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APPLICATION OF DIFFERENTIAL SEARCH ALGORITHM TO OPTIMISE THE TURNING OPERATIONS INPUT VARIABLES WHILE MACHINING E0300 ALLOY STEEL

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ABSTRACT

Turning process is one of the inevitable commonly applied machining operations almost in all the manufacturing industries which cover verities of operations to bring the configuration of the product to the desired shape and size. In such machining process the prime objectives are to achieve the concern dimensional accuracy in the product with the required surface quality is equally important. Surface quality is recognized as most important resultant parameter. This investigation mainly concerned with the optimisation of machining parameters to achieve the desired surface quality referring the Cutting speed, tool feed and depth of cut as the input machining variables while performing turning operations on the E0300 Alloy steel. The methodology adopted in this attempt is the Differential Search Algorithm linked with the statistical regression relationship between the parameters as the conditional platform for simulation through MATLAB R2017programming. Through the processing of simulation the optimised parameter combinations are identified for the surface roughness and generalized path of results for various combination of input variables also generated.

Key words- E0300, Turning, Regression, Differential Search Algorithm, Optimisation, Minitab, MATLAB.

I. INTRODUCTION

In the present scenario of manufacturing attaining the right quality of product with reasonable cost and time is highly needed approach to every manufacturer. The identification of right methodology of operations with right selection of machining parameters combination for the selected material calls for investigation of the process through every aspect. Turning process is the most common applied one with highly automated machining centres nowadays. Though every care has been taken by machine tool manufacturers and the cutting tool developers at the time of operation the selection of suitable parameter combination is getting importance in the product end quality. Out of all resultant parameters on processing, surface finish is being identified as the highly important outcome since because the functional property of the product concerned is dependent on this. The surface finish of any product is mainly associated with the materials properties and process parameters like machining speed; tool feed rate, depth of cut, tool material and properties etc. In this present investigation the identification of the level of influence of the cutting variables on the surface finish of the E0300 alloy material in turning operations is carried out. Differential Search Algorithm is employed for identifying such parameter combination and the suitability of the algorithm is assessed for further applications. Statistical regression relationship between the process parameters is chosen as an additional support to get the improved results.

II. RELATED LITERATURE

Alakesh Manna and Sandeep Salodkar [1] have made an attempt in turning of E0300 alloy material and analysed the outcome of the observation with Dynamic programming and Anova technique. They have developed a mathematical model for surface roughness height, *R*a and proposed for proper selection of the turning parameters. The developed model can aid directly to evolutes the *R*a value under different machining combination during turning. Wang et al. [2] have conducted experiment, optimized the machining variables with the aid of the deterministic approach and suggested to choose the cutting conditions economically in single pass turning operation. Puertas Arbizu and Luis Perez [3] have identified through their experiment that the effect of the machining input parameters feed rate and the depth of cut as the adverse effect on the surface finish through employing factorial design. Tekiner and Yesilyurt [4] have examined on the appropriate process parameters in the turning operations AISI 304 austenitic stainless steels. Muthukrishnan et al. [5] have assessed on the application of ANN as well as ANOVA analysis for optimization of machining parameters in turning AlSiC composites and declared that both ANOVA and ANN modeling offer an organized and efficient method on optimization. Chang [6] declared in their study that the tool geometry too cause for the vibration on the machine tool during operations related to other parameters. Feng [7] has investigated through the fractional factorial experimentation method that the machining speed, cutting tool feed rate, the tool geometry and the properties of the work material have a significant influence on the surface quality of the product. Basavarajappa et al. [8] have revealed the influence of speed and feed on drilling of hybrid metal matrix composites through Taguchi techniques through their experimental investigation. Tosun [9] has declared his findings regarding the application of grey relational analysis to optimise the drilling process parameters for surface roughness and the burr height is introduced. That attempt particularly notified for grey relational analysis approach successful application to other operations in which presentation is resolute by several parameters at many quality requests. Yang JL & Chen JC [10] have stated that the surface roughness, R_a can be presented through the mathematical relationship.

In this attempt the analysis and forecasting on the optimized parametric combination is carried out through Differential Search Algorithm by MATLAB programming. Based on the fitness of the regression equation developed in Minitab, as a new approach of feeding the regression equation relationship as input instead of random approach is done and the optimised parameters combinations are identified with the tuned results.

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III. EXPERIMENTAL PLAN AND OBSERVED DATA

E0300 alloy steel was selected as work-piece material and experiment conducted in the Kirloskar Centre Lathe. The cutting tool used for this process was PVD coated with an identical thin coating (Ti Al and Si) N imparted via a low voltage arch process of specification DNMG15608EF, grade 8030 (nose radius 0.8mm) single point cutting tool.

Table 3.1 Input machining parameters level selection

Turning parameters	Units	Level 1	Level 2	Level 3
Cutting Speed	(m / min)	40	100	160
Feed	(mm / rev)	0.16	0.32	0.48
Depth of cut	(mm)	0.50	0.75	1.0

The input parameters are cutting speed (m / min), feed (mm / rev), and depth of cut (mm) where the output parameter chosen for investigation was the surface quality. Three levels of input parameters selection was mentioned in the Table 3.1. The surface quality of the machined surface was measured at three different positions through the TSK Surfcom 130A, surface texture measuring instrument and the average value was taken for investigation. Then arrived observed experimental data are mentioned in the Table 3.2

Table 3.2 Experimental observed data set

Ex. No.	Cutting Speed (m/min)	Feed Rate (mm/ rev)	Depth of Cut (mm)	Average surface roughness (Ra), µm
1	40	0.16	0.50	1.93
2	40	0.16	0.75	2.83
3	40	0.16	1.00	2.62
4	40	0.32	0.50	1.86
5	40	0.32	0.75	3.11
6	40	0.32	1.00	2.99
7	40	0.48	0.50	2.36
8	40	0.48	0.75	3.19
9	40	0.48	1.00	3.73
10	100	0.16	0.50	2.06
11	100	0.16	0.75	2.07
12	100	0.16	1.00	1.83
13	100	0.32	0.50	2.11
14	100	0.32	0.75	2.39
15	100	0.32	1.00	2.04
16	100	0.48	0.50	2.49
17	100	0.48	0.75	2.70
18	100	0.48	1.00	2.68

19	160	0.16	0.50	1.10
20	160	0.16	0.75	1.13
21	160	0.16	1.00	1.62
22	160	0.32	0.50	1.65
23	160	0.32	0.75	1.40
24	160	0.32	1.00	1.88
25	160	0.48	0.50	2.93
26	160	0.48	0.75	1.73
27	160	0.48	1.00	2.19

IV. MATHEMATICAL MODELLING

With the Minitab17 software the influence of the input machining parameters (speed, feed and depth of cut) on the output parameter (surface roughness) are analysed by statistical regression relationship. The second order regression relationship between the variables shows higher level significance than the first order regression through the values of the R – sq. Both the first and second order statistical values of R-sq can be viewed from the Table 4.1.

Table 4.1 Regression model comparison for surface roughness

Parameter	Regression	S	R-sq	R-sq(adj)	R-sq(pred)	Durbin - Watson
Df	1st order	0.373373	70.32%	66.45%	56.88%	2.40514
	2nd order	0.354473	80.23%	69.76%	41.89%	2.36162

The second order regression equations through the Minitab17 for the surface roughness parameter in terms of input parameter combination are

Surface roughness = (0.60) + (0.0034*Cutting speed) – (1.58*Feed Rate) + (3.93*doc) – (0.000008*Cutting speed^2) + (5.06*Feed Rate^2) – (0.92* doc ^2) + (0.0095*Cutting speed*Feed Rate) – (0.33*Feed Rate* doc) – (0.01767*Cutting speed* doc) (4.1)

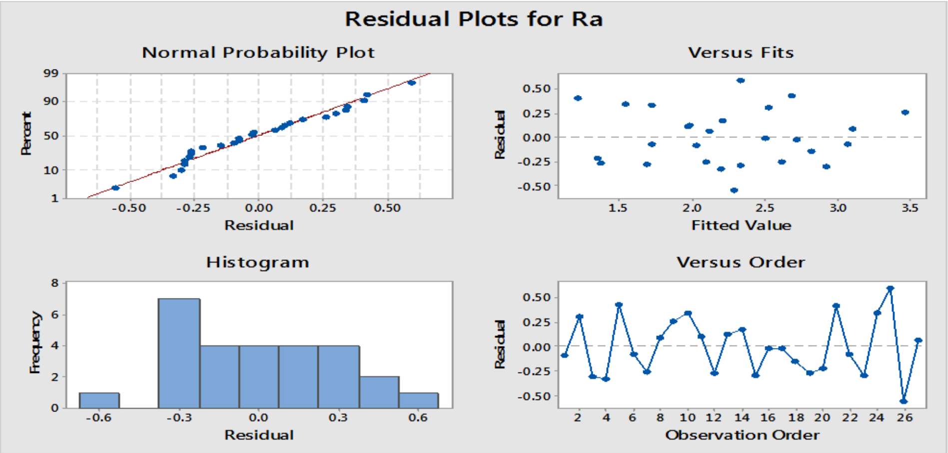

Figure 4.1 Residual plots of surface roughness

The residual plots through Minitab analysis for the surface roughness are depicted in Figure 4.1. Through performing the best subset regression analysis the parameter depth of cut registered the higher level influence on the surface roughness. The second level of influence on the surface roughness is given by speed comparing to feed rate.

V. OPTIMISATION METHODOLOGY

Optimization of the parameters in the present investigation is carried out with the application of Differential Search Algorithm. Forecasting of the optimized Surface roughness in the turning process on the E0300 specimen was carried out by way of taking the prime objective as minimum surface roughness as the result. To analyze the influence of the cutting speed and the feed on the surface roughness through DSA, MATLAB R2017 platform with the Elman Back Propagation approach is applied. The number of iterations initiated for this simulation is 50000 turns. The suitability of the DAS methodology is assessed through the accuracy level in computation which is from the error rate as the indicator. Figure 5.1 shows the progress of the training data in MATLAB.

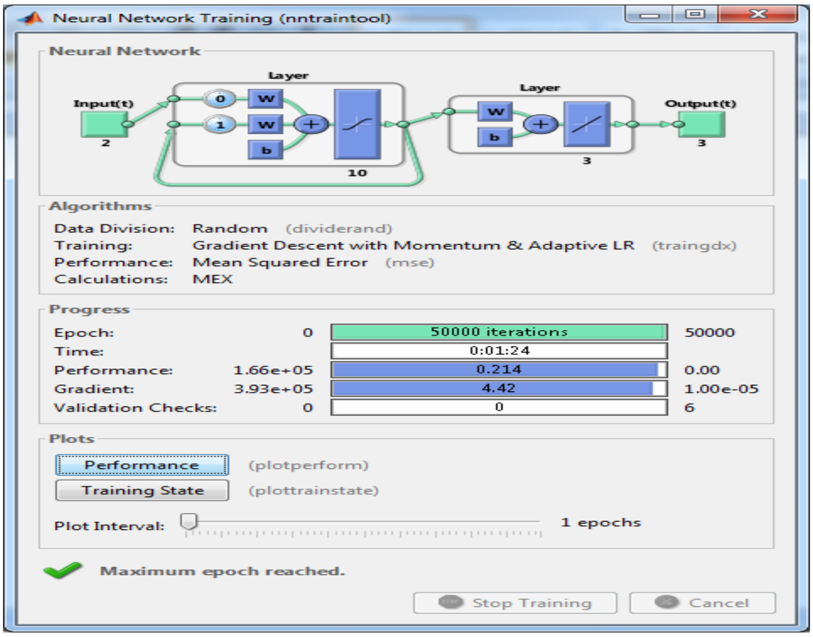

Figure 5.1 Data training progress of 50000 iterations

The accuracy level of the DSA was 5.28 x 10^{-5} while computation was effected by taking the experimental observed output parameter values as the input to the programme. Later the regression relationship is added in the programme instead of taking random selection of input parameters combination and the accuracy level is noticed as 3.64 x 10^{-5} which indicated the improvement in the simulation. Finally the regression values calculated through the programme referring to the input parameter combination fed in the programme and processed. The result recorded was 2.31 x 10^{-5} error value. After confirming the steady improvement stage by stage in computation, in order to draw a smooth path of the process outcomes the parameters selected was sub divided with the step value 10 m / min in speed, 0.004 step value in feed and 0.10 mm step value in depth of cut. The computed results of the surface roughness through this approach for all combination of the parameter input given to the programme are listed in the Table 5.1 to Table 5.5.

Table 5.1 Ra for the speed 40 m /min Vs all combination of feed and depth of cut

Speed 40 m / min									
DOC	Feed 0.16	Feed 0.20	Feed 0.24	Feed 0.28	Feed 0.32	Feed 0.36	Feed 0.40	Feed 0.44	Feed 0.48
0.50	1.90	2.03	2.07	2.12	2.03	2.27	2.37	2.48	2.89
0.60	2.23	2.50	2.28	2.33	2.39	2.47	2.58	2.69	3.23
0.70	2.26	2.31	2.47	2.52	2.59	2.67	2.62	2.91	3.11
0.80	2.61	2.87	2.65	2.69	2.76	2.84	2.93	3.42	3.32
0.90	2.45	2.78	2.81	2.85	2.92	3.14	3.29	3.45	3.58
1.00	2.90	2.80	3.01	3.01	2.90	3.05	3.14	3.17	3.19

Table 5.2 Ra for the speed 50 m /min Vs all combination of feed and depth of cut

Speed 50 m / min									
DOC	Feed 0.16	Feed 0.20	Feed 0.24	Feed 0.28	Feed 0.32	Feed 0.36	Feed 0.40	Feed 0.44	Feed 0.48
0.50	1.97	1.99	2.03	2.08	2.04	2.55	2.34	2.79	2.82
0.60	2.48	2.19	2.22	2.28	2.34	2.43	2.53	2.65	3.15
0.70	2.46	2.36	2.40	2.45	2.52	2.60	2.52	2.79	2.98
0.80	2.43	2.52	2.56	2.61	2.67	2.76	2.86	3.38	3.28
0.90	2.65	2.67	2.70	2.75	2.78	2.99	3.13	3.28	3.42
1.00	3.12	2.88	2.96	2.90	2.85	3.01	3.11	3.15	3.15

Table 5.3 Ra for the speed 60 m /min Vs all combination of feed and depth of cut

Speed 60 m / min									
DOC	Feed 0.16	Feed 0.20	Feed 0.24	Feed 0.28	Feed 0.32	Feed 0.36	Feed 0.40	Feed 0.44	Feed 0.48
0.50	1.92	1.95	1.98	2.04	1.98	2.49	2.32	2.75	2.77
0.60	2.41	2.12	2.16	2.22	2.30	2.39	2.49	2.61	3.05
0.70	2.31	2.29	2.33	2.38	2.45	2.54	2.44	2.68	2.87
0.80	2.44	2.43	2.47	2.52	2.59	2.68	2.78	3.32	3.23
0.90	2.53	2.55	2.59	2.64	2.67	2.87	2.99	3.12	3.26
1.00	2.64	2.84	2.90	2.83	2.81	2.96	3.07	3.12	3.12

Table 5.4 Ra for the speed 140 m /min Vs all combination of feed and depth of cut

Speed 140 m / min									
DOC	Feed 0.16	Feed 0.20	Feed 0.24	Feed 0.28	Feed 0.32	Feed 0.36	Feed 0.40	Feed 0.44	Feed 0.48
0.50	1.48	1.53	1.61	1.69	1.69	1.92	2.06	2.21	2.59
0.60	1.40	1.57	1.65	1.73	1.84	1.95	2.10	2.03	2.41
0.70	1.64	1.59	1.66	1.75	1.85	1.77	1.95	2.05	2.12

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0.80	1.54	1.59	1.66	1.75	1.85	1.96	2.29	2.33	2.37
0.90	1.52	1.58	1.64	1.47	1.83	1.94	2.07	2.41	2.37
1.00	1.49	1.54	1.61	1.69	1.79	2.14	2.19	2.30	2.42

Table 5.5 Ra for the speed 160 m /min Vs all combination of feed and depth of cut

Speed 160 m /min									
DOC	Feed 0.16	Feed 0.20	Feed 0.24	Feed 0.28	Feed 0.32	Feed 0.36	Feed 0.40	Feed 0.44	Feed 0.48
0.50	1.35	1.41	1.50	1.59	1.69	1.83	1.98	2.14	2.54
0.60	1.35	1.42	1.49	1.59	1.70	1.97	1.84	1.83	2.31
0.70	1.49	1.40	1.48	1.57	1.68	1.69	1.85	1.93	1.99
0.80	1.31	1.37	1.44	1.54	1.64	1.96	1.99	2.07	2.15
0.90	1.26	1.31	1.39	1.44	1.59	1.71	1.85	2.26	2.21
1.00	**1.19**	1.25	1.32	1.41	1.51	1.86	1.90	2.02	2.17

The scatter plots generated through the Minitab for the above results are shown in the following Figures 5.2 to 5.6

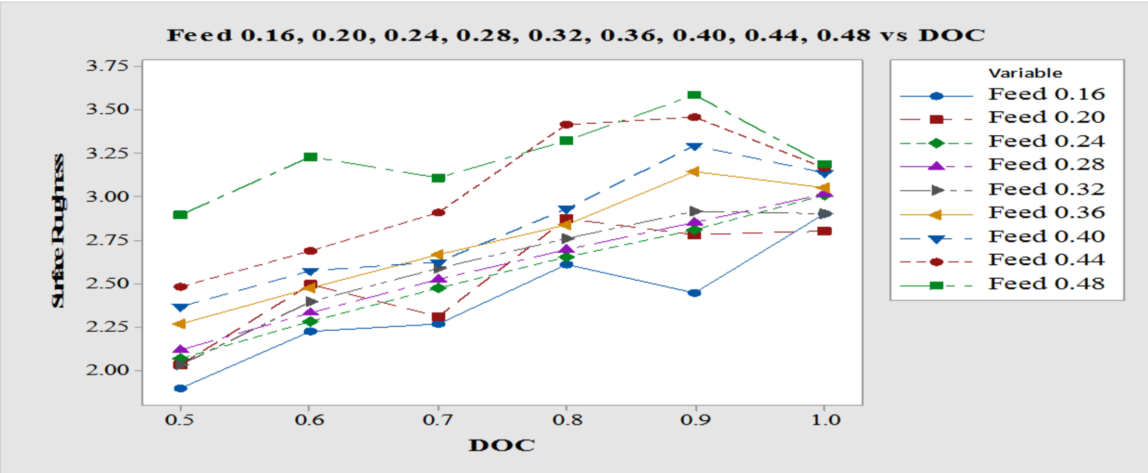

Figure 5.2 Surface roughness plots for the speed 40 m / min

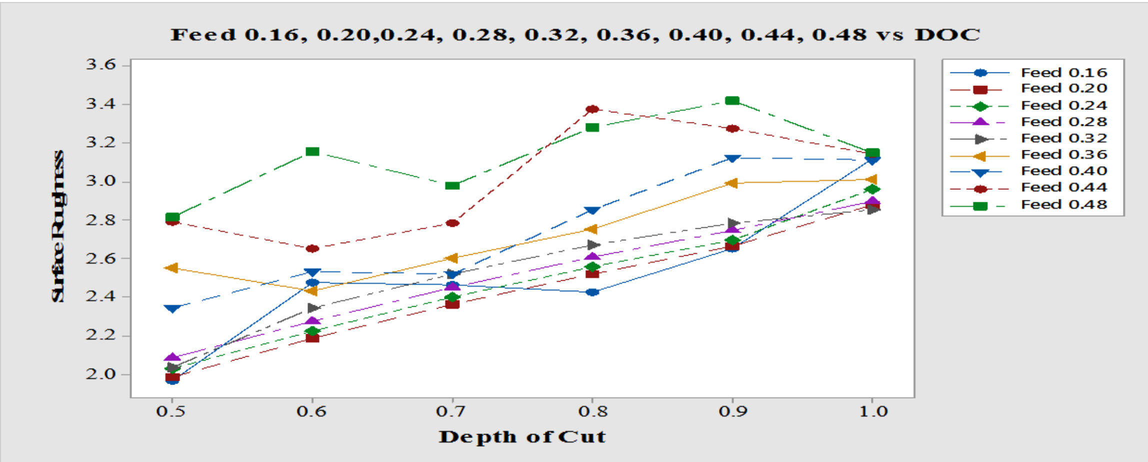

Figure 5.3 Surface roughness plots for the speed 50 m / min

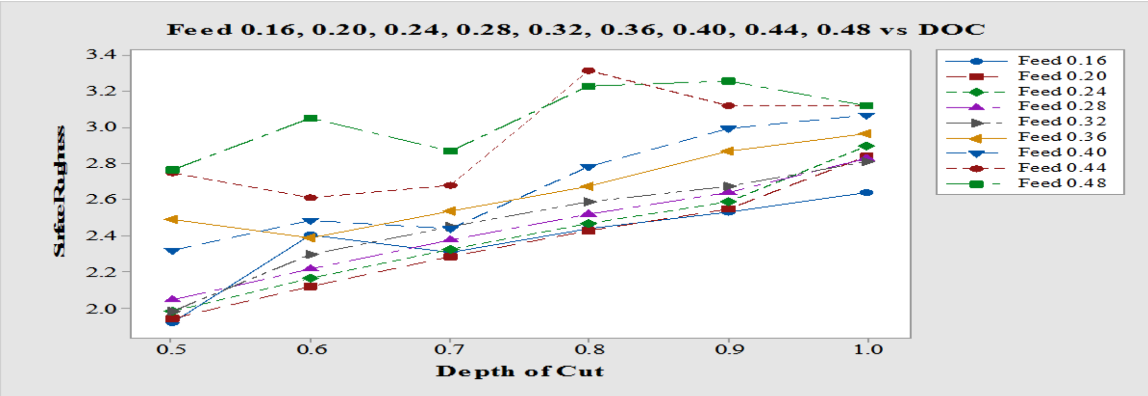

Figure 5.4 Surface roughness plots for the speed 60 m / min

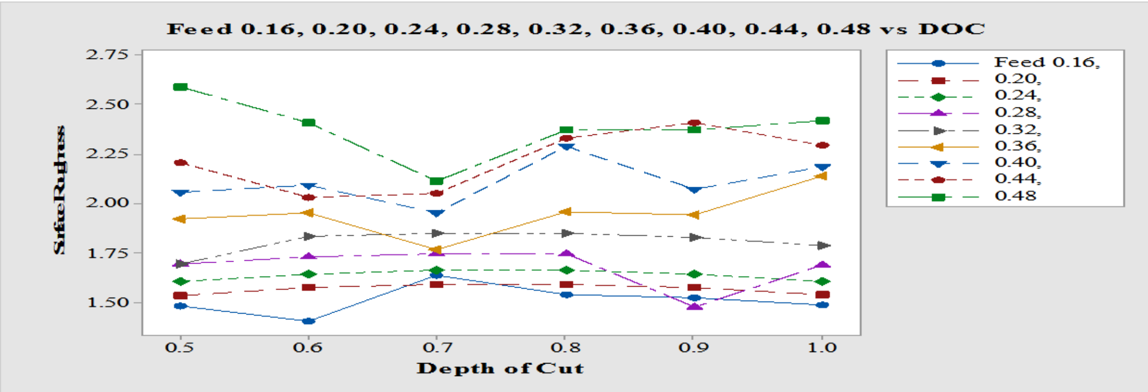

Figure 5.5 Surface roughness plots for the speed 140 m / min

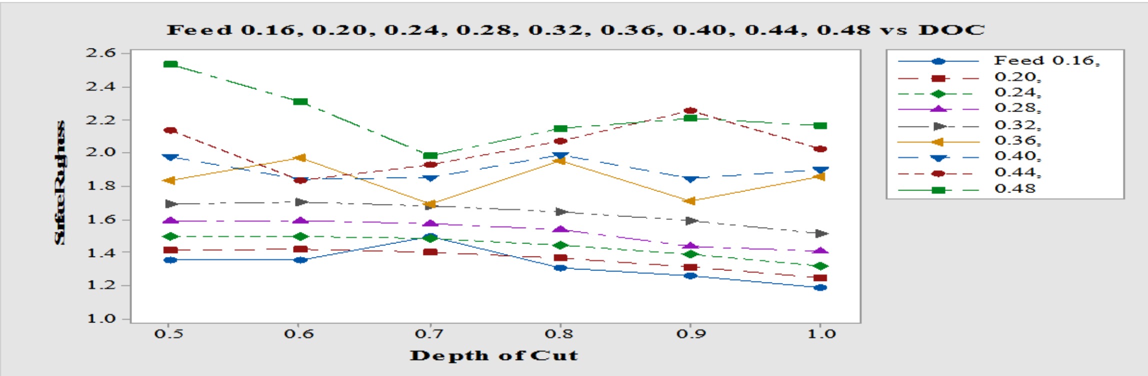

Figure 5.6 Surface roughness plots for the speed 160 m / min

VI. RESULTS AND CONCLUSION

Turning experiment conducted on the E0300 alloy material. Cutting Speed (m / min), Feed (mm / rev), depth of cut (mm) are taken as input variables and the Surface roughness (µm) is taken as output variable for investigation. As the 2nd order regression relationship between the input , output variables are significant statistically it was taken as the input for the programme. DSA was employed in MATLAB platform towards optimizing. On replacing with the random process with regression relationship, feeding the regression computed values as input the accuracy level in computation is tune to the finest level for the set of values. By selecting the equal interval values the computation is performed and graphs are plotted with the Minitab software. Depth of cut registered the higher level influence on the surface roughness. The second level of influence on the surface roughness is given by speed which subsequently followed by tool feed rate.

The optimum value of Surface roughness R_a is 1.60 µm for the speed 160 m / min, with 0.60 mm / rev feed, 1.0 mm depth of cut combination. The plotted graphs generated for the reference to the processing manufacturers, with respect to the end product quality requirement. Further subdivision of input parameters may give further more smooth curves which will be useful to the processing industry. Nominating the regression values and the regression relationship as the input boundary conditions to the programme to be taken care of based on the statistical significance.

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