# Optimization of Control Factors for Machining Time in CNC Milling of Al-7075 based MMCs Using Taguchi Robust Design Methodology

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**Abstract -** *Every day's scientists are developing new materials and each for new material for the milling machining operation. For the CNC milling machining operation, the work piece should be normally economical and efficient. Al-7075 based MMCs is carried out as the work piece in the end milling operation because it has high strength and stiffness, less density, high electrical performance and high wear resistance. Taguchi methodology is carried out for the experiment to optimize the various machining parameters as it reduces the number of experiments. This paper is dealing with the optimization of selected milling process parameter that's spindle speed, feed rate and depth of cut. In the optimization technique Taguchi orthogonal array containing 3 columns which represent 3 factors and nine rows which represent the nine experiments to be conducted and value of each parameter was obtained. The machining time value is considered for the responses of the experiment. The main objective of SN ratio is to predicted and verified test values are valid when compared to the optimum values. The main objective of the paper is to found the SN ratio value and verified the limits with corresponding to the Taguchi design.*

*Key Words*: Al-7075 Based MMCs, CNC Milling, Machining time, SN Ratio, Taguchi Design

## 1. INTRODUCTION

The main objective of the research work is to find out the optimum values for the selected control factors in order to reduce machining time (MT) using Taguchi's robust design methodology and to develop the prediction models for machining time considering the control factors. In the present work Taguchi method is used to determine the optimum cutting milling parameters are more efficiently and the three cutting parameter are spindle speed, feed rate and depth of cut are used in three different level in the project work. The Al-7075 based metal matrix composite is used as the work piece. Taguchi method is used to optimize the process parameter i.e. surface roughness and MRR using signal to noise ratio for milling process of the work piece materials. The Taguchi experiments are carried out using L9 (3³) orthogonal array.

Milling is process of removing extra material from the work piece with a rotating with a rotating multi-point cutting tool is called multi cutter. The primary factor of the milling machining operation are spindle speed, feed rate and depth

of cut. Other factor of the milling process is depending open the tool material and adjusting of the control factor etc.

In the CNC milling operation is controlled by the computer numerical method. In modern CNC system, end-to-end component is designed in highly automated using computer aided design and computer aided manufacturing process. The CNC machine is the general term used for systems which control the functions of the machine tool using coded instructions processed by a computer. The part program of the CNC machine enhances the ability of the machine to perform repeat tasks with high degree of accuracy. The CNC machine program is coded by G-code and M-code. The G-code is used for tool movements, linear cutting movements. The M-codes is used for CNC to command on/off signals to the machine function.

Machining Time is the essential responses of the milling operation which depends upon the input factors. It affects the total machining process and depends upon the material removal rate. The values of the machining time w.r.t to the input factor in this experiment are defined below. The result of the machining time is different depending upon the input factor. The machining time is affected the machining process and economy of the process.

### 1.1 Literature Review

Arkiadass et. al [1] calculated the flank wear of end milling of LM25 Al/SiCp and also found the spindle speed . They predicted the surface roughness depends upon the composition of Al/SiCp composite material .Grossi et. Al [2] explained during machining of Aluminum 6082-T4 alloy the chatter formation depend upon the cutting force, no of revolution and depth of cut. Sammy et. al [3] proposed that it was the cyclic interaction between the tool and the work piece by increasing of chip production depending upon the increasing feed rate. The better surface finish occurred due to minimum feed & depth of cut. Vishnu et. al[4] optimized the parameter of EN-31 steel alloy, mainly feed rate, depth of cut, coolant flow by taguchi optimization method. Arokiadass et. al [5] studied the machining characteristics of LM 25Al/SiCp composite material and found the tool wear by response surface methodology and another optimization technique used that was CCD ( Central Composite Design ) method. Hung et. al [6] profoundly studied the graphical representation of cutting distance and cutting & flank wear , from the graph the cutting speed impacted on tool wear & flank wear . The tool wear was high depending upon the increased cutting speed. Chang et. al. [7] described on work

piece S545C medium carbon steel by using as high speed steel tool & it was coated with TiN .The performance characteristics commonly used for evaluating side milling process were, feeding direction roughness, axial direction roughness & waviness. Wouw et al. [8] investigated on stable and unstable chip formation from the SLD diagrammed depending upon the material model & machine model. They concluded that the three model analysis was affected the chip formation & it depended on the surface roughness model. Mustafa et. al. [9] experimented on steel composites by CNC milling and optimized the tool wear and high speed developed higher temperatures that cause softening and reducing of the adhered material on tool. Baek et. al.[10] explained the optimal feed rate of face milling operation presented on considering the profile and run out error which was operated on work piece AISI 1041 with milling cutter made by tungsten. Karakas et. al. [11] explained the better performance in the work piece occurred by coated tool as compare to uncoated tool and flank wear gradually decreased with decrease in cutting speed. FangHong et. al. [12] explained that the cutting temperature calculation depends on the various cutting speed and the cutting temperature increased if the cutting speed was increased. A better surface integrity was depending upon the low cutting speed, the tool wear was calculated as the rake face wear, flank wear other edge corner.

## 2. Experimental Setup & Machining Process

The aim of the experimental work is find out the combination of optimum values for the selected control factors in order to machining time using Taguchi's Robust Design Methodology. The Workpiece of the experiment is taken as the Al 7075 based MMCs (Metal Matrix Composite Materials). The DOE (Design of Experiments) are conducted using L9 ($3^3$) orthogonal array.

### 2.1 CNC Vertical Milling Machine

The End milling operation was done by Surya5 CNC milling machine. The machining tests are conducted by different conditions of spindle speed, feed rate & depth of cut. The machine specifications of the CNC machine are:

**Table -1:** CNC Milling Machine Specification

| Machine Characteristics | Specification |
|---|---|
| Name Of The CNC Machine | SURYA 5 |
| Type Of the CNC Machine | CNC Vertical Milling Machine |
| Series Of the machine | Fanuc Series Mate MD |
| Make of the machining | HFW- BHARAT FRITZ WERNER LTD. |
| Year Of Commissioning Of machine | 2013 |
| Axis Specification of the milling machine | (800×350×380)mm |
| Accuracy Of the machine | 10 micron |

| Cost of the machine | 1.8 million |
|---|---|
| Motor Power of the milling machine | 0.5 HP |



**Fig -1**: CNC milling setup

## 2.2 Work piece Material

In this present work Al-7075 based Metal Matrix Composites (MMCs) material is used. The dimension of the work piece material is diameter ($\varphi$) is 45mm & Height of the material is 20mm. The percentages of the reinforcement and matrix materials are (Al-7075-97% , Al2O3-2%, B4C-1%). The MMC material is manufactured by stir casting method.



**Fig -2**: Workpiece Material

## 2.3 Cutting Tool Material

In the CNC End milling operation the HSS (High Speed Steel) material is used as the cutting tool material. The dimensions of the cutting tool are (diameter- 10mm, Helix angle - 38°, No of flutes – 4, Tool length – 72mm, Cutting edge length – 24mm). It consists of very high hardness and good toughness and it is principally used for roughing of super alloys and steel alloys.

**Fig -3:** HSS end milling tool

## 3. Design of Experiments (DOE)

The experimental process is taken as the three process parameters with three levels are chosen as the input parameters are sufficiently far apart so that they covered wide range. The process parameters and their ranges finalised by the literature review, books and machine operator's experience. The selected three input parameters are spindle speed, feed rate and depth of cut. Al – 7075 based MMCs is machined by this input parameter with three different levels (low, medium, high). The input parameter and their level defined in this table.

**Table -2:** Design of Experiment of the Control Factor

| Sl No | Factors | Symbol | Level-1 (Low) | Level-2 (Medium) | Level-3 (High) |
|---|---|---|---|---|---|
| 1 | Spindle speed | A | 800 RPM | 1200 RPM | 1500 RPM |
| 2 | Feed Rate | B | 200 mm/min | 350 mm/min | 500 mm/min |
| 3 | Depth of Cut | C | 0.4 mm | 0.8 mm | 1 mm |

## 3.1 Selection of Orthogonal Array

Selection procedure of the OA (orthogonal Array) depends on the number of factors, levels of each factor and the total degrees of freedom. The steps of the selections of the Orthogonal Array are.

1) Number of control Factors = 3
2) Number of levels for each control factors = 3
3) Number of experiments to be conducted = 9

Factor assignment for L9 (33) has shown in table which is defined by the control factor with different table.

**Table -3:** Experimental Data of the Milling machine operation

| Sl No | Spindle Speed (A) | Feed Rate (B) | Depth of Cut (C) |
|---|---|---|---|
| 1 | 800 | 200 | 0.4 |
| 2 | 800 | 350 | 0.8 |
| 3 | 800 | 500 | 1 |
| 4 | 1200 | 200 | 0.8 |
| 5 | 1200 | 350 | 1 |
| 6 | 1200 | 500 | 0.4 |
| 7 | 1500 | 200 | 1 |
| 8 | 1500 | 350 | 0.8 |
| 9 | 1500 | 500 | 0.4 |

## 4. Result & Discussion

The Al-7075 based MMCs are prepared for the conducting experiment. Using different levels of the process parameters the specimens have been machined accordingly, depending open the spindle speed, feed rate & depth of cut in different conditions. The machining time is measured by time required by the machining process. The machining time result of the experiments has been show in below the table.

**Table -4:** Output table for the machining time

| SL NO | SPINDLE SPEED | Feed Rate | Depth Of Cut | Machining Time (in Sec) |
|---|---|---|---|---|
| 1 | 800 | 200 | 0.4 | 238 |
| 2 | 800 | 350 | 0.8 | 82 |
| 3 | 800 | 500 | 1 | 54 |
| 4 | 1200 | 200 | 0.8 | 123 |
| 5 | 1200 | 350 | 1 | 68 |
| 6 | 1200 | 500 | 0.4 | 106 |
| 7 | 1500 | 200 | 1 | 104 |
| 8 | 1500 | 350 | 0.8 | 77 |
| 9 | 1500 | 500 | 0.4 | 108 |

The below table describes the result of SN ratio calculated for the machining time considering smaller is the better because when the time is less it affects the MRR and machining economy.

**Table -5:** SN ratio output of the Machining Time

| Sl No | Spindle Speed | Feed Rate | Depth Of Cut | Machining Time (In Sec) | S/N Ratio(MT) |
|---|---|---|---|---|---|
| 1 | 800 | 200 | 0.4 | 238 | -47.5315 |
| 2 | 800 | 350 | 0.8 | 82 | -38.2763 |
| 3 | 800 | 500 | 1 | 54 | -36.6479 |
| 4 | 1200 | 200 | 0.8 | 123 | -41.7981 |
| 5 | 1200 | 350 | 1 | 68 | -36.6502 |
| 6 | 1200 | 500 | 0.4 | 106 | -40.5061 |
| 7 | 1500 | 200 | 1 | 104 | -40.3407 |
| 8 | 1500 | 350 | 0.8 | 77 | -37.7298 |
| 9 | 1500 | 500 | 0.4 | 108 | -40.6685 |

From the graph it is significant that the Signal to Noise ratio performance as compared to the input factor is calculated for the machining time. Here S/N ratio calculation for machining time is calculated by smaller is better because when the machining time is small it affects the complete machining process. In the first case the amount of spindle speed is increased from 800 RPM to 1500 RPM. The S/N ratio value also gradually increases as compared to the input factor from -40.15 to -39.58. In second case the feed rate value gradually increase from 200mm/min to 500 mm/min. It indicates the S/N ratio value increase to a certain point then decrease. It is increasing from -42.90 to -39.27 then decrease from -39.27 to -37.21. In the third case the depth of cut value is gradually increased it affects S/N ratio value which gradually increase from -42.90 to -37.21.
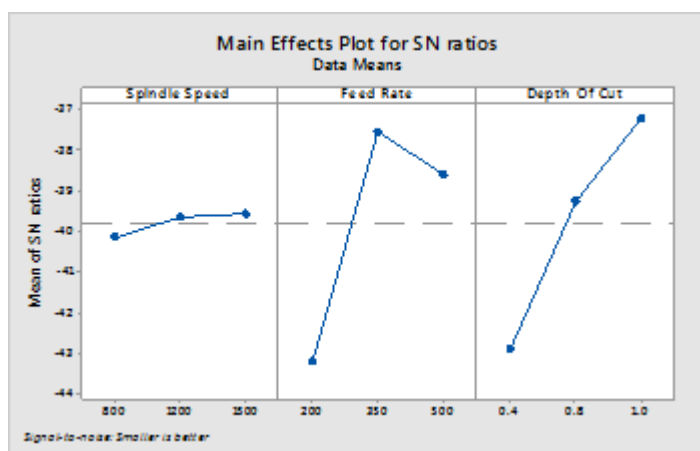


**Fig -4:** SN ratio Plot of Machining time

The table represents the rank of the input factor with respect to the S/N ratio. From the table it is represented that depth of cut is the most significant influencing parameter compared to feed rate & spindle speed in machining time.

**Table -6:** Rank calculation of SN ratio of Machining Time

| Level | Spindle Speed | Feed Rate | Depth of Cut |
|---|---|---|---|
| 1 | -40.15 | -43.22 | -42.90 |
| 2 | -39.65 | -37.55 | -39.27 |
| 3 | -39.58 | -38.61 | -37.21 |
| Delta | 0.57 | 5.67 | 5.69 |
| Rank | 3 | 2 | 1 |

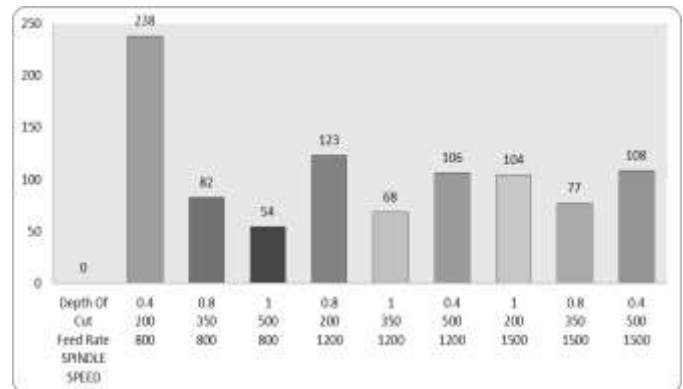## 4.1 Effect of cutting parameters on Machining Time



**Fig -5:** Histogram Graph Between Input Parameter Vs Machining Time

From the above histogram it represented that the machining time fluctuates with respect to the input factor. The below graph is represented that when the depth of cut is constant but the spindle speed & the feed rate increases the machining time value is decreased, as in first experiment & last experiment the depth of cut is constant (0.4) but the spindle speed increases from 800 RPM to 1500 RPM & the feed rate increase from 200mm/min to 500mm/min as a result the machining time value is decreased from 238 second to 108 second. Hence it proves that the machining time depends upon the input factor.
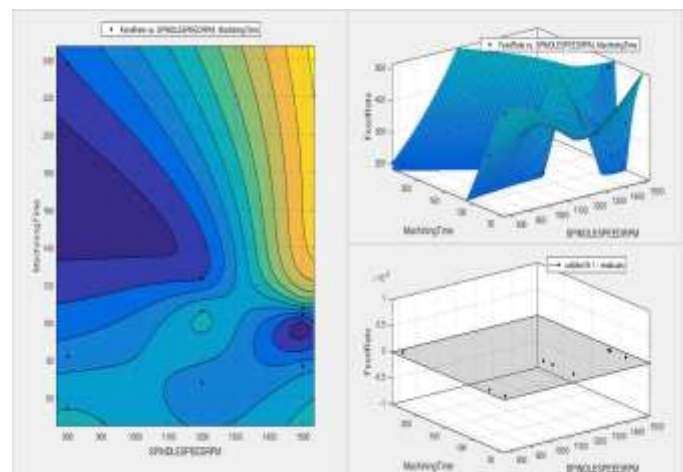


**Fig -6:** Graph between spindle speed and machining time

The above figure ig generated by the MATLAB tool. It defined that the graphical representation between the spindle speed and machining time. Here it also defined that when the spindle speed value is increased, the amount of machining time is less.

## 5. CONCLUSIONS

The objective of the present work is to find out the set of optimum values in order to optimize the machining time using Taguchi's robust design method considering the

control factors (spindle speed, feed rate and depth of cut) with three levels for the Al-7075 based MMCs.

Based on the results of the present experimental investigations the following conclusions are:

1) In the present experiment the optimum value of the machining time is considered for the combination of the control factor of the control combination are 800 rpm, 500mm/min and 1mm.The optimum value is predicted by the SN ratio value. From the SN ratio value it indicated the rank of the control factor w.r.t the surface roughness value.

2) In this research, it defines the graphical representation between the experimental result (machining time value) and the level of control factor. From this representation it explains that the relation between the experimental value and the control factor.

3) In this paper it represents that graphical representation between spindle speed and machining time with the help of MATLAB tool.

## 6. Future Scope

In this work, the optimum values are obtaining using Taguchi technique. Hence there is a large scope of future work to be carried.

1) In future work can be carried out by selecting the factors to be significant using ANOVA technique, Grey Taguchi and ANN method.

2) In future to calculate the chip thickness and another response value of the MMCs using this 3-level of the control factors.

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