Artificial Neural Network Modeling and Analysis of EN24 &EN36 Using CNC Milling Machine

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Abstract

Metal cutting is one of the most significant manufacturing processes in the area of material removal. It is Block it is defined metal cutting as the removal of metal chips from a work piece in order to obtain a finished product with desired attributes of size, shape, and surface roughness.The imperative objective of the science of metal cutting is the solution of practical problems associated with the efficient and precise removal of metal from work piece. It has been recognized that the reliable quantitative predictions of the various technological performance measures, preferably in the form of equations, are essential to develop optimization strategies for selecting cutting conditions in process planning. In this thesis experiments has to be conducted to improve the surface finish quality of a work piece by using carbide tips. The type is bull nose tip. A series of experiments have to be done by varying the milling parameters spindle speed, feed rate and depth of cut and modeling is done by ANN. and Analysis is done by ANSYS.

Introduction

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 chip forming processes. Metal cutting is a machining process by which a work piece is given as follows

- A desired shape
- A desired size
- 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.

The increase of customer needs for quality products (more precise tolerances and better product surface roughness) have driven the metal cutting process. In the global antagonism, manufacturing organizations are working in the direction of improving the product quality and performance of the product with lower cost in short span of time, but practices aimed at lowering the costs don't usually improve quality.

There is hierarchical relationship between cost and quality. The intense international competition has focused the attention of the manufacturers on automation as means to increase productivity and improve quality. To realize full automation in machining, computer numerically controlled (CNC) machine tools have been implemented during the past decades. CNC machine tools require less operator input, provide greater improvements in productivity and increase the quality of the machined part.

Among several CNC industrial machining processes, milling is a fundamental machining operation. End milling is the most common metal removal operation encountered. It is widely used in a variety of manufacturing industries including the aerospace and automotive sectors, where quality is an important factor in the production of slots, pockets, precision molds and dies etc.,.

The surface roughness plays an imperative role in the manufacturing industry. The quality of surface affects functional requirements and plays a very important role in the performance of the milling as a good quality of milled surface significantly improves fatigue strength, corrosion resistance or creep life. Surface roughness also affects the several functional attributes of parts such as contact causing surface friction, wearing, light reflection, heat transmission and ability of distributing and holding lubricant coating or resisting fatigue. Therefore the desired finish surface is usually specified and the appropriate processes are selected to reach the required quality.

Several factors will influence the final surface roughness in a CNC milling operation. The final surface roughness might be considered as the sum of two independent effects.

1. The ideal surface roughness is a result of the geometry of the tool & feed and
2. The natural surface roughness is a result of the irregularities in the cutting operation. (Boothoryd and Knight, 1989).

In this work, the design of experiments techniques such as orthogonal arrays in Taguchi design, ANOVA and Artificial Neural Network has been implemented to develop model and analysis for a better product quality.

II DESIGN OF EXPERIMENTS (DOE):

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors affecting a process and the output of that process. Conducting and analyzing controlled tests to evaluate the factors that control the value of a parameter or group of parameters. “Design of Experiments" (DOE) refers to experimental methods used to quantify indeterminate measurements of factors and interactions between factors statistically through observance of forced changes made methodically as directed by mathematically systematic tables.

2.1Design of Experiment Techniques

1. Factorial Design.
2. Response Surface methodology.
3. Mixture Design.
4. Taguchi Design.

Among those we had selected Taguchi Design for optimizing surface finish and cutting forces in face milling Operation.

2.2Orthogonal array

In order to reduce the total number of experiments "Sir Ronald Fisher" developed solution:" orthogonal arrays". The orthogonal array can be thought of as a distillation mechanism through which the engineers experiment passes (Ealey, 1998). The array allows the engineer to vary multiple variables at one time and obtain the effects which that set of variables has an average and the dispersion. Taguchi method can be calculated based on the degrees of freedom approach.

$$N_{TAGUCHI} = 1 + \sum_{i=1}^{NV}(L_i - 1) \quad \text{---------- (3.1)}$$

Taguchi employs design experiments using specially constructed table, known as "Orthogonal Arrays (OA)" to treat the design process, such that the quality is build into the product during the product design stage. Orthogonal Arrays (OA) are a special set of Latin squares, constructed by Taguchi to lay out the product design experiments. An orthogonal array is a type of experiment where the columns for the independent variables are "orthogonal" to one another. Orthogonal arrays are employed to study the effect of several control factors. Orthogonal arrays are used to investigate quality. Orthogonal arrays are not unique to Taguchi, they were discovered considerably earlier (Bendell, 1998). However Taguchi has simplified their use by providing tabulated sets of standard orthogonal arrays and corresponding linear graphs to fit specific projects (ASI, 1989; Taguchi and Kenishi, 1987).

Table3.1 A typical L_9 orthogonal array: (3^4)

	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

In this array the columns are mutually orthogonal. That is for any pair of columns all combination of factors occurs; and they occur an equal number of times. Here there are 4 parameters, A, B, C and D each at three levels. This is called an 'L_9' design; with the 9 indication the nine rows, configurations or prototypes to be tested. Specific test characteristics for each experimental evaluation are identified in the associated row of the table. Thus L_9 (3^4) means that nine experiments are to be carried out to study four variables with three levels. There are greater savings in testing for larger arrays.

III EXPERIMENTATION

Experiments have been performed in order to investigate the effects of one or more factors of the process parameters (spindle speed, feed rate and depth of cut) on the surface finish of the machined surface.

The main aim of the project is to determine the influence of radius carbide tips in metal working. The investigation is based on surface roughness during milling of EN24 and EN36 steel with carbide tool. The cutting parameters considered are feed rate, spindle speed and depth of cut.

3.1Experimental Procedure

This experiment employed a CNC vertical milling machine. Carbide cutting tool is used. The experiment has been done under conditions of feed rate 700mm/min, 980mm/min, 1400 mm/min, 1900 mm/min and 2600 mm/min. For EN24 Spindle speeds are2000rpm, 1800rpm, 2100rpm, and depth of cut 0.25mm, And for EN36, spindle speeds are 2100rpm, 2200rpm, 2300rpm, 2400rpm and 2500rpm.

Five square pieces of EN 24 material and EN36 material are taken for machining.

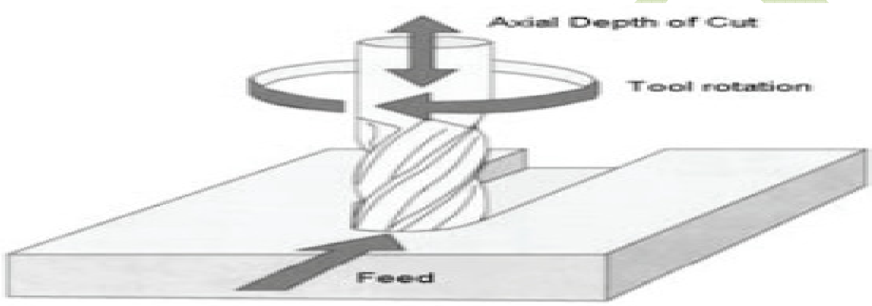

fig3.1 spindle rotation

3.2Cemented carbide Tool

Advantage of cemented carbide in around 1905 made a break through at that time in the history of cutting tool materials though got later superseded by many other novel tool materials like cemented carbides and ceramics which could machine much faster than the HSS tools. The basic composition of HSS is 94% WC, 6.0% CO, 1% and rest Fe. Such carbide tool could machine (turn) mild steel jobs at speed only up to 20 ~ 30 m/min

Carbide is used as cutting tool material where;

• The tool geometry and mechanics of chip formation are complex, such as helical twist drills, reamers, gear shaping cutters, hobs, form tools, broaches etc.
• Brittle tools like carbides, ceramics etc. are not suitable under shock loading
• The small scale industries cannot afford costlier tools
• The old or low powered small machine tools cannot accept high speed and feed.

Table 3.1 CNC milling machine and its specifications

DESCRIPTION	SPECIFICATION
Model	CKEN 40
Table clamping area	2M/1800
Travel X-axis Y-axis Z-axis	1800 mm 850 mm 750mm

Table size	2000 X 800mm
Spindle Motor Capacity	0.5 HP
Spindle speeds	150 - 4500RPM
Power Source	230V, Single Phase, 50 Hz
Feed rates	BT 50
Rapid traverse x, y, z-axis	0-1 m/min
CNC control system	PNEUMATIC
Machine Dimensions	1000x575x650mm

Fig.3.2. CNC milling machine CKEN 40

Table 3.2 Material Input Parameters of EN-24
SECTION-A

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)
1.	700	2000	0.25
2.	980	1800	0.25
3.	1400	2100	0.25
4.	1900	2000	0.25
5.	2600	2000	0.25

Table 3.3 Machining input Parameters of EN 24

SECTION-B

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)
1.	700	2100	0.25
2.	980	2200	0.25
3.	1400	2300	0.25
4.	1900	2400	0.25
5.	2600	2500	0.25

Table 3.4 Material Input Parameters of EN-36

SECTION-A

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)
1.	700	2000	0.25
2.	980	1800	0.25
3.	1400	2100	0.25
4.	1900	2000	0.25
5.	2600	2000	0.25

Table 3.5 Machining input Parameters of EN 36

SECTION-B

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)
1.	700	2100	0.25
2.	980	2200	0.25
3.	1400	2300	0.25
4.	1900	2400	0.25
5.	2600	2500	0.25

3.3 Surface finish measurement

Talysurf meter instrument is widely used to measure the shape or form of components. A profile measurement device is usually based on a tactile measurement principle. The surface is measured by moving a stylus across the surface. As the stylus moves up and down along the surface, a transducer converts these movements into a signal which is then transformed into a roughness number and usually a visually displayed profile. Multiple profiles can often be combined to form a surface representation. Talysurf meter is shown in fig 4.4.

Fig.3.3. Talysurf roughnessmeter

3.4 Experimental procedure

i) The parameters which influence the milling process and their levels are listed based on previous works (table 4.4 and 4.5).
ii) Milling operation is performed on EN24 and EN36 by using the CNC Milling machine.
iii) The surface finish values of work are measured using Talysurf meter (table 4.6).
The experimental results are presented in Table.-3.6

Table 3.6Material Surface Finish Result for EN-24

SECTION-A

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)	Surface finish (R_a) µm
1.	700	2000	0.25	4.36+2.78/2=3.57
2.	980	1800	0.25	4.1+2.85/2=3.475
3.	1400	2100	0.25	1.16+3.76/2=2.46
4.	1900	2000	0.25	1.34+1.30/2=1.32
5.	2600	2000	0.25	1.2+1.24/2=1.22

Table 3.7Material Surface Finish Result for EN-24
SECTION-B

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)	Surface finish (R_a) μm
1.	700	2100	0.25	4.23+2.90/2=3.63
2.	980	2200	0.25	4.6+2.97/2=3.785
3.	1400	2300	0.25	1.45+3.92/2=2.685
4.	1900	2400	0.25	2.13+1.72/2=2.785
5.	2600	2500	0.25	1.61+1.4/2=2.31

Table 3.8 Experimental results Raof EN24
SECTION-A

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)	Surface finish (R_a) μm
1.	700	2000	0.25	4.76+3.1/2=3.93
2.	980	1800	0.25	4.41+3.1/2=3.755
3.	1400	2100	0.25	1.32+3.86/2=3.25
4.	1900	2000	0.25	1.53+1.71/2=1.62
5.	2600	2000	0.25	1.3+1.56/2=1.96

Table 3.9 Experimental results Ra of EN36
SECTION-B

S.NO.	FEED (mm/min)	SPEED (rpm)	DEPTH OF CUT (mm)	Surface finish (R_a) μm
1.	700	2100	0.25	4.86+3.31/2=4.085
2.	980	2200	0.25	4.92+3.42/2=4.17
3.	1400	2300	0.25	1.61+3.92/2=2.765
4.	1900	2400	0.25	2.42+2.1/2=2.26
5.	2600	2500	0.25	1.71+1.52/2=1.615

RESULTS AND DISCUSSIONS

Thrust Force and Torque Calculations of Materials - En-24 and En-36b

Cutter dia = 25R5
Width of Workpiece = 75mm
No of Teeth on cutter = 4 = nc
Depth of Cut = d = 0.2
Width of Cut = b = 5mm
Width of chip = bc = 5mm
V = Cutting Velocity
rt = Chip Thickness Ratio
rt = t/tc = vc/v = lc/l
LC = Length of Chip = 7mm
L = Uncut Chip Length = 75mm
∝ = Rake Angle = 20°
β = Friction Angle = 40
∅ = Shear Angle

Speeds (RPM)	Feed (mm/min)
3000	200
2500	300
2000	400

Chip Thickness Ratio
$rt = t/tc = vc/v = L_C/L$
$rt = L_c/L = 7/75 = 0.093$
Shear Angle (∅)
$\tan \emptyset = (r_t \cos\alpha)/(1-r_t \sin\alpha)$
$\tan \emptyset = (0.093 \cos 20)/(1-0.093 \sin 20)$
$\emptyset = 5.781$
To Calculate Thrust Force
$Ft = \mu [(HA_c)/3 \; ((\cot\emptyset)/\sqrt{3}+1)]+A_F (0.62H\sqrt{(43H/E)})$
AC = Cross – Section of Chip
Af = Area of Tool Flank Face
∅ = Shear Angle in w/p
μ = Friction Coefficient on Rake Face
H = Hardness of w/p
E = Young's Modulus of w/p

EN-24 Material with speed of 2000rpm, feed 700mm/min.

Cutting speed (V)=πDN/1000m/min
Where D=cutter dia =25mm
N= spindle speed = 2000rpm
V=cutting speed
$V=(\pi\times25\times2000)/1000=157.07$ m/min
Feed per tooth of cutter :
$ft=F/((n_c \times N))$ mm/rev/tooth
n_c = no.of cutting edges or teeth on cutter = 4
F = 700mm/min= table feed
$ft=700/((4\times2000))=0.087$ mm/rev/tooth
Ac = plan area of cut =cross section of chip

$A_c = w \times d$

w =width of work piece being cut =75mm

d = depth of cut

Ac= 15sq.mm

A=feed length for cutter to reach full depth = Af =area of tool flank face

$A = \sqrt{(D-d)\times d} = \sqrt{(25-0.25)\times 0.25} = 2.487\text{mm}$

Cutting Forces in Orthogonal Cutting

Fh=horizontal force component parallel to cutting velocity

Fv=vertical force component normal to Fh

Fs=force component parallel to shear plane

Fp= force component normal to Fs

Ft= force component parallel to tool rake face

Fn= force component normal to Ft

$F_S = R\cos(\emptyset+\beta-\alpha)$

$F_h = R\cos(\beta-\alpha)$

$F_n = R\cos(\beta)$

$F_V = R\sin(\beta-\alpha)$

$F_S = R\sin(\emptyset+\beta-\alpha)$

$F_t = R\sin\beta$

WHERE

$R = (t.b.K)/\sin[\emptyset\cos(\emptyset+\beta-\alpha)]$

Where k= yield stress of material in shear =325Mpa

Thrust Force Calculation

$F_t = \mu[(HA_c)/3 (\cot \emptyset/\sqrt{3}+1)] + A_f (0.62H\sqrt{43H/E})$

$A_c = w\times d = 15\text{sq.mm}$

w = 75mm=width of work piece being cut

d=depth of cut=0.25

$A = A_f$=area of tool flank face = 2.487

$A = \sqrt{(D-d)d}$

Where D = cutter dia

d=depth of cut

$A = \sqrt{(25-0.25)0.2}$ 5

$A = A_f = 2.487$

μ=friction angle=tan [β=0.8]

Where β=90

H=hardness of the work piece = 292

Density = 0.000007850 J/goC

E=young's modulus of work piece =213000 Mpa

$F_t = 0.8[(292\times15)/3 (\cot 5.781/\sqrt{3}+1)] + 2.487(0.62\times292\sqrt{(43\times292)/213000})$

$F_t = 55350.39\text{N}$

EN-36 Material with speed of 2000rpm, feed 700mm/min.

Cutting speed (V)=πDN/1000m/min

Where D=cutter dia =25mm

N= spindle speed = 2000rpm

V=cutting speed

$V = (\pi\times25\times2000)/1000 = 157.07$ m/min

Feed per tooth of cutter :

$ft=F/((n_{(c)}\times N))$ mm/rev/tooth

$n_{(c)}$ = no.of cutting edges or teeth on cutter = 4

F = 700mm/min= table feed

$ft=700/((4\times 2000))=0.087$ mm/rev/tooth

Ac = plan area of cut =cross section of chip

$Ac= w\times d$

w =width of work piece being cut =75mm

d = depth of cut

Ac= 15sq.mm

A=feed length for cutter to reach full depth = Af =area of tool flank face

$A = \sqrt{((D-d)\times d)}=\sqrt{((25-0.25)\times 0.25)}=2.487$mm

Cutting Forces in Orthogonal Cutting

Fh=horizontal force component parallel to cutting velocity

Fv=vertical force component normal to Fh

Fs=force component parallel to shear plane

Fp= force component normal to Fs

Ft= force component parallel to tool rake face

Fn= force component normal to Ft

$F_S=R\cos(\emptyset+\beta-\alpha)$

$F_h=R\cos(\beta-\alpha)$

$F_n=R\cos(\beta)$

$F_V=R\sin(\beta-\alpha)$

$F_S=R\sin(\emptyset+\beta-\alpha)$

$F_t=R\sin\beta$

WHERE

$R=(t.b.K)/\sin[\emptyset\cos(\emptyset+\beta-\alpha)]$

Where k= yield stress of material in shear =325Mpa

Thrust Force Calculation

$F_t=\mu[(HA_c)/3(\cot\emptyset/\sqrt{3}+1)]+A_f(0.62H\sqrt{(43H/E)})$

$A_c=w\times d=15$sq.mm

w = 75mm=width of work piece being cut

d=depth of cut=0.25

A= A_f=area of tool flank face = 2.487

$A=\sqrt{((D-d)d)}$

Where D = cutter dia

d=depth of cut

$A=\sqrt{((25-0.25)0.2)}\ 5$

$A = A_f=2.487$

μ=friction angle=tan [β=0.8]

Where β=90

H=hardness of the work piece = 341

Density = 0.000007850 J/goC

E=young's modulus of work piece =207000 Mpa

$F_t=0.8[(341\times 15)/3(\cot 5.781/\sqrt{3}+1)]+2.487(0.62\times 341\sqrt{((43\times 341)/207000)})$

$F_t=64650.93$N

CONCLUSION:

In this thesis, experiments are conducted to improve the surface finish quality of a work piece by using carbide tips. The type of tip is bull nose tip. A series of experiments is done by varying the milling parameters spindle speed, feed rate. The experiments are conducted on vertical milling machine of make Chenho. The work piece materials are alloy steel EN24 and EN36.

Two sets of each work piece material are machined by specifying following parameters: Feed rates of 700mm/min, 980mm/min, 1400mm/min, 1900mm/min and 2600mm/min, Spindle speeds of 2000rpm, 1800rpm, 2100rpm, and 2000rpm. By observing the experimental results, for EN24 material machining at 2600mm/min feed rate and spindle speed of 2000rpm yields better results as the surface finish is good.

For material EN36 machining at 1900mm/min and 2000rpm yields better results as the surface finish is good.Theoretical calculations are done to calculate the thrust force and torque. Structural analysis is also done to verify the strength and modeling is done in ANN