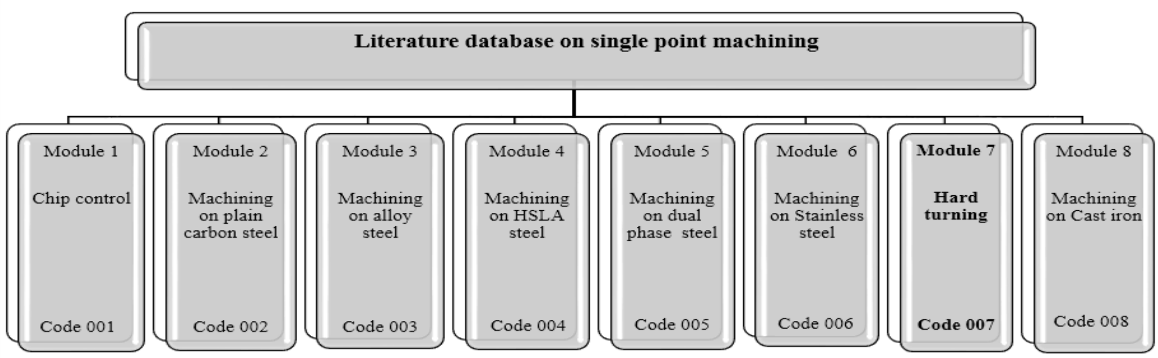
I. INTRODUCTION

Design of experiments (DOE) is a statistical tool to determine the relationship between factors affecting (process parameter) a process and the output of that process. This technique can be considered as cause-and-effect relationships.

As an initial task, the literature database was prepared. The database has been prepared considering all machining aspects as different modules.

The machining field as such can be comprising of various sub-areas like chip control, machining of plain carbon steel, machining of alloy steel, machining on HSLA steel, machining on dual phase steel, machining on stainless steel, hard turning and machining on cast iron etc. Preliminary studies have been made on various area under various modules as stated and subsequently it was proposed to carry out work on machining on hard turning. Matlab computer programming was developed on the literature database for vast area of machining with specific emphasis on hard turning.

In the literatures database, list of relevant literatures are placed under various modules depending upon type of work material and type of machining. The database works on various coding. Each coding refers list of literature for various aspects under various module. In the literature database both the modules as well as aspects are coded with numbers. The above text has been shown schematically below



The purpose of making this literature database is to support the interpretation of the findings of a specific work. Present study will be on hard turning of two varieties of steels as for example, D2 cold wok steel and AISI H13 steel[3]. This study of hard turning is taken into consideration in order to develop some concepts on hard turning of the above mentioned steels[2]. Hard turning means turning of hard material having Rockwell hardness greater than or equal to 45 HRC. Hard turning replaces the method of grinding in a better way. All the disadvantages of grinding process can be eliminated using hard turning instead of grinding[5]. Hard turning can be performed both for roughing operation as well as for finishing operation. Surface roughness of hard turning product can be as good as surface roughness on ground product. While obtaining various results out of hard turning often it becomes difficult to interpret the findings. This step of the work can be made easy by referring the literature database under specific module in the developed program.

In this paper process parameters (input parameters) are speed, feed and depth and the output parameters are Surface Roughness and Metal Removal Rate(MRR). The intension of selecting the process parameter i.e. speed, feed and depth is that they play the crucial role while machining the material. The output parameters i.e. Surface Roughness and MRR decide the performance of machining in terms of quality and productivity.

Steps of work carried out in the present section have been shown in FIGURE 1.

Hybrid Taguchi fuzzy logic system helps to obtain the optimal parameters and ranking in terms of influence by the parameters which can be better illustrated by FIGURE 2.

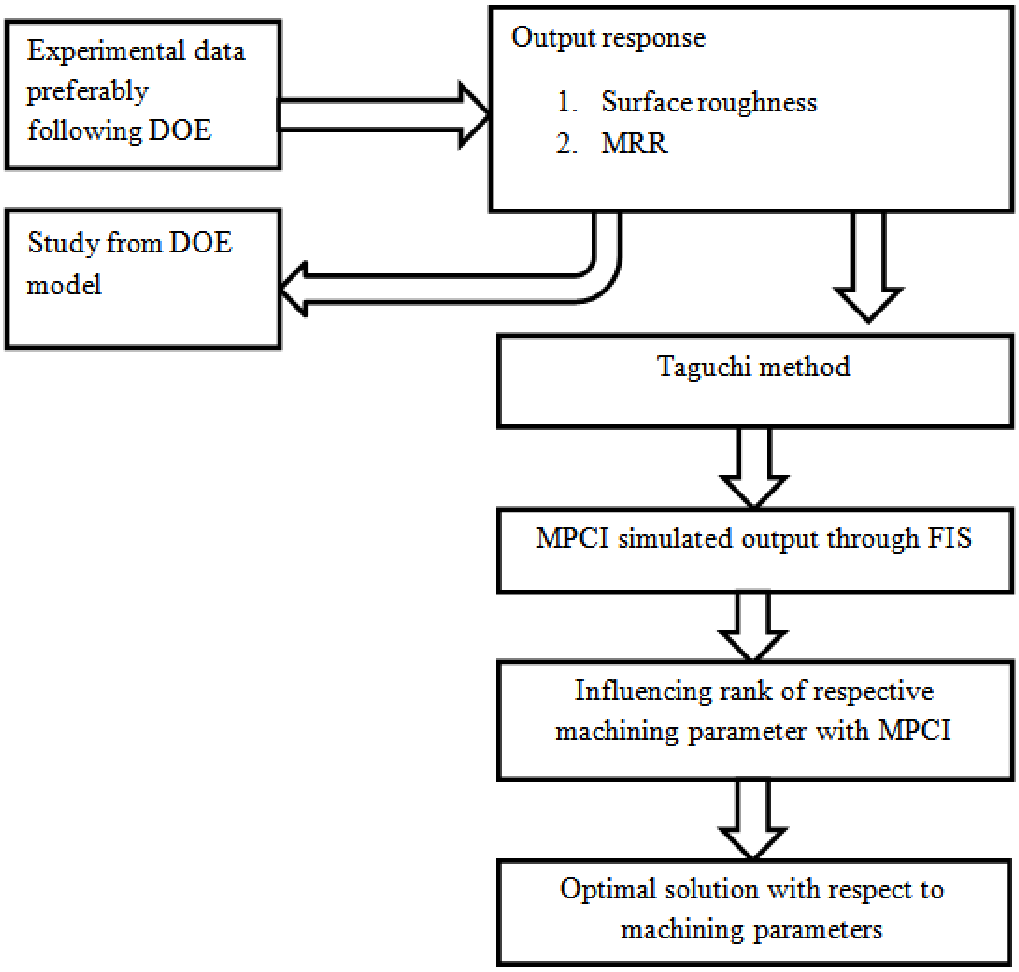


FIGURE 1 Module assembling to develop the machining software

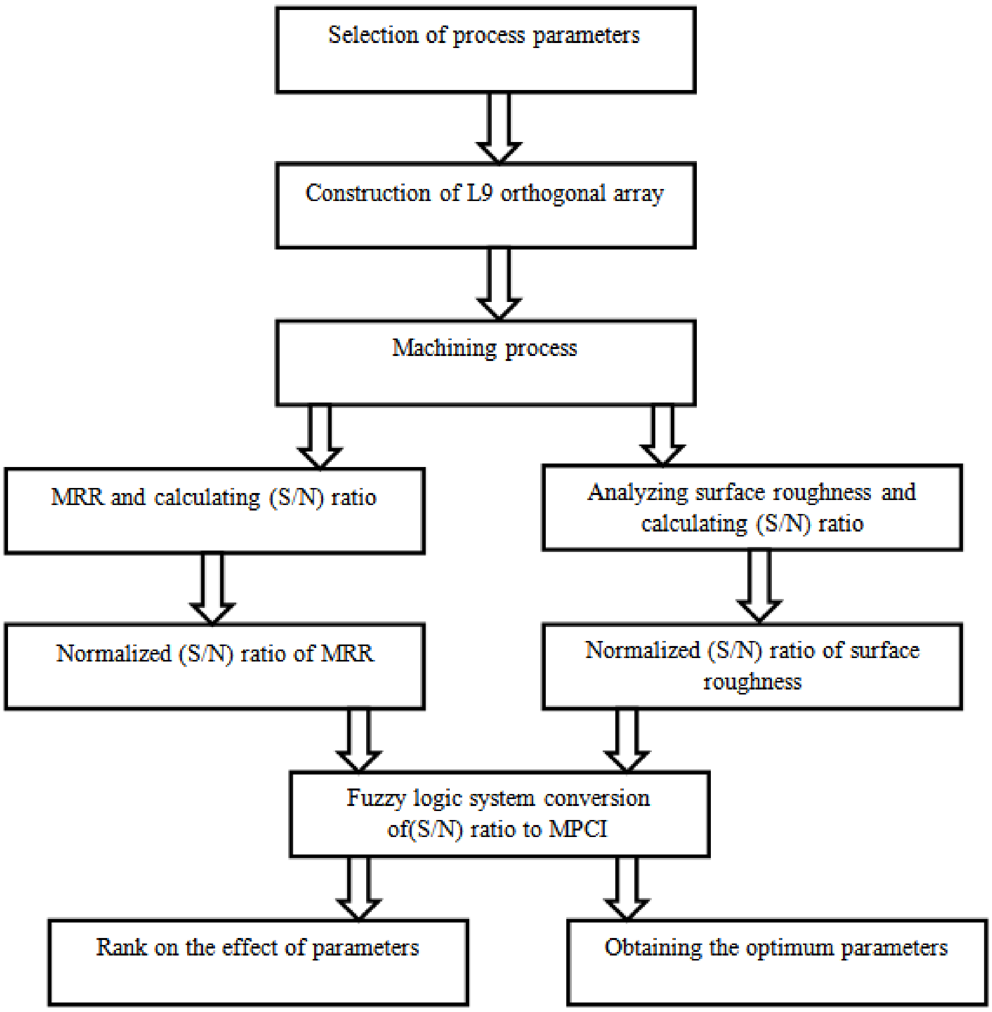


FIGURE 2 Research procedure methodology of MPCI

Methodology: Application of fuzzy logic for selection of machining parameters through soft computing.

Built up matlab software on fuzzy logic can be implemented for metal cutting parameter selection. But, for cutting process control, often it becomes essential to implement a fuzzy logic model for metal cutting parameter selection during hard turning[6]. Fuzzy logic model can be established based on the database formed considering the machinability data on the metal cutting hand book. Selection of machining parameters can be possible from this expert database which can be incorporated in computerized automated system. The fuzzy logic strategy can simulate the experience and expertise in decision making process.

Experimental Design

Experimental data as necessary for the above mentioned work were collected for case study from literature [1]. First, the material considered for the present study was AISI D2 steel. Experiments were performed by turning AISI D2 steel (cold work)bar of dia. 40mm with the following composition (carbon 1.55%, silicon 0.4%, manganese 0.4%,chromium 11.80%,molybdenum 0.7 %, vanadium 0.5 %, tungsten 0.6 %, sulphur 0.03%, phosphorus 0.03%). The bar was heat treated and found to be 53 HRC. Uncoated carbide tool was used to remove a layer of rust and scales from the surface of work piece prior to machining in a way so as to make the work piece diameter/length=(1/4). Commercially available multilayer coated ($TiCN/Al_2O_3/TiN$) tungsten carbide insert (golden) was used for experimentation. The insert has the geometry designated by ISO as CNNG 120408GS with 0.8mm nose radius.

For the purpose of the DOE each process parameter contain different levels(1,2,3) and coded as -1,0,1 as presented in table 1. The combination of different levels of process parameters and finding out the output i.e Surface Roughness and MRR.

TABLE 1 Experimental values of process parameters and subsequent coding [1]

	Levels		
	1	2	3
v (cutting speed, m/min)	80	150	220
f(feed, mm/rev)	0.05	0.1	0.15
t(depth of cut, mm)	0.1	0.2	0.1
Code	-1	0	1

Total number of combination can be made from the above mentioned level are 27(3*3*3) as presented in table 2.
For this paper presented the experimental data is considered from the literature.

TABLE 2 Experimental data collected from source literature for AISI D2 steel [1]

S.no	Code			Surface Roughness Ra(mm)	MRR(mm³/min)
1	-1	-1	-1	0.55	400
2	0	-1	-1	0.44	750
3	1	-1	-1	0.31	1100
4	-1	0	-1	0.81	800
5	0	0	-1	0.72	1500
6	1	0	-1	0.60	2200
7	-1	1	-1	1.17	1200
8	0	1	-1	0.68	2250
9	1	1	-1	0.97	3300
10	-1	-1	0	0.58	800
11	0	-1	0	0.48	1500
12	1	-1	0	0.38	2200
13	-1	0	0	0.85	1600
14	0	0	0	0.76	3000
15	1	0	0	0.64	4400
16	-1	1	0	1.22	2400
17	0	1	0	1.15	4500
18	1	1	0	1.05	6600
19	-1	-1	0	0.62	1200
20	0	-1	1	0.51	2250
21	1	-1	1	0.42	3300
22	-1	0	1	0.88	2400
23	0	0	1	0.8	4500
24	1	0	1	0.68	6600
25	-1	1	1	1.29	3600
26	0	1	1	1.21	6750
27	1	1	1	1.11	9900

By regression of the date presented in table 2, D.O.E model for surface roughness and D.O.E model for MRR has been created.
D.O.E model for surface roughness

$$Y(Ra)=0.7422 -0.1006x_1 +0.3089x_2 +0.0706x_3 +0.0350x_1^2+0.0367x_2^2 -0.0250x_3^2 +0.0075x_1x_2 +0.0058x_1x_3 +0.0450x_2x_3 \quad (1)$$

D.O.E model for MRR

$$Y(MRR)= 2998.1 +1400x_1 +1497.2x_2 +1497.2x_3 +5.6x_1^2 -2.8x_2^2 -2.8x_3^2 +700x_1x_2 +700x_1x_3 +745.8x_2x_3 +8x_2x_3 \quad (2)$$

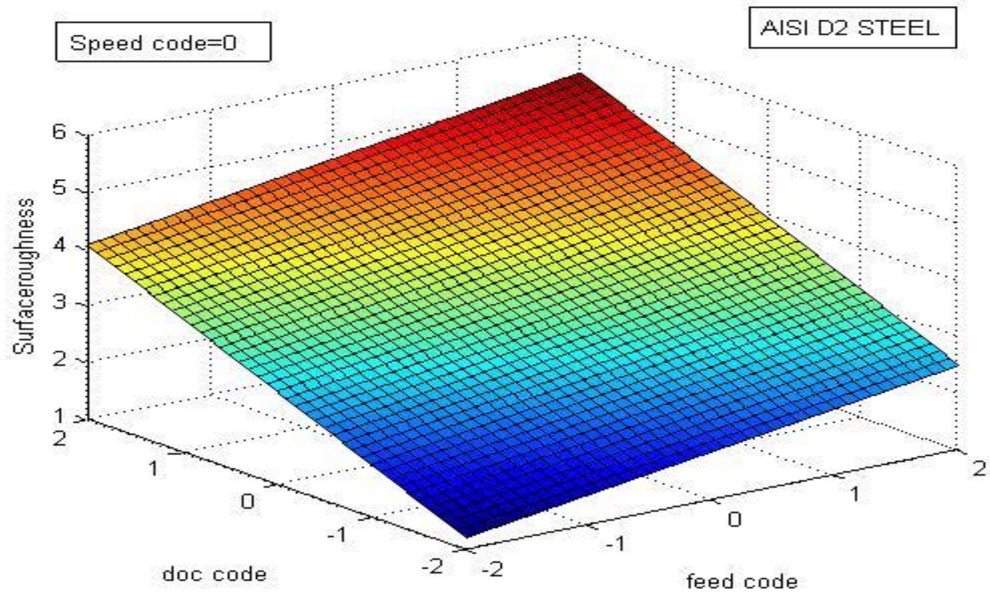


FIGURE 3 Surface roughness variation w.r.t doc and feed (speed code 0)

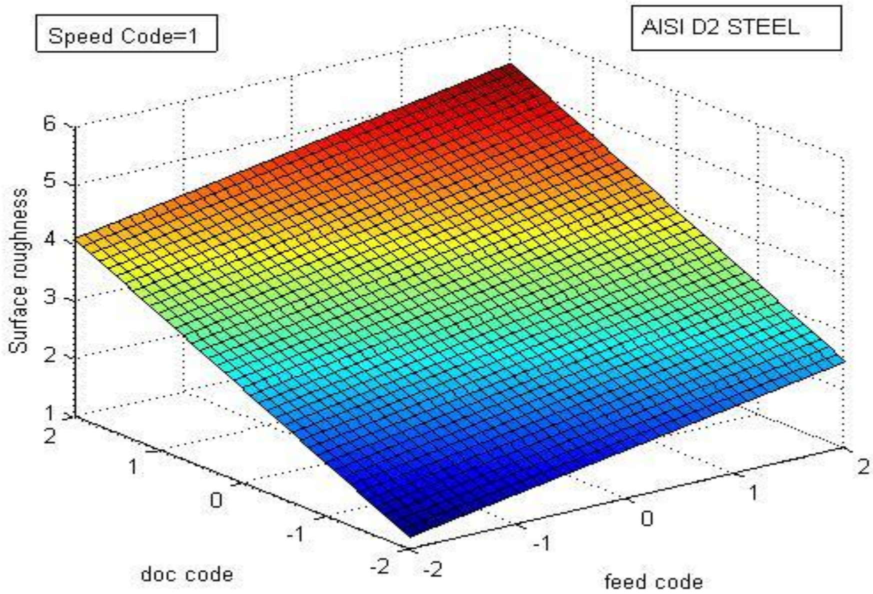


FIGURE 4 Surface roughness variation w.r.t doc and feed (speed code 1)

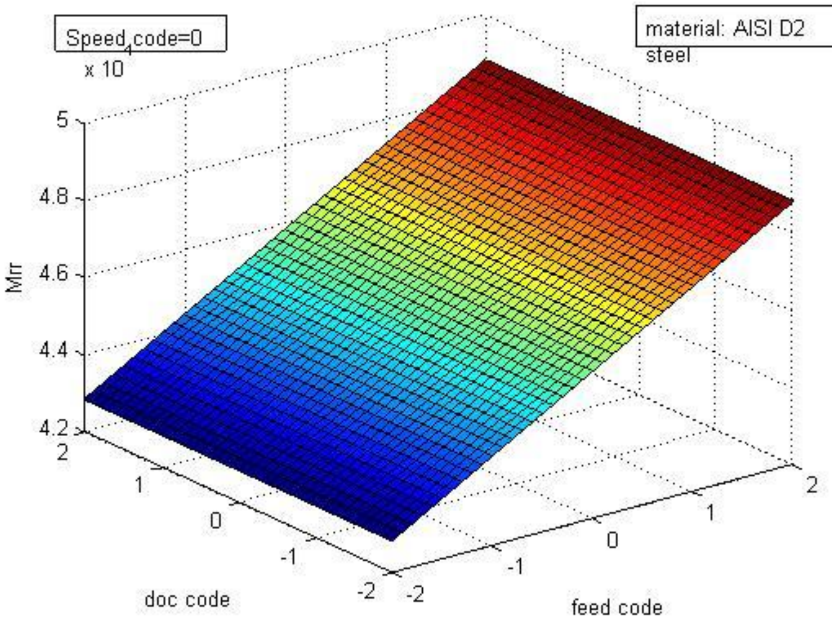


FIGURE 5MRR variation w.r.t doc and feed (speed code 0)

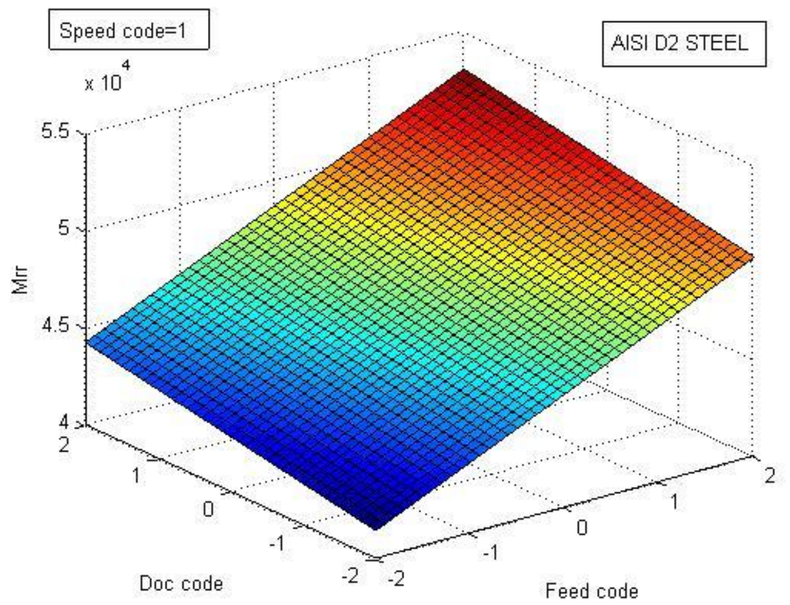


FIGURE 6MRR variation w.r.t doc and feed (speed code 1)

From the developed RSM models the following data on the surface roughness and MRR were obtained [TABLE 3]. L9 orthogonal array were there after prepared using the RSM models [TABLE 3]. All the estimated data on MRR and Ra were converted to S/N ratio following Taguchi methodology.

For MRR higher, the better concept was followed and for Ra, lower the better concept was followed. All the S/N ratio data were then normalized to get the normalized value in the form of L9 orthogonal array. DOE statistical tool is used to prepare orthogonal array found in Minitab statistical software.

After preparing the array subsequent values has been used from the table 2.

TABLE 3L_9 orthogonal array of machining parameters and corresponding machining response

S no.	Speed m/min	Feed mm/rev	Depth of cut mm	Ra	MRR mm^3/min
1	1 (-1)	1 (-1)	1 (-1)	0.55	400
2	1 (-1)	2 (0)	2 (0)	0.85	1600
3	1 (-1)	3 (1)	3 (1)	1.29	3600
4	2 (0)	1 (-1)	2 (0)	0.48	1500
5	2 (0)	2 (0)	3 (1)	0.8	4500
6	2 (0)	3 (1)	1 (-1)	0.97	3300
7	3 (1)	1 (-1)	3 (1)	0.42	3300
8	3 (1)	2 (0)	1 (-1)	0.60	2200
9	3 (1)	3 (1)	2 (0)	1.05	6600

Signal to noise ratio has been calculated correcting to MRR and Surface Roughness

TABLE 4S/N ratio for MRR and Ra

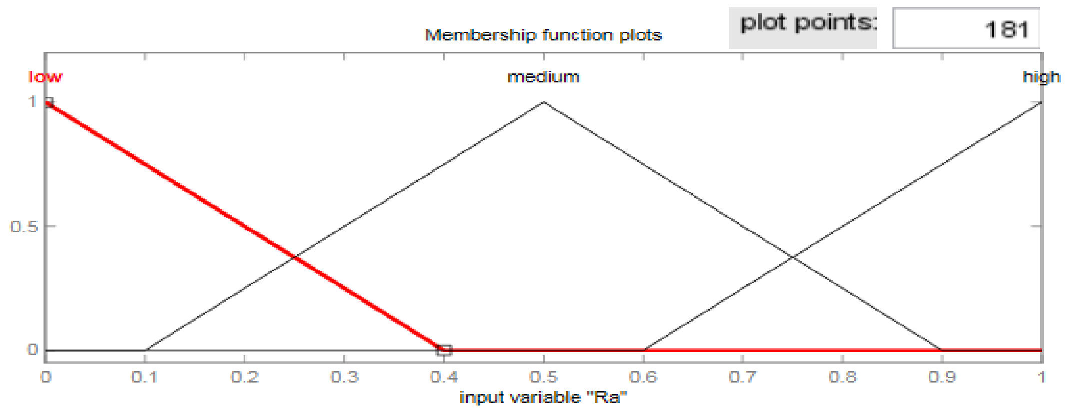
S. no.	S/N ratio for MRR	S/N ratio Ra
1	52.0412	5.1927
2	64.0824	1.4116
3	71.1261	-2.2118
4	63.5218	6.3752
5	73.0643	1.9382
6	70.3703	0.2646
7	70.3703	7.5350
8	66.8485	4.4370
9	76.3909	-0.4238

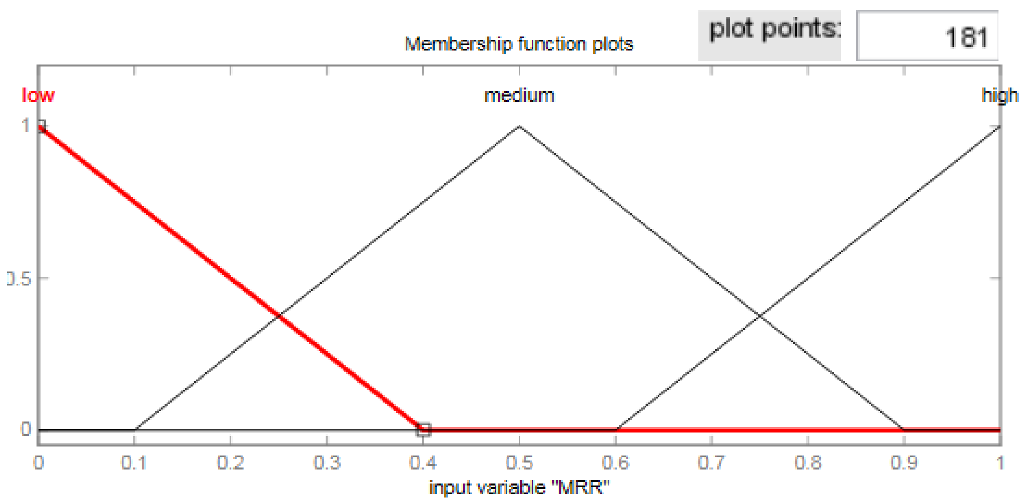
To get more meaningful information values of signal to noise ratio has been normalized.

TABLE 5 Normalized values

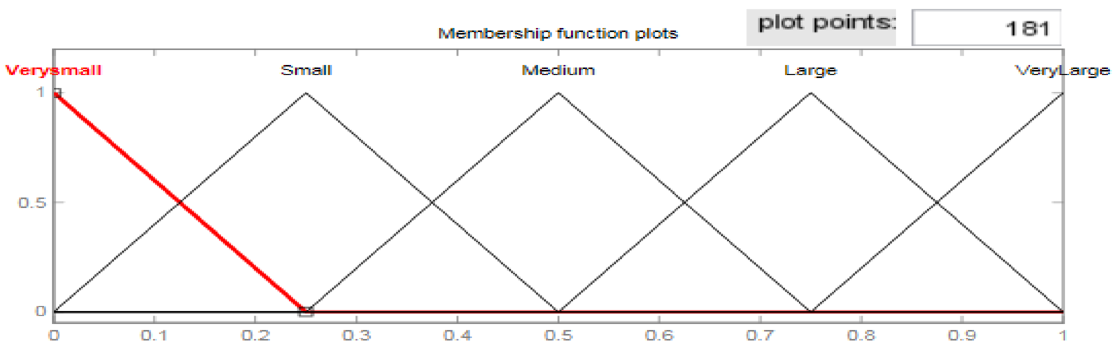
S. no.	Normalized S/N ratio of MRR	Normalized S/N ratio of Ra
1	0	0.7597
2	0.4945	0.3718
3	0.7838	0
4	0.4715	0.8810
5	0.8634	0.4258
6	0.7527	0.2541
7	0.7527	1
8	0.6081	0.6821
9	1.0000	0.1834

After getting the normalized values membership functions has been created for the MRR, Surface Roughness and MPCI further calculating the MPCI value as an output as shown in the figure below.

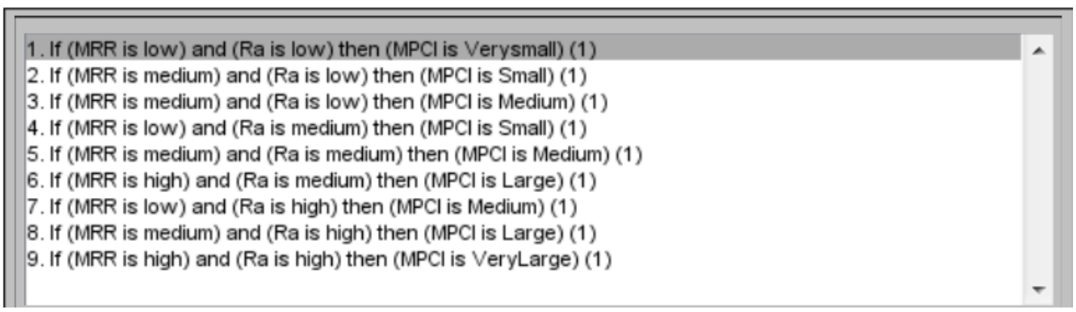




The fuzzy model was implemented for the simulation task in order to find out the simulated result on MPCI (Multi performance characteristic index). The following fuzzy rules were implemented [rules].



Rules


1. If (MRR is low) and (Ra is low) then (MPCI is Verysmall) (1)
2. If (MRR is medium) and (Ra is low) then (MPCI is Small) (1)
3. If (MRR is medium) and (Ra is low) then (MPCI is Medium) (1)
4. If (MRR is low) and (Ra is medium) then (MPCI is Small) (1)
5. If (MRR is medium) and (Ra is medium) then (MPCI is Medium) (1)
6. If (MRR is high) and (Ra is medium) then (MPCI is Large) (1)
7. If (MRR is low) and (Ra is high) then (MPCI is Medium) (1)
8. If (MRR is medium) and (Ra is high) then (MPCI is Large) (1)
9. If (MRR is high) and (Ra is high) then (MPCI is VeryLarge) (1)

Fuzzy modelling and simulation work were performed to obtain the simulated result on MPCI. The following table present the values of simulated MPCI and corresponding S/N ratio of MPCI (db).

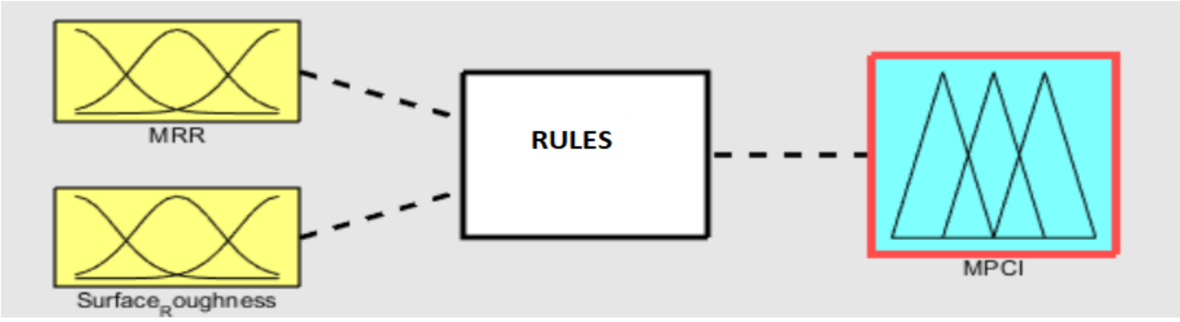


FIGURE 7 Fuzzy modelling

After simulating the fuzzy logic following results are obtained

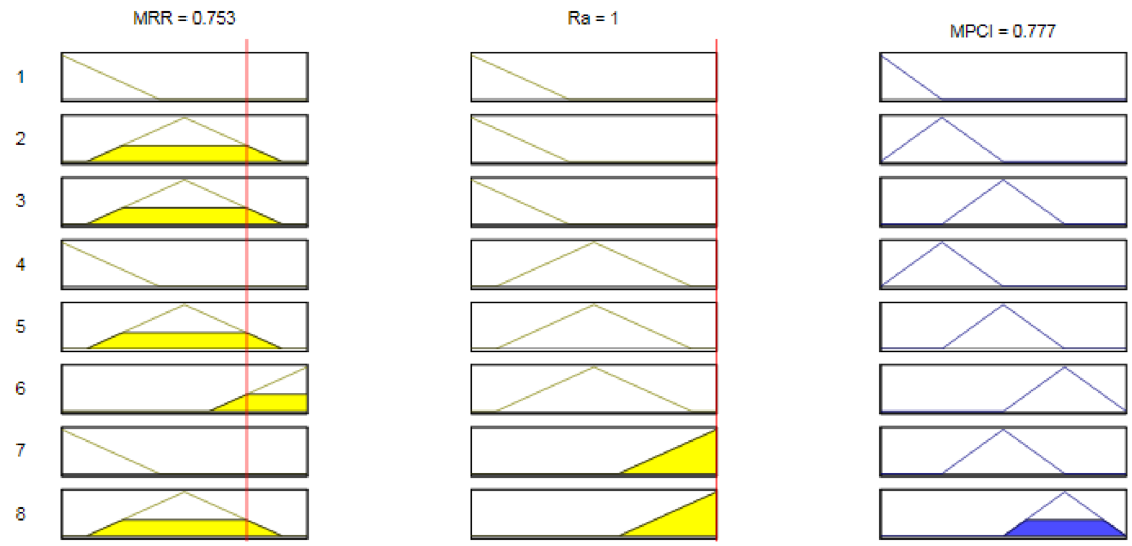


FIGURE 8 Simulation result (FIS)

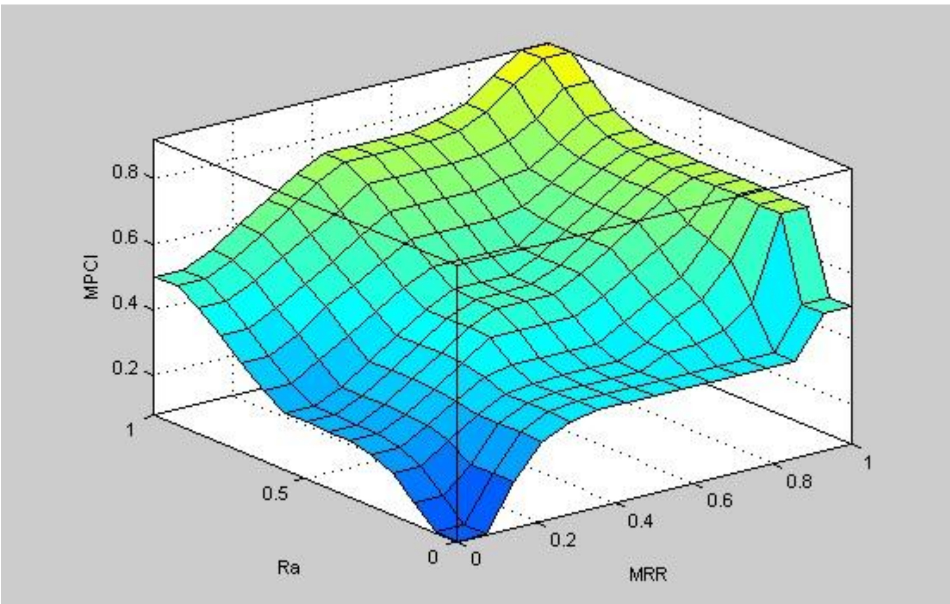


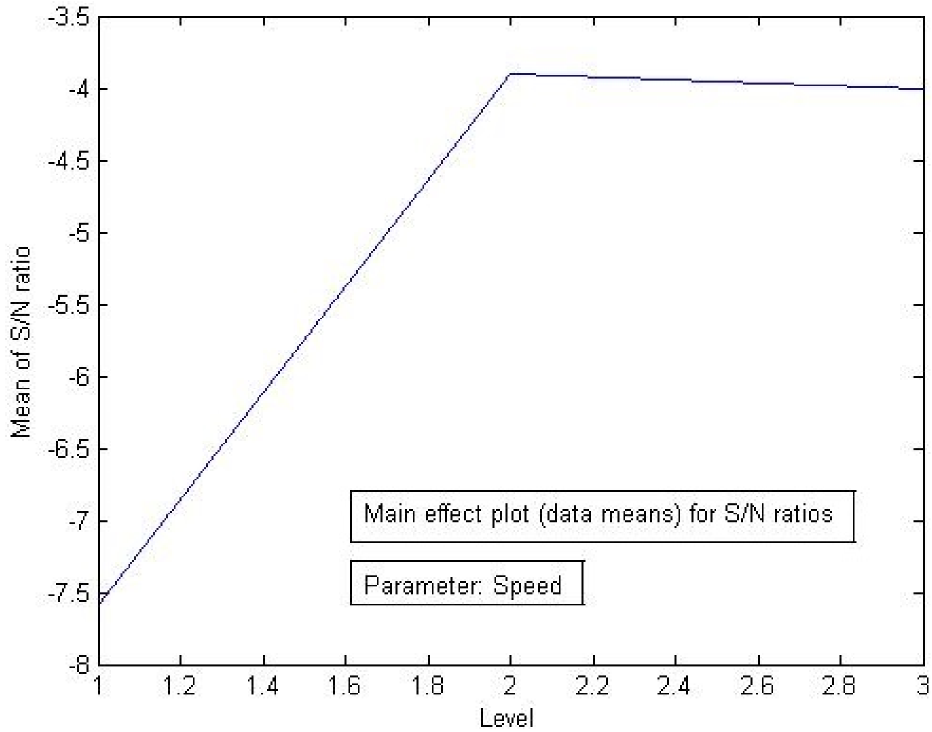
FIGURE 9MPCI variation

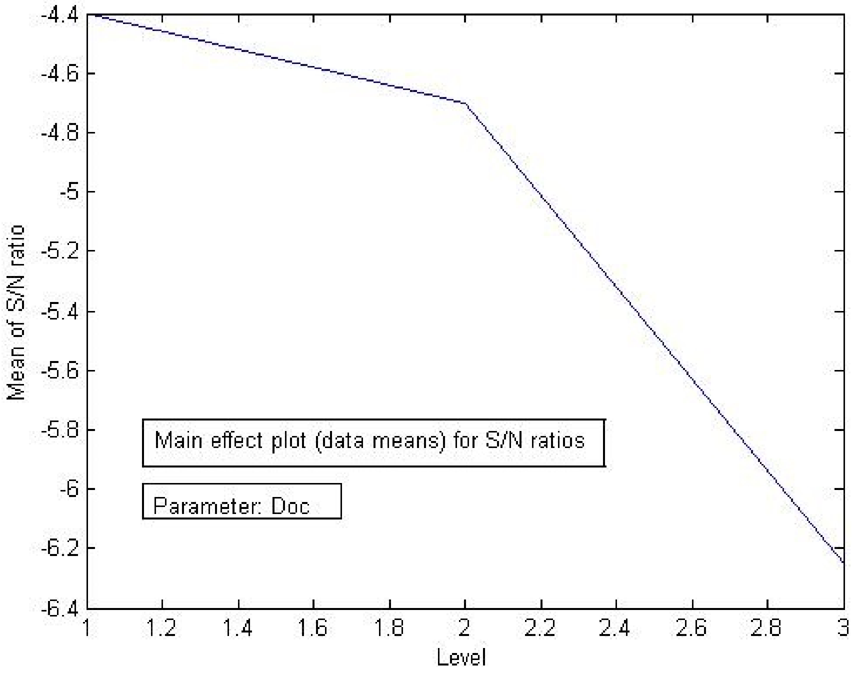
TABLE6 Simulated MPCI through FIS and corresponding S/N ratio of MPCI

S. no.	MPCI	S/N ratio of MPCI (db)
1	0.383	-8.9960
2	0.473	-6.5028
3	0.401	-7.9371
4	0.732	-2.7098
5	0.716	-2.9017
6	0.504	-5.9514
7	0.777	-2.1916
8	0.572	-4.8521
9	0.573	-4.8369

TABLE 7 Mean response table (S/N ratio for MPCI)

Level	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	-7.5920	-4.4125	-6.3798
2	-3.8543	-4.7522	-4.6832
3	-3.9602	-6.2418	-4.3435
Delta (Max-Min)	3.7377	1.8293	2.0363
Rank	1	3	2





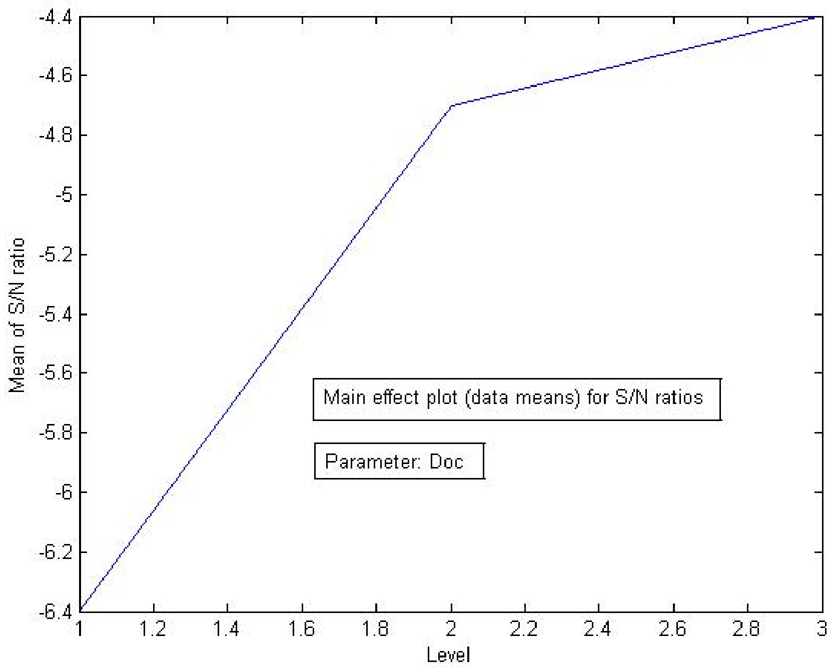


FIGURE 10 Mean of S/N ratio

II. RESULTS AND DISCUSSION

After plotting the 3D model for surface roughness and MRR some and conclusions of are drown as discussed below.

It was decided to study the influence of machining parameters on surface roughness and MRR, keeping speeds at low (0) and high (1) values from FIGURE 3. It is seen that as feed increases surface roughness also increases at constant depth of cut. Similarly depth of cut is also found to increase the surface roughness with increased depth of cut at constant feed. It is understood that increase of feed influences much to increase the surface roughness as compared to increased depth of cut that is depth of cut has almost negligible influence on surface roughness values. At high speed (1)(FIGURE 4) it is observed that in a similar manner as happened with the previous case that is the surface roughness value increased with increased feed and depth of cut. Influence of feed on surface roughness was again found to effect much on surface roughness compared to influence of depth of cut. Comparative assessment of the above mentioned two cases showed better improvement on surface roughness value at high speed (1).Variation of MRR with respect to depth of cut and feed has been shown in FIGURE (5) and (6). It is seen that MRR increases with increased speed, feed and depth of cut in both the cases at low speed (0) and high speed (1). Comparative assessment showed that MRR becomes higher at high speed (1).

From the mean response table (S/N ratio for MPCIs) it is seen that speed effect is more (1) influencing followed by depth of cut and feed. Main effects plots (data means) for S/N ratios were prepared and optimal solution was noted at (2 1 3).

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