Optimization of Process Parameters for Milling of Nickel Alloy Inconel 625 by using Taguchi Method

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Abstract

Metal cutting is one of the most significant manufacturing processes in the area of material removal. Black 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 will be conducted to improve the surface finish quality of a nickel alloy Inconel 625 work piece by using carbide tips. The type is bull nose tip. A series of experiments will be done by varying the milling parameters spindle speed, feed rate and depth of cut. The spindle speeds are 3000rpm, 2500rpm and 2000rpm. The feed rates are 200mm/min, 300mm/min and 400mm/min. Depth of cut is 0.2mm and 0.3mm. Structural analysis will be also done to verify the strength. Modeling will be done in Pro/Engineer and analysis will be done in Ansys.

Taguchi method is used to study the effect of process parameters and establish correlation among the cutting speed, feed and depth of cut with respect to the major machinability factor, surface finish. Validations of the modeled equations are proved to be well within the agreement with the experimental data.

I. LITERATURE SURVEY

In the paper by Dražen Bajić, etal [1], examines the influence of three cutting parameters on surface roughness, tool wear and cutting force components in face milling as part of the off-line process control. The experiments were carried out in order to define a model for process planning. Cutting speed, feed per tooth and depth of cut were taken as influential factors. In the paper by K. Adarsh Kumar, etal[2], Surface finish is one of the prime requirements of customers for machined parts. The purpose of this research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in facing by regression analysis. In the paper by H. K. Dave, etal[3], presents on experimental investigation of the machining characteristics of different grades of EN materials in CNC turning process using TiN coated cutting tools. In the paper by B. Sidda Reddy, etal[4], minimization of surface roughness has been investigated by integrating design of experiment method, Response surface methodology (RSM) and genetic algorithm. In the paper by Yang Yang, etal [5], a method based on gene expression programming (GEP) has been proposed to construct the prediction model of surface roughness. GEP combines the advantages of the genetic algorithm (GA) and genetic programming (GP).

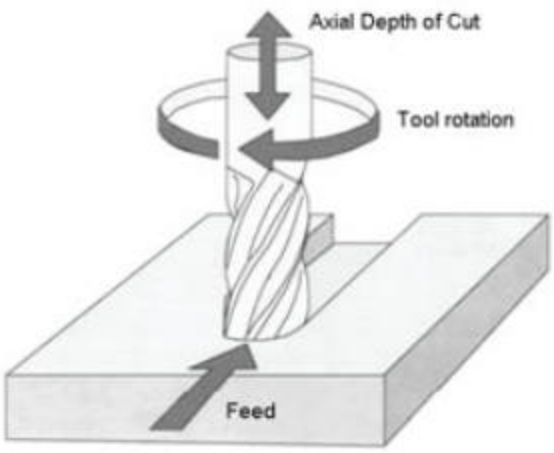
II. EXPERIMENTAL SETUP AND PROCEDURE

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.

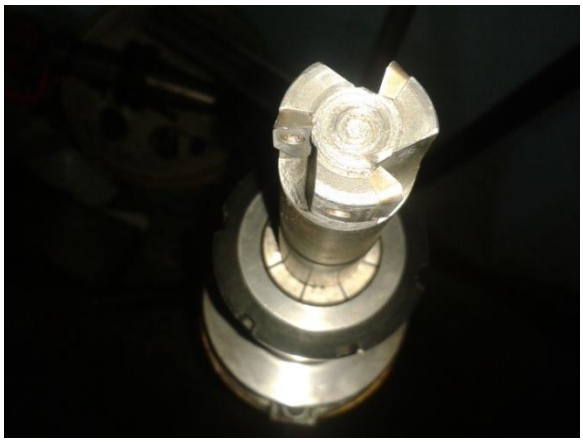
The main aim of the project is to determine the influence of radius carbide tips in metal working. The investigation is based on surface roughness during milling of Nickel alloy Inconel 625 with carbide tool. The cutting parameters considered are feed rate, spindle speed and depth of cut.

This experiment employed a CNC vertical milling machine. Carbide cutting tool is used. The experiment has been done under conditions of feed rate 200mm/min, 300mm/min, 400 mm/min. Spindle speeds are 2000rpm, 2500rpm, 3000rpm, and depth of cut 0.2mm and 0.3mm,

Square pieces of Inconel 625 material are taken for machining.



CARBIDE TOOL



EXPERIMENTAL RESULTS

S.NO.	FEED	RPM	DEPTH OF CUT (mm)	Surface finish (R_a) µm
1.	200	2000	0.2	3.36+2.80/2=3.08
2.	300	2000	0.2	3.12+2.71/2=2.915
3.	400	2000	0.2	3.05+2.55/2=2.8
4.	200	2500	0.2	2.87+2.64/2=2.755
5.	300	2500	0.2	2.39+2.02/2=2.205
6.	400	2500	0.2	1.61+1.1/2=1.355
7.	200	3000	0.3	1.34+1.09/2=1.215
8.	300	3000	0.3	1.16+1.02/2=1.09
9.	400	3000	0.3	1.08+1.01/2=1.045

OPTIMIZATION OF PARAMETERS FOR SURFACE FINISH

TAGUCHI PARAMETER DESIGN FOR MILLING PROCESS

In order to identify the process parameters affecting the selected machine quality characteristics of turning, the following process parameters are selected for the present work: cutting speed (A), Feed Rate (B) and Depth of Cut (C). The selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

Selection of Orthogonal Array

The process parameters and their values are given in table. It was also decided to study the two – factor interaction effects of process parameters on the selected characteristics while turning. These interactions were considered between Cutting speed and Feed Rate (AXB), Feed Rate and Depth of cut (BXC), Cutting speed and Depth of cut (AXC).

FACTORS	PROCESS PARAMETERS	LE VEL1	LEVEL2	LEVEL3
A	Cutting Speed(rpm)	2000	2500	3000
B	Feed Rate (mm/min)	200	300	400
C	Depth of cut(mm)	0.2	0.2	0.2

TAGUCHI ORTHOGONAL ARRAY

JOB NO.	Spindle Speed (rpm)	Feed Rate (mm/min)	DEPTH OF CUT (mm)
1	2000	200	0.2
2	2000	300	0.2
3	2000	400	0.2
4	2500	200	0.2
5	2500	300	0.2
6	2500	400	0.2
7	3000	200	0.2
8	3000	300	0.2
9	3000	400	0.2

OBSERVATION

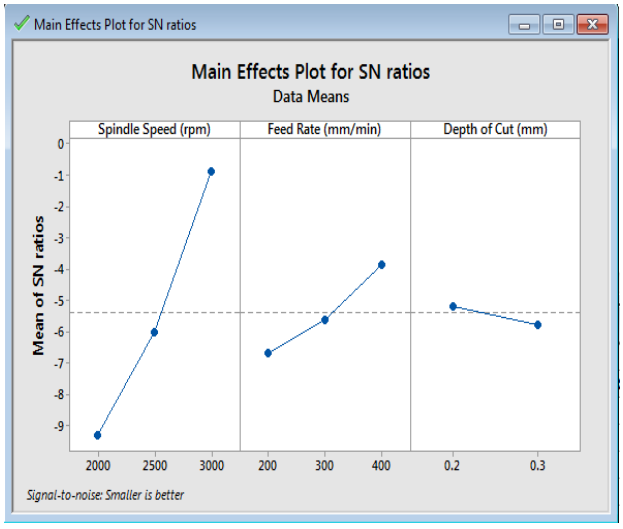
The following are the observations made by running the experiments three times. The surface finish values measured experimentally.

SURFACE FINISH VALUES

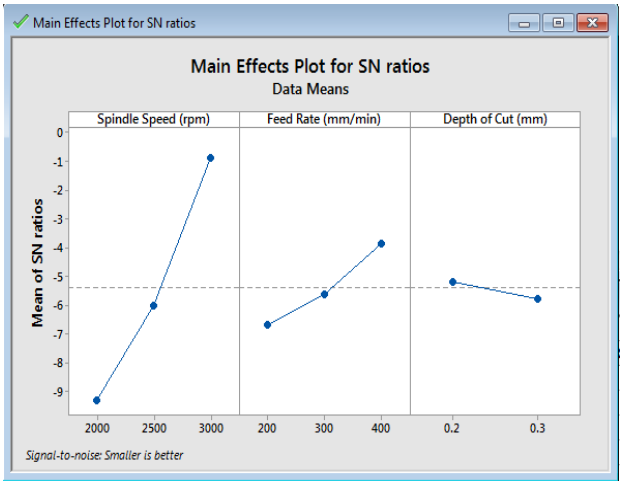
TRAIL 1	TRAIL 2
3.08	3.07
2.915	2.913
2.8	2.78
2.755	2.7
2.205	2.195
1.355	1.3
1.215	1.2
1.09	1.08
1.045	1.02

OPTIMIZATION OF PARAMETERS FOR BETTER SURFACE FINISH USING MINITAB SOFTWARE

RESULTS



Effect of milling parameters on surface roughness for S/N ratio



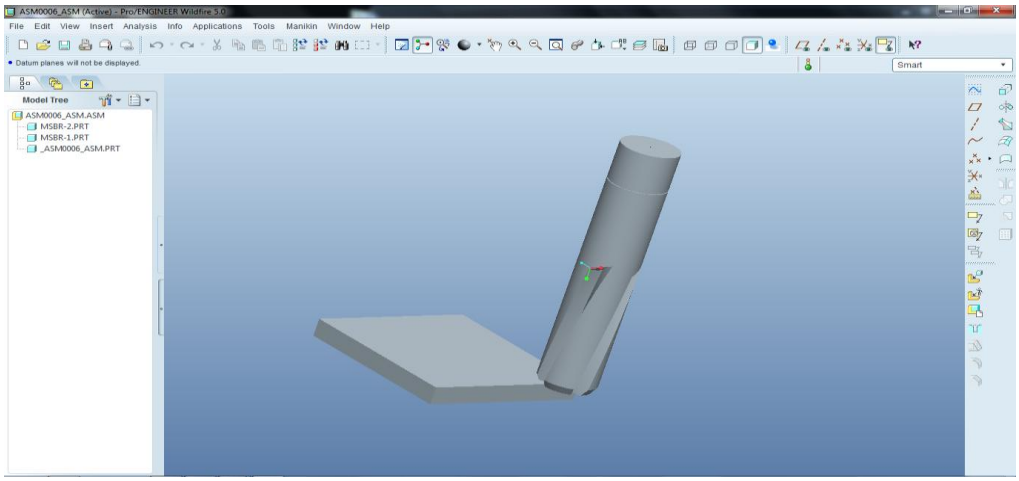
Effect of milling parameters on surface roughness for S/N ratio

Cutting Speed :- The effect of parameters cutting speed on the surface roughness values is shown above figure for S/N ratio. The optimum cutting speed is level 3 i.e. 3000rpm.

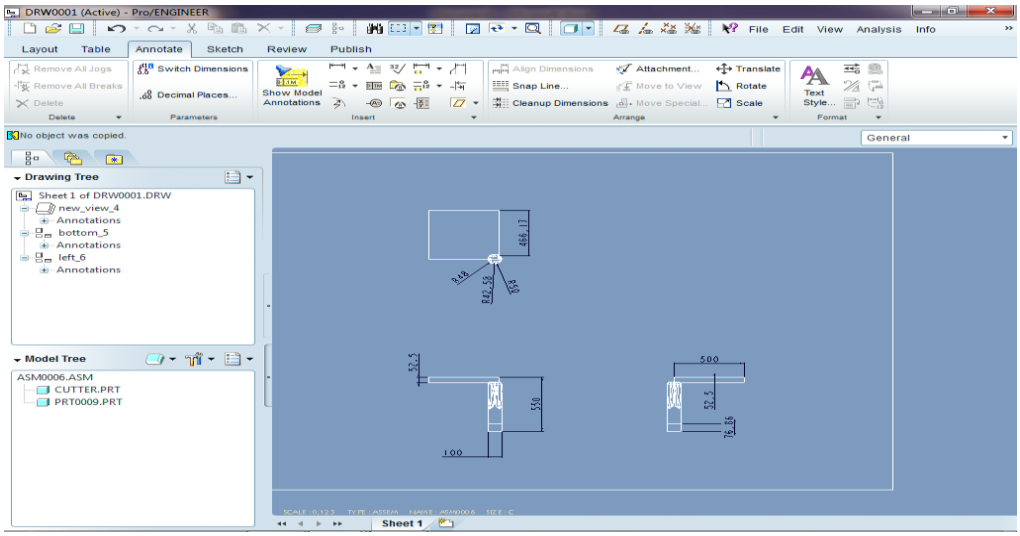
Feed Rate :- The effect of parameters friction speed on the surface roughness values is shown above figure S/N ratio. The optimum feed rate is level 3 i.e. 400mm/min.

Depth of cut :- The effect of parameters surface roughness on the surface roughness t values is shown above figure for S/N ratio. The optimum depth of cut is level 1 i.e. 0.2mm.

3D MODEL OF ASSEMBLY OF WORKPIECE AND CUTTER



2D DRAWING



CALCULATIONS OF CUTTING FORCE AND TORQUE

Ap = depth of cut

n=spindle speed

V_f =feed rate (table feed)

α = rake angle

^{Dcap} =cutter dia

No .of teeth on cutter

a_e= working engagement

a)i)n=3000rpm, v_f =200 mm/min

$D_{cap}= D_c + \frac{2 \times ap}{tankr}$

Feed for tooth

$F_Z=\frac{V_f}{n \times z_c}$

$Q = \frac{ap \times ae \times vf}{1000}$

$a_e = \sqrt{(Dc - ap) \times ap}$

Torque $M_c = \frac{pc \times 30 \times 10^3}{\pi \times n}$

$P_c = \frac{a_p \times a_e \times v_f \times k_c}{60 \times 10^6}$

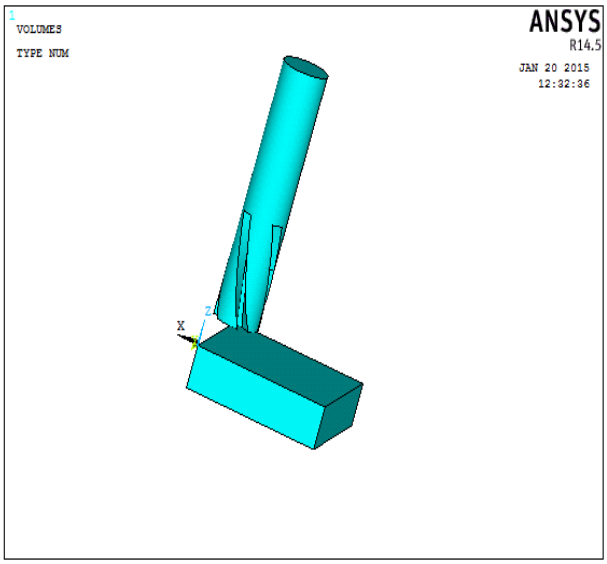
$H_m = \frac{360 \times \sin kr \times a_e \times f_z}{\pi \times \text{Dcap} \times \text{arc cost } (1 - \frac{2 \times ae}{Dcap})}$

K_r = entering angle

Cutting force $K_c = k_{c1}\, H\text{m}^{-mc} \times (1 - \frac{\gamma_0}{100})$

STRUCTURAL ANALYSIS INCONEL 625
PRESSURE – 0.188N/mm^2

Import IGES model



Work piece material:

Young's Modulus (EX) : 160000Mpa

Poisson Ratio (PRXY) : 0.329

Density : 0.00000844 kg/mm^3

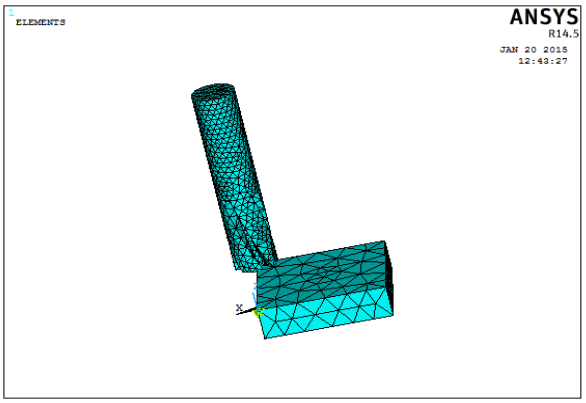
Cutting material:

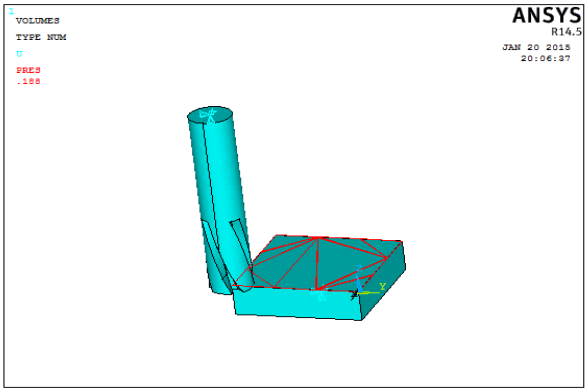
Young's Modulus (EX) : 590000Mpa

Poisson Ratio (PRXY) : 0.19

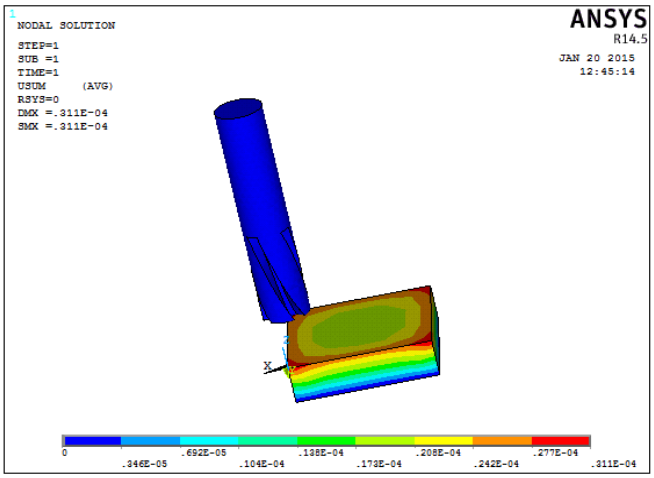
Density : 0.0000148 kg/mm^3

Meshed model

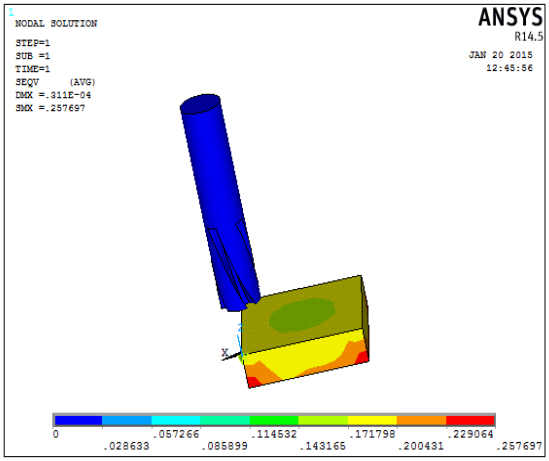




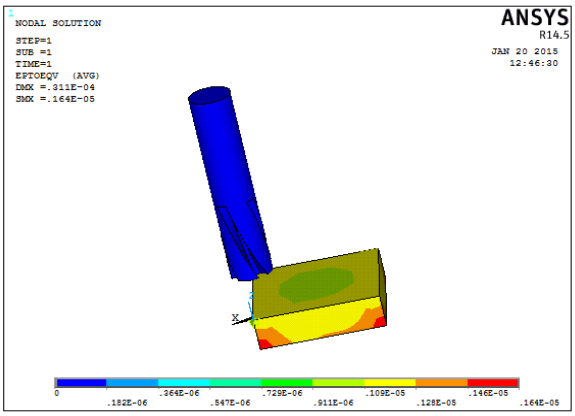
Displacement



Stress



Strain



RESULTS SUMMERY

	Displacement (mm)	Stress (N/mm^2)	Strain
Pressure 0.188 N/mm^2	0.311E-04	0.25769	0.164E-05
Pressure 0.153N/mm^2	0.253E-04	0.209721	0.133E-05
Pressure 0.133 N/mm^2	0.220E-04	0.182307	0.116E-05
Pressure 0.027 N/mm^2	0.447E-05	0.03701	0.236E-06
Pressure 1.4 N/mm^2	0.232E-03	1.91902	0.122E-04
Pressure 1.213 N/mm^2	0.201E-03	1.66269	0.106E-04
Pressure 1.530 N/mm^2	0.253E-03	2.09721	0.133E-04
Pressure 1.249 N/mm^2	0.207E-03	1.71204	0.109E-04
Pressure 1.0816N/mm^2	0.179E-03	1.48258	0.944E-05

CONCLUSION

In this paper, experiments are conducted to improve the surface finish quality of Inconel 625 work piece by using carbide tips. The type of tip is bull nose tip. A series of experiments are done by varying the milling parameters spindle speed, feed rate. The experiments are conducted on vertical milling machine of make Chenho. The work piece material is machined by specifying following parameters:

Feed rates of 200mm/min, 300mm/min, 400mm/min Spindle speeds of 2000rpm, 2500rpm, 3000rpm and depth of cut 0.2mm and 0.3mm. By observing the experimental results, for Inconel 625 material machining at 400mm/min feed rate and spindle speed of 3000rpm yields better results as the surface finish is good. The optimization of parameters is done using taguchi technique. By observing the S/N ratio, the optimum parameters are spindle speed 3000rpm, feed rate 400mm/min and depth of cut 0.2mm.

Theoretical calculations are done to calculate the thrust force and torque. Structural analysis is also done to verify the strength. Modeling is done in Pro/Engineer and analysis is done in Ansys. The stress values are less than the yield strength of work piece.

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