IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 5 (Sep. - Oct. 2013), PP 38-47
www.iosrjournals.org

Cutting Parameters Optimization in Milling Of P – 20 Tool Steel And EN31B

M. Yaswanth Kumar, Dr. G. Shankaraiah
1 (Mechanical Engineerig,G.Pulla Reddy Engineerig College (Autonomous) /J Ntu Anantapur , India)
2 (Mechanical Engineerig,G.Pulla Reddy Engineerig College (Autonomous) /J Ntu Anantapur , India)

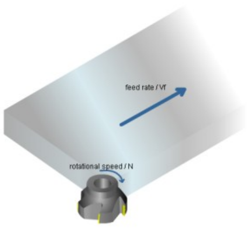
Abstract: *The objective of the paper is to obtain an optimal setting of CNC machining process parameters, cutting speed, feed rate resulting in optimal values of the feed and radial forces while machining P – 20 tool steel and EN31B with TiN coated tungsten carbide inserts. The effects of the selected process parameters on the chosen characteristics and the subsequent optimal settings of the parameters have been accomplished using Taguchi's parameter design approach.The process parameters considered are – Cutting speed 3000rpm, 2500rpm and 2000rpm. Feed rate 200mm/min, 300mm/min and 400mm/min and depth of cut is 0.2mm.The effect of these parameters on the feed force, radial force are considered for analysis.The analysis of the results shows that the optimal settings for low values of feed and radial forces are high cutting speed, low feed rate and depth of cut.The thrust force and feed force are also taken experimentally using dynamometer for above Cutting speeds, feed rate and depth of cut. The optimal values for speed, feed rate and depth of cut are taken using Taguchi technique.**Taguchi methods** are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to, engineering, biotechnology, marketing and advertising.Process used in this project is milling process. Machine selected is Vertical milling center. Machine model selected is BFW Agni 45. Modeling is done in Pro/Engineer and analysis is done in ANSYS.*
Keywords: *Cutting parameters, CNC machining process, feed force, Radial force, Taguchi approach, P – 20 Tool steel, Coated carbide inserts.*

I. Introduction

Milling is the process of cutting away material by feeding a work piece past a rotating multiple tooth cutter. The cutting action of the many teeth around the milling cutter provides a fast method of machining. The machined surface may be flat, angular, or curved. The surface may also be milled to any combination of shapes. The machine for holding the work piece, rotating the cutter, and feeding it is known as the **Milling machine.**

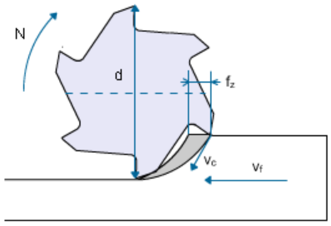
1.1 Cutting And Feed Movements :

Milling is a forming operation whereby chips are removed using a cutting tool known as a "milling cutter". This has several cutting edges laid out around its axis of rotation, and is subjected both to a rotational movement and a feed motion. This type of operation is carried out on what is called a milling machine.



1.2 Cutting Parameters

A milling operation is characterised by the following parameters:
a_p: Axial engagement of the tool, also known as the axial pass depth in mm.
a_e: Radial engagement of the tool in mm.
N: Rotational speed in rev min^{-1}.
v_c: Cutting speed in m min^{-1}.
f_z: Feed per tooth in mm $tooth^{-1}$.
v_f: Feed rate in mm min^{-1}.
Q: Material removal rate in cm^3 min^{-1}



1.3 Tool Geometry

The choice of tool for a milling operation is dependent on several criteria:

The shape of the part to be produced
The type of alloy
The range: Rough, finish
The characteristics of the machine
The quantity of parts (price)

Aluminium alloy milling operations can be classified into two categories of application:

Where the volume of material to be removed is very high (e.g.: aeronautical parts, die holders).
Where the machining time (chip-to-chip time) is short but the number of different operations is high (e.g.: automotive).

PCD insert milling cutters *Monolithic milling cutters* *Solid milling cutter*

1.4 Insert Geometry:

In general, carbide manufacturers offer inserts that are specifically designed for the cutting of aluminium: a very positive cutting angle, with high sharpness (sharp edge).The shape and dimensions of the inserts are coded according to ISO 1832-1991 standard.

II. Literature Survey

To provide satisfaction to the customer and to stand in the competitive market, the producer has to acknowledge that considerable advantage can be obtained by controlling quality at the design stage instead of controlling quality at the manufacturing stage or through the inspection of final products. This is the basic idea of off-line quality control and the Taguchi's method is one of the most comprehensive and effective systems of off-line quality control.

Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. Taguchi's robust parameter design strategy provides a powerful and efficient method for designing products and processes that operate consistently and optimally over a variety of conditions. Robust design is capable of (i) making product performance insensitive to raw material variation, thus allowing the use of lower grade alloys and components in most cases; (ii) making designs robust against manufacturing variations, thus reducing labor and material cost for rework and scrap; (iii) making the design least sensitive to the variation in operating environment, thus improving reliability and reducing operating cost; and (iv) using a new structured development process so that engineering time is used more productively

Taguchi has built upon Deming's observation that 85% of poor quality is attributable to the manufacturing process and only 15% to the worker. Thus, his attempt has been to develop robust manufacturing systems that are insensitive to daily and seasonal variations of environment, machine wear, etc.

Taguchi recommends a three-stage process to achieve desirable product quality by design-system design, parameter design and tolerance design. While system design helps to identify the working levels of the design parameters, parameter design seeks to determine the parameter levels that produce the best performance of the product or process under study. The optimum condition is selected so that the influence of uncontrollable factors (noise factors) causes minimum variation to system performance. The orthogonal arrays, variance and signal to noise analysis are the essential tools of parameter design. Tolerance design is a step to fine-tune the results of parameter design.

III. Introduction To Cutting Tools

Cutting is the separation of a physical object, or a portion of a physical object, into two portions, through the application of an acutely directed force. An implement commonly used for cutting is the knife or in medical cases the scalpel. However, any sufficiently sharp object is capable of cutting if it has a hardness sufficiently larger than the object being cut, and if it is applied with sufficient force. Cutting also describes the action of a saw which removes material in the process of cutting.

3.1 Cutting Tools

A **cutting tool** (or **cutter**) is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, plaining and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Grinding tools are also multipoint tools. Each grain of abrasive functions as a microscopic single-point cutting edge (although of high negative rake angle), and shears a tiny chip.

3.2 Types

Linear cutting tools include tool bits (single-point cutting tools) and broaches. Rotary cutting tools include drill bits, countersinks and counterbores, taps and dies, milling cutters, and reamers. Other cutting tools, such as bandsaw blades and fly cutters, combine aspects of linear and rotary motion.

3.3 Cutting Tool Inserts

Cutting tools are often designed with inserts or replaceable tips (tipped tools). In these, the cutting edge consists of a separate piece of material, either brazed, welded or clamped on to the tool body. Common materials for tips include tungsten carbide, polycrystalline diamond, and cubic boron nitride. Tools using inserts include milling cutters (endmills, fly cutters), tool bits, and saw blades.

3.4 Materials

To produce quality parts, a cutting tool must have three characteristics:

- Hardness — hardness and strength at high temperatures.
- Toughness — toughness, so that tools don't chip or fracture.
- Wear resistance — having acceptable tool life before needing to be replaced.

Cutting tool materials can be divided into two main categories: stable and unstable.

Unstable materials (usually steels) are substances that start at a relatively low hardness point and are then heat treated to promote the growth of hard particles (usually carbides) inside the original matrix, which increases the overall hardness of the material at the expense of some its original toughness. Since heat is the mechanism to alter the structure of the substance and at the same time the cutting action produces a lot of heat, such substances are inherently unstable under machining conditions.

Stable materials (usually tungsten carbide) are substances that remain relatively stable under the heat produced by most machining conditions, as they don't attain their hardness through heat. They wear down due to abrasion, but generally don't change their properties much during use.

3.5 Construction

Cutting tools that rotate often have the following features:

Flute :

A recessed portion of the tool's cross-section that conveys chips away from a cutting edge as the tool rotates. In the common twist drill, two flutes are usually provided, one for each cutting edge. Taps and end mills may have up to six or more cutting edges and flutes.

IV. Milling Cutter

Milling cutters are cutting tools used in milling machines or machining centres. They remove material by their movement within the machine (eg: a ball nose mill) or directly from the cutters shape (a form tool such as a Hobbing cutter).

Types Of Milling Cutters:
End mill, Slot drill, Roughing end mill, Ball nose cutter, Slab mill, Side-and-face cutter, Involute gear cutter, Hob Face mill, Fly cutter, Woodruff cutter, Hollow mill, Dovetail cutter, Bull nose end mill.

Introduction To P20 Hot Work Tool Steel
Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion, their ability to hold a cutting edge, and/or their resistance to deformation at elevated temperatures (red-hardness). Tool steel is generally used in a heat-treated state.Tool steels are also used for special applications like injection molding because the resistance to abrasion is an important criterion for a mold that will be used to produce hundreds of thousands of parts.

Physical Properties	**Metric**
Density	7.81 g/cc
Mechanical Properties	**Metric**
Hardness, Brinell	290 – 341
Tensile Strength, Ultimate	1010 MPa
Tensile Strength, Yield	800 MPa
Modulus of Elasticity	205 GPa
Compressive Yield Strength	850 - 1000 MPa
Charpy Impact	5.02 - 10.0 J

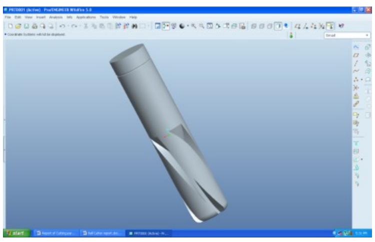
Thermal Properties	**Metric**
CTE, linear	12.6 µm/m-°C
Specific Heat Capacity	0.460 J/g-°C
Thermal Conductivity	29.0 W/m-K

V. Introduction To Cad And Pro/Engineer

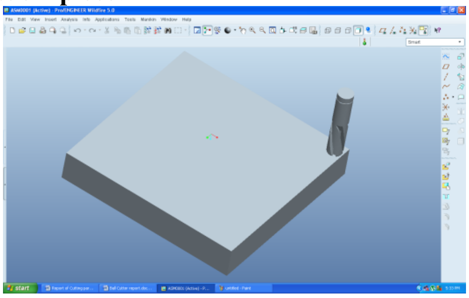
Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.
CADD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.
CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects.

VI. Models

Model Of Cutting Tool:

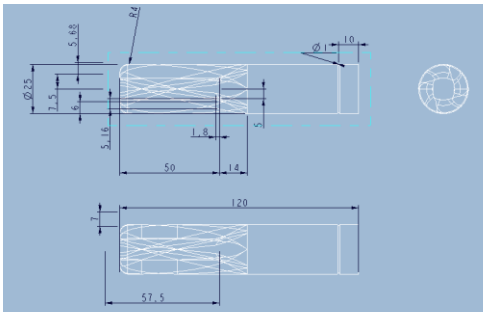


Assembly Of Cutting Tool And Workpiece:

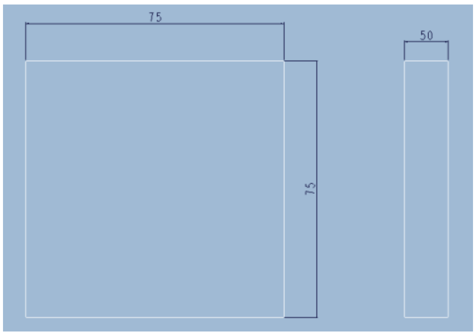


6.3 2d Drawings

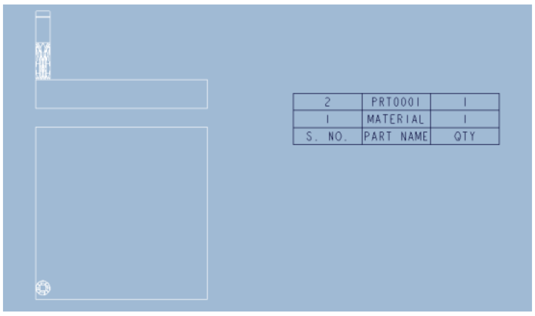
6.3.1 Cutting Tool



6.3.2 Work Piece



6.3.3assembly



VII. Equations

Thrust Force And Torque Calculations:

Material – P 20 Tool Steel:

Cutter dia = 25R5

Width of Workpiece = 75mm

No of Teeth on cutter = 4 = n_c

Depth of Cut = d = 0.2mm

Width of Cut = b = 5mm

Width of chip = b_c = 5mm

V = Cutting Velocity

r_t = Chip Thickness Ratio

$r_t = \frac{t}{tc} = \frac{vc}{v} = \frac{lc}{l}$

L_C = Length of Chip = 7mm

L = Uncut Chip Length = 75mm
$\propto$ = Rake Angle = 20°
β = Friction Angle = 40
$\emptyset$ = Shear Angle

Speeds (rpm)	Feed(mm/min)
1. 3000	200
2. 2500	300
3. 2000	400

Chip Thickness Ratio

$r_t = \frac{t}{tc} = \frac{vc}{v} = \frac{L_C}{L}$

$r_t = \frac{L_c}{L} = \frac{7}{75} = 0.090$

Shear Angle ($\emptyset$)

$\text{Tan}\ \emptyset = \frac{r_t \cos\propto}{1-r_t \sin\propto}$

$\text{Tan}\ \emptyset = \frac{0.093\ \cos 20}{1-0.093\ \sin 20}$

$\emptyset = 5.1427$

To Calculate Thrust Force

$\text{Ft} = \mu\ [\frac{HA_c}{3}\ (\frac{Cot\,\emptyset}{\sqrt{3}} + 1)] + A_F(0.62H\sqrt{\frac{43H}{E}})$

A_C = Cross – Section of Chip, A_f = Area of Tool Flank Face
$\emptyset$ = Shear Angle , μ = Friction Coefficient on Rake Face
H = Hardness of w/p, E = Young's Modulus of w/p

Cutting speed (V)= $\frac{\pi DN}{1000}$m/min
Where D=cutter dia =25mm
N= spindle speed = 3000rpm, V=cutting speed

Feed per tooth of cutter
$f_t = \frac{F}{(n_c \times N)}$ mm/rev/tooth
n_c = no.of cutting edges or teeth on cutter = 4
F = 200mm/min= table feed
A_c = 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, A_c= 15sq.mm,
A=feed length for cutter to reach full depth = A_f=area of tool flank face =73.0026mm
$A = \sqrt{(D-d)\times d} = \sqrt{(25-0.2)\times 0.2} = 2.227mm$

CUTTING FORCES IN ORTHOGONAL CUTTING

F_h=horizontal force component parallel to cutting velocity
F_v=vertical force component normal to F_h
F_s=force component parallel to shear plane
F_p= force component normal to F_s
F_t= force component parallel to tool rake face
F_n= force component normal to F_t

$F_S = R\cos(\emptyset+\beta-\alpha)$
$F_h = R\cos(\beta-\alpha)$
$F_n = R\cos(\beta)$
$F_V = R\sin(\beta-\alpha)$
$F_S = R\sin(\emptyset+\beta-\alpha)$
$F_t = R\sin\beta$

where

$$R = \frac{t.b.K}{\sin\emptyset\cos(\emptyset+\beta-\alpha)}$$

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

7.1.1 THRUST FORCE CALCULATION

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

d=depth of cut=0.2
$\mu = friction\ angle = \tan\beta = 0.8$
Where $\beta = 90$
H=hardness of the work piece = 70
Density = 0.000008 Kg/m^3
E=young's modulus of work piece =200000 Mpa

7.1.2 SHEAR PLANE TEMPERATURE

$$\theta_s = \frac{\lambda E_s}{J\rho_w C_w} + \theta_i$$

θ_i=initial temperature of work material =33°C
λ =factor representing the fraction of heat retained by the chip
assume $\lambda = 1$
J = heat equivalent of mechanical energy = 4200J
ρ_w =density of work material= 0.00000781 kg/mm^3
C_w=specific heat of work material = 0.46 J/g°C

$$E_S = \frac{K\cos\alpha}{\sin\emptyset\cos(\emptyset-\alpha)}$$

7.1.3 TORQUE

Torque = $F_t \times \frac{D}{2}$
D= cutter diameter in mm
$\theta_1 = \beta$
$\theta_2 = \emptyset + 2\beta - \alpha$
$\theta_3 = \emptyset + \beta - \alpha$

Tangential force

$F_t = z_s.k_s.f_c.w$
Z_s = Number of teeth symmetrically engaged with work piece.
Specific cutting force:

$$Ks = \frac{T_C Cos\alpha Ac}{Cos\,(\emptyset-\alpha)} + \frac{T_F Cos\alpha Sin\beta Af}{Cos\,(\emptyset+\beta-\alpha) Cos\,(\emptyset-\alpha)}$$

Specific Cutting Force:

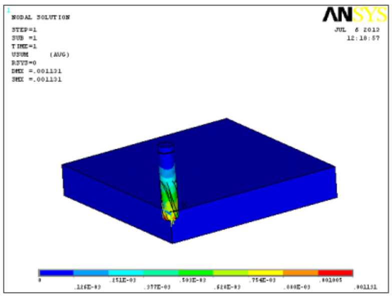
$$T_C = \frac{Thrust\ Force}{Area}$$

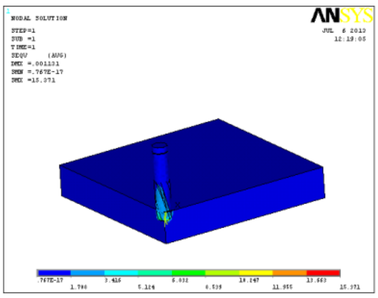
$f_c = \frac{57.3}{\theta 3} \times f_t \times$ Sin A($\mathrm{Cos}\theta 1 - Cos\theta 2$), A = Approach angle = 20°

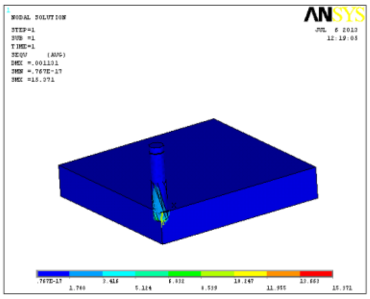
VIII. Strucutral Analysis

P20_TOOL STEEL

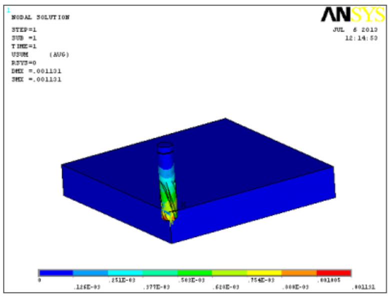
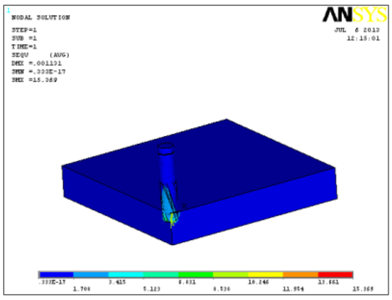
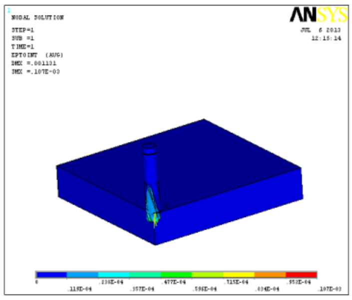
SPEED – 2500rpm, Feed – 300mm/min







Speed – 2000rpm, Feed- 200mm/min

EN31B TOOL

IX. Results Table
Structural Analysis
P20 Steel

SPEED – rpm
Feed – mm/min
Displacement – mm
Stress – N/mm^2

	DISPLACEMENT (mm)	VON MISSES STRESS (N/mm^2)	TOTAL STRAIN
SPEED -3000,FEED-200	0.001131	15.369	0.777E-04
3000, FEED -300	0.001131	15.373	0.107E-03
3000, FEED -400	0.001131	15.377	0.107E-03

	DISPLACEMENT	VON MISSES STRESS	TOTAL STRAIN
SPEED -2500,FEED-200	0.001131	15.369	0.107E-04
2500 , FEED 300	0.001131	15.371	0.107E-03
2500,FEED -400	0.001131	15.374	0.107E-03

	DISPLACEMENT	VON MISSES STRESS	TOTAL STRAIN
SPEED -2000 FEED -200	0.001131	15.369	0.777E-04
2000 ,FEED -300	0.001131	15.372	0.107E-03
2000 ,FEED -400	0.001131	15.375	0.107E-03

EN31B TOOL

	DISPLACEMENT (mm)	VON MISSES STRESS (N/mm^2)	TOTAL STRAIN
SPEED -3000, FEED -200	0.005672	51.369	0.367E-03
3000, FEED -300	0.005672	51.37	0.367E-03
3000, FEED -400	0.005672	51.371	0.367E-03

	DISPLACEMENT	VON MISSES STRESS	TOTAL STRAIN
SPEED -2500, FEED -200	0.005672	51.37	0.367E-03
2500, FEED -300	0.005672	51.371	0.367E-03
2500, FEED -400	0.005672	51.373	0.367E-03

	DISPLACEMENT	VON MISSES STRESS	TOTAL STRAIN
SPEED -2000,FEED -200	0.005672	51.37	0.367E-03
2000, FEED -300	0.005672	51.373	0.367E-03
2000,FEED -400	0.005672	51.376	0.367E-03

DYNAMIC ANALYSIS
P20 STEEL
SPEED 3000rpm, FEED 200mm/min

	DISPLACEMENT	VON MISSES STRESS	TOTAL STRAIN
10 SEC	0.01027	29.913	0.608E-04
20 SEC	0.00213	31.066	0.159E-03
30 SEC	0.00305	83.319	0.195E-03

EN31 B
SPEED 3000rpm, FEED 200 mm/min

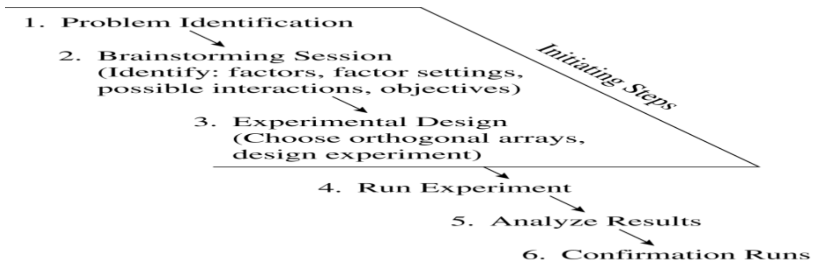
	DISPLACEMENT	VON MISSES STRESS	TOTAL STRAIN
10 SEC	0.001878	26.053	0.177E-03
20 SEC	0.003574	49.556	0.353E-03
30 SEC	0.005322	75.93	0.535E-03

X. Introduction To Taguchi Technique

- Taguchi defines Quality Level of a product as the Total Loss incurred by society due to failure of a product to perform as desired when it deviates from the delivered target performance levels.
- This includes costs associated with poor performance, operating costs (which changes as a product ages) and any added expenses due to harmful side effects of the product in use

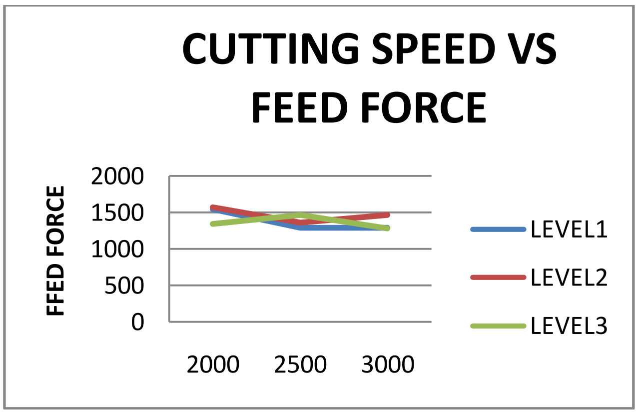
Taguchi Methods

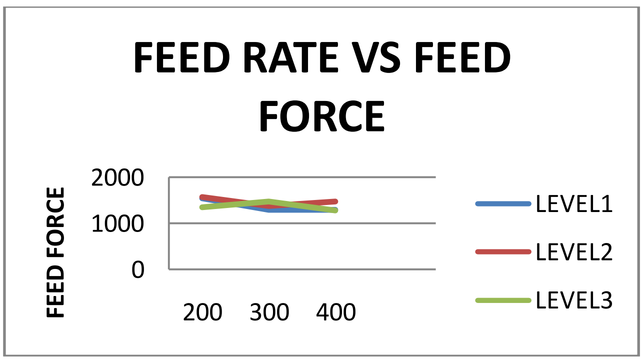
- Help companies to perform the Quality Fix!
- Quality problems are due to Noises in the product or process system
- Noise is any undesirable effect that increases variability
- Conduct extensive Problem Analyses
- Employ Inter-disciplinary Teams
- Perform Designed Experimental Analyses
- Evaluate Experiments using ANOVA and Signal-to noise techniques



XI. epresentation Of Graphs Of Cutting Speed And Feed Rate On Feed Force

MATERIAL - P20





XII. Conclusion

At present, EN31B is mostly used for dies. Nowadays P20 Tool Steel is being considered for dies. In this thesis, the effect of cutting parameters on materials P 20 Tool Steel and EN31B while machining is optimized. Different values of cutting parameters are also considered.

The parameters considered are cutting speed, feed rate and depth of cut. The cutting speeds are 3000rpm, 2500rpm and 2000rpm. The feed rates are 200mm/min, 300mm/min and 400mm/min and depth of cut is 0.2mm. Thrust Force and Torque are calculated for all the parameters. Structural and Dynamic analyses are done by applying thrust force and torque. From the analysis results, the displacement and stress values are less for all speeds and for both the materials. The stress values are very less compared with their yield stress values. By comparing the results for P 20 Tool Steel and EN31B, the stress values are less for P20 Tool Steel. So we can conclude that using P20 tool steel for die casting process is suitable.

Feed force and radial forces are taken experimentally using dynamometer by considering parameters cutting speed, feed rate and depth of cut. The optimal values for speed, feed rate and depth of cut are taken using Taguchi technique.

The optimal settings of various process parameters for CNC machining of P 20 Tool Steel to yield optimal forces are: Speed – 2500rpm and Feed rate – 300mm/min when thrust force is taken (i.e.) feed force and when torque (i.e.) radial force is taken the optimal values are Speed – 2000rpm and Feed rate – 200mm/min.
The optimal settings of various process parameters for CNC machining of EN31B to yield optimal forces are: Speed – 3000rpm and Feed rate – 400mm/min when thrust force is taken (i.e.) feed force and when torque (i.e.) radial force is taken the optimal values are Speed – 2000rpm and Feed rate – 200mm/min.

Future Scope

The literature survey reveals that the machining of difficult machine materials like P-20 tool steel is relatively a less researched area. There is also a complete dearth of interaction studies on the subject. Because of the high cost of numerically controlled machine tools compared to their conventional counterparts, there is an economic need to operate these machines as efficiently as possible in order to obtain the required payback. Cryogenic cooling (using liquid nitrogen as a coolant) during machining is also a relatively less researched area.

More researches have to be done on the machining of P – 20 tool steel. There is also scope of performing experiments about the implementation of Taguchi's technique.

References

[1]. Cutting tool applications by George Schneider
[2]. Valery Marinov, Manufacturing by Jr.CMFJE
[3]. Machining Technology Machine Tools and Operations by HELMI A. YOUSSEF
[4]. Fundamentals of Machine Tools by PYE
[5]. Park S H, Robust design and analysis for quality engineering (Chapman and Hall, London), 1996.
[6]. Unal R & Dean E B, *Taguchi approach to designoptimization for quality and cost: An Overview*, Proc 13th Annual Int Soc of Parametric Analyst, 1991.
[7]. 3 Phadke M S, *Quality engineering using robust design*(Prentice Hall, Engleewood Cliffs, NJ), 1989.
[8]. Montgomery D C, *Design and analysis of experiments* (John Wiley & Sons, New York), 1997.
[9]. Thomas M, Beaucbamp Y, Youssef Y A & Masounave I, *lnt J Qual Sci*, 2 (1997) 167-180.
[10]. Yang W H & Tarng Y S, *J Mater Process Technol*, 84 (1998) 112-129.