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Effects of Machining Parameters on the Surface Roughness of Al-Si alloy

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cutting speed, depth of cut, feed rate, surface roughness and contribution

A B S T R A C T

The effects of machining parameters, on surface roughness of aluminium alloy machined using face turning were investigated in this research. Taguchi's approach to design of experiment was employed to determine the number of runs of experiments. Three significant factors; cutting speed, depth of cut and feed rate, were taken as machining parameters at three levels to determine their combined and interaction effects on the surface roughness of the aluminium alloy machined. The experiment was designed and carried out on the basis of standard L_9 Taguchi's orthogonal array, leading to nine runs of experiments. The signal-to-noise (S/N) ratio, the analysis of variance (ANOVA) are employed to find the optimal levels and to analyze the effect of the turning parameters. It was discovered depth of cut dominantly influenced the surface roughness of the machined components by making a contribution of 67.84% and the lowest value of surface roughness was 0.6625μm.

1. Introduction

Material removal as a means of manufacturing desired product dates back to prehistoric times, when man learned to carve wood and chip stones to make hunting and farming hand tools to modern machining which has combined machine tools capable of performing more than one operation(Mohammed, et al, 2007). There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture. Out of these machining operations, the three most common types are turning, drilling, and milling(Groover, 2010)

Face turning (Figure 1) is a cutting operation that uses a single point tool and the tool is fed tangentially to cut the rotating work piece on one end to create a flatsurface at the end of operation.It has long been recognized that conditions during face turning, such as cutting tool feeding rate, cutting speed and depth of cut amongst others should be selected to optimize the economics of machining operations, as assessed by productivity, total manufacturing cost per component or some other suitable criterion. Researches have shown that an optimum or economic cutting speed exists which could maximize material removal rate (Kumar and Packiaraj, 2012; Mohammed, et al, 2007). Manufacturing industries have long depended on the skill and experience of workshop machine tool operators for optimal selection of cutting conditions and cutting tools (Sudhansu and Das, 2013).

The non-availability of the required technological performance equation represents a major obstacle to implementation of optimized cutting conditions in practice(Sudhansu and Das,2013).

This follows extensive testing that is required to establish empirical performance equations for each tool work material combination for a given machining operation, which can be quite expensive when a wide spectrum of machining operations is considered (Show-Shyan, 2009 ;Naveen, 2009).

According to Madic, et al. (2013), the demand for high quality and fully automated production focuses attention on the surface condition of the product, especially the roughness of the machined surface, because of its effect on product appearance, function, and reliability. For these reasons it is important to maintain consistent tolerances and surface finish. Also, the quality of the machined surface is useful in diagnosing the stability of the machining process, where a deteriorating surface finish may indicate workpiece material non-homogeneity, progressive tool wear, cutting tool chatter (Kumar and Packiaraj, 2012)

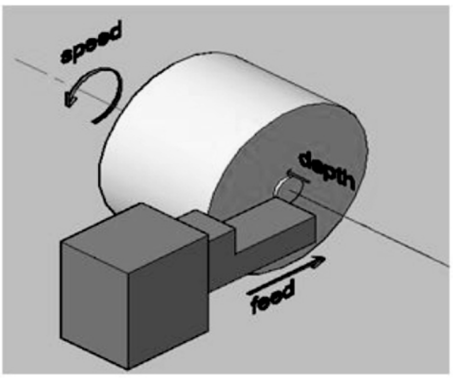

Figure 1:Schematic of face turning operation (Groover, 2010)

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Surface roughness refers to relatively finely spaced irregularities produced by the action of cutting tools on work pieces (Sharma, 2006). An Arithmetic Average (AA) method is employed to determine the value of surface roughness (R_a) whose units isμm.

Taguchi's approach to design of experiments was employed to determine the numbers of runs of experiments to achieve the purpose of economics of machining operations (Omidiji et al., 2015).The cutting conditions were taken at three levels of treatment to arrive at nine runs. The combination of each level of the three conditions is an experiment. The only dependent variable that was measured was the surface roughness, while the cutting conditions were taken as independent variables. The experiments were run with the intention that steel tools that are the most common cutting tools at shop floor. The combination of parameters that gives the lowest value of surface roughness may be identified.

2 Materials and Methods

2.1 Materials

Al-Si cast aluminium alloy, due to its wide application in automobile industry and structures, was used in this experiment and tested under spectrometer to determine the chemical composition. The chemical composition is given in Table 1. Figure 2 shows the sample tested. The alloy was sourced from market

2.2 Cutting Tool

The cutting tool used is made of cemented carbide. It is a composite of tungsten carbide particles and a binder rich in metallic cobalt. The primary reason of using cemented carbide as cutting tool material was due to its versatility (Naveen, et al., 2009). Cemented carbide is hard and tough at the same time, while other materials used for cutting tools are either hard or tough but not both. However, carbide tools exhibit higher melting temperatures than standard high speed steel tools that are the most common cutting tools at shop floor.

2.3 Machine Tool

Colchester Triumph 2000Lathe,was used for the turning operation to produce the samples. The lathe is of straight bed type *2.* with 760 mm distance between centres and an overall length of machines of 1930 mm. The lathe has 16 speeds available from 25 to 2000 rpm and is powered by a 5.6 kW base mounted electric motor that drove through four grouped v-belt drive.

2.4 Methods

Taguchi's approach to design of experiments was employed to determine the number of runs of experiments which would be representative enough for the purpose of statistical analysis. This approach reduces number of experiment drastically to cut down the cost of machining and materials. L_9 orthogonal array was used with three process parameters selected at three levels, leading to nine runs of experiments. Table 2 shows the machining parameters and their levels while Table 3 shows the L_9 Orthogonal array. From Table 3, each of those experiments was performed by using the combinations of the parameter for the experiments.

2.5 Measurement of the surface roughness

The roughness averages (Ra) of the surface of machined component after the face turning process were measured by a TR100 surface roughness tester with piezoelectric pick up type. Measurements were repeated four times to obtain average values. The roughness was the only outcome and taken as dependent variable, while the machining parameters are taken as independent variables.

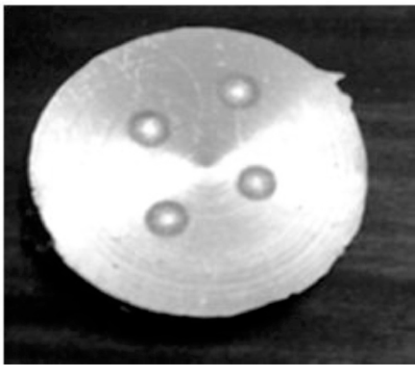


Figure 2: Surface of a machined aluminium alloy after it has been tested under spectrometer

Table 1: chemical composition of alloy

	Al	Si	Fe	Cu	Mn	Mg	Zn	Cr
1	99.23	0.3791	0.1629	<0.004	0.0187	0.0728	<0.003	<0.001
2	99.24	0.3721	0.1604	<0.004	0.0195	0.0719	<0.002	<0.003
3	99.24	0.3702	0.1594	<0.004	0.0197	0.0732	<0.003	<0.002
4	99.24	0.3702	0.1612	<0.004	0.0196	0.0718	<0.003	<0.003
AVG	99.24	0.3729	0.1610	<0.004	0.0194	0.0724	<0.003	<0.002
SD	0.0044	0.0042	0.0015	0.0004	0.0004	0.0007	0.0001	0.0007
RSD	0.0044	1.1343	0.9309	8.5251	2.2494	0.9381	2.0940	23.862

	Ni	Ti	Sr	Zr	V	Ca	Be
1	<0.000	0.0149	<0.000	<0.000	<0.007	<0.000	<0.000
2	<0.000	0.0146	<0.000	<0.000	<0.007	<0.000	<0.000
3	<0.000	0.0148	<0.000	<0.001	<0.007	<0.000	<0.000
4	<0.000	0.0146	<0.000	<0.000	<0.007	<0.000	<0.000
AVG	<0.000	0.0147	<0.000	<0.000	<0.007	<0.000	<0.000
SD	0.0000	0.0001	0.0000	0.0006	0.0002	0.0000	0.0000
RSD	0.0000	0.8814	2.8898	64.377	2.0270	0.0000	4.0736

2.6 Analysis of Results

Analysis of Variance (ANOVA) to determine the combined and interaction effects of the machining parameters on the surface roughness of the alloy was done using Minitab Statistical Software (17). The software has the capacity to bring out the surface plots and contour plots. The contour plots can be employed in useful predictions.

2.7 Determination of Signal to NoiseRatio

Signal to noise ratio cuts off any unwanted interference that may have happened in the cause of running the experiments. Taguchi's method was used to identify the optimal cutting parameter levels so as to minimize the surface roughness. Thus, lower values of the surface roughness are desirable for maintaining high cut quality; therefore smaller-the-better Signal to Noise (S/N) ratio is used and can be calculated as:

$$S/N\ (\eta) = -10\log\ \{\tfrac{1}{r}\textstyle\sum_r^1 Ra_i^2\}\ \ i=1, 2, 3...r$$

Where Ra_i is the value of surface roughness for the i th trial in r number of tests. The levels of each design parameter had been identified and analysis on the influence of machining parameters on the dependent ones was done.

3 Results and Discussion

3.1 Surface Roughness Averages

The results of the surface roughness of the aluminium alloy carried out using surface roughness tester are presented in Table 4. The process parameters that had been initially used to machine the components tested are presented in the Table 2. The signal to noise (S/N) ratio had been worked out and presented in Table 4.

3.2 Determination of Combined and Interaction Effects

Having used smaller-the better to compute S/N ratio to minimise the surface roughness in Table 4, the responses are then presented in Figures3, 4, 5 and 6. This is done using MINITAB 17 statistical software. The main effect and interaction graphs showed the change in the response and interaction between factors when the given factors go from lower level to higher level. The slope of the line determines the power of the control factors influence on surface roughness. Graphs from Figure 3 clearly suggest a dominant quantitative influence of

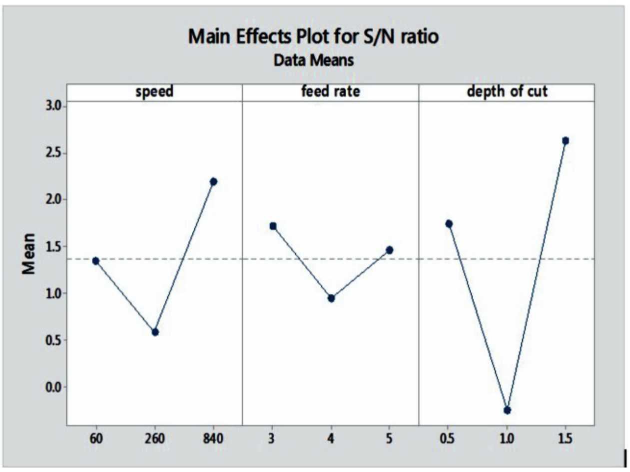


Figure 3: Main effects plot for S/N ratios of roughness

the cutting speed, feed rate and depth of cut on the surface roughness. From Figure 3, it is observed that the optimal combination cutting parameters is using cutting speed of 840 rev/min with a feed rate of 3 mm/min at a depth of 1.5 mm levels to produce minimal surface roughness. Figure 4 shows the interaction effects of the cutting parameters. For example, the interaction of speed and depth of cut indicates that the speed of 840rev/min clearly dominates as revealed in Figure 3.

Further analysis was done by plotting contour graphs (Figure 5) and surface graphs (Figure 6) of two interacting cutting parameters against surface roughness. The contour plot gives an added advantage over the interaction graph as it shows surface roughness (R_a)between two factors considered. From analysis of contour plot of $R_a$versus speed and feed rate (Figure 5a), it is observed that a better surface finish could have been obtained if speed around 650 – 750 rev/min had been selected for a feed of 4mm/rev.Figure 6 shows the surface plots of the R_a vs the two cutting parameters interacting. Due to the fact that the contour plot still have response variation between contour lines, surface plot then gives a better three dimensional view of the plots, showing if there is a turning point or not and the true surface roughness of region considered.

Table 2: Machining Parameters and Levels

Cutting Parameters	Unit	Levels		
		1	2	3
Cutting speed	rev/min	60	260	840
Feed	mm/rev	3	4	5
Depth of cut	mm	0.5	1.0	1.5

Table 3: Orthogonal Array L_9 of Taguchi with values

S/N	Cutting speed (r/m)	Feed (mm/rev)	Depth of cut (mm)
1	60	3	0.5
2	60	4	1.0
3	60	5	1.5
4	260	3	1.0
5	260	4	1.5
6	260	5	0.5
7	840	3	1.5
8	840	4	0.5
9	840	5	1.0

Table 4: The Response Table

No.	Speed (rpm)	Feed rate (mm/rev)	Depth of cut(mm)	R_a (µm)	S/N ratio
1	60	3	0.5	0.7700	1.98493
2	60	4	1.0	1.0900	-1.13760
3	60	5	1.5	0.6700	3.19438
4	260	3	1.0	0.9700	-0.17388
5	260	4	1.5	0.8475	1.35118
6	260	5	0.5	0.9075	0.60893
7	840	3	1.5	0.6625	3.35993
8	840	4	0.5	0.7200	2.64760
9	840	5	1.0	0.9025	0.59571

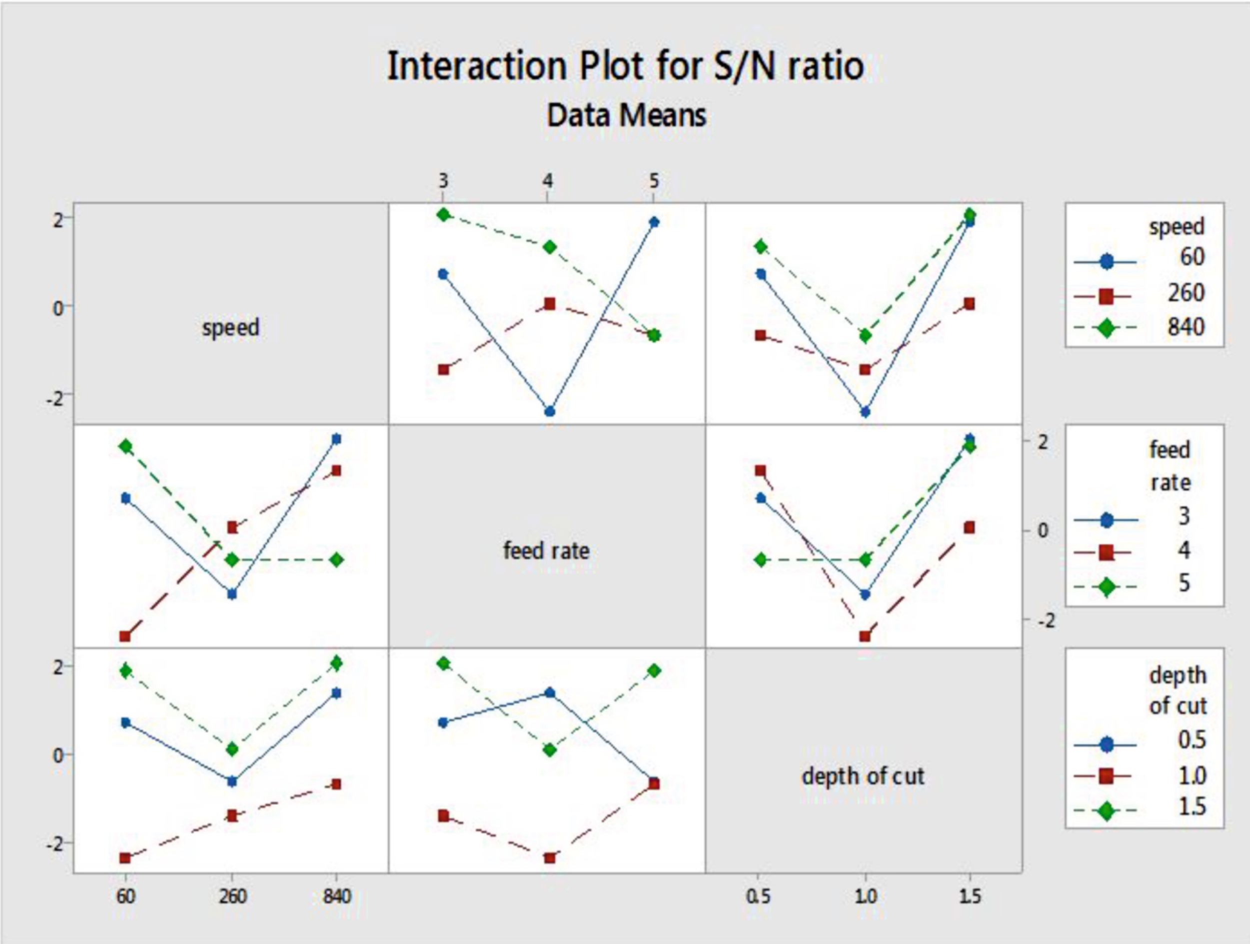
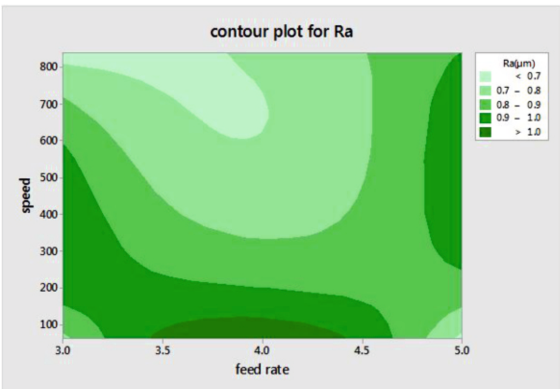


Figure 4: Interaction Plot for S/N ratio of roughness



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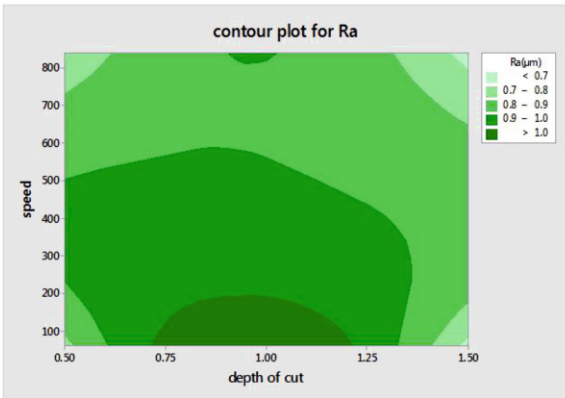

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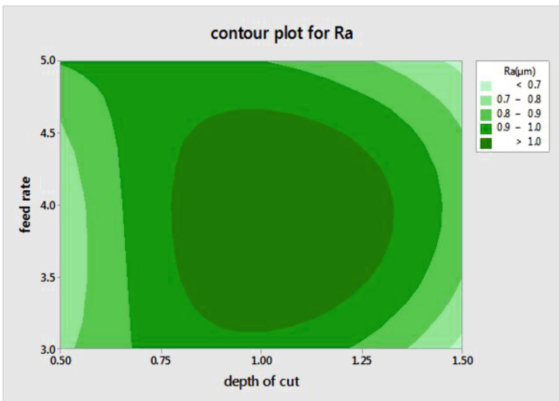

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Figure 5: Contour plots for surface roughness (R_a) against the machining parameters; (a: Speed vs Feed rate, b: Speed vs Depth of cut, c: Feed rate vs Depth of cut)

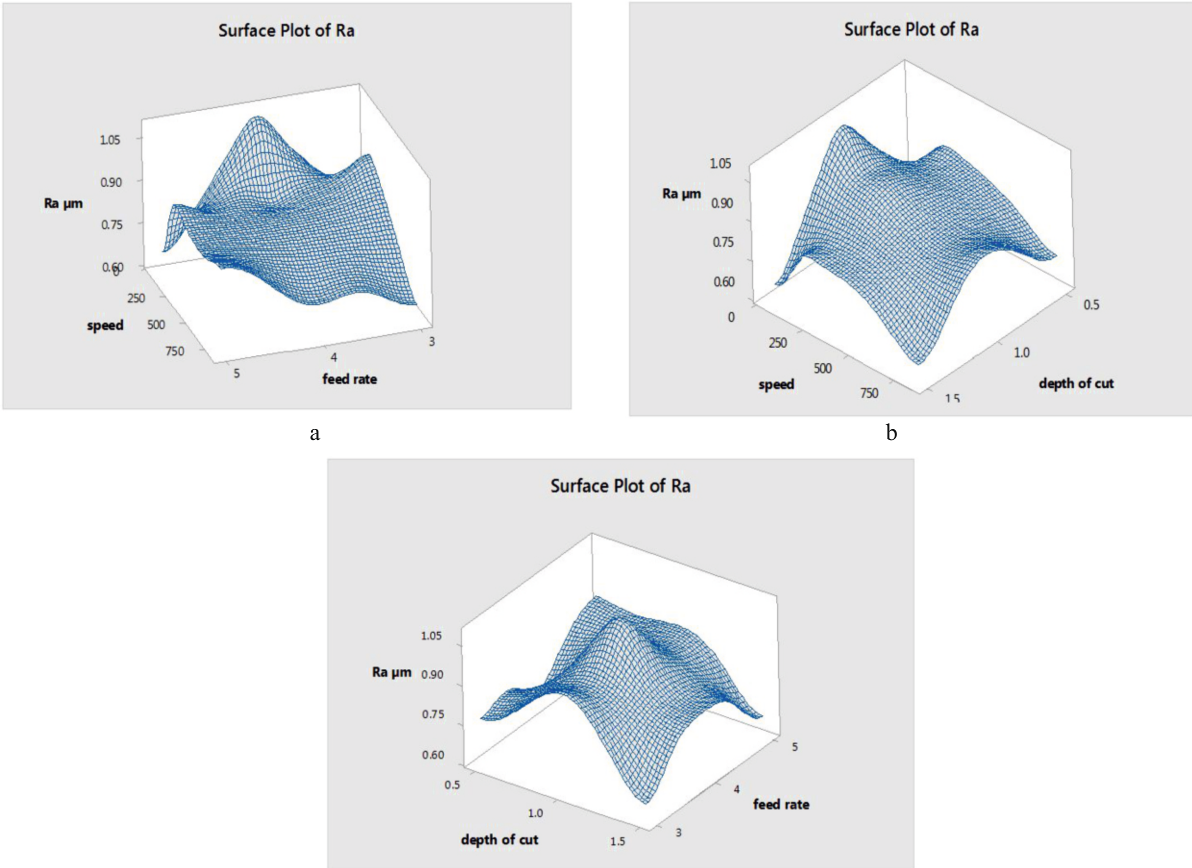

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Figure 6: Surface plot for surface roughness(R_a) against the machining parameters; a: $R_a$vs Speed and feed rate, b: $R_a$vs Sped vs Depth of cut, c: $R_a$vs Feed rate and Depth of cut

3.3 *Analysis of Variance*

The Analysis of Variance (ANOVA) establishes the relative significance of factors in terms of their percentage contribution to the response. The ANOVA is also needed for estimating the variance of error for the effects and the confidence interval of the prediction error. The analysis is performed on S/N ratios to obtain the percentage contribution of each of the factors at 95% confidence interval. Table 5 is the ANOVA for S/N ratio.

Table 5: ANOVA for S/N ratio

Source of Variation	DOF	Sum of squares	Mean of squares	F-Value	Contribution (%)
Speed	2	3.8725	1.9362	2.84	20.22%
Feed rate	2	0.9218	0.4609	0.68	4.81%
Depth of cut	2	12.9902	6.4951	9.53	67.84%
Error	2	1.3637	0.6819		7.12%
Total	8	19.1482			100%

From table 5 above, observation can be made such that the depth of cut (67.84 %) has greatest influence on surface roughness. The cutting speed and feed rate account 20.22 %, 4.81 % percent contribution respectively on the surface roughness.

4 Conclusions

From the experimentation it is found that, depth of cut had significant impact on the surface roughness of the aluminium alloy in the studied range by recording a dominating influence of 67.84%. The cutting speed made a contribution of 20.22% in the statistical analysis. The most optimal results for surface roughness were observed when cutting speed was set at 840 rev/min,feeding rate of 3 mm/rev and depth of cut 1.5mm.

References

Groover, M.P. (2010): Fundamentals of Modern Manufacturing: Materials, Processes, and Systems'. John Wiley and Sons, Inc., 111 River Street, Hoboken, NJ.

Kumar, J. P. and Packiaraj, P. (2012): Effects of Drilling Parameters on Surface Roughness, Tool Wear, Material Removal Rate and Hole Diameter Error in Drilling of OHNS. International Journal of Advanced Engineering Research and Studies. 2249-8974,150-154.

Madić, M. Radovanovic, M. and Slatineanu, L.. (2013): Surface roughness Optimization in CO_2 Laser Cutting by using Taguchi Method. U.P.B. Science bulletin, Series D. 75(1).

Mohammed, T. H., Montasser, S. T. and Joachim, B. (2007): A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process. Jordan Journal of Mechanical and Industrial Engineering. 1(1), 1-5.

Naveen, S. A., Aravindan, S. and Noorul, H. A. (2009): Influence of Machining Parameters on Surface Roughness of GFRP Pipes. Advances in Pro

Omidiji, B.V., Owolabi, H.A. and Khan, R.H. (2015): Application of Taguchi's approach for obtaining mechanical properties and microstructures of evaporative pattern castings. The Sinternational Journal of Advanced Manufacturing Technology.79, 461-468. duction Engineering and Management,, 4(1-2): 47-58.

harma, P.C. (2006): A Textbook of Production Engineering. S. Chand and Company Ltd, 7361, Ram Nagar, New Delhi.

Show-Shyan L., Ming-TsanChuang, Jeong-Lian W., and Yung-Kuang Y. (2009): Optimization of 6061T6 CNC Boring Process Using the Taguchi Method and Grey Relational Analysis. The Open Industrial and Manufacturing Engineering Journal , 2, 14-20.

Sudhansu, R. and Das, A. K., (2013): Effect of Machining Parameters on Surface Roughness in Machining of Hardened AISI 4340 Steel using Coated Carbide Inserts. International Journal of Innovation and Applied Studies , 445-453.