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Comparative Analysis of Face Milling in Dry and Wet Condition of Al 8011 For Minimum Surface Roughness in Face Milling

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Abstract*: *The quality of machined components is evaluated in respect of how closely they adhere to set product finish, and reflective properties. Dimensional accuracy, tool wear and quality of surface finish are three factors that manufacturers must be able to control at the machining operations to ensure better performance and service life of engineering component. Aluminum alloys are extensively used as a main engineering material in various industries such as automotive industries, the mould and the die components manufacture and the industry in which weight is the most important factor. The purpose of this research is to investigate the effect of the main factors of the surface roughness and flatness in aluminum 8011 face milling with dry and wet condition. This experimental investigation to be conducted by using VMC controlled milling machine with 30mm face milling cutter with carbide multiple inserts. The same parameters were executed during the operation only difference minimum quantity lubricant for one set of operation and another set of operation without lubricant. The experimental results were evaluated using Taguchi technique minimum surface finish obtained at medium speed and maximum feed and depth of cut 0.222 µm in the dry condition during the face milling operation. The minimum flatness was obtained 0.012 mm at wet condition. minimum surface finish obtained through dry condition. Optimal control factor and ANNOVA calculations were found for face milling operation of AA8011.

Keywords: AA8011, face milling, Ra, CMM, flatness error

I. INTRODUCTION

In modern industry the goal is to manufacture low-cost, high-quality products in short time. Automated and flexible manufacturing systems are employed for that purpose along with CNC machines that are capable of achieving high accuracy and very low processing time. Face millings the second most common method (after turning) for metal cutting and especially for the finishing of machined parts. According to theoretical models the cutting force depends on the area of the chip (feed and depth of cut), the tool path (width of cut), the material and cutting tool properties and some experimentally determined constants. Restrictions concerning the available power, chip fraction mechanism and the dynamic characteristics of the workpiece – cutting tool – machine system, have an impact on cutting conditions, which is reflected on surface roughness, surface texture and dimensional deviations of the product. Surface roughness is a measure of the technological quality of a product and a factor that greatly influences manufacturing cost. It describes the geometry of the machined surface and combined with the surface texture, which is process dependent, can play an important role on the operational characteristics of the part (e.g. appearance of excessive friction and/or wear). The achievement of a desirable value is a repetitive and empirical process that can be very time consuming. The part must be machined more than once until an acceptable value is obtained.

A. Milling

Milling is the process of removing metal by feeding the work past a rotating multipoint cutter. In milling operation, the rate of metal removal is rapid as the cutter rotates at a high speed and has many cutting edges. Thus, the jobs are machined at a faster rate than with single point tools and the surface finish is also better due to multipoint cutting edges. The action of the milling cutter is vastly different from that of a drill or lathe tool. In milling operation, the cutting edge of the cutter is kept continuously in contact with the material being cut. The cuts pick gradually. The cycle of operation to remove the chip produced by each tooth is first a sliding action at the beginning, the cutter meets the metal and then crushing action takes place just after it is leading finally to the cutting actions. The versatility and accuracy of the milling process causes it to be widely used in modern manufacturing.

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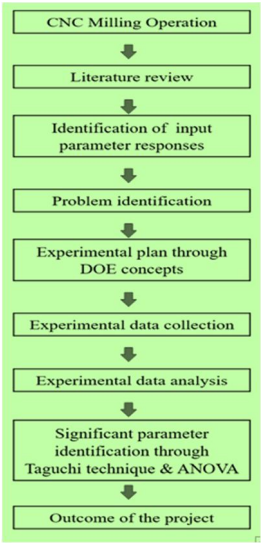
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B. CNC Machining

The optimization of various processing parameters of a CNC milling machine effectively determines some critical process control factors/parameters or combinations of such parameters who will establish a close relation with the desired output of a machine. By considering all above, in this project, a new & basic approach is taken to study & analyze the relative significance of factors/parameters & their special combinations using suitable standard Experimental Design Methodology Method and Suitable analysis software. After determining the relative significance; it can be simple to understand the factors/parameters or their special combinations to be changed to increase process efficiency & output characteristics of CNC milling machine. The selection of optimal cutting parameters is a very important issue for each machining machine in order to enhance process efficiency & output characteristics of CNC milling machine which further leads towards an influence on surface quality of machining products. Thus, to improve the process efficiency & output characteristics of CNC milling machine it is very important & necessary to optimize the various processing parameters of CNC milling machine.

C. Experimental Plan

The proposed work approach and methodology has been elaborately shown in the flow chart.



II. CNC MILLING OVERVIEW & INPUT PARAMETERR

A. Vertical Millimg Machine

Computer Numerical Control (CNC) Milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC Mills are classified according to the number of axes that they possess. Axes are labeled as x and y for horizontal movement, and z for vertical movement, as shown in this view of a manual mill table. A standard manual light-duty mill (such as a Bridgeport™) is typically assumed to have four axes: Table x.

1) Table y.
2) Table z.
3) Milling Head z.

The number of axes of a milling machine is a common subject of casual "shop talk" and is often interpreted in varying ways. We present here what we have seen typically presented by manufacturers. A five-axis CNC milling machine has an extra axis in the form of a horizontal pivot for the milling head, as shown below.

This allows extra flexibility for machining with the end mill at an angle with respect to the table. A six-axis CNC milling machine would have another horizontal pivot for the milling head, this time perpendicular to the fifth axis. CNC milling machines are traditionally programmed using a set of commands known as G-codes. G-codes represent specific CNC functions in alphanumeric format.

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Fig 1: Vertical Milling Machine

B. Experimental Setup

The experiments were conducted based on L 9 orthogonal array with respect to full factorial design. The three factors and each three levels with two replicates were considered based on machine tool specifications and tool manufacturer recommendations.

1) *Machine Specifications:* The experiments were conducted based on L9 orthogonal array with Taguchi design. BATLIBOI CHETAK-75MC model was used to perform the coated and uncoated end milling operation. The Specification of Milling machine is Table size is 950x520mm, X-Axis Traverse is 762mm, Y-Axis Traverse is 510 mm, z Axis traverse is 510mm.

III. MACHINING PARAMETER

A. Taguchi Approach

Basically, experimental design methods were developed original fisher. However experimental design methods are too complex and not easy to use. Furthermore, many experiments must be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal – to – noise (S/N) ratio to measure the quality characteristics deviating from the desired values. Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the – lower – better, the – higher – better, and the – nominal – better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, a statistically significant with the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design.

B. Design Of Experiment

TABLE I: PROCESS PARAMETERS AND THEIR LEVELS

LEVELS	PROCESS PARAMETERS		
	SPEED RPM	FEED m/min	DOC mm
1	1250	150	0.2
2	1500	175	0.3

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C. An Orthogonal Array L_9 Formation- (Dry & Wet)

TABLE II: L9 ARRAY FORMATION

TRIAL	DESIGNATION	SPEED RPM	FEED mm/min	DOC mm
1	$A_1B_1C_1$	1250	150	0.2
2	$A_1B_2C_2$	1250	175	0.3
3	$A_1B_3C_3$	1250	200	0.4
4	$A_2B_1C_2$	1500	150	0.3
5	$A_2B_2C_3$	1500	175	0.4
6	$A_2B_3C_1$	1500	200	0.2
7	$A_3B_1C_3$	1750	150	0.4
8	$A_3B_2C_1$	1750	175	0.2
9	$A_3B_3C_2$	1750	200	0.3

D. Experimental Data - (Dry & Wet)

TABLE III: INPUT PARAMETERS AND OUTPUT RESPONSES

SL.NO	SPEED RPM	FEED mm/min	DOC mm	MT min	RA-WET µm	RA-DRY µm	FLATNESS-ERROR-WET-mm	FLATNESS-ERROR-DRY-mm
1	1250	150	0.2	0.97	0.790	0.415	0.012	0.077
2	1250	175	0.3	0.89	0.667	0.514	0.058	0.033
3	1250	200	0.4	0.83	0.358	0.417	0.099	0.141
4	1500	150	0.3	1.00	0.719	0.310	0.180	0.171
5	1500	175	0.4	0.92	0.380	0.351	0.115	0.147
6	1500	200	0.2	0.88	0.780	0.222	0.051	0.073
7	1750	150	0.4	1.02	0.759	0.235	0.056	0.043
8	1750	175	0.2	0.94	0.689	0.391	0.081	0.039
9	1750	200	0.3	0.88	0.531	0.351	0.148	0.031

E. Machining Time (Analysis of Result)- (Dry & Wet)

TABLE IV SN RATIO VALUE OF MACHINING TIMING

SL.NO	SPEED	FEED	DOC	MT min	SN-RATIO
1	1250	150	0.2	0.97	0.26457
2	1250	175	0.3	0.89	1.01220
3	1250	200	0.4	0.83	1.61844
4	1500	150	0.3	1.00	0.00000
5	1500	175	0.4	0.92	0.72424
6	1500	200	0.2	0.88	1.11035
7	1750	150	0.4	0.62	4.15217
8	1750	175	0.2	0.94	0.53744
9	1750	200	0.3	0.88	1.11035

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TABLE V ANALYSIS OF VARIANCE FOR MT, USING ADJUSTED SS FOR TESTS

SOURCE	DF	SEQ SS	ADJ SS	F	P	% CONTRIBUTION
SPEED	2	0.022689	0.011344	0.71	0.586	23
FEED	2	0.005689	0.002844	0.18	0.849	6
DOC	2	0.037422	0.018711	1.17	0.462	38
Error	2	0.032089	0.016044			33
Total	8	0.097889				100

F. Surface Roughnesses (Analysis Of Result)

TABLE: VI SN RATIOS VALUES IN SURFACES ROUGHNESS

TRIAL	SPEED	FEED	DOC	Ra	SNRA1
1	1250	150	0.2	0.415	7.6390
2	1250	175	0.3	0.514	5.7807
3	1250	200	0.4	0.417	7.5973
4	1500	150	0.3	0.310	10.1728
5	1500	175	0.4	0.351	9.0939
6	1500	200	0.2	0.222	13.0729
7	1750	150	0.4	0.235	12.5786
8	1750	175	0.2	0.391	8.1565
9	1750	200	0.3	0.351	9.0939

G. Surface Roughness Response For Each Level Of The Process Parameter

TABLE: VII ANALYSIS OF VARIANCE FOR RA, USING ADJUSTED SS FOR TESTS-DRY CONDITION

SOURCE	DF	SEQ SS	ADJ SS	F	P	% OF CONTRIBUTION
SPEED	2	0.039930	0.019965	8.37	0.107	59
FEED	2	0.017697	0.008848	3.71	0.212	26
DOC	2	0.005758	0.002879	1.21	0.453	8
Error	2	0.004770	0.002385			7
Total	8	0.068154				100

H. Surface Roughness And S/N Ratios Values For The Experiments-Wet

TABLE: VIII SN RATIOS VALUES IN SURFACES ROUGHNESS

TRIAL	SPEED	FEED	DOC	Ra	SNRA1
1	1250	150	0.2	0.790	2.04746
2	1250	175	0.3	0.667	3.51748
3	1250	200	0.4	0.358	8.92234
4	1500	150	0.3	0.719	2.86542
5	1500	175	0.4	0.380	8.40433
6	1500	200	0.2	0.780	2.15811
7	1750	150	0.4	0.759	2.39516
8	1750	175	0.2	0.689	3.23562
9	1750	200	0.3	0.531	5.49811

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TABLE: IX ANALYSIS OF VARIANCE FOR RA, USING ADJUSTED SS FOR TESTS-WET CONDITION

SOURCE	DF	SEQ SS	ADJ SS	F	P	% OF CONTRIBUTION
SPEED	2	0.004814	0.002407	0.09	0.913	3
FEED	2	0.072558	0.036279	1.43	0.412	32
DOC	2	0.098431	0.049215	1.94	0.340	43
Error	2	0.050739	0.025369			22
Total	8	0.226542				100

IV. FLATNESS MEASURING SYSTEM

A. Overview of CMM

The typical 3 "bridge" CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three-dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. The machine then uses the X, Y, Z coordinates of each of these points to determine size and position with micrometer precision typically. A coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y, and Z coordinates of the target, points are generated which can then be analyzed via regression algorithms for the construction of features.

B. Flatness Error (Analysis Of Result)

1) Flatness and S/N Ratios Values For The Experiments-Dry

TABLE: X SN RATIOS VALUES FOR FLATNESS

TRIAL	SPEED	FEED	DOC	FLATNESS	SNRA1
1	1250	150	0.2	0.077	22.2702
2	1250	175	0.3	0.033	29.6297
3	1250	200	0.4	0.141	17.0156
4	1500	150	0.3	0.171	15.3401
5	1500	175	0.4	0.147	16.6537
6	1500	200	0.2	0.073	22.7335
7	1750	150	0.4	0.043	27.3306
8	1750	175	0.2	0.039	28.1787
9	1750	200	0.3	0.031	30.1728

2) Flatness Response For Each Level Of The Process Parameter

TABLE: XI ANALYSIS OF VARIANCE

SOURCE	DF	SEQ SS	ADJ SS	F	P	% OF CONTRIBUTION
SPEED	2	0.012881	0.006440	1.89	0.346	54
FEED	2	0.000886	0.000443	0.13	0.885	4
DOC	2	0.003500	0.001750	0.51	0.660	14
Error	2	0.006806	0.003403			28
Total	8	0.024073				100

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3) Flatness And S/N Ratios Values For The Experiments-Wet

TABLE: XII SN RATIOS VALUES FOR FLATNESS

TRIAL	SPEED	FEED	DOC	FLATNESS	SNRA1
1	1250	150	0.2	0.012	38.4164
2	1250	175	0.3	0.058	24.7314
3	1250	200	0.4	0.099	20.0873
4	1500	150	0.3	0.180	14.8945
5	1500	175	0.4	0.115	18.7860
6	1500	200	0.2	0.051	25.8486
7	1750	150	0.4	0.056	25.0362
8	1750	175	0.2	0.081	21.8303
9	1750	200	0.3	0.148	16.5948

4) Flatness Response For Each Level Of The Process Parameter

TABLE: XIII ANALYSIS OF VARIANCE

SOURCE	DF	SEQ SS	ADJ SS	F	P	% OF CONTRIBUTION
SPEED	2	0.005390	0.002695	0.85	0.542	24
FEED	2	0.000497	0.000248	0.08	0.928	3
DOC	2	0.009766	0.004883	1.53	0.395	44
Error	2	0.006372	0.003186			29
Total	8	0.022025				100

V. CONCLUSION & RESULT

A. Conclusion

In this study, the Taguchi technique and ANOVA were used to obtain optimal milling parameters of AA8011 under wet and dry conditions. The experimental results were evaluated using ANOVA. The following conclusion can be drawn. In this study, the Taguchi technique and ANOVA were used to obtain optimal parameters in the Milling of aluminium under wet and dry conditions. The experimental results were evaluated using Taguchi technique minimum surface finish obtained at medium speed and maximum feed and depth of cut 0.222 µm in the dry condition during the face milling operation. The minimum flatness was obtained 0.012 mm at wet condition. Below Taguchi design result and annova ere illustrated.

B. Result Optimal Control Factor

1) Surface Roughness (Dry) -A_1 (Speed-1250) B_2 (Feed-175mm/min) C_3 (DOC-0.6 mm)
2) Surface Roughness (Wet) -A_3 (Speed-1750) B_2 (Feed-175mm/min) C_1 (DOC-0.2 mm)
3) Machining Timing (Wet & Dry)- A_2 (Speed-1500) B_3 (Feed-200 mm/min) C_1 (DOC-0.2 mm)
4) Flatness (Dry) - A_1 (Speed-1250) B_3 (Feed-200 mm/min) C_2 (DOC-0.4 mm)
5) Flatness (Wet)- A_2 (Speed-1500) B_3 (Feed-200 mm/min) C_1 (DOC-0.2 mm)

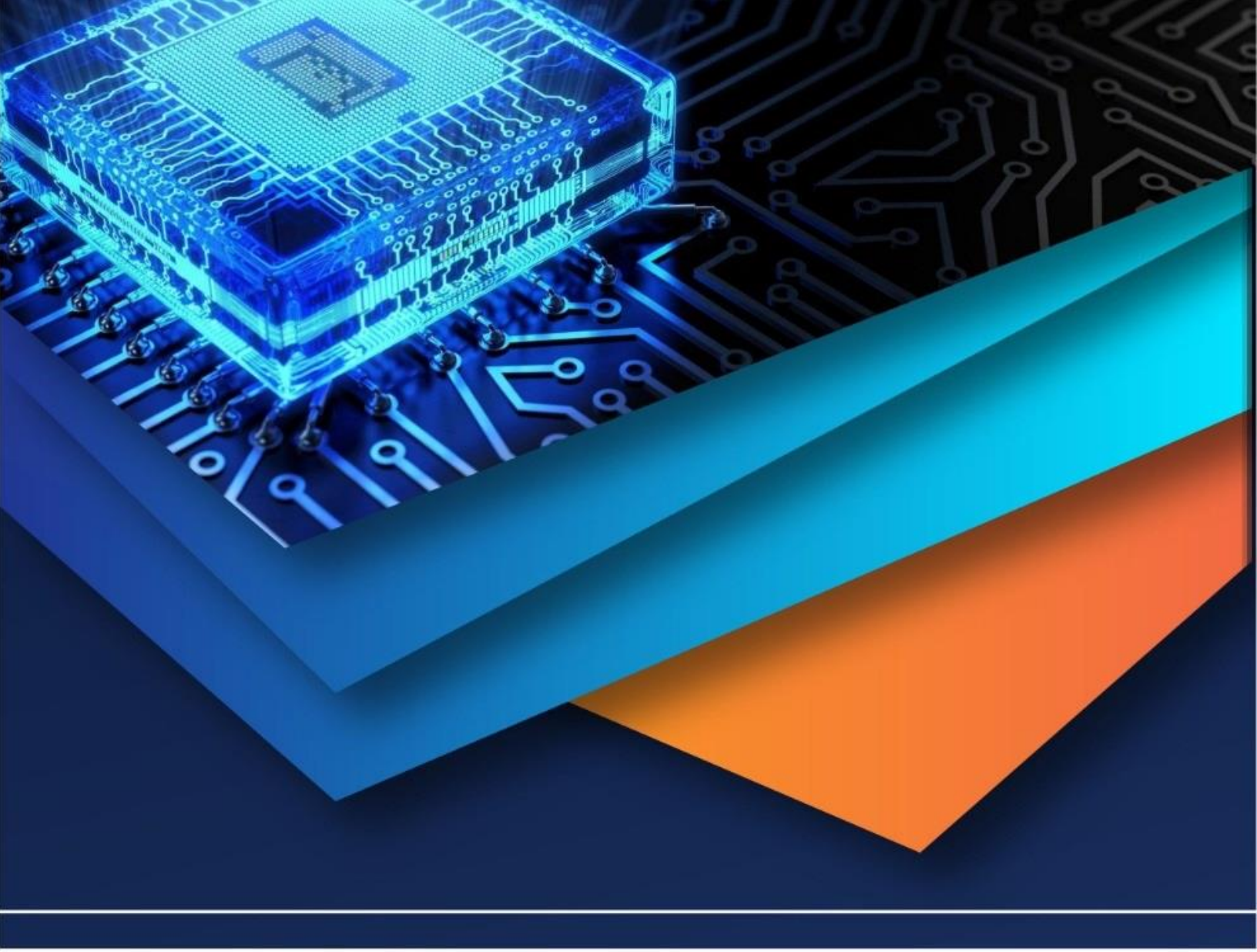
C. Percentage Of Contribution Of Process Parameter

1) Surface Roughness (Dry) - Speed 59%
2) Surface Roughness (Wet) - DOC 43%
3) Machining Timing- DOC 38%
4) Flatness Error- (Dry) - Speed 54%
5) Flatness Error- (Wet) - DOC 44%

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