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OPTIMIZATION OF MACHINING PARAMETERRS FOR FACE MILLING OPERATING IN A VERTICAL CNC MILLING MACHINE USING TAGUCHI METHOD

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Abstract: *Milling machine is one of the important machining operations. In this operation the work piece is fed against a rotating cylindrical tool. The rotating tool consists of multiple cutting edges (multipoint cutting tool). Normally axis of rotation of feed given to the work piece Milling operation is distinguished from other machining operations on the basis of orientation between the tool axis and the feed direction; however, in other operations like drilling, milling, etc. the tool is fed in the direction parallel to axis of rotation. The cutting tool used in milling operation is called milling cutter, which consists of multiple edges called teeth. The machine tool that performs the milling operations by producing required relative motion between work piece and tool is called milling machine.*

I. INTRODUCTION

It provides the required relative motion under very controlled conditions. These conditions will be discussed later in this unit as milling speed, feed rate and depth of cut. Normally, the milling operation creates plane surfaces. Other geometries can also be created by milling machine. Milling operation is considered an interrupted cutting operation teeth of milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to bear the above stated conditions. Depending upon the positioning of the tool and work piece the milling operation can be classified into different types.

OBJECTIVES:

After studying this unit, you should be able to understand

- introduction and working principle of milling machine,
- different type of milling operations,
- different type of milling machine and their main parts,
- specifications of milling machines,
- different cutting parameters as setting of a milling machine,
- introduction and categorization of milling cutters,
- different operations that can be performed on a milling machine, and
- Indexing, different methods of indexing.

1.2: TYPES OF MILLING MACHINES:

Milling operation is broadly classified as peripheral milling and face milling .Peripheral milling. This operation is also called plain milling operation. In this operation axis of rotating tool is always kept parallel to the surface being machined. This operation is done by the cutting edges on outside periphery of the milling cutter. Different type of peripheral milling operations are possible as described below. Slab Milling In this milling operation the cutter width extends beyond the work piece on both sides. Slotting it is also a type of milling operation, also called as slot milling operation. In this case width of the cutter is less than the width of work piece. It is used to make slot in the work piece. Thin slots can be made by using very thin milling cutters. The work piece can be cut into two pieces by making a very thin slot throughout the depth of work piece. Cutting the work piece this way be slot milling is called saw milling. Side milling. The cutter is used for milling of sides of a work piece. Straddle Milling It is just like side milling with difference that cutting (milling operation) takes place simultaneously on both the sides of work piece. All the above types of milling operations are also demonstrated in as per their respective article number.

FIG 1:Milling machine

II LITERATURE SURVEY

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S. M. Pandey, et al (1):"Optimization of Machining Parameters for Face Milling Operation in a Vertical CNC Milling Machine using Taguchi Method." Investigated the optimization of machining parameters for face milling on a vertical CNC milling machine, emphasizing the application of the Taguchi method.

V. R. Satheesh Kumar, et al (2):"Optimization of Machining Parameters in CNC Milling of Al6061-T6 Alloy Using Taguchi Method." Studied the optimization of machining parameters in CNC milling, providing insights into the Taguchi method's effectiveness.

M. K. Pradhan, et al (3):"Optimization of Machining Parameters for Surface Roughness in CNC Milling of AISI 316 Stainless Steel Using Taguchi Method." Explored the optimization of surface roughness in CNC milling of stainless steel, applying the Taguchi method.

S. Pal, et al (4): "Optimization of CNC Milling Parameters for Surface Roughness Using Taguchi Method." Investigated the optimization of CNC milling parameters for surface roughness, emphasizing the Taguchi method.

B. K. Biswal, et al (5): "Optimization of Surface Roughness in CNC Milling of Al 6061-T6 Using Taguchi Method." Explored the optimization of surface roughness in CNC milling of aluminium alloy, employing the Taguchi method.

K. K. Mohanta, et al (6):"Optimization of Machining Parameters in CNC Milling of Aluminium Alloys Using Taguchi Method." Studied the optimization of machining parameters in CNC milling of aluminium alloys, emphasizing the application of the Taguchi method.

A.S. M. Limon, et al. (7):"Optimization of Machining Parameters in CNC Milling for Minimization of Surface Roughness." Investigated the optimization of machining parameters in CNC milling with a focus on minimizing surface roughness, utilizing the Taguchi method.

R. S. Pawar, et al, (8):"Optimization of Cutting Parameters in CNC Milling for Al 6061 Alloy Using Taguchi Method." Explored the optimization of cutting parameters in CNC milling for aluminium alloy, applying the Taguchi method.

S. H. Gawande, et al, (9):"Application of Taguchi Optimization Technique in CNC Milling for Surface Roughness and Material Removal Rate." Investigated the application of the Taguchi method in optimizing surface roughness and material removal rate in CNC milling.

M. M. Hossain, et al.(10):"Optimization of Cutting Parameters in CNC Milling for Surface Roughness Using Taguchi Method." Explored the optimization of cutting parameters in CNC milling with a focus on surface roughness, employing the Taguchi method. Sourabh K.Saha, 2006,"Genetic Algorithm based optimization and post optimality analysis of multi pass face milling", Department of mechanical engineering, IIT Kanpur. Sourabh K.Saha, 2006,"Genetic Algorithm based optimization and post optimality analysis of multi pass face milling", Department of mechanical engineering, IIT Kanpur.

Daniyan et al.(11): studied the optimization of process parameters in face milling using the approach of Taguchi orthogonal array with an aim of energy consumption reduction while the process of machining with enhanced surface finish and improved MRR.

III METHODOLOGY

Research Objective

The objectives of proposed research work are as follows:

- Obtain different parameters of face milling operation using taguchi method.
- To investigate different parameters named below:
  - Cutting tool material
  - Work piece material
  - Feed rate
  - Cutting speed
  - Depth of cut
- Understanding the different materials with various sizes during the process.
- To carry out the comparative study of different parameters used in "Taguchi Method".

Methodology

To achieve the above mentioned objectives the following methodology is adopted

- Exhaustive literature survey on different parameters by using "Taguchi method".
- Raw materials such as different Aluminum alloy.
- Processing of the material using CNC machine (TAGUCHI method)
- Experimental test on standard specimens to determine the parameters of the materials.
- As a result of using greater cutting rates, conditions are formed for processing by material removal under significantly different conditions, according to examination of physical phenomena.

The Taguchi Process

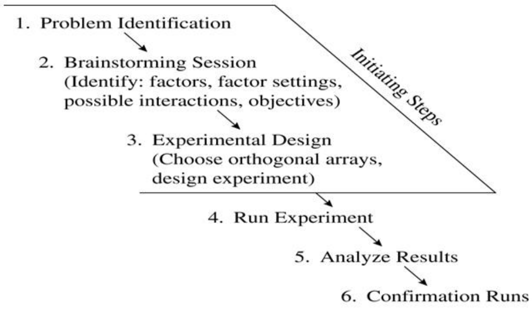

Fig 12: Flow chart

1. Problem Identification Locate the problem source not just the symptom
2. Brainstorming Session: Attended at least by project leader/facilitator and workers involved in the process. Other participants may include managers and technical staff.
3. The purpose is to identify critical variables for the quality of the product or service in question (referred to as factors by Taguchi): **Control factors, Signal factors**
4. Define different factor levels (three or four) and identify possible interaction between factors, Determine experiment objectives: Less-the-better, Nominal-is-best, More-the-better
5. Experimental Design: Using factor levels and objectives determined via brainstorming. Taguchi advocates off-line-experimentation as a contrast to traditional on-line or in-process experimentation
6. Care should be taken to selecting number of trials, trial conditions, how to measure performance etc.
7. Experimentation: Various rigorous analysis approaches like ANOVA and Multiple Regression can be used but also simpler customized methods are available.
8. Analysis: The experimentation provides ”best” levels for all factors, If interactions between factors are evident ⇒ Either ignore or run a full factorial experiment
9. Conforming Experiments: The results should be validated by running experiments with all factors set to ”optimal” levels

IV MATERIAL SELECTION AND CALCULATIONS

MATERIAL SELECTION

The material used for the experiment is an aluminium alloy (Al). In this project we are using 9 slots of aluminium alloy according to taguchi design. The work piece material compositions are as follows.

Material	Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
Al	0.93	0.36	0.1	0.57	0.55	0.134	0.014	97.342

Table 4.1**:** Work piece material composition

CUTTING FORCE CALCULATIONS:

SPEED – 1800rpm

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Feed = 200mm/min, Depth of cut – 0.4mm

Cutting Force

Ne = (Depth X Feed X Cutting Speed X Ks) / (60 X 10^3 X Coefficient of Efficiency)

Ne = 4.65KW

Ks = (Ne X60 X 10^3 X Coefficient of Efficiency)/ (Depth of cut X Feed X Cutting Speed)

Coefficient of Efficiency = 0.8

Ks = (4.65×60 X 10^3 X0.8)/(0.4X200 X1800)

Ks=1150N

Feed = 250mm/min, Depth of cut – 0.5mm

Ks = (4.65×60 X 10^3 X0.8)/(0.5X250 X1800); Ks=992N

Feed = 300mm/min, Depth of cut – 0.6 mm

Ks = (4.65×60 X 10^3 X0.8)/(0.6X300 X1800)

Ks=688N

2. SPEED – 1200rpm

Feed = 200mm/min, Depth of Cut – 0.4mm

Cutting Force

Ne = (Depth X Feed X Cutting Speed X Ks) / (60 X 10^3 X Coefficient of Efficiency)

Ne = 4.65KW

Ks = (Ne X60 X 10^3 X Coefficient of Efficiency)/ (Depth X Feed X Cutting Speed)

Coefficient of Efficiency = 0.8

Ks = (4.65×60 X 10^3 X0.8)/(0.4X200 X1200)

Ks=550N

Feed = 250mm/min, Depth of cut – 0.5mm

Ks = (4.65×60 X 10^3 X0.8)/(0.5X250 X1200); Ks=375N

Feed = 300mm/min, Depth of cut – 0.6mm

Ks = (4.65×60 X 10^3 X0.8)/(0.6X300 X1200)

Ks=270N

3. SPEED – 600rpm

Feed = 200mm/min, Depth of cut – 0.4mm

Ks = (4.65×60 X 10^3 X0.8)/(0.4X200X600)

Ks=465.2N

Feed = 250mm/min, Depth of cut – 0.5mm

Ks = (4.65×60 X 10^3 X0.8)/(0.5X250 X600)

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Ks=297.6N

Feed = 200mm/min, Depth of cut – 0.6mm

Ks = $(4.65\times60 \ X \ 10^3 \ X0.8)/(0.6X200 \ X600)$

V.EXPERIMENTAL INVESTIGATION

The experiments are done on the CNC milling machine with the following parameters:

CUTTING TOOL MATERIAL	Cemented Carbide Tool
WORK PIECE MATERIAL	Aluminum alloy
FEED	200mm/min, 300mm/min, 400mm/min
CUTTING SPEED	2000rpm, 3000rpm, 3500rpm
DEPTH OF CUT	0.2mm, 0.3mm, 0.4mm

Table 5.1: Parameters

Instruments for the experimentation:

FIG 13: CNC milling machine

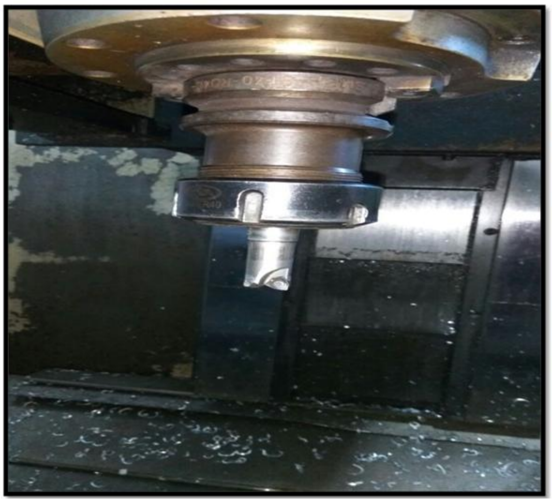


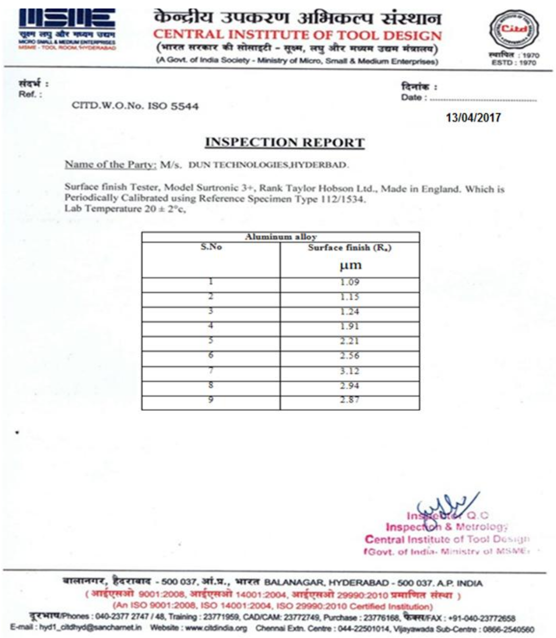
FIG14: Milling cutter

SURFACE FINISH VALUES:

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Surface finish (R_a) µm
1	2000	200	0.2	1.09
2	2000	300	0.3	1.15
3	2000	400	0.4	1.24
4	3000	200	0.2	1.91
5	3000	300	0.3	2.21
6	3000	400	0.4	2.56
7	3500	200	0.2	3.12
8	3500	300	0.3	2.94
9	3500	400	0.4	2.87

Table 5.3: Test report (Surface finish values)

Test Report



केन्द्रीय उपकरण अभिकल्प संस्थान
CENTRAL INSTITUTE OF TOOL DESIGN
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(A Govt. of India Society - Ministry of Micro, Small & Medium Enterprises)

स्थापित : 1970
ESTD : 1970

संदर्भ :
Ref. : CITD.W.O.No. ISO 5544

दिनांक :
Date : 13/04/2017

INSPECTION REPORT

Name of the Party: M/s. DUN TECHNOLOGIES,HYDERBAD.

Surface finish Tester, Model Surtronic 3+, Rank Taylor Hobson Ltd., Made in England. Which is Periodically Calibrated using Reference Specimen Type 112/1534.
Lab Temperature 20 ± 2°c,

Aluminum alloy	
S.No	Surface finish (R_a) µm
1	1.09
2	1.15
3	1.24
4	1.91
5	2.21
6	2.56
7	3.12
8	2.94
9	2.87

Inspector Q.C
Inspection & Metrology
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VI RESULT AND DISCUSSION

Using randomization technique, specimen was turned and cutting forces were measured with the three – dimensional dynamometer. The experimental data for the cutting forces have been reported in Tables. Feed and radial forces being 'lower the better' type of machining quality

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characteristics, the S/N ratio for this type of response was and is given below:

$$\text{S/N ratio} = -10 \log\left[\frac{1}{n}(y_1^2 + y_2^2 + ... + y_n^2)\right] \qquad ...(1)$$

Where $y_1, y_2, \ldots, y_n$ are the responses of the machining characteristics for each parameter at different levels.

TAGCHI ORTHOGONAL ARRAY:

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)
1	2000	200	0.2
2	2000	300	0.3
3	2000	400	0.4
4	3000	200	0.2
5	3000	300	0.3
6	3000	400	0.4
7	3500	200	0.2
8	3500	300	0.3
9	3500	400	0.4

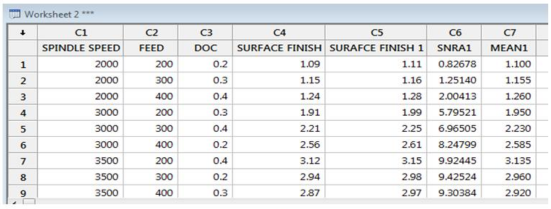
Table 6.1: Spindle speed, feed rate depth of cut

Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The cutting force is considered as the quality characteristic with the concept of "the larger-the-better". The S/N ratio for the larger-the-better is:

$S/N = -10 * \log (\Sigma (Y^2)/n))$

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration above Eqn. with the help of software Minitab 17.

The force values measured from the experiments and their corresponding S/N ratio values are listed in Table


Worksheet 2 ***

↓	C1	C2	C3	C4	C5	C6	C7
	SPINDLE SPEED	FEED	DOC	SURFACE FINISH	SURAFCE FINISH 1	SNRA1	MEAN1
1	2000	200	0.2	1.09	1.11	0.82678	1.100
2	2000	300	0.3	1.15	1.16	1.25140	1.155
3	2000	400	0.4	1.24	1.28	2.00413	1.260
4	3000	200	0.3	1.91	1.99	5.79521	1.950
5	3000	300	0.4	2.21	2.25	6.96505	2.230
6	3000	400	0.2	2.56	2.61	8.24799	2.585
7	3500	200	0.4	3.12	3.15	9.92445	3.135
8	3500	300	0.2	2.94	2.98	9.42524	2.960
9	3500	400	0.3	2.87	2.97	9.30384	2.920

FIG 19: Worksheet 2

Analysis and Discussion:

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Spindle Speed: -The effect of parameters spindle speed on the surface finish is shown above figure for S/N ratio. So the optimum spindle speed is 3500 rpm.

Feed Rate: - The effect of parameters feed rate on the surface finish is shown above figure S/N ratio. So the optimum feed rate 200 mm/min.

Depth of Cut:- The effect of parameters depth of cut on the surface finish is shown above figure for S/N ratio. So the optimum depth of cut is 0.4mm.

Design of Orthogonal Array:

First Taguchi Orthogonal Array is designed in Minitab17 to calculate S/N ratio and Means which steps is given below:

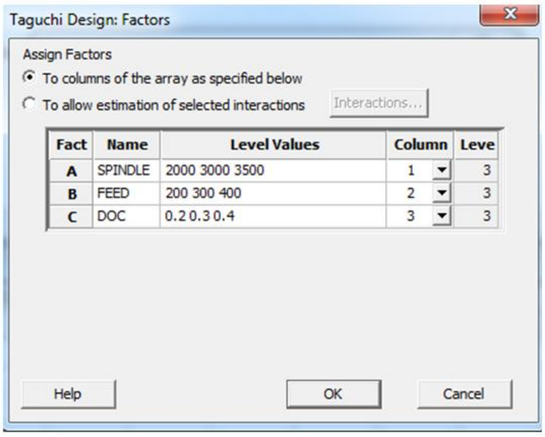
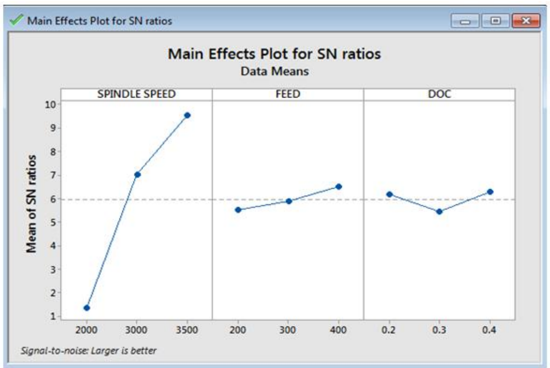
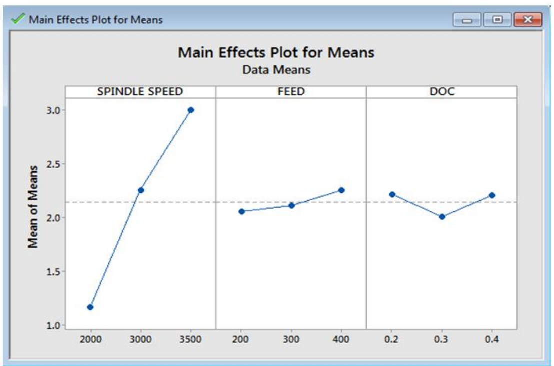


FIG 20: Factors



GRAPH 1: S/N ratio plot



GRAPH 2: Means plot

The following are the observations made by running the experiments. The cutting forces are measured using dynamometer.

CUTTING FORCES, SURFACE FINISH AND MATERIAL REMOVAL RATE

Surface finish (R_a) µm
1.09
1.15
1.24
1.91
2.21
2.56
3.12
2.94
2.87

Table 6.2: Surface Finish (R_a) µm

VII CONCLUSION

In this thesis an attempt to make use of Taguchi optimization technique to optimize cutting parameters during high

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speed milling of aluminium alloy using cemented carbide cutting tool.

The cutting parameters are cutting speed, feed rate and depth of cut for milling of work piece aluminium alloy. In this work, the optimal parameters of cutting speed are 2000rpm, 3000rpm and 3500rpm, feed rate are 200mm/min, 300mm/min and 400mm/min and depth of cut are 0.2mm, 0.3mm and 0.4mm. Experimental work is conducted by considering the above parameters. Cutting forces, surface finish and cutting temperatures are validated experimentally.

By observing the experimental results and by taguchi, the following conclusions can be made:

To get better surface finish, the optimal parameters are spindle speed – 3500rpm, feed rate – 200mm/min and depth of cut – 0.4mm.

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