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# Optimization of Cutting Parameters in High Speed Turning of Nickel Alloy

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*Abstract* – **Inconel 718 is one of the important alloys among all the Nickel and Nickel based alloy Inconel 718 has found its niche in many industries, owing to its unique properties. Inconel 718 material is widely used in as aircraft engine parts, steam turbine power plants, space vehicles, But due to peculiar characteristics such as lower thermal conductivity, work hardening, presence of abrasive carbide particles it difficult to machine, Cost effective machining with generation of good surface finish on the Inconel 718 components during turning operation is a challenge to the manufacturing engineers in practice. Considering all the above facts the present work aims to study the influence of different cutting parameters like cutting speed, feed rate and depth of cut of super alloy Inconel 718 and AISI 52100 Steel during high speed turning. Test results were analyzed to determine the better parameters for optimal cutting during high speed machining of Inconel 718 cubic boron nitride tool. A parametric model of cutting tool and work piece is designed using 3D modelling software Pro/Engineer. Analytical investigations are to be made on the model by applying the forces by taking different values of cutting speed, feed rate and depth of cut. Analysis is done in Ansys.**

*Keywords:* **ANSYS, Cutter material is cubic boron nitride, Inconel 718, Optimal parameters (cutting speed, feed rate and depth of cut), ProE**

## I. INTRODUCTION

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path 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). Super alloy, Inconel 718 is one of the important alloys among all the Nickel and Nickel based alloy. Inconel 718 has found its niche in many industries, owing to its unique properties. Inconel 718 material is widely used in as aircraft engine parts, steam turbine power plants, space vehicles, medical applications, marine applications, pollution control equipment, automotive sector etc. But due to peculiar characteristics such as lower thermal conductivity, work hardening, presence of abrasive carbide particles, hardness, affinity to react with tool material etc. makes it difficult to machine. Hence, it is classified as "Difficult-to-cut materials". Cost effective machining with generation of good surface finish on the Inconel 718 components during turning operation is a challenge to the manufacturing engineers in practice. Since machining is basically a finishing process with specified dimensions, tolerances and surface finish, the type of surface that a machining operation generates and its characteristics are of great importance in manufacturing. Carbide cutting tools are the oldest amongst the hard cutting tool materials. Tungsten carbides are mainly used for continuous cutting operations Carbide tools are used to machine nickel-base super alloys in the speed range of 10–30 m/min. However, with the increasing demand to achieve fast material removal rate and better surface quality.

## II. LITERATURE REVIEW

### A. *Turning*

Turning is one of the most common of metal cutting operations. In turning, a work piece is rotated about its axis as single-point cutting tools are fed into it, shearing away unwanted material and creating the desired part. Turning can occur on both external and internal surfaces to produce an axially-symmetrical contoured part. Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC.

### *B. Cutting Theory*

The usual conception of cutting suggests clearing the substance apart with a thin knife or wedge. When metal is cut the action is rather different and although the tool will always be wedge shaped in the cutting area and the cutting edge should always be sharp the wedge angle will be far too great for it to be considered knife shaped. Consequently a shearing action takes place when the work moves against the tool. Fig shows a tool being moved against a fixed work piece. When the cut is in progress the chip presses heavily on the top face of the tool and continuous shearing takes place across the shear plane AB. Although the Figure shows a tool working in the horizontal plane with the work piece stationary, the same action takes place with the work piece revolving and the tool stationary.

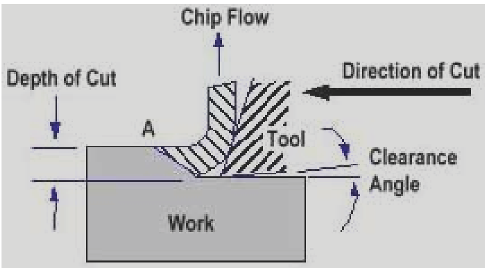

Fig.1 Basic Metal Cutting Theory

### *C. Characteristics of tool material*

For efficient cutting a tool must have the following properties:

***1. Hot Hardness:*** This means the ability to retain its hardness at high temperatures. All cutting operations generate heat, which will affect the tools hardness and eventually its ability to cut.

***2. Strength and Resistance to Shock****:* At the start of a cut the first bite of the tool into the work results in considerable shock loading on the tool. It must obviously be strong enough to withstand it.

***3. Low Efficient of Friction :*** The tool rubbing against the workpiece and the chip rubbing on the top face of the tool produce heat which must be kept to a minimum.

### *D.Tool materials in common use*

***1. High Carbon Steel*** Contains 1 - 1.4% carbon with some addition of chromium and tungsten to improve wear resistance. The steel begins to lose its hardness at about 250°C, and is not favoured for modern machining operations where high speeds and heavy cuts are usually employed.

***2. High Speed Steel (H.S.S.):*** Steel, which has a hot hardness value of about 600° C, possesses good strength and shock resistant properties. It is commonly used for single point lathe cutting tools and multi point cutting tools such as drills, reamers and milling cutters.

***3. Cemented Carbides:*** An extremely hard material made from tungsten powder. Carbide tools are usually used in the form of brazed or clamped tips. High cutting speeds may be used and materials difficult to cut with HSS may be readily machined using carbide tipped tool.

**E. Tool life** As a general rule the relationship between the tool life and cutting speed is

VTn = C

where;

V = cutting speed in m/min

T = tool life in min

C = a constant

For high-speed steel tools the value of C ranges from 0.14 to 0.1 and for carbide tools the value would be 0.2.

## III. Methodologies

a. The effect of parameters cutting speed, feed rate and depth of cut while turning of AISI 52100 steels are formulated mathematically. The cutting parameters considered are spindle speed – 216rpm, 347rpm and 536rpm, feed rate – 0.388mm/rev, 0.418mm/rev and 0.458mm/rev, depth of cut – 0.9mm, 1mm, 1.1mm.

b. A parametric model of cutting tool and work piece is designed using 3D modelling software Pro/Engineer.

c. Analytical investigations are to be made on the model by applying the forces by taking different values of cutting speed, feed rate and depth of cut. Analysis is done in Ansys.

## IV. FINITE ELEMENT ANALYSIS

FEA is now an extremely sophisticated tool for solving numerous engineering problems and is widely accepted in many branches of industry. It is a numerical technique for finding approximate solutions to boundary value problems. Finite Element Analysis is used to solve numerically the governing equations for stress within the wall material. The solutions provide a complete stress distribution in the saddle supports.

### *A. Finite Element Model*

It operates under the circumstances of ANSYS APDL Technology. We created the complete solid models of the pressure vessel and saddle support. The pressure vessel is filled with liquid and is subjected to the operating weight. Map meshing is done to the complete solid model. The scope of analysis is limited to study the stresses for saddle support region under defined loading conditions. Appropriate extents of support saddles located at sliding and fixed side are considered for application of displacement boundary condition.

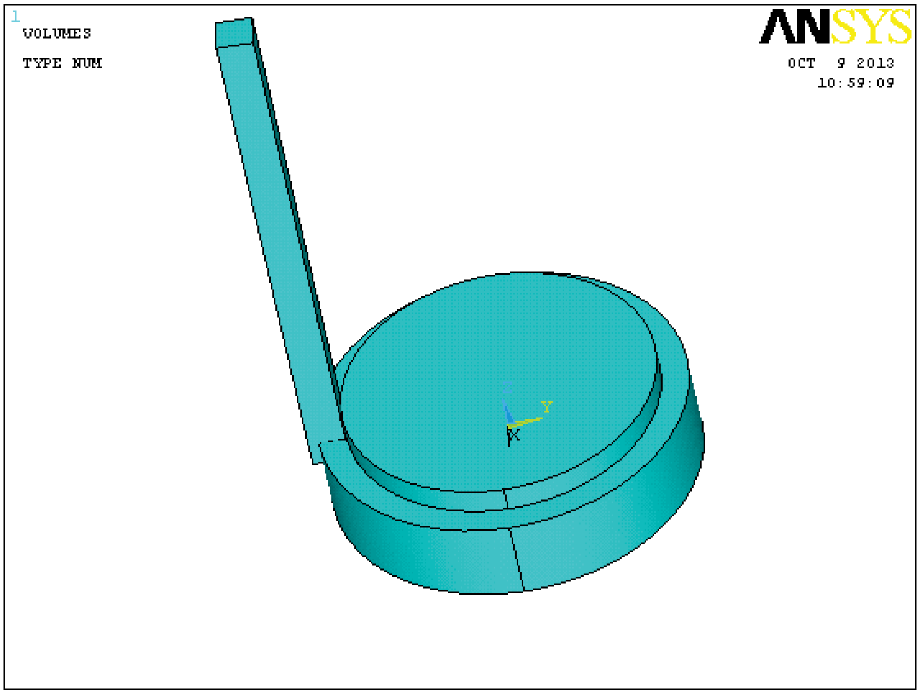

Fig. 2 Assembly of cutting tool and work piece

### *B. Boundary conditions*

Cutter material-Cubic Boron Nitride

Feed- 250mm/min, Speed- 2000rpm

Material Properties

Work piece –Inconel 718

Young modulus- 200GPa

Poisson’s ratio-0.294

Density- 8.19g/cc

Depth of cut- 0.9mm

### *C. Mesh Model*

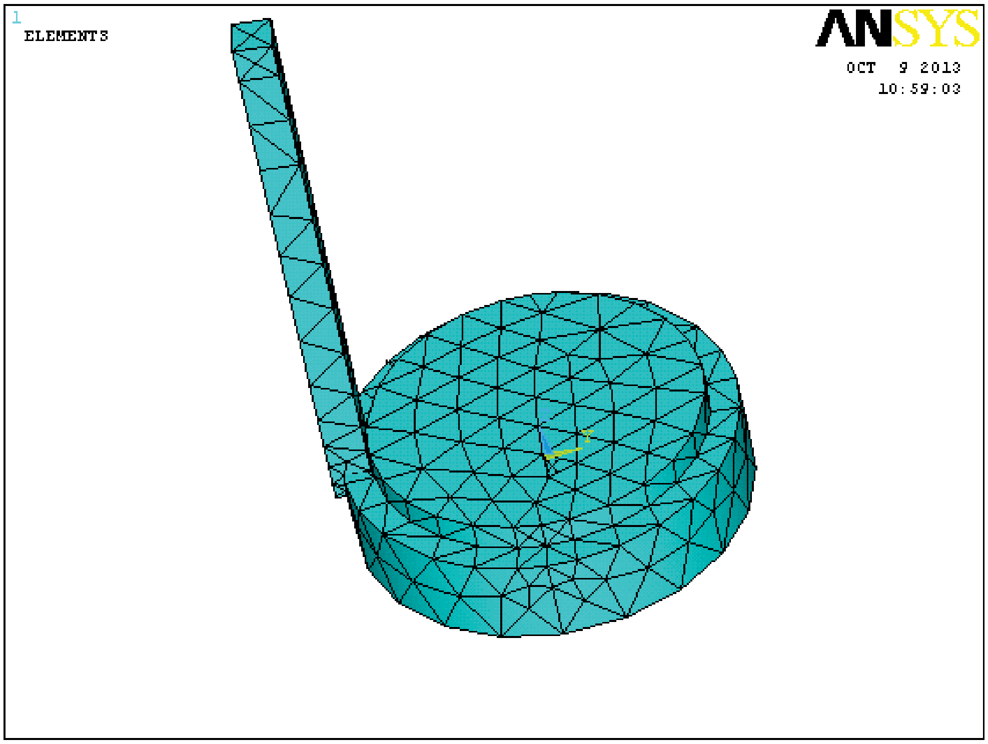

Fig.3 Mapped mesh of assembly

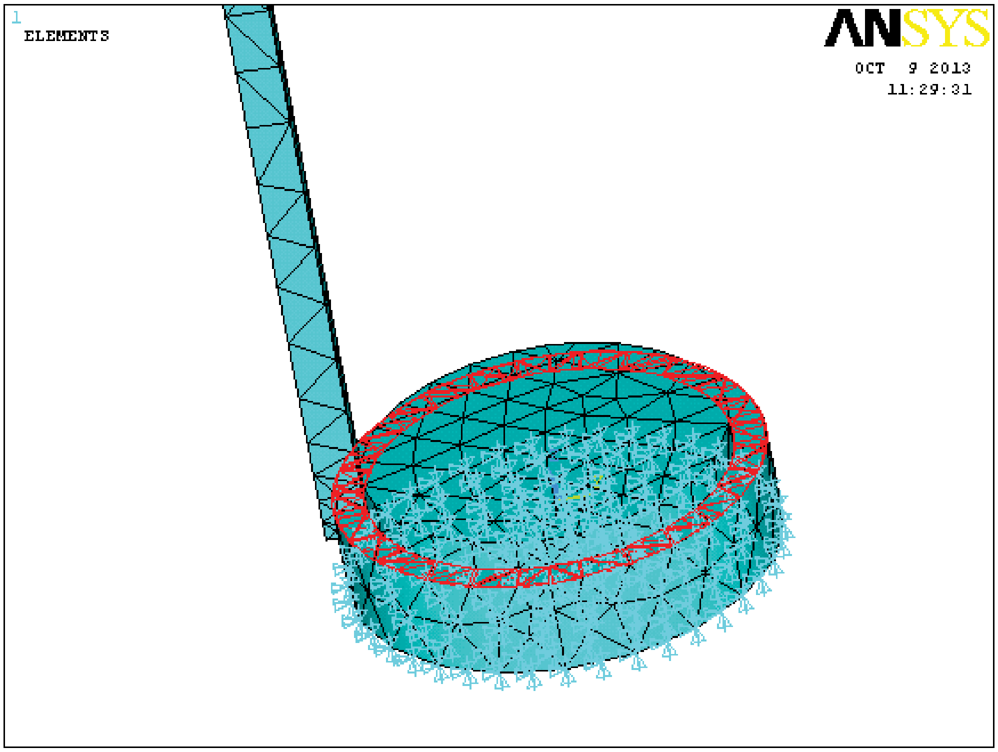

Fig.4 Boundary conditions of assembly

### *D. Optimization Analysis*

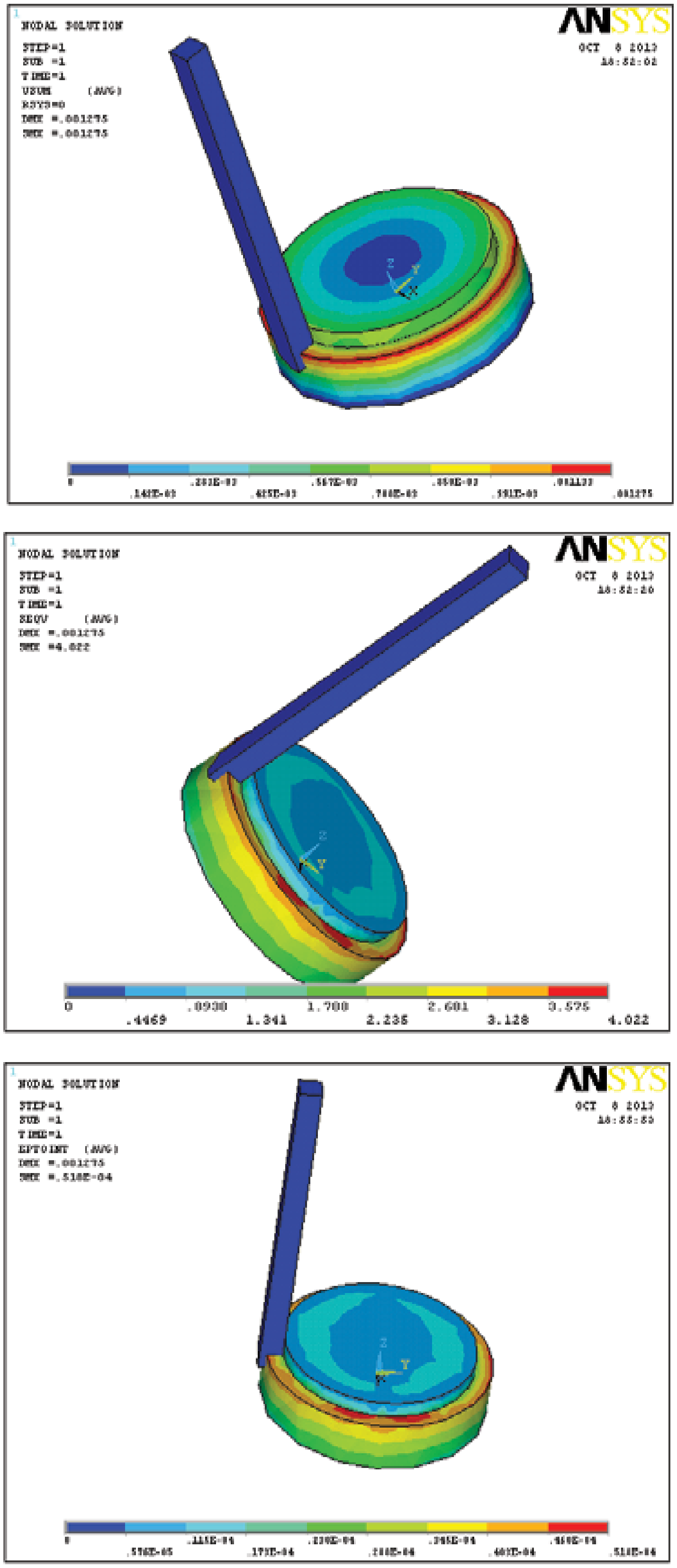

Fig.5 Nodal solutions, vonmisses stress, total strain intensity of feed– 250mm/min speed– 2000rpm

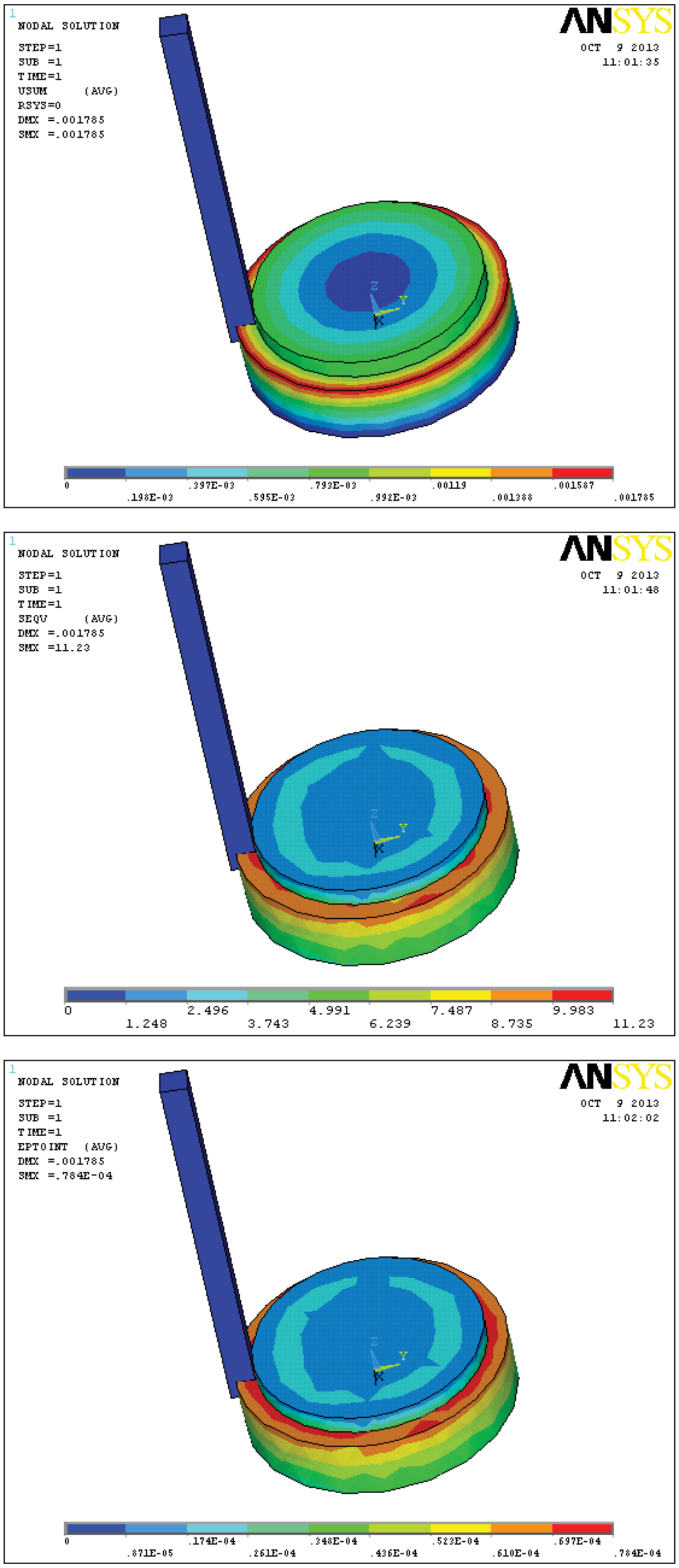

Fig.6 Nodal solutions vonmisses stress total strain intensity of feed– 250mm/min speed– 5500rpm

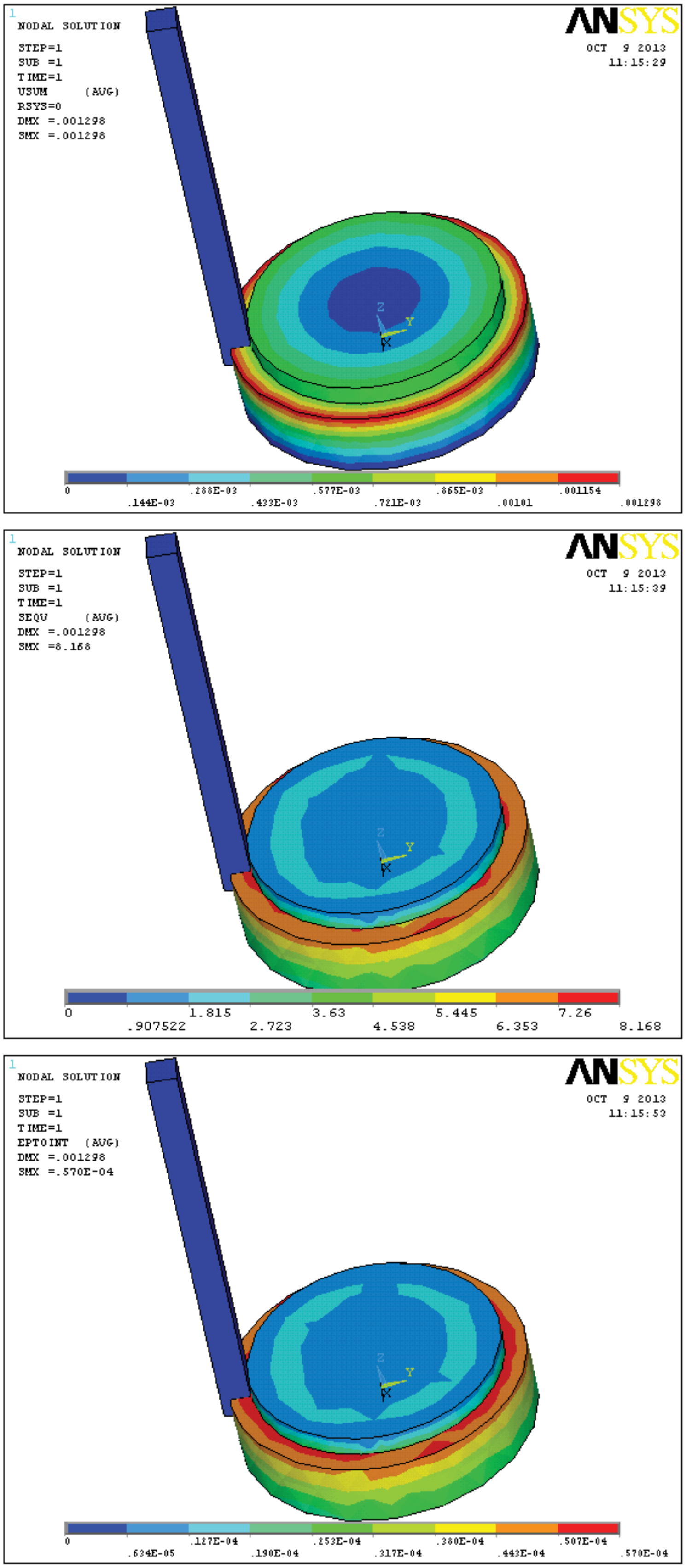

Fig.7 Nodal solutions, vonmisses stress,s total strain intensity of feed– 500mm/min speed– 2000rpm

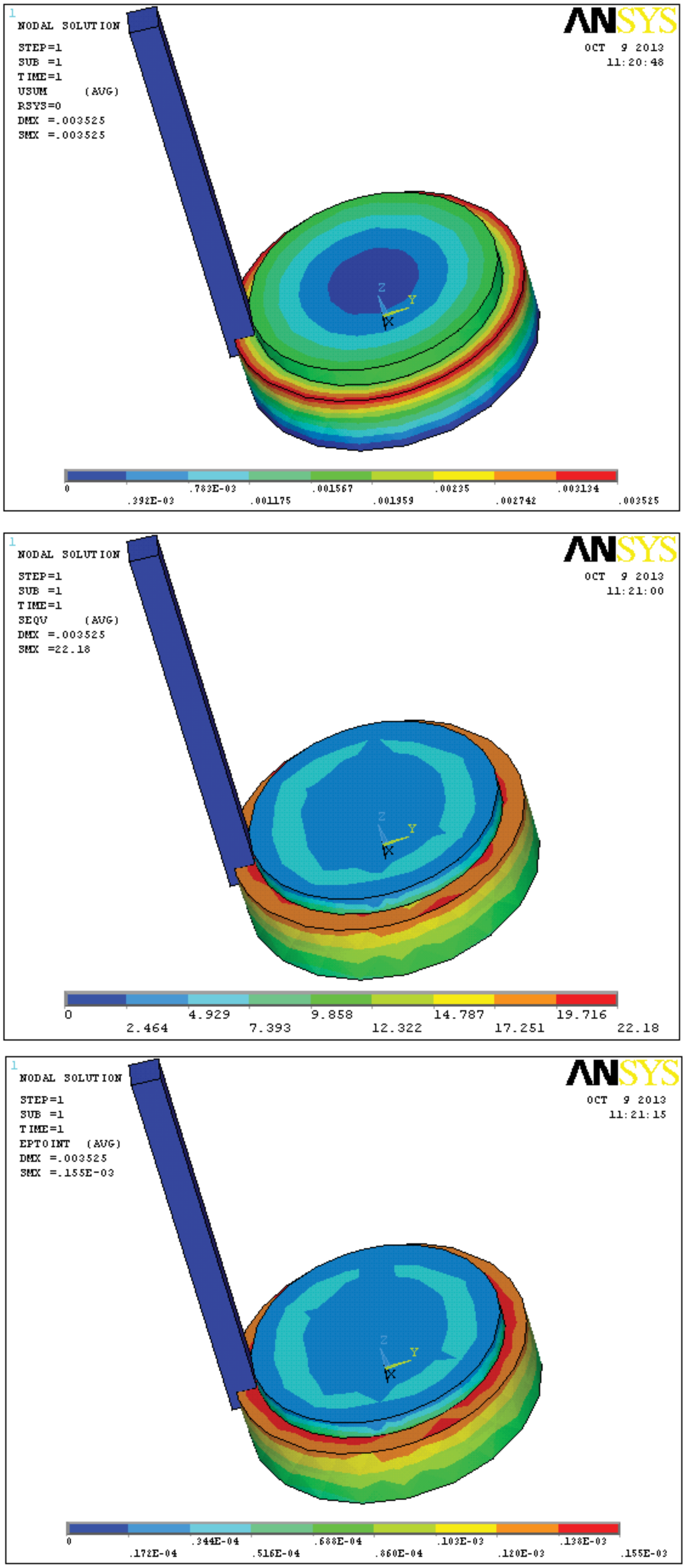

Fig.8 Nodal solutions vonmisses stress total strain intensity of feed– 500mm/min speed– 5500rpm

## V. Result and Discussion

| | Displacement (mm) | Stress ($N/mm^2$) | Strain |
|---|---|---|---|
| CUTTING SPEED-2000 rpm FEED RATE-250 mm/min | 0.001275 | 4.022 | 0.518E -04 |
| CUTTING SPEED-5500rpm FEED RATE-250mm/min | 0.001785 | 11.23 | 0.784E -04 |
| CUTTING SPEED-2000rpm FEED RATE-500mm/min | 0.001298 | 8.168 | 0.570E -04 |
| CUTTING SPEED-5500rpm FEED RATE-500mm/min | 0.003525 | 22.18 | 0.155E -03 |

## VI. Conclusion

By observing the analysis results, by taking cutting speed of 2000rpm and feed rate of 250mm/min is optimal for both the materials since the stresses analyzed are less when compared to other parameters for depth of cut of 0.9mm. But if we take cutting speed of 5500rpm and feed rate of 500mm/min, the cutting is done without any failure since the stresses are not more than that of their yield stress values for both work piece and cutting tool

More experiments have to be done practically for using cutting speed of 5500rpm and feed rate of 550mm/min if the depth of cut is increased.

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