# EXPERIMENTAL INVESTIGATION ON CUTTING FORCES IN FACE MILLING OF EN-31 STEEL BY USING TAGUCHI MECHOD

[1]Mr. MD ANWAR BASHA, [2]Mr. Tota Giri Kesava
[1] M.Tech (Advanced Manufacturing Systems), [2] M.Tech, M.I.E, M.I.S.T.E
[1,2] Mechanical Engineering Department,
[1,2] SKD Engineering College, Gooty, India.

***Abstract :***

**EN31** is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance. EN-31 steel is widely used in automotive industry for producing automotive components such as roller bearing, ball bearing, spline shaft, shearing blades, die parts etc. Therefore this steel is chosen for experimental investigation.

The important goal in the modern industries is to manufacture the products with lower cost and with high quality in short span of time. There are two main practical problems that engineers face in a manufacturing process. The first is to determine the values of process parameters that will yield the desired product quality (meet technical specifications) and the second is to maximize manufacturing system performance using the available resources. Taguchi method is a powerful tool to design optimization for quality, is used to find the optimal cutting parameters for milling operations. An orthogonal array signal-to –noise (S/N) ratio, and analysis of variance (ANOVA) are employed to investigate the cutting characteristics of EN 31 steel using tungsten carbide cutting tools. Through this study, not only can the optimal cutting parameters for face milling operation be obtained, but also main cutting parameters that affect the cutting performance in running operations can be found.

This study presented the prediction of tool life, volume of material removed and cutting forces in face milling of EN-31 steel by using the taguchi method and found that the predicted values increased when compare to the values getting in experiment. The results lead to conclusions that for optimum tool life and volume of material removed 450 approach angle is better and for optimum cutting forces 550 approach angle is good. Feed rate affecting all the output values more and minimum feed is better for getting good result

***Keywords*- CUTTING FORCES, FACE MILLING, EN-31 STEEL, TAGUCHI METHOD.**

## I. INTRODUCTION:

The primary aim of an analysis of the mechanics of metal cutting is to understand the basic phenomenon of chip formation, forces, temperature distribution and tool wear so as to predict the performance of cutting tools. In view of the various machining process which are seemingly so very different from each other it is necessary to develop a representive model for metal cutting which will lend it to ease of chip formation.

The important goal in the modern industries is to manufacture the products with lower cost and with high quality in short span of time. There are two main practical problems that engineers face in a manufacturing process. The first is to determine the values of process parameters that will yield the desired product quality (meet technical specifications) and the second is to maximize manufacturing system performance using the available resources.

Machining is the process of removing the unwanted material from the work piece in the form of chips. If the work piece is a metal, the process is often called as metal cutting process or chip forming processes. Metal cutting is a machining process by which a work piece is given

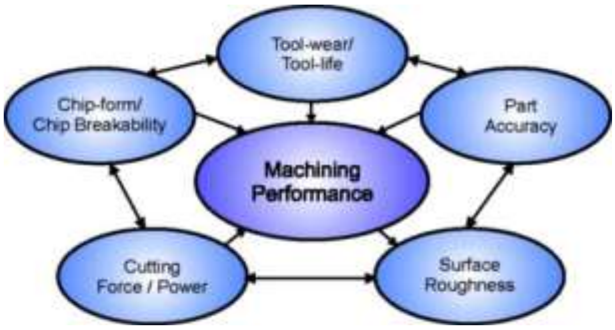
1. A desired shape
2. A desired size
3. A desired surface finish

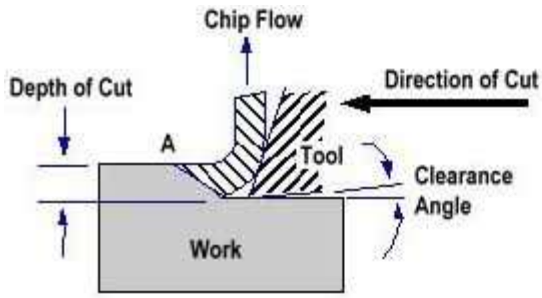
To achieve one or all of these, the excess (undesired) material is removed (from the work piece) in the form of chips with the help of some properly shaped and sized tools. Metal cutting processes are performed on metal cutting machines, more commonly termed as Machine Tools by means of various types of cutting tools.

A machine tool is a power driven metal cutting machine which changes the size and shape of the work piece material. A cutting tool is a body having teeth or cutting edges on it. A single point cutting tool (such as a lathe tools) has only one cutting tool (such as a milling cutter) has a number of teeth or cutting edges on it periphery.

In metal cutting (machining) process, working motion is imparted to the work piece and cutting tool by the mechanisms of machine tool so that the work and tool travel relative to each other and cut the work piece material in the form of chips. The work-piece can be effectively shaped by using various other manufacturing processes. Among them metal cutting plays an important role, being one of the most versatile processes in manufacturing. Its versatility can be attributed to so many factors, of some which are:

1. Machine tools do not require elaborate tooling.
2. The process of machining can employed to all engineering materials
3. The wear of tool is not costly, if it is kept with in limits.
4. A large number of parameters which come into play during machining can be suitably controlled in order to overcome technological and economical difficulties.




## II. LITERATURE SURVEY:

A S EREFAYKUTA et.al(journal of materials and design 2007) did research on cobalt base super alloys which are used extensively in applications requiring good wear, corrosion and heat resistance. The main goal of this study is to examine the effect of machining conditions (cutting speed, feed rate and depth of cut) on tool wear, chip morphology andcutting forces in symmetric face milling of cobalt base super alloy with physical vapour deposition coated and uncoated inserts. Withthe aim of achieving to achieve this goal, 90 milling experiments were carried out with different cutting speeds, feed rate and depth ofcut under dry cutting conditions. The settings of machining parameters were determined by using general full factorial design method.Chip morphology, cutting forces and tool wear were compared by using PVD coated and uncoated hard metal inserts which are obtaineddependent on feed rate, cutting speed and cutting depth. The cutting forces increase as the feed rate and depth of the cut increases, butcutting speeds' effect on cutting forces has not been observed for symmetric face milling. The chip shapes obtained from the experiments with different cutting conditions are compared for coated and uncoated cutting tools. The chip shapes obtained from the experiments with different cutting conditions are compared for coated and uncoated cutting tools.

W.H. Yang et.al (Journal of Materials Processing Technology 1998)done study on the Taguchi method, a powerful tool to design optimization for quality, is used to find the optimal cutting parameters for turning operations. An orthogonal array, the signal-to-noise (S:N) ratio, and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of S45C steel bars using tungsten carbide cutting tools. Through this study, not only can the optimal cutting parameters for turning operations be obtained, but also the main cutting parameters that affect the cutting performance in turning operations can be found. Experimental results are provided to confirm the effectiveness of this approach. The confirmation experiments were conducted to verify the optimal cutting parameters. The improvement of tool life and surface roughness from the initial cutting parameters to the optimal cutting parameters is about 250%.

A. JAWAID et.al (Journal of Materials Processing Technology 2000), did the research on the performance and the wear mechanisms of coated carbide tools have been investigated when face milling titanium alloy,Ti±6Al±4V. The two tools used were PVD±TiN and CVD±TiCN.Al2O3 coated. Tool life, tool failure modes and wear mechanisms were examined for various cutting conditions. Both tools experienced long tool life at the low cutting speed of 55 m/min and feed of 0.1 mm pertooth. When considering the volume of material removed and tool lives, the CVD coated tools gave a better performance than the PVDcoated tools. Excessive chipping at the cutting edge and chipping and/or flaking on the rake face were the dominant failure modes under most cutting conditions. Analysis carried out with the SEM suggests that coating delamination, adhesion of work material.Attrition and diffusion wear mechanisms were responsible for the flank and rake face wear of both of the coated tools. Evidence of the diffusion of cobalt and tungsten into the adhered workpiece was found at the flank and rake faces of the tools and The thermal cracks observed were thought to be responsible for the severe chipping and/or flaking of the inserts at both the rake and flank faces

## III. EXPERIMENTAL DETAILS:

### PROCEDURAL STEPS:

1. Design of three cartridges of different approach angles.
2. Design the experiments with different parameters.
3. Conduct the experiments as per design.
4. Measure the cutting forces (kistler dynamometer).
5. Measure the tool wear (Toolmaker microscope).

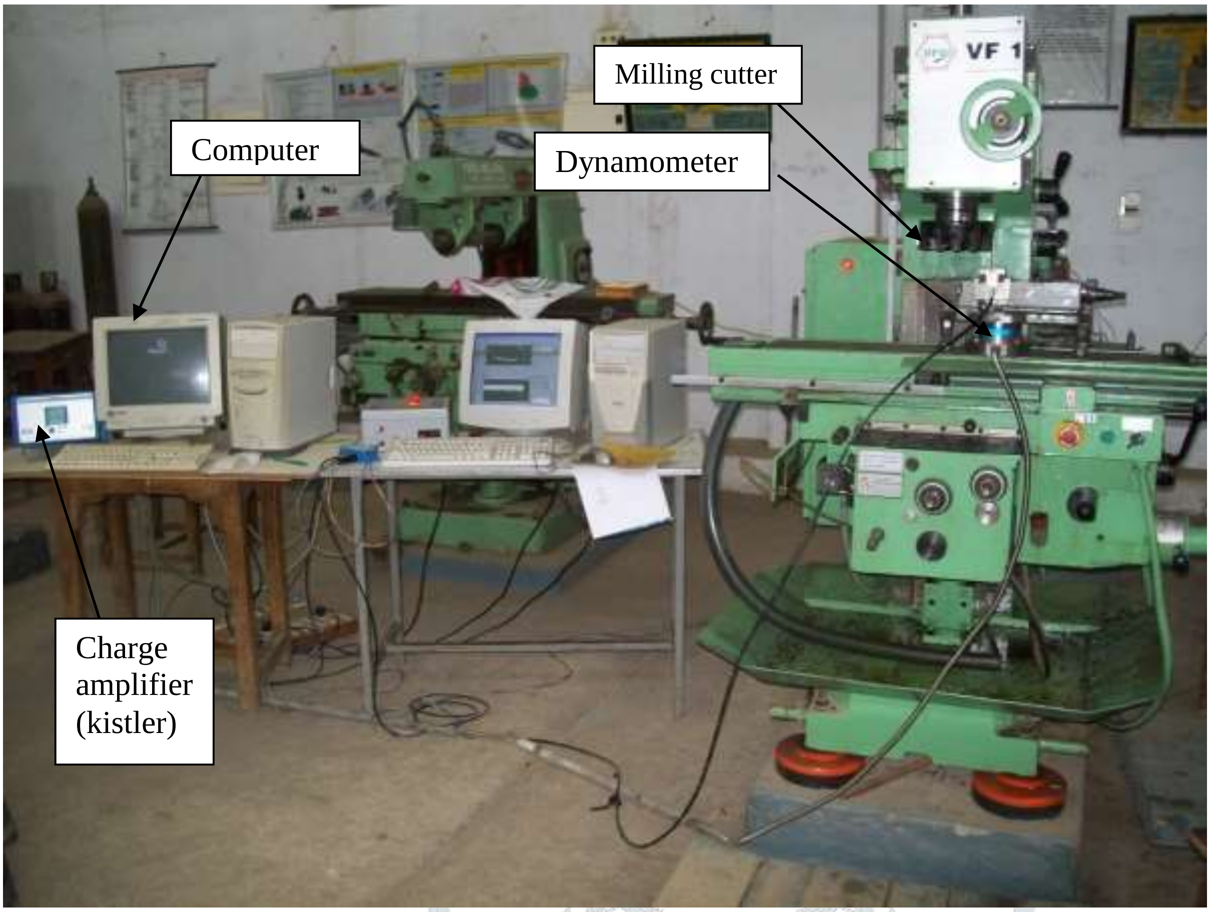



**Figure: EXPERIMENTAL SET UP**

## DESIGN OF CARTRIDGES:

Three cartridges have been designed for M400 milling cutter for different approach angles and single tip seat design. The design of all cartridges is based on past drawings and design standards of Kennametal. The axial rake angle – 60 and radial rake angle – 80 are used

for design. These two angles are provided on the tip seat of the cartridge. The design is carried for all the cartridges by maintaining the same axial and radial rake angle and only the approach angle is varied. These two rake angle should same for all cartridges because these angles will influence the cutting forces the important dimensions, such as overall length of cartridge after fixing in the insert (47 mm), thickness of cartridge (which is measured from base to the highest point of insert-15.88mm), counter bore dimension, thickness (15 mm) and width (20mm) of cartridges are kept constant for all cartridges.

All the geometrical tolerances and surface finish value are specified and the drawings are released for manufacturing.42CrMo4 material is used for manufacturing cartridges. Hardness of material is around 40 to 44 HRC.


**Figure CARTRIDGES**

### CUTTING FORCE AND TOOL WEAR MEASUREMENT:

| | | |
|---|---|---|
| Machine tool | - | Vertical Milling Machine |
| Work material | - | EN 31 |
| Tool material | - | Tungsten Carbide |
| Insert designation | - | SPMW 120408 TTMS |
| Milling cutter | - | WIDIA M400 Face milling cutter |

| | | |
|---|---|---|
| Cutting speeds (rpm) | - | 180, 250, 355. |
| Feed (mm/rev) | - | 0.1, 0.2, 0.3. |
| Depth of cut (mm) | - | 1, 1.5, 2. |
| Approach angles (deg) | - | 35, 45, 55. |

**SPECIFICATIONS OF CONVENTIONAL VERTICAL MILLING MACHINE:**

| | | |
|---|---|---|
| Made | - | BHARAT FRITZ WERNER LTD |
| Longitudinal movement | - | 560 mm |
| Transverse movement | - | 250 mm |
| Vertical movement | - | 390 mm |
| Speed range | - | 45-2000 rpm |
| Feed range | - | 16-800 mm/min |
| Motor power | - | 3 KW |

**WORK MATERIAL and its SPECIFICATIONS:**

**EN31:**

**EN31** is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance. EN-31 steel is widely used in automotive industry for producing automotive components such as roller bearing, ball bearing, spline shaft, shearing blades, die parts etc. Therefore this steel is chosen for experimental investigation.

**Applications:**

Gas cylinders, Rollers & chain links (conveyor belts), Structural tubing in cranes, bridges, platforms, Printing rollers, Flow lines, Guide rods in linear bearings, Pulley blanks.

**Chemical composition &Mechanical Properties of En31**

**Chemical composition(wt%)**

| Material | C | Mn | Si | Cr | S | P |
|---|---|---|---|---|---|---|
| EN31 | 0.9-1.2 | 0.3-0.75 | 0.1-0.35 | 1.0-1.6 | 0.05 | 0.05 |

**Mechanical properties for En 31**

| | |
|---|---|
| Poisson's ratio | 0.3 |
| Elastic modulus(Gpa) | 202 |
| Hardness(HB) | 290 |
| Density(x1000kg/$m^3$ ) | 8.745 |
| Tensile strength(MPa) | 525.8 |
| Yield strength(MPa) | 373.4 |
| Elongation (%) | 32.4 |
| Reduction in area (%) | 61.5 |
| Impact strength(J) | 46.2 |

**TOOL MATERIAL and its SPECIFICATIONS**

A tool material should have the requisite hardness,strength,thermal stability and ease in manufature and all this at an economic cost.

**REQUISITES OF TOOL MATERIALS:**

**HARDNESS:** should exceed the material being cut to ensure good wear resistance.

**TOUGHNESS:** to eithstand impact and vibrations inherentin metal cutting.

**HEAT RESISTANCE(RED HARDNESS)** can retain shape and hardness at high temperatures confronted in metal cutting.

**WORKABILITY** is particularly important when the tool must be shaped(formed)to suit the workpiece. High speed steels can be ground precisely, while carbides must be moulded(compacted) to the required shape and lapped by diamond wheels as grinding is uneconomical, and machining impossible.

**ECONOMY** even the most ideal tool material cannot be availed, if it is too dear compared to the advantages it offers.

**PROPERTIES OF TUNGSTEN CARBIDE:**

| | | |
|---|---|---|
| Material composition (Wt %) | - | WC–10wt%Co, 0.6% others |
| Density (g/cm$^3$) | - | 14.5 |
| Hardness (HRa) | - | 92.3 |
| Melting point (◦C) | - | 2597 |
| Transverse rupture strength (MPa) | - | 4000 |
| Compressive strength (MPa) | - | 6600 |
| Thermal expansion coefficient (K$^{-1}$) | - | $5.5\times10^{-6}$ |

**CARBIDES:**

Carbides also known as cemented carbides or sintered carbides were introduced in the 1930s and have high hardness over a wide range of temperatures, high thermal conductivity, high Young's modulus making them effective tool and die materials for a range of applications. Extremely hard and brittle tungsten carbide powder is mixed with soft and tough cobalt (bond) powder. The mixture is pressed to form blanks. These are pre-intered at 900$^0$ C to impart it strength and machinability of chalk. The blanks can be suitable shaped by turning, drilling, grinding, etc. Before a second sintering is carried out between 1400$^0$C and 1600$^0$C. The second sintering melts the cobalt bond and facilitatesabsorption of carbides.

Solidifiation at 1350$^0$C during cooling imparts excellent toughness and wear resistance to cemented carbides. Finer carbide grains enhance hardness while coarse grain and more cobalt increases toughness. Addition of tantalum and nibium carbides improves wear resistance making the tool more suitable for steel and other materials producing long continuous chip. ISO grades with predix P have high wear resistance while prefix K indicates higher toughness.

Harder materials can be cut well by tougher grades which are also suitable for deep cut, high feed roughing, and intermittent cutting with impact loads. Precision finishing with light cuts, and long chip materials causing high crater wear call for wear- resistant ‘P‘ grades. Cuting speed should be reduced suitably for deeper cuts and higher feed rates.

The proportion of cobalt (the usual matrix material) present has a significant effect on the properties of carbide tools. 3 - 6% matrix of cobalt gives greater hardness while 6 - 15% matrix of cobalt gives a greater toughness while decreasing the hardness, wear resistance and strength. Tungsten carbide tools are commonly used for machining steels, cast irons and abrasive non-ferrous materials. Titanium carbide has a higher wear resistance than tungsten but is not as tough. With a nickel-molybdenum alloy as the matrix, TiC is suitable for machining at higher speeds than those which can be used for tungsten carbide. Typical cutting speeds are: 30 - 150 m/min or 100 - 250 when coated.

**1.3.5 INSERT DESIGNATION:**

**Type: SPMW 120408 TTMS**

S – Insert shape (square)

P – Normal clearance angle (11$^0$ )

M – Tolerance class

W – Characteristic of insert fixing (With hole, without chip grooves,
and one counter sink(40$^0$ -60$^0$))

12 – Length of insert (12 mm).

04 – Thickness (4.76 mm).

08 – Nose radius (0.8 mm).

TTMS – grade of insert
Uncoated carbide
Used for medium machining
Used for alloy steel

**MILLING CUTTER:**

For conducting experiments M400 face milling cutter of dia 150mm is used as shown in the figure 3.3. M400, the cartridge based milling system has been developed for flexibility. Whether it is face milling or square shoulder milling, roughing or finishing, the

M400 system meets the entire requirement. The design features replaceable cartridges which accept various types of insert from WIDIA standard milling range.

**Figure 3.3 M400 MILLING CUTTER**

The cartridges are fitted securely on the cutter body by means of high tensile M8 screw. Axial positioning is assured by a locating ring bolted on the cutter body. Twelve different types of cutters can be made from single cutter body by changing only the cartridges and inserts. This flexibility helps to create the right for any given application.

**TOOL WEAR MEASUREMENT**

**TOOLMAKER MICROSCOPE**: Toolmaker microscope is widely used to measure the tool wear. Tool wear measurement is of great concern in machining industry, as it affects the surface qualities, dimensional accuracy and production costs of the machined components.

**Figure 3.6 TOOLMAKER MICROSCOPE**

**INTRODUCTION:**

The large Tool Maker's Microscope (TMM) essentially consists of the cast base, the main lighting unit, the upright with carrying arm and the sighting microscope. The rigid cast base is resting on three foots screws by means of which the equipment can be levelled with reference to the build-in box level. The base carries the co-ordinate measuring table, consists of two measuring slides; one each for directions X and Y and a rotary circular table provided with the glass plate

**WORK MATERIAL PREPARATION:**

The raw work material of size is 100 ×100 × 500mm; it is cut into required dimension 50 ×50 × 80mm, with help of power hacksaw, shaping machine and milling machine.

**Table Experiments**

| Sl.no | App. angle | Speed (rpm) | Feed rate (mm/min) | Depth of cut (mm) | Tool life (min) | VMR ($mm^3$) | Fx (N) | Fy (N) |
|---|---|---|---|---|---|---|---|---|
| 1 | 35 | 180 | 20 | 1 | 70 | 127.5 | 1034 | 915 |
| 2 | 35 | 250 | 50 | 1.5 | 45 | 337.5 | 2348 | 2510 |
| 3 | 35 | 355 | 100 | 2 | 6.5 | 130 | 2890 | 2056 |
| 4 | 45 | 180 | 40 | 2 | 47.5 | 380 | 2510 | 2252 |
| 5 | 45 | 250 | 80 | 1 | 38.75 | 263 | 1667 | 1765 |
| 6 | 45 | 355 | 40 | 1.5 | 46.25 | 235 | 1342 | 1304 |
| 7 | 55 | 180 | 50 | 1.5 | 75 | 478 | 1919 | 2000 |
| 8 | 55 | 250 | 25 | 2 | 36 | 180 | 1345 | 1199 |
| 9 | 55 | 355 | 80 | 1 | 16.25 | 110 | 1537 | 1723 |

## IV. RESULTS:

**S/N response table for TOOL LIFE**

| parameter | Level1 | Level 2 | Level 3 | Max-min |
|---|---|---|---|---|
| Approach angle | 28.73 | **32.86** | 30.94 | 4.13 |
| Cutting speed | **35.97** | 31.98 | 24.58 | 11.39 |
| Feed rate | **33.77** | 30.26 | 28.50 | 5.27 |
| Depth of cut | 30.95 | **34.62** | 26.96 | 7.66 |

Average =30.84

Optimum cutting parameters are Approach angle =45°

Cutting speed =180 rpm

Feed rate =0.1 mm/rev

Depth of cut =1.5 mm

Predicted tool life :

$\mu$ (pridicted S/N ratio) $=\bar{Y}+(A2-\bar{Y})+(B1-\bar{Y})+(C1-\bar{Y})+(D2-\bar{Y})$

$=30.84+(32.86-30.84)+(35.97-30.84)+(33.77-30.84)+(34.62-30.84)$

$=44.7$ dB

$\mu =-10\log(1/\text{predicted } T^2)$

$44.7 =-10\log(1/ T^2)$

$\text{Log}(1/ T^2) =-4.47$

$(1/ T^2) =\text{Anti log}(-4.47)$

$(1/ T^2) =3.388 * 10^{-5}$

$T^2 =29512.09$

$T =171.7$ min

| Sl.no | App angle | Speed (rpm) | Feed rate (mm/min) | Depth of cut (mm) | Tool life (min) | Vol of matrl removed | Fx (N) | Fy (N) | S/N Tool life | S/N Vol of matrl rem | S/N Fx | S/N Fy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 35 | 180 | 20 | 1 | 70 | 127.5 | 1034 | 915 | 36.90 | 42.11 | -60.29 | -59.22 |
| 2 | 35 | 250 | 50 | 1.5 | 45 | 337.5 | 2348 | 2510 | 33.06 | 50.56 | -67.41 | -67.99 |
| 3 | 35 | 355 | 100 | 2 | 6.5 | 130 | 2890 | 2056 | 16.25 | 42.27 | -69.21 | -66.26 |
| 4 | 45 | 180 | 40 | 2 | 47.5 | 380 | 2510 | 2252 | 33.53 | 51.59 | -67.99 | -67.05 |
| 5 | 45 | 250 | 80 | 1 | 38.75 | 263 | 1667 | 1765 | 31.76 | 48.41 | -64.43 | -64.93 |
| 6 | 45 | 355 | 40 | 1.5 | 46.25 | 235 | 1342 | 1304 | 33.30 | 47.45 | -62.55 | -62.30 |
| 7 | 55 | 180 | 50 | 1.5 | 75 | 478 | 1919 | 2000 | 37.50 | 53.59 | -65.66 | -66.02 |
| 8 | 55 | 250 | 25 | 2 | 36 | 180 | 1345 | 1199 | 31.12 | 45.10 | -62.57 | -61.57 |
| 9 | 55 | 355 | 80 | 1 | 16.25 | 110 | 1537 | 1723 | 24.21 | 40.86 | -63.73 | -64.72 |

**Anova for TOOL LIFE**

| Parameter | DOF | SS | MS | F | P |
|---|---|---|---|---|---|
| Approach angle | 2 | 25.57 | 12.78 | 2556 | 7.16 |
| Cutting speed | 2 | 200.37 | 100.18 | 20036 | 56.11 |
| Feed rate | 2 | 43.18 | 21.59 | 4318 | 12.09 |
| Depth of cut | 2 | 87.91 | 43.95 | 8790 | 24.62 |
| Error | 2 | 0.01 | 0.005 | - | 0.002 |
| Total | 10 | 357.04 | - | - | 100 |

**S/N response table for VOLUME OF MATERIAL REMOVED**

| parameter | Level1 | Level 2 | Level 3 | Max-min |
|---|---|---|---|---|
| Approach angle | 44.98 | **49.15** | 46.52 | 4.16 |
| Cutting speed | **49.10** | 48.02 | 43.53 | 5.57 |
| Feed rate | 44.89 | 47.68 | **48.09** | 3.2 |
| Depth of cut | 43.79 | **50.54** | 46.33 | 6.74 |

Average =46.88 dB

Optimum cutting parameters are Approach angle =45°
Cutting speed =180 rpm
Feed rate =0.3 mm/rev
Depth of cut =1.5 mm

Pridicted volume of material removed :

μ (pridicted S/N ratio) = $\bar{Y}+(A2-\bar{Y})+(B1-\bar{Y})+(C3-\bar{Y})+(D2-\bar{Y})$

= 56.24

μ =-10log(1/pridicted $VMR^2$)

56.24 =-10log(1/$VMR^2$)

$VMR^2$ =420726.62

VMR =648.63 $cm^2$

**Anova for VOL OF MATERIAL REMOVED**

| Parameter | DOF | SS | MS | F | P |
|---|---|---|---|---|---|
| Approach angle | 2 | 26.68 | 13.34 | 1334 | 15.99 |
| Cutting speed | 2 | 52.39 | 26.19 | 2619 | 31.4 |
| Feed rate | 2 | 18.18 | 9.09 | 909 | 10.89 |
| Depth of cut | 2 | 69.56 | 34.78 | 34.78 | 41.69 |
| Error | 2 | 0.02 | 0.01 | - | 0.01 |
| Total | 10 | 166.83 | - | - | 100 |

**S/N response table for FEED FORCE Fx**

| parameter | Level1 | Level 2 | Level 3 | Max-min |
|---|---|---|---|---|
| Approach angle | -65.64 | -65 | **-63.99** | 1.65 |
| Cutting speed | **-64.65** | -64.81 | -65.17 | 0.52 |
| Feed rate | -61.81 | **-66.38** | -66.44 | 4.63 |
| Depth of cut | **-62.82** | -65.21 | -66.60 | 3.77 |

Average =-64.96 dB

Optimum cutting parameters are Approach angle =55$^o$
Cutting speed =180 rpm
Feed rate =0.2 mm/rev
Depth of cut =1.0 mm

Pridicted FEED FORCE Fx:
μ (pridicted S/N ratio) = Ȳ+(A3- Ȳ)+(B1- Ȳ)+(C2- Ȳ)+(D1- Ȳ)
= -58.36 dB
μ = -10log(pridicted $Fx^2$)
-58.36 = -10log(1/VMR $Fx^2$)
$Fx^2$ =685488.2265

Fx =827.94 N

**Anova for FEED FORCE Fx**

| Parameter | DOF | SS | MS | F | P |
|---|---|---|---|---|---|
| Approach angle | 2 | 4.14 | 2.07 | 51.75 | 6.01 |
| Cutting speed | 2 | 0.42 | 0.21 | 5.25 | 0.61 |
| Feed rate | 2 | 42.35 | 21.17 | 529.25 | 61.51 |
| Depth of cut | 2 | 21.86 | 10.93 | 273.25 | 31.75 |
| Error | 2 | 0.08 | 0.04 | - | 0.11 |
| Total | 10 | 68.85 | - | - | 100 |

**S/N response table for TANGENTIAL FORCE Fy**

| parameter | Level1 | Level 2 | Level 3 | Max-min |
|---|---|---|---|---|
| Approach angle | -64.49 | -64.76 | **-64.11** | 0.66 |
| Cutting speed | **-64.10** | -64.83 | -64.43 | 0.73 |
| Feed rate | **-61.04** | -66.59 | -65.74 | 5.55 |
| Depth of cut | **-62.96** | -65.44 | -64.96 | 2.48 |

Average =-64.44 dB

Optimum cutting parameters are Approach angle =55$^o$

Cutting speed =180 rpm
Feed rate =0.1 mm/rev
Depth of cut =1.0 mm

Pridicted FEED FORCE Fy:

μ (pridicted S/N ratio) = $\bar{Y}$+(A3- $\bar{Y}$)+(B1- $\bar{Y}$)+(C1- $\bar{Y}$)+(D1- $\bar{Y}$)
= -58.89 dB

μ =-10log(predicted $Fy^2$)

-58.89 =-10log($Fy^2$)

$Fy^2$ =774461.79

Fy =880.03 N

**Anova for TANGENTIAL FORCE Fy**

| Parameter | DOF | SS | MS | F | P |
|---|---|---|---|---|---|
| Approach angle | 2 | 0.65 | 0.325 | 65 | 0.99 |
| Cutting speed | 2 | 0.80 | 0.4 | 80 | 1.22 |
| Feed rate | 2 | 53.75 | 26.87 | 5374 | 81.93 |
| Depth of cut | 2 | 10.39 | 5.19 | 1038 | 15.83 |
| Error | 2 | 0.01 | 0.005 | - | 0.02 |
| Total | 10 | 65.6 | - | - | 100 |

Sample caluculation :
Experiment No: 1
Approach angle =35
Cutting speed =180 rpm =84.82 m/min
Feed rate =0.1 mm/rev =20 mm/min
Depth of cut =1 mm
Total number of passes =30
Volume of material removed in one pass = l* b* doc
= 50* 85* 1
= 4250 $mm^3$
Total volume of material removed =4250 *30 =127,500 $mm^3$
Machining time for one pass =length/feed
=50 /20
= 2.5 min
Total machining time = 2.5 *30 =70 min

**S/N ratio for tool life:**

Larger the better i.e. S/N ratio = -10 log (MSD)

$$MSD = (1/m)* \sum_{i=1}^{m}(\frac{1}{T^2})$$

S/N 1 = - 10 log ($1/70^2$))
= 36.90 dB

S/N P1,1 =(SN1+SN2+SN3)/3
=( 36.90+33.06+16.25)/3=28.73

Average = (SN1+SN2+SN3+SN4+SN5+SN6+SN7+SN8+SN9)/9
$n_m$= (36.90+33.06+16.25+33.53+31.76+33.30+37.50+31.12+24.21)/9
=30.84

DOF= Level-1 =3-1 =2

Sum of squares = $(\text{total of A1})^2/n1 + (\text{total of A2})^2/n2 + (\text{total of A3})^2/n3 – (\text{total of A})^2/n$
SSd=25.57

Mean squares = Sum of squares/DOF
= 25.57/2
=12.78

Sum of squares of Total $=\sum_{i=1}^{n} (n_m-n_i)^2$
SSt=357.04

Sum of squares of error = (SSt – (SSd1+SSd2+SSd3))
=0.01
Mean squares of error = (Sum of squares of error/ DOF)
= 0.01/2
SSe = 0.005
F = (Mean squares of P1/ Mean squares of error)
=12.78/0.005
=2556
P = (Sum of squares/ Sum of squares of Total)
=25.57/357.04
=7.16 %

By using Taguchi optimization technique, the results are

1. From the analysis of Tool life, we can observe that the cutting parameters, Approach angle (P=7.16%), Cutting speed (P=56.11%), Feed (P=12.09%), depth of cut (P=24.60%) have statistical and physical significance on the tool life obtained, especially the speed.
2. From the analysis of Volume of material removed (VMR), we can observe that the cutting parameters, Approach angle (P=15.99%), cutting speed (P=31.4%), Feed (P=10.89%), depth of cut (P=41.69%), have statistical and physical significance on VMR obtained, especially the Depth of cut
3. From the analysis of Feed force (Fx), we can observe that the cutting parameters, Approach angle (P=6.01%), cutting speed (P=0.61%), Feed (P=61.51%), depth of cut (P=31.75%), have statistical and physical significance on the Fx obtained, especially the feed.
4. From the analysis of Cutting force (Fy), we can observe that the cutting parameters, Approach angle (P=0.99%), cutting speed (P=1.22%), Feed (P=81.93%), depth of cut (P=15.83%), have statistical and physical significance on the Fy obtained, especially the feed.
5. From the cutting force and tool wear graphs it is observed that cutting forces increases as the tool wear increases.
6. From the cutting force and no of passes graphs it is observed that cutting forces increases as the tool wear increases.

## V. CONCLUSION:

From the results obtained during the experimental investigations on face milling using carbide tools with EN31 as the work piece material at different approach angles, cutting speed, feed and depth of cut. The conclusions are made as follows:

1. The Tool life is more for the approach angle $45^0$, The parameter cutting speed have more effect on tool life. This is due to the increase in the cutting speed the tool would remove more material in less time so that loads and temperatures would increase so the tool life would be decreases.
2. The results show that Volume of material removed increases with the increase in speed and depth of cut. These are the two parameter effecting the Volume of material removed more. It was observed that $45^0$ is the optimum approach angle for maximum material removal and hence manufacturers most commonly use $45^0$ approach angles for rough milling operations. It is observed that feed contribution is less in the Volume of material removed
3. It is found that feed is the most significant parameter for feed force($F_x$) and cutting force ($F_y$) as compared to the cutting speed, approach angle and depth of cut. It is also observed that feed force decreases with the increase in approach angle whereas cutting force decreases with the decrease in approach angle. For cutting forces it is observed that $55^0$ approach angle is suitable because we will get the minimum force values for this angle.
4. It is found that feed is the significant parameter affecting the tool life and cutting forces. Hence lower feed can be recommended for achieving better results.
5. It has been predicted from the analysis that the tool life is maximum, at the optimum set of parameters with $45^0$ approach angle,180 rpm cutting speed,0.1 mm/rev feed rate and 1.5mm depth of cut.
6. It has been predicted from the analysis that the volume of material removed is maximum, at the optimum set of parameters with $45^0$ approach angle,180 rpm cutting speed,0.3 mm/rev feed rate and 1.5mm depth of cut.

## VI. REFERANCES:


- **W.H. Yang, Y.S. Tarng,** Design optimization of cutting parameters for turning operations based on the Taguchi method, Journal of Materials Processing Technology 84 (1998) 122–129.
- **P. J. Ross,** Taguchi Techniques for Quality Engineering, Mc-Graw Hill, New York, 1998.
- Work shop Technology (vol.II) by B.S. RAGHUWANSHI, DHANPAT RAI & CO. (P) LTD.

- **Seref Aykut et al,** Experimental observation of tool wear, cutting forces and chip morphology in face milling of cobalt based super-alloy with physical vapour deposition coated and uncoated tool, Materials and Design 28 (2007) 1880–1888.
- **Shunmugam SV et.al** selection of optimum Conditions in Multi-pass Face milling using a Genetic Algorithm. Int J Mach Tool Manuf 2000;40:4014-414
- **P. J. Cheng et. al** A Study on instantaneous cutting force coefficients in face milling Int. J. Math. Tools Manufact. VoL 37. No. 10, VoL 37. No. 10, pp. 1393-1, 1997.
- **S.J. WILCOX et.al** The use of cutting force and acoustic emission signals for the monitoring of tool insert geometry during rough face milling, journal of technical tools manufacture, Vol. 37, No. 4, pp. 481-494, 1997.
- **Chung-Shin et. al A** study of high efficiency face milling tools, Journal of Materials Processing Technology 100 (2000) 12±29.
- **D.G. Thakur** et.al(journalof Materials and Design 2009) An experimental investigation on the machinability of superalloy Inconel 718 during high speed turning using tungsten carbide insert (K20) tool.
- **M. Nouari et.al** Experimental verification of a diffusion tool wear model using A 42crmo4 steel with an uncoated cemented tungsten Carbide at various cutting speeds, wear 259 (2005).
- **R.G. Vargas et.al** wear mechanisms of WC inserts in face milling Of gamma titanium aluminides, wear 259 (2005).
- **Z.Q. Liu et. al** Wear patterns and mechanisms of cutting tools in high-speed face milling, Journal of Materials Processing Technology 129 (2002).