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An Experimental Investigation of Machining Parameters on Surface Roughness in End Milling: A Case Product Problem

Balwant Singh[1], Ravinder Kumar[2], Raman Kumar[3]
[1]*Research scholar, LCET, Punjab (India)*
[2]*Assistant Professor, Department of Mechanical Engineering, LCET, Punjab (India)*
[3]*Assistant Professor, Department of Mechanical Engineering, Chandigarh University, Gharuan, Punjab (India)*

ABSTRACT: *Milling operation is one of the most important operations in manufacturing industry. The milling has a wide variety of different operations from small individual parts to large heavy duty parts. Milling is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes. In this research work a experimental work will be perform to optimize the process parameters of milling operation. The milling operation will be done on specimen with different process input parameters in order to improve the Surface finish of case product. Literature review revealed that researched were successfully implemented different techniques like Taguchi method, ANNOVA, RSM, grey relation analysis. The optimization technique will be applied to optimize the process parameters of case problem. A logical way to deal with arrangement the investigations is a need for effective behavior of trials. By the statistical of experiments the procedure of arranging the examination is completed, so that suitable information will be gathered and analyzed by measurable strategies bringing about substantial and target conclusions.*

I. INTRODUCTION

In metal machining processes many operations are used for machining from which Milling Operation is widely used for machining. At least one stage of every designed part must be machined by milling machine before its fabrication. The qualities of the designed milled parts are identified with the study of surface finishing of milled surface. The milled surface quality is basically dependent upon the tool geometry and cutting conditions.The MRR (material removal rate) and surface finish factors are basically dependent upon spindle speed, feed rate and depth of cut. To obtain the maximum value of MRR and minimum value of surface roughness proper selection of cutting parameters can be done

1.1 Surface Roughness

Surface roughness often shortened to roughness, is a component of surface texture. The smooth surface wears less and have low friction coefficient as compare to high rough surface. While during machining it is extremely hard to control the surface roughness in light of the fact that it is basically dependent upon the type of machining process done on the case product. According to criteria of designed product like (functionality, costs etc) the quality of surface must be defined in designed phase of product development. Many optimization techniques and scientific research projects were deal for obtaining the best level of surface quality and to accomplish the minimum value of surface roughness the proper selection of cutting parameters can be done which also helps to increase the tool life and MRR. With the help of various artificial intelligence and statistical models, surface roughness and MRR have been predicted. Poor surface finish have high peaks of micro irregularities which will lead to rupture of oil films on the peaks due to which finishing process can be done to obtain micro surface finish. The various parameters that affect surface roughness are shown in figure 1.1

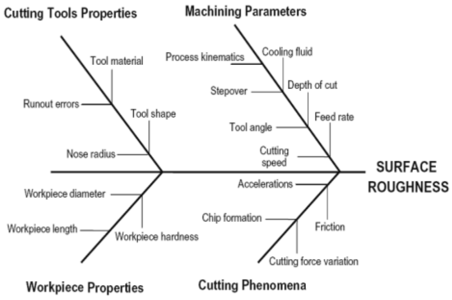


Figure 1.1: Parameter that affects surface roughness

1.1.1 Surface Texture: The surface which deviates from a nominal surface is called Surface Texture. The randomness or repetitiveness of various deviations from a nominal surface gives the values of roughness, waviness, lay and flaws.

1.1.2Real Surface: The peripheral skin of an object which separates it from the surroundings called real surface. The real surface has no structural deviations such as errors, waviness, and surface roughness in the surface texture.

1.1.3Roughness: The continuous and finer irregularities on surface texture called Roughness. The inherent action in production process effects the irregularities on surface texture. The roughness and waviness profiles are shown in Figure 1.2.

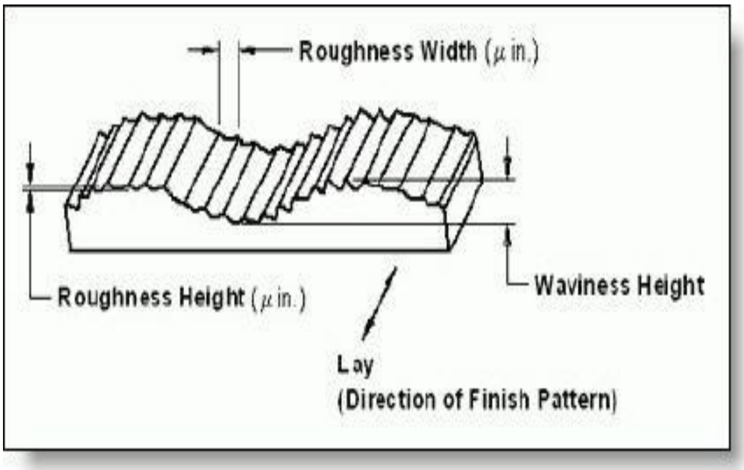


Figure 1.2: Roughness and Waviness Profile.

1.1.4Roughness Width: The parallel distance between the two successive peaks or ridges of the nominal surface called Roughness width. It constitute the dominating example of roughness.

1.1.5Roughness Width Cutoff: Roughness Width cutoff serves to discover the higher spacing surface irregularities that it is incorporated in the estimation of average roughness value. It is evaluated in a great many an inch. Standard tables list roughness width cutoff estimations of 0.003, 0.10, 0.030, 0.100, 0.300 and 1.000 inches. In the event that no value is determined, a rating of 0.030" is accepted.

1.1.6Waviness: Waviness ought to incorporate widely spaced in surface texture. It comprise of all irregularities in surface texture from more noteworthy than the roughness examining length and not exactly the waviness sampling length.

1.1.7Waviness Height: Waviness height is the maximum height or peak-to-valley distance from the nominal surface which is appraised in inches.

1.1.8Waviness Width: Waviness width is the distance or space between the two progressive wave crests or progressive wave valleys which is evaluated in inches.

1.1.9Lay: Lay is basically dependent upon the production method. It is direction of predominant finishing surface pattern.

1.1.10Flaws: Flaws are blemish, accidental, mark, sudden, and other imperfections in the mars of ordinary part surface.

1.1.11Roughness Sampling Length: It determines the average of surface roughness. The designated profile irregularities are separated with help of Roughness Sampling Length.

1.2 Surface Finish Parameters

1.2.1Roughness Average (Ra): Roughness Average (Ra) is otherwise called CLA (center line average), arithmetic mean roughness value. Ra is mostly used as a global parameter of roughness and also it is universally recognized. Subsequently,

$R_a = 1/L\times|yx|dx$ 1.1

Where; Ra= arithmetic normal deviation from mean line

L= sampling length

Y= ordinate of the profile curve

It is the mean of the takeoff of the roughness profile from the mean line.

1.2.2Root-Mean-Square (rms) roughness (Rq): Root-mean-square roughness parameter relating to Ra:

$Rq=(-1/L \times Y \times x)^2 dx$ 1.2

1.2.3Maximum Peak-To-Valley Roughness Height (Ry or Rmax): Maximum Peak-To-Valley Roughness Height is the separation between the two parallel lines and mean line between the upper and lower points at surface roughness profile.

This is the detachment between two lines parallel to the mean line that contacts the persuading upper and lower points on the profile inside of the roughness inspecting length. The mostly parameters used in industry are Ra and Rq. In this study Ra was selected to express surface roughness.

1.3 Surface Roughness Measurement

1.3.1 Stylus Profilers for Measuring Surface Finish: Stylus profilers are used for measuring the surface finishing with physically touching the surface are also called contact profilers. Stylus profilers have diamond tip on its balanced arm which is dragged upon the surface to encounters the peaks and valleys. The diamond tip is raised up and down on an uneven surface otherwise it forms a straight line as shown in figure 1.3

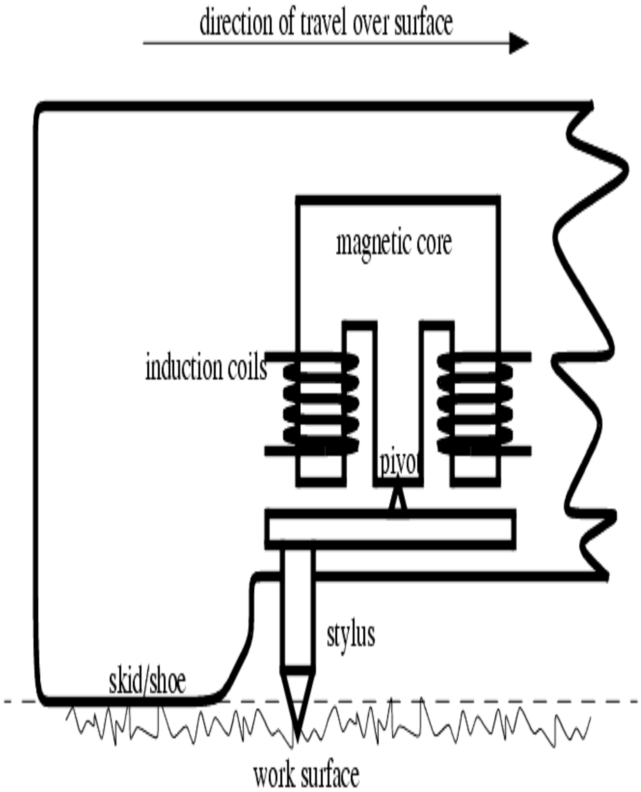


Figure 1.3 Stylus Profilers for Measuring Surface Finish.

1.3.2 Measuring Surface Finish with Non-contact Profilers

In non-contact method, to get same information an optical profilometer was used rather than stylus based profilometer as shown in figure 1.4.

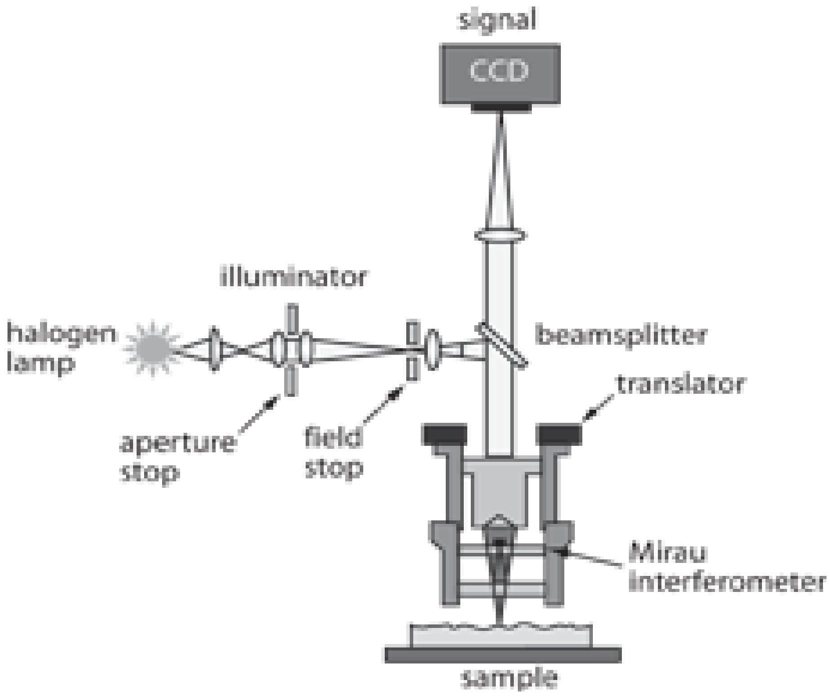


Figure 1.4 Non contact profiler

1.3.3Specifications on Drawings

To specify the surface texture of any part some of the following specifications can be used on drawing are:
Waviness width - the distance between two peaks or valleys.
Roughness width cutoff–the best spacing of redundant surface irregularities in light of the fact that it is incorporated in the estimation of normal roughness height.Typical values are (0.0762mm, 0.254mm, 0.762mm, 2.54mm, 7.62mm)
Waviness height - the separation from a peak to a valley
Lay– the direction of predominant finishing surface pattern.
Some of the following examples shows the specifications used in drawings to define the surface texture. The drawing specifications are shown in figure 1.5 and 1.6.

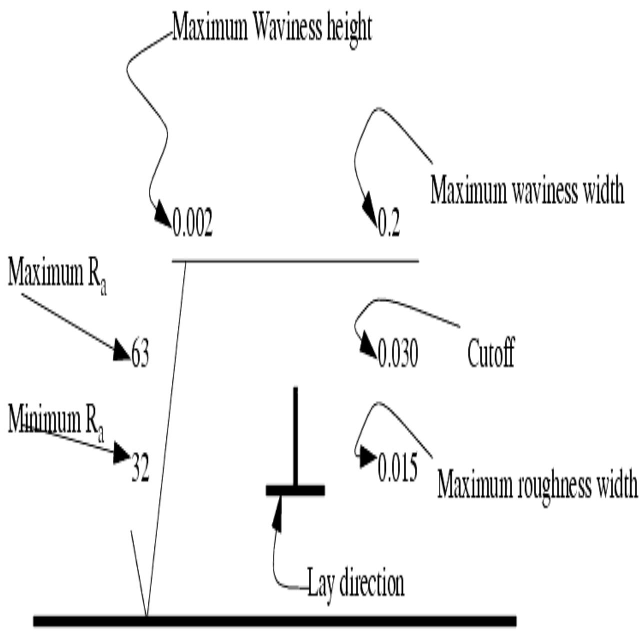


Figure 1.5 waviness height and width

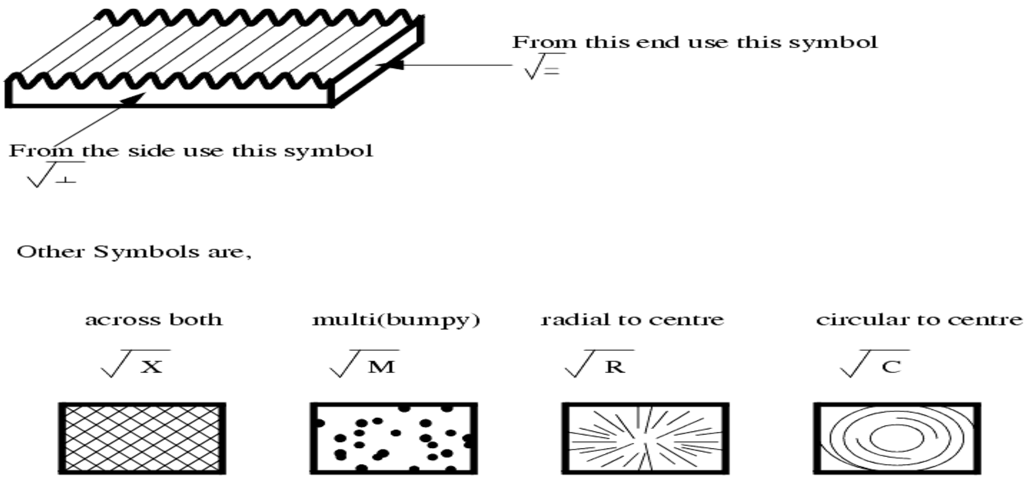


Figure 1.6 Symbols specify how the roughness is to lay

II. METHODOLOGY

In this research work a experimental work will be perform to optimize the process parameters of milling operation. The milling operation will be done on specimen with different process input parameters in order to improve the MRR, Surface finish and Impact strength of case product. Literature review revealed that researched were successfully implemented different techniques like Taguchi method, ANNOVA, RSM, grey relation analysis. The optimization technique will be applied to optimize the process parameters of case problem. A logical way to deal with arrangement the investigations is a need for effective behavior of trials. By the statistical of experiments the procedure of arranging the examination is completed, so that suitable information will be gathered and analyzed by measurable strategies bringing about substantial and target conclusions. The upsides of design of experiments are as per the following:

- Quantities of trials is fundamentally decreased.
- Critical choice variables which control and enhance the execution of the product or the procedure can be recognized.
- Ideal setting of the parameters can be figured out.
- Subjective estimation of parameters can be made.
- Trial error can be evaluated.

2.1 Taguchi Experimental Design and Analysis

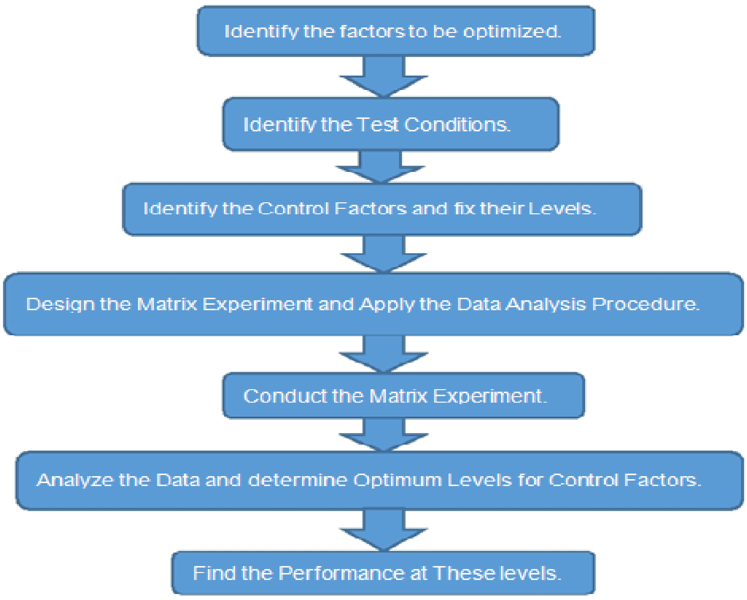


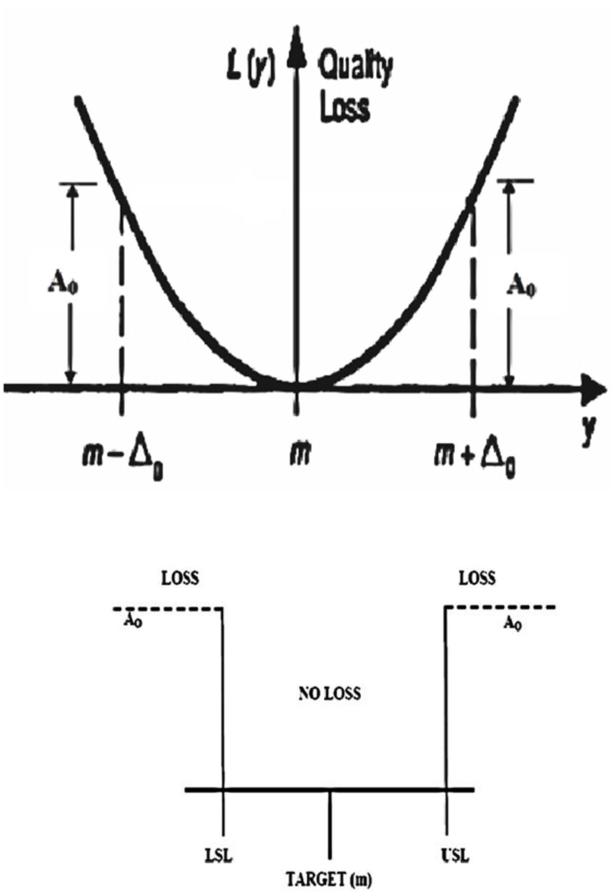
Figure2.1 Flow chart for Taguchi method

2.2 Experimental Design Strategy
In the Taguchi technique the consequences of the investigations are analyze to accomplish one or a greater amount of the accompanying targets:
- To build up the best or the ideal condition for a product or procedure.
- To estimate the commitment of individual parameters and connections.
- To estimate the reaction under the ideal condition.

2.3 Loss Function
Loss is measured regarding financial units and is identified with quantifiable product trademark. By and large, there are three sorts of loss functions :
- Higher is Better
- Nominal is Best
- Lower is Better

Loss = K [S_2 + (y - n) 2] 2.1
Where,
L = loss in money related units
n = value at which the trademark ought to be set
y = genuine estimation of the trademark
K = constant depending upon the size of the characteristic and the monetary unit involved

The loss of function represented in Eq. 3.1 graphically it is shown in Figure 2.2.a. The attributes of the loss function are as follows:
- The more remote the product′s characteristics changes from the objective esteem, the more prominent is the loss. The loss must be zero when the quality characteristics for a product meet its objective value.
- The loss is a ceaseless function and not a sudden step as on account of traditional (objective post) methodology (Figure 2.2b). This result of the ceaseless loss function shows the point that only making a product within the defined limits does not so much imply that product is of good quality.



(a) Taguchi loss function (b)Traditional (Gaol post) approach
Figure 2.2 (a,b) The Taguchi Loss Function and the Traditional Approach

2.4 Average Loss Function For Product Population

In a large scale manufacturing process.the normal loss per unit is expressed as:

$$L(y) = 1\,\frac{1}{n}\,\{K\,(y_1 - m)\,2 + K\,(y_2 - m)\,2 + \ldots + K\,(y_n - m)\,2\} \qquad 2.2$$

Where

$y_1, y_2 \ldots y_n$ = Actual estimated value of the characteristic for unit 1, 2…n respectively
n = Number of units in a given specimen
k = Constant depending on the magnitude of the characteristic and the money related unit included
m = Target value at which the characteristics ought to be set
The Eq. 2.2 can be simplified as:

$$L(y) = K\,(MSDNB) \qquad 2.3$$

Where,
MSDNB = Mean squared deviation or the average of squares of all deviations from the target or nominal value
NB = "Nominal is Best"

2.5Other loss functions

The loss function can likewise be connected to product qualities other than the circumstance where the nominal worth is the best esteem (m). The function of loss for a "smaller is better" kind of product characteristics (LB) is indicated in Figure 2.3.a. The loss-function is indistinguishable to the "nominal is-best" kind of circumstance when m=0, which is the best esteem for "smaller is better" characteristic (no negative quality). The loss-function for a bigger is-better kind of product characteritics (HB) is additionally demonstrated in Figure 2.3.b, where likewise m=0.

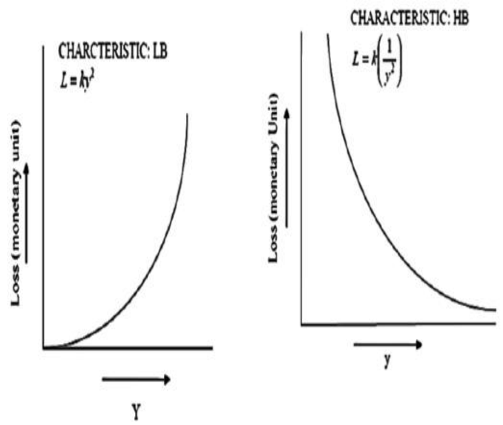


Figure 2.3 (a,b) The Taguchi Loss Function for LB and HB Characteristics

2.6 Process Variables And Their Levels

Table 2.1 demonstrates the different estimations of speed, feed rate and depth of cut.

Table 2.1 Maximum and Minimum Values Of Parameters

Limiting values	Spindle speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)
Maximum value	95	31	3
Minimum value	40	13	1

In the present experimental work, spindle speed, feed rate, depth of cut has been considered as process variables. The procedure with their units (and documentations) are recorded in table 2.2

Table 2.2 Variable Factor Levels

Controllable factor	Units	Level 1	Level 2	Level 3
A. Spindle speed	Rpm	40	70	95
B. Feed rate	mm/min	13	20	31

2.6.1 Experiment design

Experiment has been done utilizing Taguchi method experiment design which comprises of 9 combinations of spindle speed, longitudinal feed rate and depth of cut. It comprises three process parameters to be differed in three discrete levels. The experimental design has been demonstrated in Table 2.3

Table 2.3 L9 Standard Orthogonal Array

Experiment no.	A Spindle speed (rpm)	B Feed rate (mm/min)	C Depth of cut (mm)
1	A1	B1	C1
2	A1	B2	C2
3	A1	B3	C3
4	A2	B1	C2
5	A2	B2	C3
6	A2	B3	C1
7	A3	B1	C3
8	A3	B2	C1
9	A3	B3	C2

Table2.4 Orthogonal Array (L9)

Experiment no.	A Spindle speed (rpm)	B Feed rate (mm/min)	C Depth of cut (mm)
1	40	13	1
2	40	20	2
3	40	31	3
4	70	13	2
5	70	20	3
6	70	31	1
7	95	13	3
8	95	20	1
9	95	31	2

2.7 Experimental Setup

The analysis were led according to the procedure specified above at CTR, Ludhiana and Prem Engineering Works, Ludhiana. The points of experimentation are given beneath:

2.7.1 Machine tool used

VERTICAL MILLING MACHINE

For present work, the Vertical milling machine demonstrated in Figure 2.4 is utilized. Its features are

1 Integrated special composite cast iron bed with basic solidified and ground guide ways.

2 It have high power high speed spindle with faster travel of bed axially.

Figure 2.4 Vertical Milling Machine At Prem Engineers Works, Ludhiana

Table 2.5 Specification of Milling machine

	Technical Specifications of VerticalMilling Machine	**9" x 40"** **220 x 975 mm**
1	Table size of Vertical Drive Milling Machine	220 x 975
2	Longitudinal Travel Manual	535mm
3	Vertical Travel	345mm
4	Cross Travel	245
5	Table to Spindle	0 Min.
6	Power Feed	520mm/Min
7	Head Tilt 45º Up & Down	...do..
8	Head move 90º Left & Right Horizontal	...do..
9	Quill spindle diameter	86mm Hardened & Grinded
10	Head & Ram Rotate Parallel on body	360º
11	Ram Travel	250
12	T-Slot	3 - 12 mm
13	Motor	1 H.P.
14	No. of Speeds	8 Min 75 RPM Max 3000 RPM
15	Max. Weight of Work Piece	250Kg.
16	Net Weight of machine	950Kg.
17	Overall Height, Width & Length	1800x1200x1300

2.7.2 Cutting Inserts

The high quality high speed steel tool is used as named below:
End Mill Cutter as shown in figure 3.5.
Tool make-putto
Tool material- High Speed Steel(HSS)M2

Figure 2.5 End mill cutter

2.7.3 Workpiece Used

In present experimental work EN24 is used as a workpiece material. The dimensions of EN24 material gear blank specimens are such as outer diameter=45 mm, thickness=15mm, and inner diameter=12mm as shown in figure 2.6.

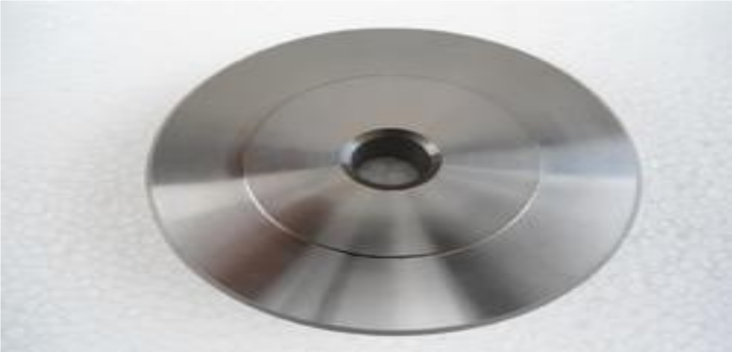


Figure 2.6 Workpiece

Table 2.6 Composition Of EN24

Element	C	Mg	Si	S	P	Cr	Ni	Mo
Wt.%	.35-.45	.45-.70	.10-.35	.040	.040	.90-1.40	1.30-1.80	.20-.40

2.7.4 Roughness Measurement

The roughness measurement has been done utilizing a versatile stylus type profilometer, Tr110 indicated in figure 3.7 TR110 is a defensive slid to cover the pick-up sensor while not being used.

Figure 2.7 Portable Surface Roughness Tester - TR110

III. RESULT

3.1 Result Of Experiment

The cutter profile and environment condition are kept steady or constant according to literature review.] Test are led by configuration demonstrated in table 3.1 and the outcomes for Ra worth are exhibited in table 3.2

Table 3.1 Experiment values

Experiment no.	A Spindle speed (rpm)	B Feed rate (mm/min)	C Depth of cut (mm)
1	40	13	1
2	40	20	2
3	40	31	3
4	70	13	2
5	70	20	3
6	70	31	1
7	95	13	3
8	95	20	1
9	95	31	2

Table 3.2 Details of measurement of R_a (µm)

S. No.	RUN1(µm)	RUN2(µm)	RUN3(µm)	R_a(µm)	SNRA	MEAN
1	1.22	1.24	1.25	1.24	-1.86843	1.24
2	1.13	1.16	1.15	1.15	-1.21396	1.15
3	1.4	1.49	1.48	1.46	-3.28706	1.46
4	1.38	1.42	1.41	1.40	-2.92256	1.4
5	1.49	1.54	1.53	1.52	-3.63687	1.52
6	1.19	1.23	1.20	1.21	-1.65571	1.21
7	1.52	1.58	1.57	1.56	-3.86249	1.56
8	1.25	1.31	1.24	1.27	-2.07607	1.27
9	1.40	1.44	1.39	1.41	-2.98438	1.41

Table 3.3 Results of Experiments for average surface roughness R_a

Experiment no.	A Spindle speed (rpm)	B Feed rate (mm/min)	C Depth of cut (mm)	Surface roughness R_a (µm)
1	40	13	1	1.24
2	40	20	2	1.15
3	40	31	3	1.46
4	70	13	2	1.40
5	70	20	3	1.52
6	70	31	1	1.21
7	95	13	3	1.56
8	95	20	1	1.27
9	95	31	2	1.41

Table3.3 shows consequences of surface roughness with the three parameters taken for the test as discussed about in table 3.1.

IV. CONCLUSION

In this study, the surface roughness of EN24 bevel gear were displayed and investigated through taguchi method. Spindle speed, feed rate and depth of cut have been utilized to complete the exploratory study. Summarizing the elements, the accompanying conclusion can be drawn.

1. Dissected with ANOVA the investigation result demonstrated that depth of cut contributed 66.4% whereas spindle speed and feed rate contributed 15% and 1.4% respectively for Ra (surface roughness).
2. The trial result with ANOVA examination demonstrated that the depth of cut contributes more than by other parameters feed rate and spindle speed individually for Ra (surface roughness).

5. Scope For Future Work

In this present examination work just three parameters have been concentrated on as per their belongings. Perspective of future extension, the further research can be done as:

1. To study the tool geometry effect on surface roughness.
2. To breaks down the effect of wear rate of tool and forces acting during cutting operation.
3. To study the various factors like consumption of power, life of tool, etc. can be examined.
4. To study the effect of controlling parameters like cutter diameter, helix angle etc. on surface roughness.
5. To study effect of different cutting tools on response variables.
6. To compare the different performance characteristics on bevel gear sample after heat treatment.
7. To compare the different performance characteristics on different composition of EN24.

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