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Taguchi Optimization Technique for Cutting Parameters of High Speed Turning of Inconel 718 by using Cubic Boron Nitride and Alumina Ceramic KY 1615

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Abstract – Alloy Inconel 718, a nickel based superalloy, developed initially for use in rotating parts in aerospace and gas turbine applications, has become the preferred material for the manufacture of Wellhead Components, Auxiliary and Down Hole Tools and Sub-Surface Safety Valves. Super alloy Inconel 718 is widely used in sophisticated applications due to its unique properties desired for the engineering applications. Due to its peculiar characteristics machining of Super alloy Inconel 718 is difficult and costly. The present work is an attempt to make use of Taguchi optimization technique to optimize cutting parameters during high speed turning of Inconel 718 using Cubic Boron Nitride and Alumina Ceramic KY 1615. The cutting parameters are cutting speed, feed rate and depth of cut for turning of work piece material Super Alloy Inconel 718. In this work, the optimal parameters are cutting speed, feed rate and depth of cut. The parametric model of cutting tool and work piece assembly is done in Pro/Engineer and analysis is done in Ansys. The cutting parameters considered are Cutting Speed – 2000rpm,3500rpm and 5500rpm, Feed Rate – 250mm/min,500mm/min and750mm/min and Depth of Cut is0.3mm,0.6mm and 0.9mm. Taguchi method is a powerful design of experiments (DOE) tool for engineering optimization of a process. It is an important tool to identify the critical parameters and predict optimal settings for each process parameter. 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, cutting forces such as cutting force and feed force. Validations of the modeled equations are proved to be well within the agreement with the experimental data. Process used in this project is turning process. Modeling is done in Pro/Engineer and analysis is done in ANSYS.

Index Terms – Cutting force, Feed force, Chip analysis, Taguchi method.

1. INTRODUCTION

1.1. Introduction to Turning

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical toolpath by moving more or less linearly while the work piece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the nonmathematical sense). Usually the term "turning" is reserved for the generation of *external* surfaces by this cutting action, whereas this same essential cutting action when applied to *internal* surfaces (that is, holes, of one kind or another) is called "boring". Thus the phrase "turning and boring" categorizes the larger family of (essentially similar) processes. The cutting of faces on the work piece (that is, surfaces perpendicular to its rotating axis), whether with a turning or boring tool, is called "facing", and may be lumped into either category as a subset.

1.2. Introduction to Cad and Pro/Engineer

Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modelling of products and components.

There are several good reasons for using a CAD system to support the engineering design

Function:

- To increase the productivity
- To improve the quality of the design
- To uniform design standards
- To create a manufacturing data base

Created by Dr. Samuel P. Geisberg in the mid-1980s, Pro/ENGINEER was the industry's first successful parametric, 3D CAD modeling system. The parametric modeling approach uses parameters, dimensions, features, and relationships to capture intended product behavior and create a recipe which enables design automation and the optimization of design and product development processes.

2. CHAPTER II

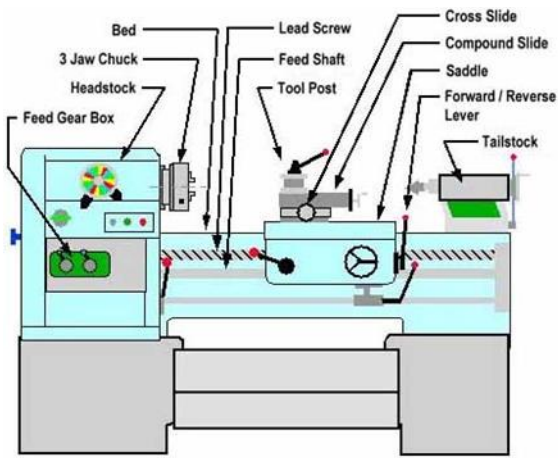

Fig 1. Example of a Typical Centre Lathe

2.1. Cutting Tools

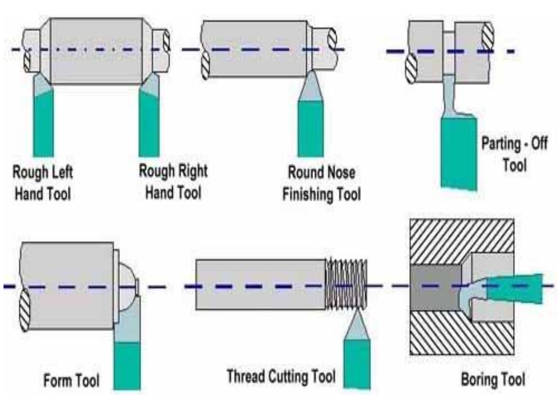

Figure 2 Types of Cutting Tool

The tool used in a lathe is known as a single point cutting tool. It has one cutting edge or point whereas a drill has two cutting edges and a file has numerous points or teeth.

The lathe tool shears the metal rather than cuts as will be seen later and it can only do so if there is relative motion between the tool and the workpiece. For example, the work is rotating and the tool is moved into its path such that it forms an obstruction and shearing takes place. Of course the amount of movement is of paramount importance - too much at once could for instance result in breakage of the tool.

2.2. 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

Parameter Design:

Tests For Levels Of Parameter Values

- Selects "Best Levels" For Operating Parameters to be Least Sensitive to Noises
- Develops Processes Or Products That Are Robust
- A Key Step To Increasing Quality Without Increased Cost

Tolerance Design:A "Last Resort" Improvement Step

- Identifies Parameters Having the greatest Influence On Output Variation
- Tightens Tolerances On These Parameters
- Typically Means Increases In Cost

Selecting Parameters for Study and Control

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- Select The Quality Characteristic
- Define The Measurement Technique
- Ennumerate, Consider, And Select The Independent Variables And Interactions
- Brainstorming
- Shainin's technique where they are determined by looking at the products

FMEA – failure mode and effects analysis

Preliminary Steps in Improvement Studies

- To Adequately Address The Problem At Hand We Must:

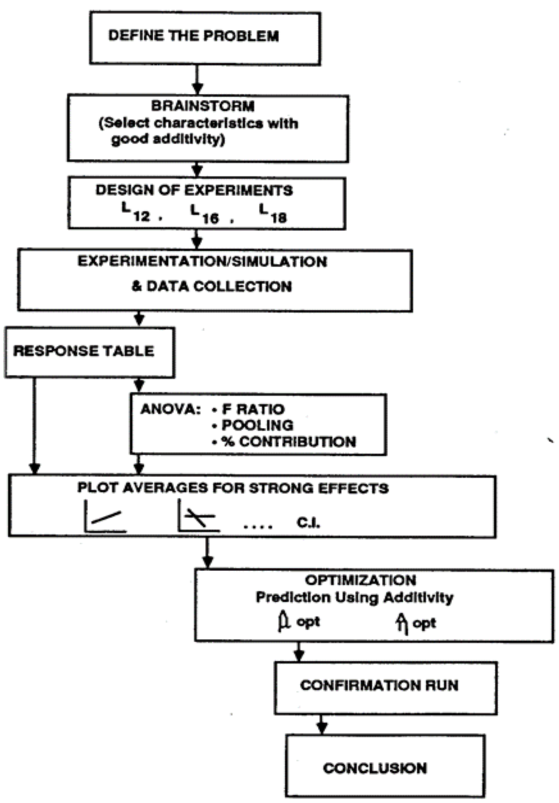
1. Understand Its Relationship With The Goals We Are Trying To Achieve

2. Explore/Review Past Performance compare to desired Solutions

3. Prepare An 80/20 Or Pareto Chart Of These Past Events

4. Develop A "Process Control" Chart -- This Helps To Better See The Relationship between Potential Control And Noise Factors

- A Wise Person Can Say: A Problem Well Defined Is *Already* Nearly Solved!!



3. CHAPTER III

3.1. Work Piece – Inconel 718, Cutting Tool – Alumina Ceramic Ky 1615

MATERIAL PROPERTIES

WORK PEICE-

YOUNG MODULUS- 200GPa

POISSON'S RATIO - 0.294

DENSITY- 8.19 g/cc

CUTTING TOOL – AL CERMIC KY 1615

YOUNG MODULUS – 351.63 GPa

POISSON'S RATIO - 0.22

DENSITY- 0.0000023 kg/mm

CUTTING PARAMETERS

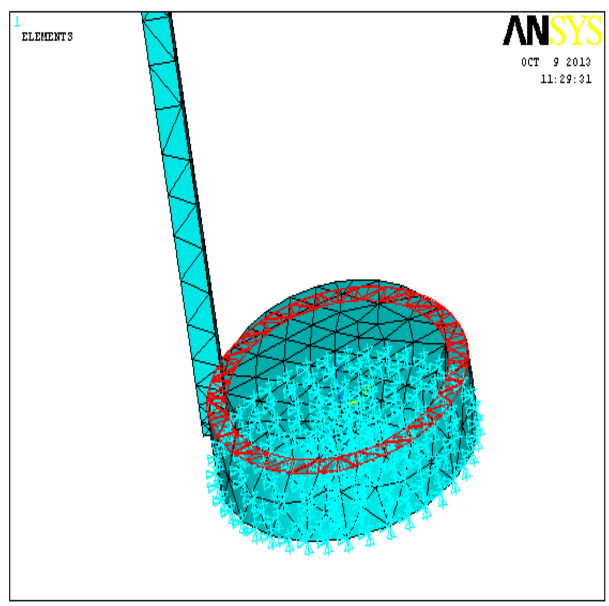
CUTTING SPEED-2000rpm

FEED RATE- 750mm/min

DEPTH OF CUT-0.9mm

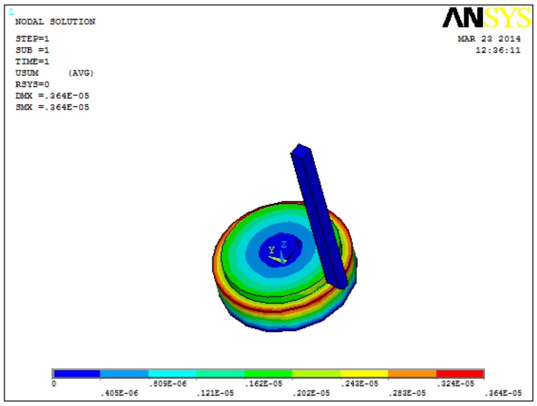
Loads- define loads- apply- structural- displacement – on Areas-ok

Pressure –on Areas- 0.0189 N/mm^2-ok.

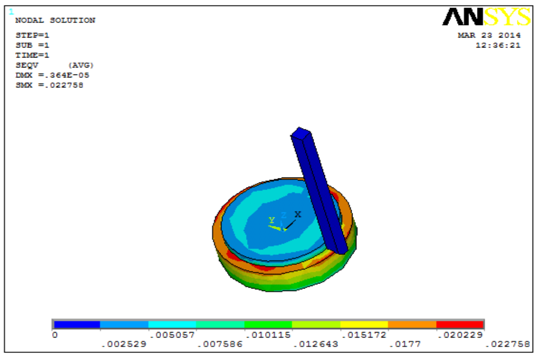


Solution- solve – current l.s – ok

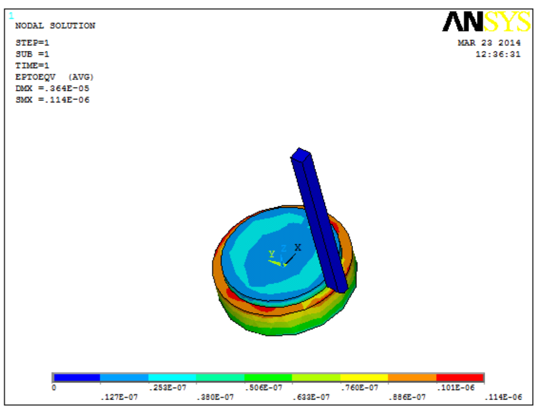
General postprocessor-plot results- contour plots- nodal solutions- displacement vector sum-ok



General postprocessor-plot results- count our plots nodal solution- stress- von mises stress



General postprocessor-plot results- contour plots nodal solution- strain- total strain intensity



CUTTING PARAMETERS

CUTTING SPEED-3500rpm

FEED RATE- 250mm/min

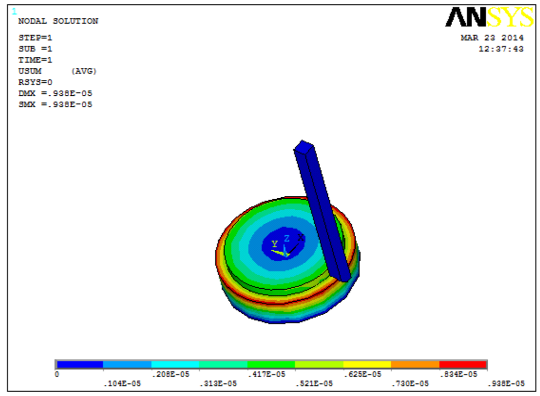
DEPTH OF CUT-0.6 mm

Loads- define loads- apply- structural- displacement – on Areas-ok

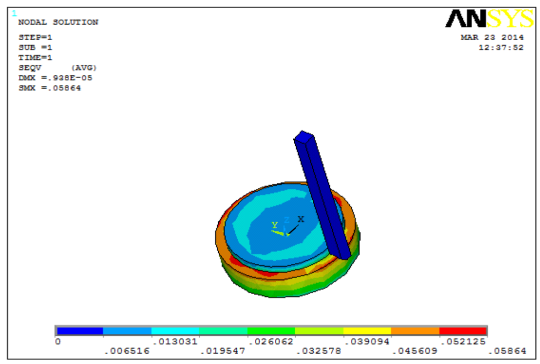
Pressure –on Areas- 0.0487 N/mm^2-ok.

Solution- solve – current l.s – ok

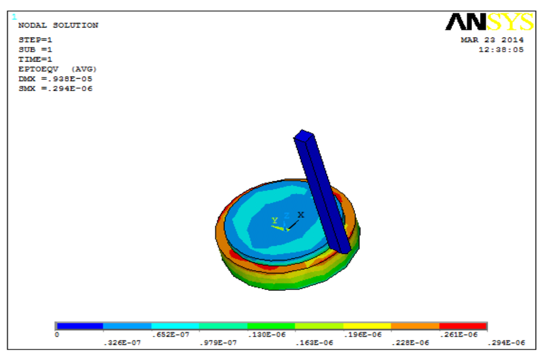
General postprocessor-plot results- contour plots- nodal solutions- displacement vector sum-ok



General postprocessor-plot results- count our plots nodal solution- stress- von mises stress



General postprocessor-plot results- contour plots nodal solution- strain- total strain intensity



CUTTING PARAMETERS

CUTTING SPEED-5500rpm

FEED RATE- 500mm/min

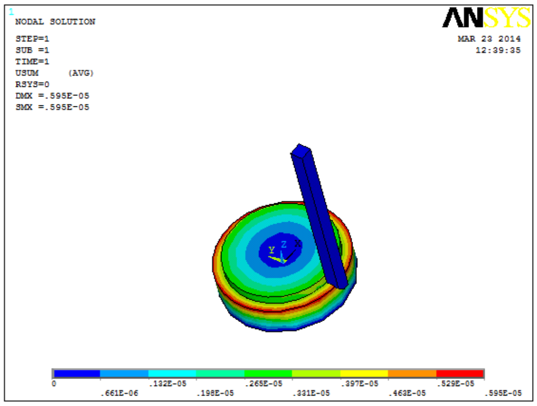
DEPTH OF CUT-0.3mm

Loads- define loads- apply- structural- displacement – on Areas-ok

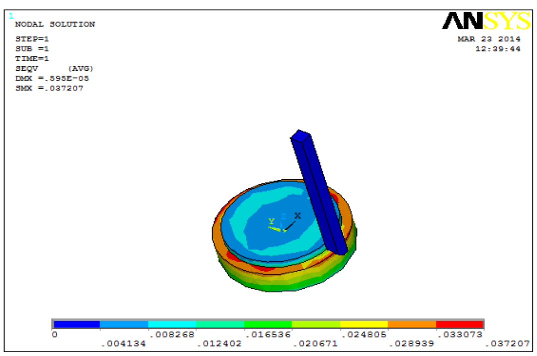
Pressure –on Areas- 0.0309 N/mm^2-ok.

Solution- solve – current l.s – ok

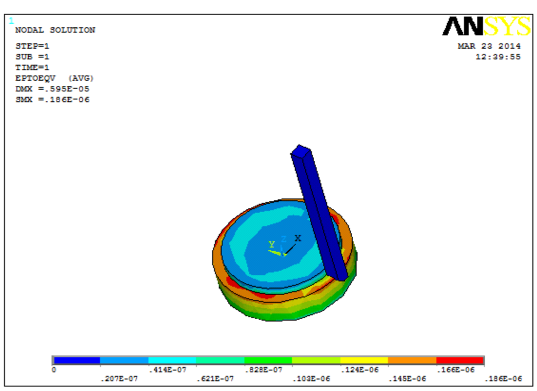
General postprocessor-plot results- contour plots- nodal solutions- displacement vector sum-ok



General postprocessor-plot results- count our plots nodal solution- stress- von misses stress



General postprocessor-plot results- contour plots nodal solution- strain- total strain intensity



4. CHAPTER-4

Results Table

4.1 Cutting Tool – Tungsten Carbide

	Displacement (mm)	Stress (N/mm^2)	Strain
CUTTING SPEED-2000rpm FEED RATE-250mm/min DEPTH OF CUT-0.3mm	$0.327 e^{-04}$	0.204699	$0.102 e^{-05}$
CUTTING SPEED-3500rpm FEED RATE-500mm/min DEPTH OF CUT-0.9mm	$0.328 e^{-05}$	0.019266	$0.965 e^{-07}$
CUTTING SPEED-5500rpm FEED RATE-750mm/min DEPTH OF CUT-0.6mm	$0.199 e^{-05}$	0.012438	$0.623 e^{-07}$

4.2. Cutting Tool – Cubic Boron Nitride

	Displacement (mm)	**Stress (N/m m^2)**	**Strain**
CUTTING SPEED-2000rpm FEED RATE-500mm/min DEPTH OF CUT-0.6mm	$0.821 e^{-05}$	0.051295	$0.257 e^{-06}$
CUTTING SPEED-3500rpm FEED RATE-750mm/min DEPTH OF CUT-0.3mm	0.039013	$0.195 e^{-06}$	$0.624 e^{-05}$
CUTTING SPEED-5500rpm FEED RATE-250mm/min DEPTH OF CUT-0.9mm	$0.397 e^{-05}$	0.024805	$0.124 e^{-06}$

4.3. Cutting Tool – Alumina Ceramic Ky 1615

	Displacement (mm)	**Stress (N/mm^2)**	**Strain**
CUTTING SPEED-2000rpm FEED RATE-7250mm/min DEPTH OF CUT-0.9mm	$0.364 e^{-05}$	0.022758	$0.114 e^{-06}$

CUTTING SPEED-3500rpm FEED RATE-250mm/min DEPTH OF CUT-0.6mm	0.938 e^{-05}	0.05864	0.294 e^{-06}
CUTTING SPEED-5500rpm FEED RATE-500mm/min DEPTH OF CUT-0.3mm	0.595 e^{-05}	0.037207	0.186 e^{-06}

5. CONCLUSION

In this thesis, the effect of parameters cutting speed, feed rate and depth of cut while turning of Nickel alloy Inconel 718 are formulated mathematically using three different cutting tools

Tungsten carbide,Alumina Ceramic KY1615 and Cubic Boron Nitride. A parametric model of cutting tool and work piece is designed using 3D modeling software Pro/Engineer.

Experimental investigations are done to determine the cutting forces. By observing the results, spindle speed of 5500rpm, feed rate of 750mm/min and depth of cut 0.6mm yields better results as the cutting forces are less. The cutting tool is Tungsten Carbide.

Analytical investigations are made on the model by applying the forces by taking different values of cutting speed, feed rate and depth of cut. The parameters considered are: Spindle Speed – 2000rpm,3500, 5500rpm; Feed Rate – 250mm/min, 500mm/min,750mm/min;

Depth of Cut – 0.3mm,0.6mm,0.9mm.Tool Material-TC,CBN,AC. Structural Analysis is done in ANSYS.

By observing the structural analysis results, the analyzed stress values are less than the yield stress values of the respective materials for all speeds and feed rates. The displacement values are also very less.

And also while using Tungsten Carbide as cutting tool, the optimal parameters are 5500rpm, feed rate 750mm/min and 0.6mm depth of cut has less stress values.

While using Cubic Boron Nitride as cutting tool, the optimal parameters are 5500rpm, feed rate 250mm/min and 0.9mm depth of cut has less stress values.

And also while using Alumina Ceramic as cutting tool, the optimal parameters are 2000rpm, feed rate 450mm/min and 0.9mm depth of cut has less stress values.

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