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Research Article

SURFACE INTEGRITY OF AA 6351 –T6 WHEN MACHINED USING DISTINCT CUTTING DIAMETERS & TERMINOLOGY UNDER A DRY CUTTING CONDITION

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Key words: Dry cutting, Milling operation, Surface finish, Material removal rate, Power Consumption, Optimization

ABSTRACT

Objectives: it is the common observation that industries nowadays demand high product quality with optimized machining parameters for getting Quality of the product. The required quality and nature of material dictates these parameters. With new material discovered periodically, setting these parameters optimized to require outcome on machining these materials has become challenging.

Methods/Statistical analysis: In this study, to optimize three machining outputs, namely surface finish, material removal rate (MRR) and power consumption for 3 input parameters, namely cutting speed, feed rate and depth of cut (2 and 3 inserts) for AA6351-T6 by employing ANOVA technique with a Taguchi orthogonal array table for planning of the experiments in Minitab.

Findings: AA6351 is a high strength low corrosion alloy of aluminum that has a lot of application in naval engineering. Cutting speed, depth of cut and feed rate are pivotal for machining processes. Surface roughness (using a wide range of cutting speed, feed per tooth and axial depth of cut when HSM AA 6351 –T 4 with different values of cutter diameter of 16 mm (2 inserts) another one having 25 mm (3 inserts) where the Taguchi L9 orthogonal array method was applied), power consumption (power consumption) and MRR (MRR) were chosen as the output parameters since they are easily measurable and provide a measure of quality of the machining process.

Application / Improvement: Mathematical models for cutting parameters and cutter diameter were obtained from regression analyses to calculate values of surface finish, MRR, Power consumption. S/N ratio and ANOVA analyses were also performed.

INTRODUCTION

The Quality of the product has always been one of the most significant essentials in manufacturing operations. Today continuous improvement in product quality has become the major priority for major corporations all over the world. So, new and improved equipment and tools have been manufactured in order to produce high quality products (Kim, *et al.*, 1997; Medicus, *et al.*, 2001; Gadelmawla, *et al.*, 2002). Machining processes should be performed correctly to obtain the desired quality (Saï and Bouzid, 2005). One of the primary aims is to achieve proper finish and surface smoothness. The reasons for the above are as follows: 1. Smooth and

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scratch free surface creates the proper impression on people. 2. Surfaces affect safety. 3. Surfaces interact with the environment (wear, corrosion, lubrication). General defects produced during manufacturing can affect the surface quality of the component (Rajyalakshmi and Venkata, 2015). The reasons for defects are: Defects in original material. 1. Methods by which surface is provided. 2. Lack of proper control of parameters was causing excessive stress and temperature. (For example, roughness is a measure of the texture of a surface and is an outcome of the cutting parameters, tool geometry, etc. used at some stage in the machining process. Depending on how rough the surface is (deepness of the grooves left by the tool on the machined surface) a piece can wear more rapidly and have high friction coefficients than a smoother surface) (Babu, *et al*., 2015; Kalpakjian, 2003). From the last decade, high speed cutting is one of the most advanced manufacturing technologies due to: 1. Its potential for faster production rates, shorter lead times. 2. Reduced costs 3. Improved part quality. This technique combines high spindle speed with increased feed rate. This results in a high chip-forming rate and minor milling forces and produces improved surface quality. However, appropriate tools and cutting parameters should be used to complete the machining process without harmful the cutting tool. So, prediction and control of the surface roughness and tool wear are important. In recent years, several proposals have been given for different models for surface roughness prediction during a milling process. The proposed various models are: The analyzed the effects of the insert run out errors and the variation of the feed time on the surface roughness operation using a surface roughness form. The experiments were conducted in AISI 1041 ductile steel (Baek, *et al*., 2001). The influence of cutting conditions and tool geometry on the surface roughness when slot end milling aluminum alloy 2014-T6. The developed surface roughness models for both dry cutting and coolant conditions were built using a response surface methodology (RSM). The results showed that the dry-cut roughness was reduced by applying cutting fluid (Wang and Chang, 2004). The research contributes to the development of a numerical model for surface roughness profile prediction when using round inserts. The model relates the feed, the cutting tool geometry and the tool errors, incorporating an algorithm that makes possible the variation of the surface roughness from the values that can be adopted by the tool errors (Franco, *et al*., 2004). The predicted the surface roughness by using RSM (response surface methodology) coupled with GA (genetic algorithms). The studies were made in Al 7075-T6 (Oktema, *et al*., 2005). The effect of tool geometry (radial rake angle and tool nose radius) and cutting conditions (cutting speed and feed rate) on the machining performance during end milling of medium carbon steel. First and second order mathematical models, regarding of machining parameters were developed for surface roughness prediction using RSM. The results showed that the cutting speed, the feed, the radial rake angle and the tool nose radius are the primary factors influencing the surface roughness of medium carbon steel during end milling processes (Reddy, *et al*., 2006). The study of plane surface generation mechanism in flat end milling process (Ryua, *et al*., 2006). They concluded that the bottom of a flat end milling has an end cutting edge angle that plays a major role in surface texture and that the surface texture is produced by superposition of conical surfaces generated by the end cutting edge rotation. The evaluation of the generated surface texture characteristic was done using RSM. the development of a statistical model for surface roughness estimation in a high-speed flat end milling process, under wet cutting conditions, using machining variables such as spindle speed, feed rate, depth of cut and step over (Ozcelik and Bayramoglu, 2006). The proposed the development of a novel hybrid neural network (NN) trained with genetic algorithm (GA) and particle swarm optimization (PSO) for the prediction of surface roughness. The proposed hybrid NN was found to be competent in terms of computational speed and efficiency over the NN model (Jesuthanam, *et al*., 2007). The Taguchi design application to optimize the surface quality of a face milling operation when using a CNC. The results verified that the Taguchi design was successfully in optimizing the milling parameters for surface roughness (Zhang, *et al*., 2007). Developed a generalized model based on particle swarm optimization (PSO) technique to achieve a desired surface roughness when face milling aluminum. The machining time was included as input parameter together with cutting speed, feed and depth of cut. They concluded that the use of optimization technique replaces the selection of cutting parameters by trial and error method (Bharathi and Baskar, 2012). In 2013 compiled different advances in the modeling of machining processes. In its paper the advances in predictive, analytical, computational and empirical models among others for the prediction of variables such as surface roughness, cutting forces, stresses, chip formation, etc. are highlighted. All proposed models are based on computation, numerical analysis and complex mathematical calculus. They address the use of end milling processes for round inserts with a specific number of teeth and tool diameter. Based on above findings, aim of this research is to develop a model for surface roughness prediction based solely on geometry when face milling with square inserts. These models will help in prediction of roughness before conducting trial and error experiments, and will save time and cost. Validation of the model will be assured by conducting an experiment on Al-alloy (7075-T7351) (Arrazola, *et al*., 2013; Sivam, *et al*., 2015; Sivam, *et al*., 2016; Sivam, *et al*., 2016; Sivam, *et al*., 2016).

EXPERIMENTAL PROCEDURE

The design of experiments technique is a powerful tool, which permits us to carry out the modeling and analysis of the influence of sequence variables on the response variables. The response variables are an unknown function of the progression variables, which are known as design factors. There are a large number of factors that can be considered for machining of a particular material in face milling. In the present study width of cut (W, mm), Spindle Speed (S, rpm) feed rate (f, mm/min) and width of cut (b, mm) are selected as design factors while other parameter have been assumed to be constant over the experimental field. Therefore the independent and dependent effects of each manufacturing variables can be investigated on the response function. For this study manufacturing variables considered according to Table 1.

Experimental Setup and Equipment's

The machine used for the milling test is "LV45" CNC Machining Center having a control system Fanuc OI Mate with a vertical Milling head and operational with maximum spindle speed 8000 rpm, Maximum Feed Rate 10 m/min, 10 kW driver motor and accuracy 0.001 mm Roughness Measurement was done using surfcom 1400G. The profilometer was set to a cut-off length of 0.8mm, filter 2CR, travel speed 1mm/sec and 4 mm evaluation length. Roughness measurements in the transverse direction, on the workpiece were continual three times and average of three measurements of them recorded. All the work pieces were selected from AA 6351-T6 with the dimension of 75 mm × 75 mm × 75 mm. Also the cutting tools are two different diameters as shown in the (Fig. 1). The tool and inserts that were used for the machining trials were purchased from SANDVIK tools. As previously stated, the tool and inserts that were chosen were recommended by requirements since they had already proven capable of machining AA 6351-T4. A SANDVIK R220.69-0050-18-4A 16 mm and 25 mm diameter tool with different helix angle and cutting edges was used to cut all of the samples and properties are shown in Tables 2 and 3. A picture of the tool and inserts is shown in (Fig. 1).

RESULT AND DISCUSSION

In this the obtained results will be calculated and plotted on the graphs and tables from Minitab software.

The procedure involved in finding the optimum parameters of surface roughness of AA 6351-T6 is with the help of Design of experiments is shown in the Tables 4 and 5. The parameter design is the key step in the Taguchi method in achieving high quality without increasing the costs. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire factor space with a small number of experiments only. The obtained results shown in the Tables 6 and 7, were transferred to Minitab software and DOE results were acquired, the result are depicted in graphical and statistical form using Taguchi design.

Table 1. Experimental factors and levels for both diameters

Control Factors	Input levels		
Spindle Speed S (Rpm)	6000	6500	7000
Feed per tooth f (mm/rev)	0.02	0.04	0.06
Depth of cut d (mm)	0.5	1.0	1.5

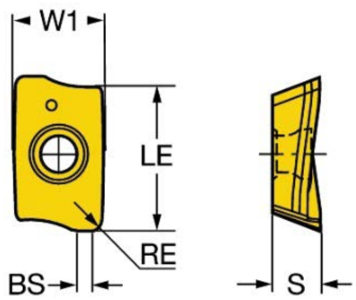

Fig. 1 A SANDVIK R220.69-0050-18-4A 50 mm diameter tool coupled with four SANDVIK XOMX 180640R-M10-F40M inserts

Table 2. Cutting tool properties for Ø16 mm

D (mm)	N (Flute)	L Flute (mm)	Overhang (mm)	Helix Angle
16	2	25	150	90

Table 3. Cutting tool properties for Ø25 mm

D (mm)	N (Flute)	L Flute (mm)	Overhang (mm)	Helix Angle
25	3	32	150	45

From the signal to noise ratio for response (Tables 8 and 9), According to rank of the parameters, in 2 inserts and 3 inserts, Feed rate is highly influencing whereas spindle speed is second influencing parameter in 2 inserts and in 3 inserts depth of cut makes the secondary influence. By delta values of each parameter, the machinability can be predicted, as nominal value has to be chosen, it is clear that 3 inserts has high machinability.

Table 4. Taguchi L9 orthogonal array DOE used for Ø16 mm with response

Ex. No	No of Inserts	Spindle Speed (Rpm)	f (mm/rev)	DOC (mm)	b (mm)	f (mm/min)	Ra	MRR Q (mm^3/min)	Pc (kW)
1	2	6000	0.02	0.5	16	240	0.2439	0.16	0.00288
2	2	6000	0.04	1	16	480	0.3242	0.64	0.01152
3	2	6000	0.06	1.5	16	720	0.3611	1.44	0.02592
4	2	6500	0.02	1	16	260	0.1798	0.32	0.00624
5	2	6500	0.04	1.5	16	520	0.1807	0.96	0.01872
6	2	6500	0.06	0.5	16	780	0.1203	0.48	0.00936
7	2	7000	0.02	1.5	16	280	0.3306	0.48	0.01008
8	2	7000	0.04	0.5	16	560	0.114	0.32	0.00672
9	2	7000	0.06	1	16	840	0.1696	0.96	0.02016

Table 5. Taguchi L9 orthogonal array DOE used for Ø25 mm with response

Ex.No	No of Inserts	S (Rpm)	f (mm/rev)	DOC (mm)	b (mm)	f (mm/min)	Ra	MRR (mm^3/min)	Pc (kW)
1	3	6000	0.02	0.5	25	360	0.2458	0.25	0.003375
2	3	6000	0.04	1	25	720	0.273	1	0.0135
3	3	6000	0.06	1.5	25	1080	0.3493	2.25	0.030375
4	3	6500	0.02	1	25	390	0.2421	0.5	0.0073125
5	3	6500	0.04	1.5	25	780	0.2117	1.5	0.0219375
6	3	6500	0.06	0.5	25	1170	0.1867	0.75	0.01096875
7	3	7000	0.02	1.5	25	420	0.2505	0.75	0.0118125
8	3	7000	0.04	0.5	25	840	0.3229	0.5	0.007875
9	3	7000	0.06	1	25	1260	0.2519	1.5	0.023625

Table 6. Taguchi L9 orthogonal array DOE used for Ø16 mm and Ø25 mm diameters with response

Ex. No	S (Rpm)	f (mm/rev)	DOC (mm)	Ra for 2 inserts	MRR Q (mm^3/min) for 2 inserts	Pc (kW) for 2 inserts	Ra for 3 inserts	MRR Q (mm^3/min) for 3 inserts	Pc (kW) for 3 inserts
1	6000	0.02	0.5	0.2439	0.16	0.00288	0.2458	0.25	0.003375
2	6000	0.04	1	0.3242	0.64	0.01152	0.273	1	0.0135
3	6000	0.06	1.5	0.3611	1.44	0.02592	0.3493	2.25	0.030375
4	6500	0.02	1	0.1798	0.32	0.00624	0.2421	0.5	0.0073125
5	6500	0.04	1.5	0.1807	0.96	0.01872	0.2117	1.5	0.0219375
6	6500	0.06	0.5	0.1203	0.48	0.00936	0.1867	0.75	0.01096875
7	7000	0.02	1.5	0.3306	0.48	0.01008	0.2505	0.75	0.0118125
8	7000	0.04	0.5	0.114	0.32	0.00672	0.3229	0.5	0.007875
9	7000	0.06	1	0.1696	0.96	0.02016	0.2519	1.5	0.023625

Table 7. Surface roughness and S/N ratio values for specimen

Ex. No	Spindle Speed (Rpm)	Feed Per Tooth (mm/rev)	DOC (mm)	S/N FOR Ø16 mm	S/N FOR Ø 25 mm
1	6000	0.02	0.5	-0.482382542	0.23447
2	6000	0.04	1	-1.320063704	-4.3193
3	6000	0.06	1.5	-4.609839003	-6.9858
4	6500	0.02	1	-0.87025024	-1.5851
5	6500	0.04	1.5	-5.910394563	-7.3749
6	6500	0.06	0.5	-4.572739951	-4.7352
7	7000	0.02	1.5	-0.155439998	-3.2874
8	7000	0.04	0.5	-2.856114074	-0.4531
9	7000	0.06	1	-6.152130459	-6.551

Table 8. Signal to noise ratios for response

Level	S (Rpm)	f (mm/rev)	d (mm)
1	-2.1374	-0.5027	-2.6371
2	-3.7845	-3.3622	-2.7808
3	-3.0546	-5.1116	-3.5586
Delta	1.6470	4.6089	0.9215
Rank	2	1	3

Table 9. Signal to noise ratios for response

Level	S (Rpm)	f (mm/rev)	d (mm)
1	-3.690	-1.546	-1.651
2	-4.565	-4.049	-4.152
3	-3.430	-6.091	-5.883
Delta	1.135	4.545	4.231
Rank	3	1	2

From the response (Tables 10 and 11), by delta values of each parameter, the machinability can be predicted by high data means, as nominal value has to be chosen, 3 inserts has high machinability.

From the response result (Tables 12 and 13), by delta values of each parameter, the machinability can be predicted by low standard deviation, as nominal value has to be chosen, it is depicted that 2 inserts has less standard deviation than 3 insert.

From the (Fig. 2 and 3), Main effect plot of mean illustrates the total effect on machinability, in 2 & 3 insert the optimal machinability can be achieved by Speed: 7000 rpm ; Feed: 0.04 (mm/rev); Doc: 1mm.

From the (Fig. 4), For 2 inserts the mean SN ratio predicted to be -2.992. For optimal machinability Speed: 7000 rpm; Feed rate: 0.04 (mm/min); DOC: 1 mm.

From the (Fig. 5), For 3 inserts the mean SN ratio is -4.411 for optimal machinability, the conditions are Speed: 6000 rpm; Feed: 0.04 (mm/rev); DOC: 1 mm.

Basically the standard deviation must be low to achieve high machinability. The standard deviation in 2 inserts (0.331) is low when compared to 3 inserts (0.5233). In 2 & 3 inserts the optimal conditions are Speed: 6500 rpm; Feed rate: 0.04 (mm/rev); DOC: 1(mm) is shown in the (Fig. 6 and 7).

From the (Fig. 8), In 2 Inserts, Normal probability plot is Long tail, that is, you are seeing more variance. In Histogram, plateau region is obtained, which means one of the parameter highly influencing the response (Tables 14 and 15).

From the (Fig. 9), In 3 Inserts, Normal probability plot is Short tail, which means it has less variance in response. In Histogram, Isolated region is obtained, which means two process taking place at same time.

From the (Fig. 10), In 2 Inserts, Normal probability plot is straight at certain points, which are no variance in response. In Histogram, Bell shaped region is generated, which means the response is normally distributed.

From the (Fig. 11), In 3 Inserts, Normal probability plot is straight at certain points, which are no variance in response. In Histogram, Isolated region,

Table 10. Response table for means

Level	S (Rpm)	f (mm/rev)	d (mm)
1	0.3566	0.1926	0.1619
2	0.2528	0.2862	0.1924
3	0.2679	0.3985	0.4230
Delta	0.1038	0.2059	0.2611
Rank	3	2	1

Table 11. Response table for means

Level	S (Rpm)	f (mm/rev)	d (mm)
1	0.4906	0.2512	0.2531
2	0.3812	0.4279	0.4235
3	0.4021	0.5948	0.5973
Delta	0.1094	0.3436	0.3442
Rank	3	2	1

Table 12. Response table for standard deviations

Level	S (Rpm)	f (mm/rev)	d (mm)
1	0.3918	0.1732	0.1759
2	0.3022	0.3256	0.3255
3	0.3014	0.4967	0.4967
Delta	0.0904	0.3235	0.3235
Rank	3	1	2

Table 13. Response table for standard deviations

Level	S (Rpm)	f (mm/rev)	d (mm)
1	0.6175	0.2548	0.2588
2	0.4789	0.5216	0.5175
3	0.4736	0.7936	0.7937
Delta	0.1440	0.5389	0.5348
Rank	3	1	2

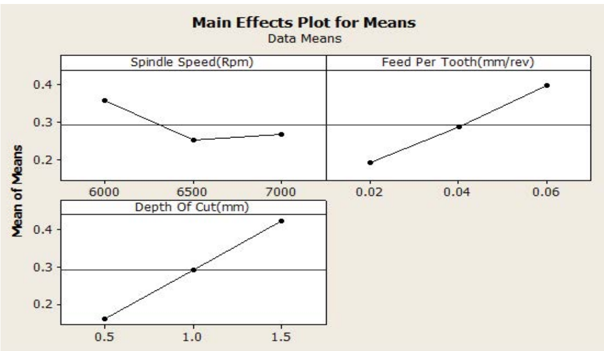

Fig. 2 Main plot for mean.

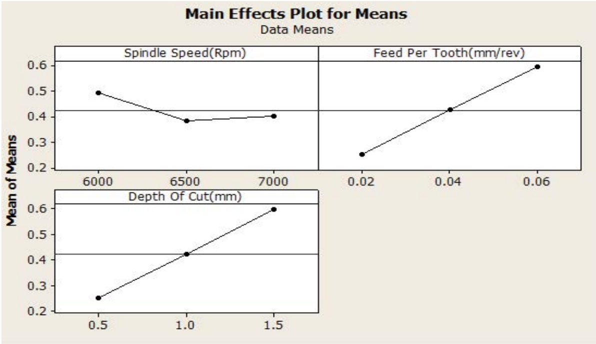

Fig. 3 Main plot for mean.

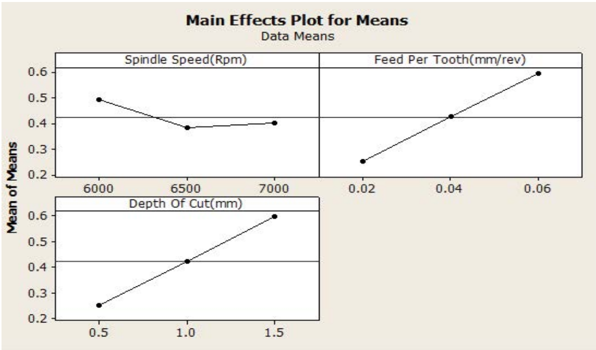

Fig. 4 Main effects for SN ratios.

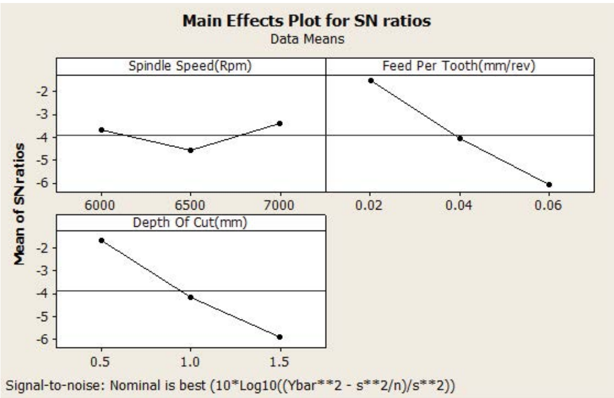

Fig. 5 Main effects for SN ratios.

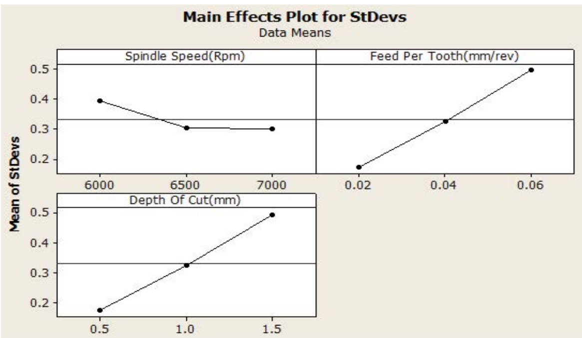

Fig. 6 Main effects plot for standard deviation.

which means two process taking place at same time. From the (Fig. 12), In 2 Inserts, Normal probability

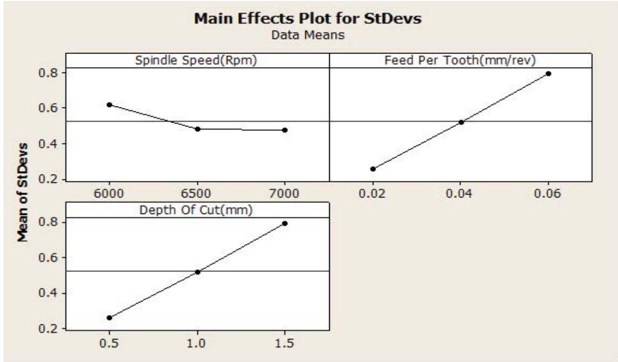

Fig. 7 Main effects plot for standard deviation.

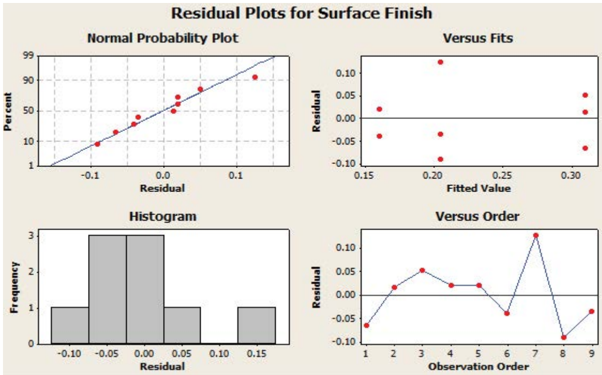

Fig. 8 Residual plots for surface finish, Ra (µm).

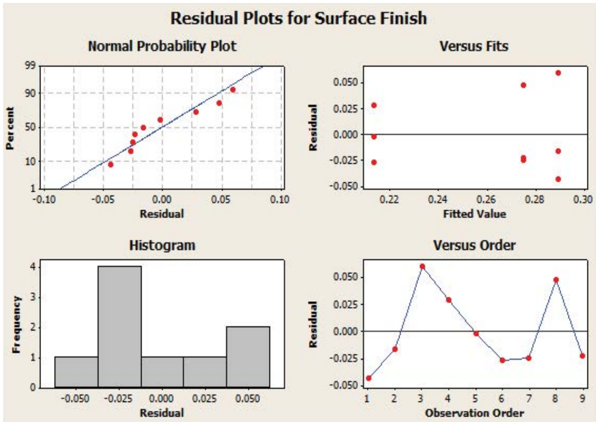

Fig. 9 Residual plots for surface roughness, Ra (µm).

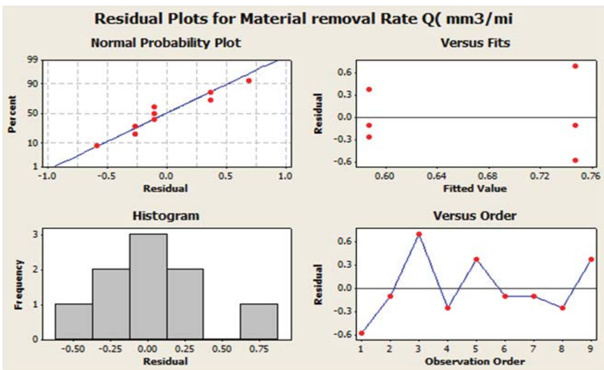

Fig. 10 Residual plots for MRR, Q (mm^3/ml).

Table 14. Response data sheet for 2 inserts

S. No	No of Inserts	S (Rpm)	f (mm/rev)	d (mm)	b (mm)	Angle	f mm/min	R_a	MRR Q (mm^3/min)	Pc (kW)	SNRA1	STDE1	MEAN1
1	2	6000	0.02	0.5	16	90	240	0.2439	0.16	0.00288	-0.4824	0.12235	0.13559
2	2	6000	0.04	1	16	90	480	0.3242	0.64	0.01152	-1.3201	0.31424	0.32524
3	2	6000	0.06	1.5	16	90	720	0.3611	1.44	0.02592	-4.6098	0.73892	0.60901
4	2	6500	0.02	1	16	90	260	0.1798	0.32	0.00624	-0.8703	0.15718	0.16868
5	2	6500	0.04	1.5	16	90	520	0.1807	0.96	0.01872	-5.9104	0.50325	0.38647
6	2	6500	0.06	0.5	16	90	780	0.1203	0.48	0.00936	-4.5727	0.24603	0.20322
7	2	7000	0.02	1.5	16	90	280	0.3306	0.48	0.01008	-0.1554	0.2401	0.27356
8	2	7000	0.04	0.5	16	90	560	0.114	0.32	0.00672	-2.8561	0.15921	0.14691
9	2	7000	0.06	1	16	90	840	0.1696	0.96	0.02016	-6.1521	0.50504	0.38325
										Min	-6.15213	0.12235	0.13559
										Max	-0.15544	0.738917	0.60900

Table 15. Response data sheet for 3 inserts

S. No	No of Inserts	S (Rpm)	f (mm/rev)	d (mm)	Angle	b (mm)	f mm/min	R_a	MRR (mm^3/min)	Pc (kW)	SNRA1	STDE1	MEAN1
1	3	6000	0.02	0.5	45	25	360	0.2458	0.25	0.003375	0.23447	0.14119	0.16639
2	3	6000	0.04	1	45	25	720	0.273	1	0.0135	-4.3193	0.51138	0.42883
3	3	6000	0.06	1.5	45	25	1080	0.3493	2.25	0.030375	-6.9858	1.20008	0.87656
4	3	6500	0.02	1	45	25	390	0.2421	0.5	0.0073125	-1.5851	0.24643	0.2498
5	3	6500	0.04	1.5	45	25	780	0.2117	1.5	0.0219375	-7.3749	0.8042	0.57788
6	3	6500	0.06	0.5	45	25	1170	0.1867	0.75	0.01096875	-4.7352	0.38608	0.31589
7	3	7000	0.02	1.5	45	25	420	0.2505	0.75	0.0118125	-3.2874	0.37669	0.33744
8	3	7000	0.04	0.5	45	25	840	0.3229	0.5	0.007875	-0.4531	0.24926	0.27693
9	3	7000	0.06	1	45	25	1260	0.2519	1.5	0.023625	-6.551	0.79473	0.59184
										Min	-7.37495	0.141192	0.166392
										Max	0.234472	1.200077	0.876558

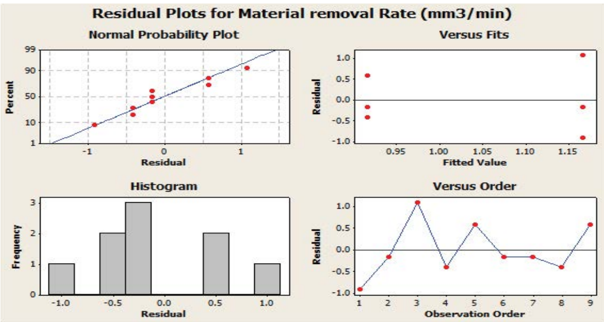

Fig. 11 Residual plots for MRR, Q (mm^3/min).

plot is slightly deviated which means one of the parameter influencing the distribution. In Histogram, Edge peaked region is generated, which means one of the parameter highly influencing the response.

From the (Fig. 13), In 3 Inserts, Normal probability plot is straight at certain points, which are no variance in response. In Histogram, Isolated region is obtained, which means two process taking place at same time.

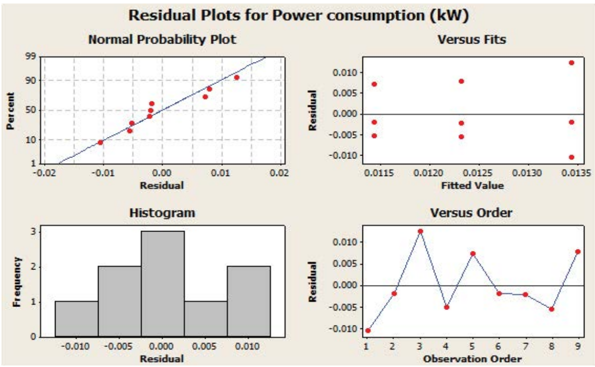

Fig. 12 Residual plots for power consumption, Pc (kW).

From the (Fig. 14 and 15), In 2 Inserts at 6000 rpm the range of surface roughness is varying from 0.25 µm to 0.36 µm. The nominal value is represented as Horizontal line where as in 3 Inserts from 0.250 µm to 0.350 µm. which is similar. In 2 Inserts at 6500 rpm the range of surface roughness is varying from 0.12 μm to 0.19 μm along with nominal value, where as in 3 Inserts from 0.190 μm to 0.250 μm. In 2 Inserts at 7000 rpm the range of surface roughness is varying from 0.260 μm with nominal value to 0.325 μm, where as in 3 Inserts from 0.250 μm to 0.350 μm. which is similar.

From the (Fig. 16 and 17), In 2 Inserts at 6000 rpm the range of MRR is varying from 0.2 mm^3/min to 1.4 mm^3/min. The nominal value is represented as Horizontal line where as in 3 Inserts from 0.4 mm^3/min to 2.3 mm^3/min.In 2 Inserts at 6500 rpm the range of MRR is varying from 0.4 mm^3/min to 0.1 mm^3/min along, where as in 3 Inserts from 0.5 mm^3/min to 1.5 mm^3/min. In 2 Inserts at 7000 rpm the range of MRR is varying from 0.4mm^3/min to 0.1 mm^3/min, where as in 3 Inserts from 0.50 mm^3/min to 0.15 mm^3/min. which is similar.

From the (Fig. 18 and 19), In 2 Inserts at 6000 rpm the range of power consumed is varying from 0.003 kW to 0.025 kW. The nominal value 0.012 kW is represented as Horizontal line where as in 3 Inserts from 0.003 kW to 0.030 kW. In 2 Inserts at 6500 rpm the range of power consumed is varying from 0.006 kW to 0.019 kW, where as in 3 Inserts from 0.008 kW to 0.021 kW. In 2 Inserts at 7000 rpm the range of power consumed is varying from 0.0080 kW with nominal value to 0.011 kW, where as in 3 Inserts from 0.008 μm to 0.025 kW.

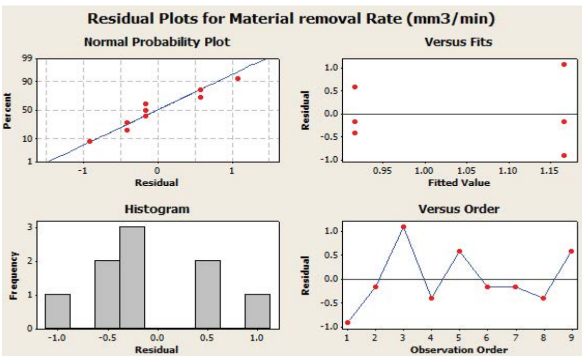

Fig. 13 Residual plots for power consumption, Pc (kW).

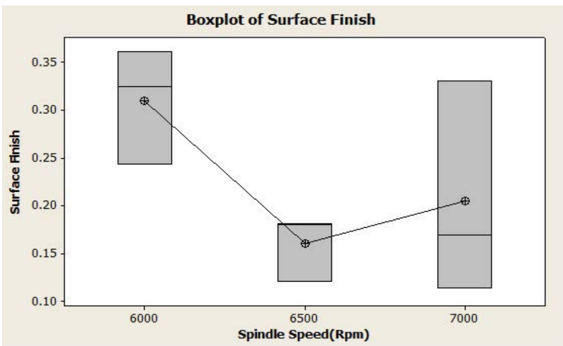

Fig. 14 Box plot for surface roughness, Ra (μm) and speed (rpm).

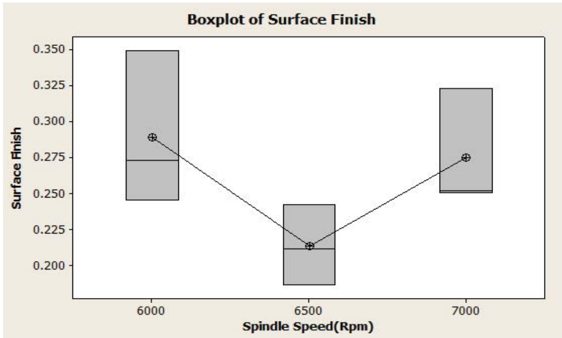

Fig. 15 Box plot for surface roughness, Ra (μm) and speed (rpm).

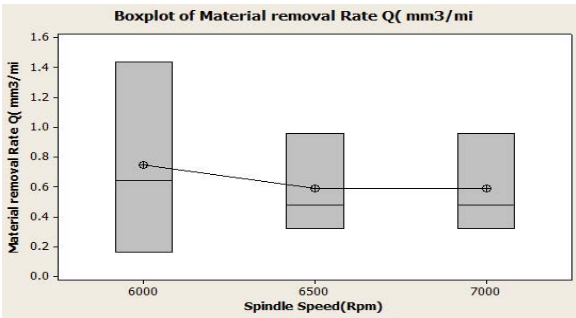

Fig. 16 Box plot for material removal rate, Q (mm^3/ml) and speed (rpm).

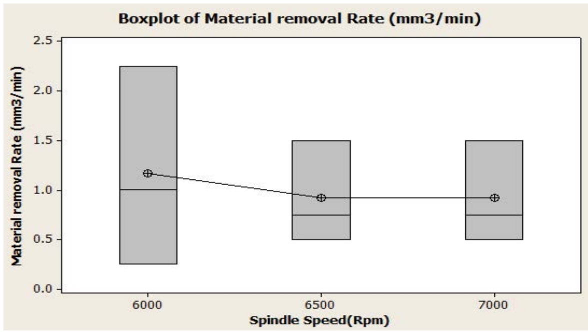

Fig. 17 Box plot for material removal rate, Q (mm^3/min) and speed (rpm).

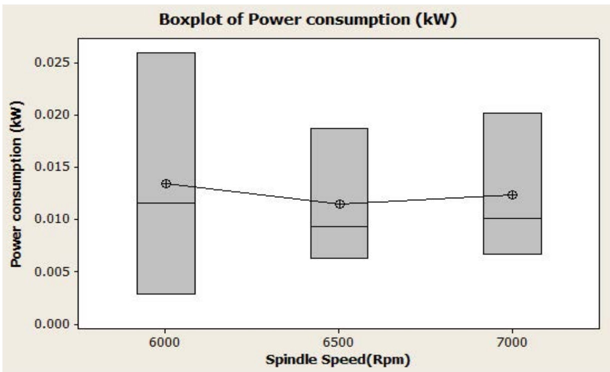

Fig. 18 Box plot 1 for power consumption, Pc (kW) and speed (rpm).

From the (Fig. 20 and 21), In 2 Inserts at 6000 rpm the range of surface roughness is varying from 0.25

μm to 0.36 μm. The nominal value is, represented as Blue line in each speed, 0.30 μm where as in 3 Inserts from 0.24 μm to 0.350 μm. In 2 Inserts at 6500 rpm the range of surface roughness is varying from 0.12 μm to 0.19 μm along with nominal value 0.210 μm, where as in 3 Inserts from 0.180 μm to 0.250 μm. In 2 Inserts at 7000 rpm the range of surface roughness is varying from 0.11 μm with nominal value at 0.20 μm to 0.325 μm, where as in 3 Inserts from 0.250 μm with nominal 0.275 μm to 0.350 μm.

From the (Fig. 22 and 23), In 2 Inserts at 6000 rpm the range of MRR is varying from 0.19 mm^3/min to 1.4 mm^3/min. The nominal value, represented as blue line, is 0.7 mm^3/min where as in 3 Inserts from 0.2 mm^3/min to 2.3 mm^3/min. In 2 Inserts at 6500 rpm the range of MRR is varying from 0.3 mm^3/min to 0.1 mm^3/min along with nominal value 0.6 mm^3/min, where as in 3 Inserts from 0.3 mm^3/min to 1.5 mm^3/min. In 2 Inserts at 7000 rpm the range of MRR is varying from 0.3 mm^3/min to 0.1 mm^3/min with nominal value of 0.6 mm^3/min, where as in 3 Inserts from 0.3 mm^3/min to 1.5 mm^3/min. which is similar.

From the (Fig. 24 and 25), In 2 Inserts at 6000 rpm the range of power consumed is varying from 0.003

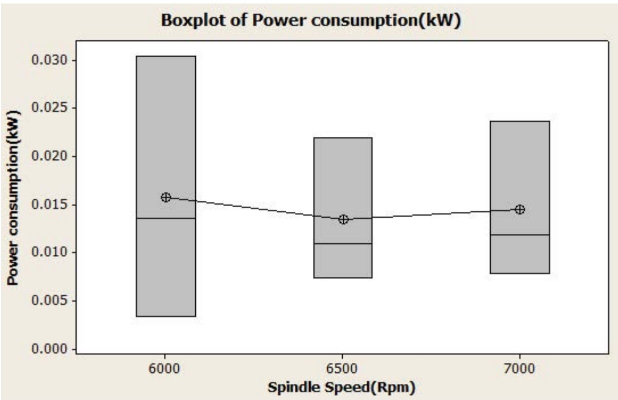

Fig. 19 Box plot 2 for power consumption, Pc (kW) and speed (rpm).

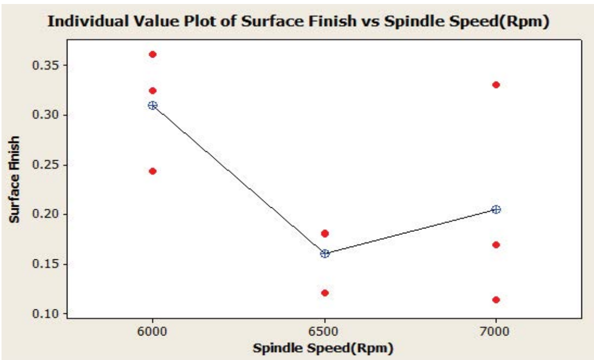

Fig. 20 Individual plots for surface finish, Ra (μm) and speed (rpm).

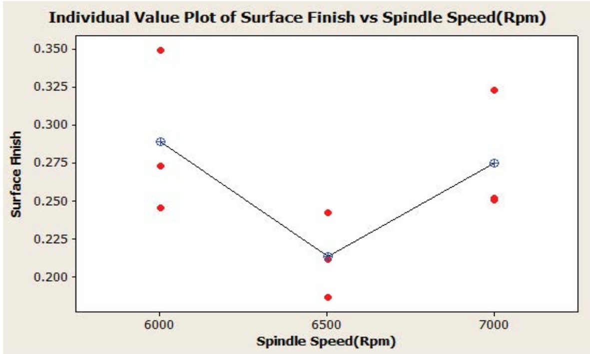

Fig. 21 Individual plots for surface roughness, Ra (μm) and speed (rpm).

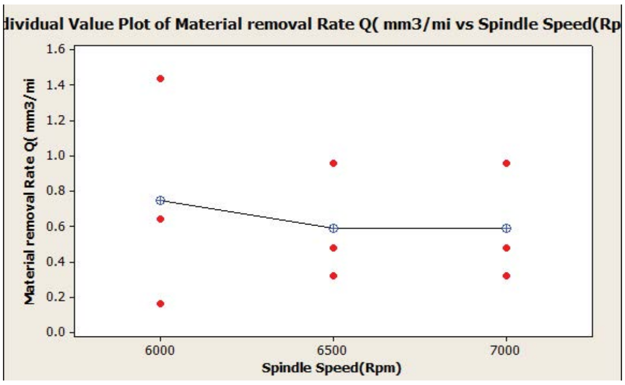

Fig. 22 Individual plots for material removal rate, Q (mm^3/ml) and speed.

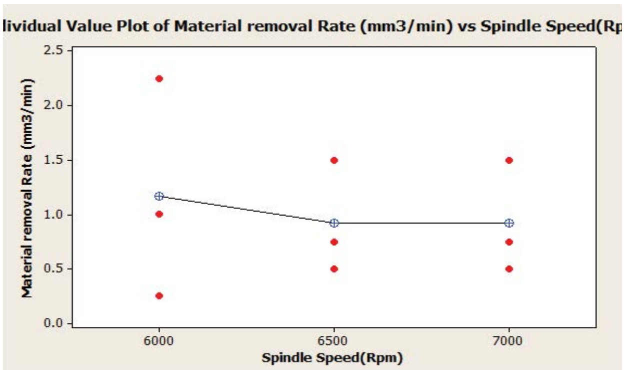

Fig. 23 Individual plots for material removal rate, Q (mm^3/min) and speed (rpm).

kW to 0.025 kW. The nominal value 0.012 kW is represented as Horizontal line where as in 3 Inserts from 0.003 kW to 0.030 kW. In 2 Inserts at 6500 rpm the range of power consumed is varying from 0.006 kW to 0.019 kW, where as in 3 Inserts from 0.008 kW to 0.021 kW. In 2 Inserts at 7000 rpm the range of power consumed is varying from 0.0080 kW with nominal value to 0.011 kW, where as in 3 Inserts from 0.008 μm to 0.025 kW.

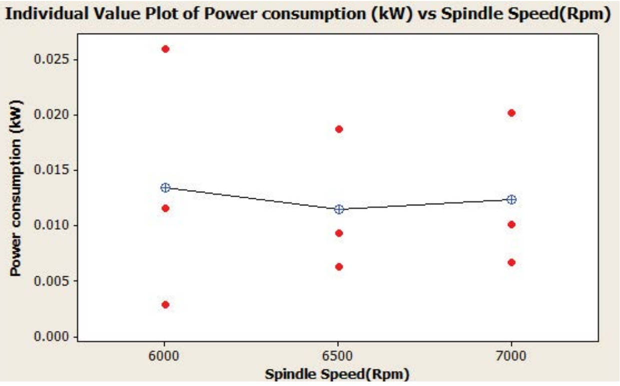

Fig. 24 Individual plot 1 for power consumption vs. spindle speed Pc (kW) and speed (rpm).

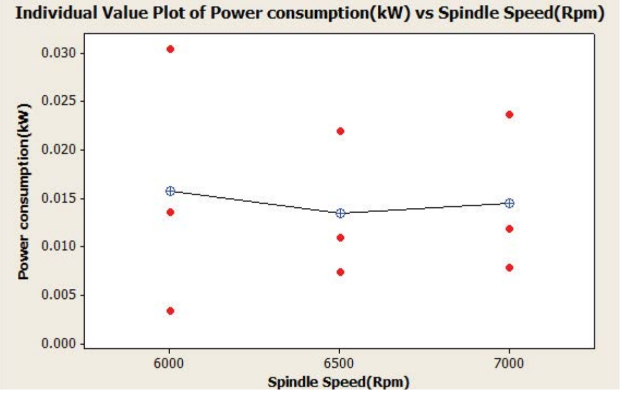

Fig. 25 Individual plot 2 for power consumption vs. spindle speed Pc (kW) and speed (rpm).

CONCLUSION

In the current study an effort has been made to determine the optimized parameter of AA 6351 –T6 for Different tool diameter. The following conclusions are made from the experimental and Graphical basis.

- From S/N and response table, it is observed that the feed is most influencing parameter for surface roughness. By increasing the feed the surface roughness increases.
- The optimal condition for 2 inserts is
- Speed: 7000 rpm (A3)
- Feed: 0.04 (mm/rev) (B2)
- Depth of cut: 1 mm (C2)
- The optimal condition for 3 inserts is
- Speed: 6000 rpm (A1)
- Feed: 0.04 (mm/rev) (B2)
- Depth of cut: 1 mm (C2)
- By Residual plots, 2 inserts have slight variance in responses and unequally distributed in few parameters whereas in 3 inserts, it shows less variance and high significance and equally distributed.
- The Box plot and Individual plot depicts the minimum Surface roughness, Power consumption and Maximum Material Removal Rate influenced by the Spindle speed is illustrated through Response mapping.

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