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Optimization of Process Parameters in Machining of AA6082 Aluminum Alloy.

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A B S T R A C T

Quality and productivity plays important role in today's manufacturing market. Now a day's due to very stiff and cut throat competitive market condition in manufacturing industries and the main objective of industries reveal with producing better quality product at minimum cost and increase productivity. In this study AA 6082 aluminum alloy was chosen to and this material can find various applications. It is commonly used for highly stressed applications, trusses, bridges, cranes, ore skips, transport applications resistance and machinability. End milling is one of the most commonly used metal removal operation in industry because of its ability to remove material faster with good surface finish and Surface roughness depends on the factors like spindle speed, depth of cut, feed rate, material and geometry of tool. The study also focuses to Optimize process parameters using Taguchi design of experiments. The three process parameters and three levels are selected and orthogonal array L9 is used for experimentation and the surface roughness is measured and optimized. Analysis of variance (ANOVA) is performed to know the impact of individual factors on surface roughness. Using regression analysis the theoretical values are predicted and compared with the experimental values for validation.

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Introduction:

In present time the technology of CNC vertical milling machine has been improved significantly to meet the advance requirements in various manufacturing fields, especially in the precision metal cutting industry. This experiment gives the effect of different machining parameters (spindle speed, feed, and depth of cut) on surface roughness in end milling. The demand for high quality and fully automated production focus attention on the surface condition of the product, surface finish of the machined surface is most important due to its effect on product appearance, function, and reliability. For these reasons it is important to maintain consistent tolerances and surface finish. Among several CNC industrial machining processes, milling is a fundamental machining operation. End milling is the most common metal removal operation encountered. It is widely used in a variety of manufacturing in industries. The quality of the surface plays a very important role in the performance of milling as a good-quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. The surface generated during milling is affected by different factors such as vibration, spindle run–out, temperature, tool geometry, feed, cross-feed, tool path and other parameters. During finish milling, the depth of cut is small. Technological parameter range plays a very important role on surface roughness. In end milling, use of high cutting speed, low feed rate and low depth of cut are recommended to obtained better surface finish for the specific test range in a specified material. This experimental investigation outlines the Taguchi optimization methodology, which is applied to optimize surface roughness in end milling operation The experiment is conducted on 6082 Aluminum alloy, the processing of the job is done by High Speed Steel (HSS) end-mill tool under finishing conditions. The machining parameters evaluated are spindle speed, feed rate and depth of cut. The experiments are conducted by using Taguchi L9 orthogonal array as suggested by Taguchi. Signal-to-Noise (S/N) ratio and Analysis of Variance (ANOVA) is employed to analyze the effect of milling parameters on surface roughness.

Literature survey:

A series of experiment have been carried out in Design of Experiments to investigate the influence of cutting parameters such as cutting speed, feed rate and depth of cut on surface roughness in face milling operation. [2] Taguchi parameter design which provides a systematic procedure that can effectively and efficiently identify the optimum surface roughness in the process control of individual end milling machines. [4] A series of experiment have been carried out in Design of Experiments to investigate the influence of cutting conditions such as cutting speed, feed rate per tooth, feed velocity on tool life, tool wear and surface finish in face milling operation. [5] Investigated the machining parameters such as number of passes, depth of cut in each pass, spindle speed and feed rate to get better surface finish, dimensional accuracy and tool wear.

Taguchi technique:

Taguchi proposes a holistic view on quality, which relates quality to cost, not just to the manufacturer at the time of production, but to the customer and society as a whole. Taguchi defines quality as, "The quality of a product is the (minimum) loss imparted by the product to the society from the time product is shipped" .This economic loss is associated with losses due to rework, waste of resources during manufacture, warranty costs, customer complaints and dissatisfaction, time and money spent by customers on failing products, and eventual loss of market share. Robust design is an engineering methodology for obtaining product and process conditions, which are minimally sensitive to the various causes of variation to produce high quality products with low manufacturing costs. Two major tools in robust design are,

• Orthogonal arrays, which accommodate many design factors simultaneously

The signal-to-noise ratios of each experimental run are calculated based on the following equation, which are listed in corresponding tables with the data. The equation is:-

$$S/N = -10 \text{ Log}_{10} [\Sigma y^2 / n] \quad - (1)$$

Where S/N is the signal to noise ratio of i^{th} term, n = number of measurements in a trial/row, in this case, n=3 and Yi is i^{th} the measured value in a run/row

Experimentation:
Experiment and Data Collection:

Experiments are designed with the help of using Taguchi L9 orthogonal array. The software used for DOE (Design of experiment) is Minitab15.

Table: 1. Process parameters and their levels

Factors	Level(1)	Level(2)	Level(3)
Spindle speed(rpm)	5000	6000	7000
Depth of cut(mm)	0.2	0.5	1.0
Feed rate(mm/min)	100	200	300

Work piece material:

AA 6082 aluminum alloy was chosen to study and this material can find various applications. The test specimen is 100×100×12 mm size, to accommodate 9 experiments machining in a piece. Specimen is rough machined on all faces to get flat surface.

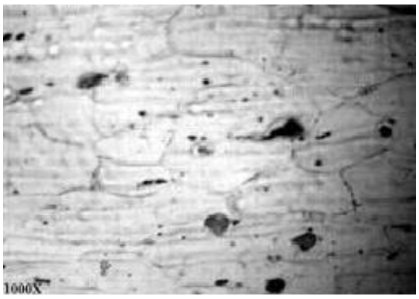

Figure: 1. Microstructure of 6082 aluminum alloy

Figure: 2. CNC End milling machine.

Experimentation:

After DOE, 9 experiments are carried out in CNC vertical End milling. After each experiment Ra is calculated. A quality characteristic for Ra is smaller is the better. The roughness readings were taken in random order to average out effects of uncontrolled variables which could be present in the experiment. Ra values were repeated at least 3 times and then average of these values was recorded

Table: 3. Surface roughness values of 6082 Aluminum alloy

Exp.	Spindle Speed(rpm)	Depth of cut(mm)	Feed rate (mm/min)	Ra (µm)
1	5000	0.2	100	0.69
2	5000	0.5	200	0.80
3	5000	1.0	300	0.92
4	6000	0.2	200	0.75
5	6000	0.5	300	0.90
6	6000	1.0	100	0.69
7	7000	0.2	300	0.87
8	7000	0.5	100	0.65
9	7000	1.0	200	0.80

Process parameters optimization by Taguchi design of experimentation:

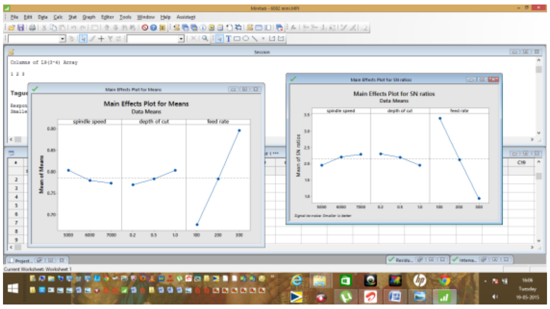

Figure: 3. Result data with graphs.

Table: 4. Response Table for Signal to Noise Ratios (Smaller is better)

Level	Spindle speed	Depth of cut	Feed Rate
1	1.9618	2.3105	3.3959
2	2.2123	2.1984	2.1251
3	2.2965	1.9618	0.9497
Delta	0.3347	0.3486	2.4463
Rank	3	2	1

Table: 5. ANOVA Results

Source	DOF	Sum of squares	Mean of squares	%
Spindle speed	2	0.001489	0.000744	1.94
Depth of cut	2	0.001689	0.000844	2.20
Feed Rate	2	0.072622	0.036311	94.78
Error	2	0.000822	0.000411	1.08
Total	8	0.076622	0.08321	100

An equation is generated to correlate the factors such as spindle speed, depth of cut, feed rate and responses such as surface roughness of CNC End milling machine of AA6082 is obtained by multiple linear regression.

Regression Analysis:

Ra versus SPINDLE SPEED, DEPTH OF CUT, FEED RATE

The regression equation for surface roughness is

Ra = 0.6320 – 0.000015 spindle speed + 0.0414 depth of cut + 0.001100 feed rate

Table: 6. Results of regression analysis for Alloy

S value	R-Sq (%)	R-Sq (adj)
0.0140335	98.71	87.94

Results and Discussion:

1. Milling Process is successfully adopted in the manufacturing of AA6082 Aluminum components.
2. The Taguchi method provides a systematic and efficient methodology for the design optimization of cutting parameters with far less effect than would be required for most optimization techniques.
3. It is found that feed rate is the most influenced process parameter from the response table and from the maximum S/N ratio values.
4. Optimum cutting parameters for better surface finish is obtained at a cutting speed at level 3, feed at level 1 and depth of cut at level 2 and the corresponding values are for optimum surface finish is occurred at a speed of 7000 rpm, feed 100 mm/min and depth of cut 0.5 mm.
5. Optimum surface finish (0.65 µm) is obtained at speed 7000 rpm, feed 100 mm/min and depth of cut 0.5 mm at the maximum value of S/N Ratio is 3.74173.
6. The percentage contribution of process parameters was determined by ANOVA analysis. It is found that feed rate contribution 94.78% is most influenced parameter in surface finish, spindle speed contribution is 1.94% and depth of cut is 2.20%.
7. Based on ANOVA results of surface finish, it can be observed that the Feed rate (94.78%) has the highly influenced parameters of surface finish, whereas the Depth of cut (2.20%) and Spindle speed (1.94%), had less influence when compared to remaining variables.
8. Regression model developed in this investigation could be used for the real time prediction of surface roughness. It is observed from the simulation results are 98.71% for surface roughness.

Conclusions:

The following salient features were obtained based on experimental investigation.

1. Experiment is completed by generating L9 orthogonal array by using MINI TAB 17 software
2. Surface finish can be improved by using different process parameters.
3. The surface finish (µm) is better at low feed rate (100 mm/min) high spindle speed (7000 rpm), and depth of cut (0.5 mm).
4. AA6082 Aluminum material can be machined with HSS tool material.
5. It is found that at high feed rate more surface finish is occurring. From this feed rate is the major parameter that influences the surface finish

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