STUDY AND STATIC STRUCTURAL ANALYSIS OF MULTIPOINT CUTTING TOOLS OF MILLING MACHINE BY FEM AND ANSYS 14.0

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ABSTRACT- In the present article, the research has been conducted for static structural analysis and the total deformation of face milling cutter (micro level) to predict the deformation developed in high speed machining operations. Under this, the work has been accomplished for predicting tool life and tool wear. This current work highlights the model of face milling cutter with tool inserts for static and dynamic components of cutting process. The computer generation has been created using CATIA V5 to stimulate the deformation process. Many simulation models use finite element analysis to calculate the reaction of cutting tool. The objective here is to consider the design and modeling of face milling cutter with inserts using CATIA V5 and FEA is carried out by using Ansys 14.0 and on comparing the two models, it has been found that cemented carbide is better due to less deformation and high strength.

Keywords: Multi Point Cutting Tool (cemented carbide), Catia v5, Ansys 14.0, Structural analysis, Static Structure, Solid Modeling and Finite Element Analysis.

INTRODUCTION

In manufacturing, the process of removal of undesirable segments of metal work pieces in the form of chips is known as machining, so as to attain a finished product of the desired size, shape, and surface quality. The machining cutting process can be branched into two major groups (i) cutting process with traditional machining (e.g., turning, milling, boring and grinding) and (ii) cutting process with modern machining (e.g., Electrical Discharge Machining (EDM) and Abrasive-Jet (AWJ)).

The basic element of the modern metal removal process consists of a machine tool, a control system and the cutting tool. An immense revolution in metal cutting practice takes place as machining is typically carried out using devoted, specially designed machining systems for mass production. A flexible, agile, or reconfigurable machining system based on Computerized Numeric Control machine tools, the development of open architecture computer based controls and progression of new tooling materials have greatly influenced metal cutting practice. Milling is the most frequent metal cutting operations in which the material is removed by advancing work piece against a rotating multiple point cutting tool. Milling is typically used to produce parts that are not axially symmetric and have multiple features, such as holes, slots, pockets, and even three dimensional surface contours. Contoured surfaces, which include rack and circular gears, spheres, helical, ratchets, sprockets, cams, and other shapes, can be readily cut by using milling operation. Recently, micro milling process has gained immense popularity due to market requirements and technological advancements which has lead to fabrication and use of micro structures. It possesses several advantages like ease of use, capability to produce complex three dimensional geometries, process flexibility, low set-up cost, wide range of machinable materials and high material removal rates.

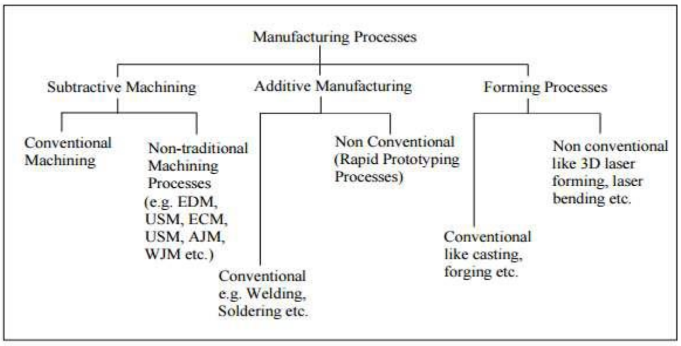


Fig. 1 Classification of Manufacturing Processes

Conventional milling has a wide range of industrial applications and is used where there is a requirement of complex shapes, removal of large amounts of material, and accuracy. However, with the advancement in technology, more and more industries are leaning towards the use and fabrication of miniaturized parts and products. In the present scenario, micromachining is increasingly finding application in various fields like biomedical devices, avionics, medicine, optics, communication, and electronics. Among all micro-machining operations, micro-milling and micro drilling are the two most important operations. In today’s competitive world, every industry is dependent on the adequate functionality of its micro components. Automobile and aerospace industries need extremely good quality machined components due to greater complexity of the workpiece, tighter tolerances, miniaturization and use of new composite materials. In case of biomedical devices, there are stringent requirements for form and finish of the product like metallic optics and cochlear implants. Good surface finish of micro-components is needed for proper functioning of the products, and for proper mating of microparts. Protruding edges at the boundary of the machined surface are called burrs. Burr removal is necessary for good surface finish. In case of conventional milling, surface finishing is done by either improving the machining setup or changing the tool geometry. Burr removal can be done by using various deburring processes. However, controlling burr formation in micro milling can be very challenging because of the sub-micrometer size of the burrs produced. Furthermore, in micro-milling operation, deburring solutions utilized in conventional machining are not allowed due to inherent material characteristics or limitations in part geometry. Deburring processes allowed in micro milling are expensive and can lead to micro structural damage. Optimization of various machine parameters, like cutting speed, feed rate and depth of cut, or tool parameters, like rake and relief angle, can help in minimization of micro-burrs in micro milling operations. An accurate surface geometry of micro milling cutters is one of the essential parameters responsible for the control of micro burrs in micro milling. Very limited work has been done on the control and minimization of micro burrs formed during micro milling operation. Virtual finite element analysis of micro burr formation during micro milling process is a cost effective method for obtaining optimized tool parameters for minimum burr formation.

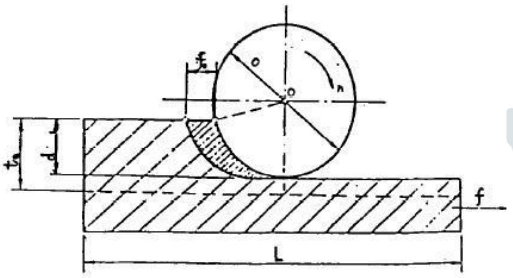


Fig. 2 working motions of plain milling operation

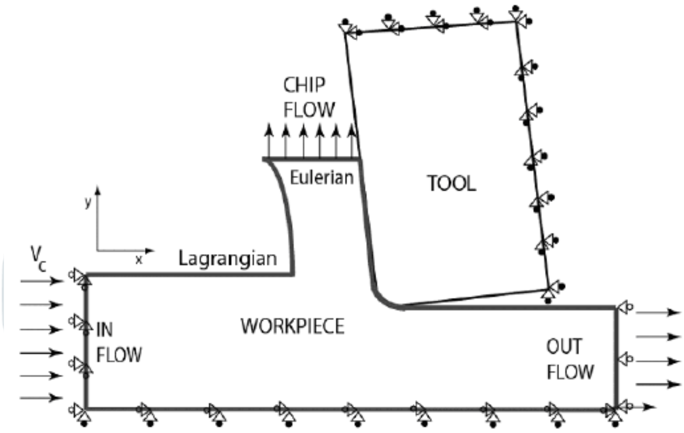


Fig. 3 Eulerian and Lagrangian boundary conditions in ALE simulation

Face mill cutter

A face mill is a cutter designed for facing as opposed to e.g., creating a pocket (end mills). The cutting edges of face mills are always located along its sides. As such it must always cut in a horizontal direction at a given depth coming from outside the stock. Multiple teeth distribute the chip load, and since the teeth are normally disposable carbide inserts, this combination allows for very large and efficient face milling.

Fig. 6 Face mill tipped with carbide inserts

FINITE ELEMENT ANALYSIS

Computer-aided engineering (CAE) is the application of computer software in engineering to evaluate components and assemblies. It encompasses simulation, validation, and optimization of products and manufacturing tools. The primary application of CAE, used in civil, mechanical, aerospace, and electronic engineering, takes the form of FEA alongside computer-aided design (CAD).

Finite element analysis

In general, there are three phases in any computer-aided engineering task:

a. Pre-processing – defining the finite element model and environmental factors to be applied to it.
b. Analysis solver – solution of finite element model
c. Post-processing of results using visualization tools.

Proposed Method for Analysis

Various outputs and characteristic of the metal cutting processes such as cutting forces, stresses, temperatures, chip shape, etc. can be predicted by using FEM without doing any experiment.

Lagrangian method Lagrangian formulation is used mainly in problems on solid mechanics. In this, the mesh moves and distorts with the material being modeled as a result of forces from neighboring elements. It is highly preferred when flow of material involved is unconstrained.

Boundaries and chip shape need not be known beforehand. Simulation of discontinuous chips or material fracture can be done by using chip separation criteria in metal cutting models based on Lagrangian formulation. However, metal being suffers severe plastic deformation and distortion occurs. Mesh regeneration is therefore needed. Chip separation criteria also must be provided. Eulerian method In Eulerian formulation, the FE mesh is fixed spatially, which allows materials to flow from one element to the next. Besides, fewer elements are required for the analysis, which reduces the computation time. However, determination of the boundaries and the chip shape needs to be done prior to the simulation. Also during the analysis, the tool-chip contact length, the contact conditions between tool-chip and the chip thickness, have to be kept constant

Arbitrary Lagrangian-Eulerian (ALE) method Arbitrary Lagrangian-Eulerian (ALE) combines the best features of Eulerian and Lagrangian formulations. In ALE formulation, the material flow is followed and Lagrangian step is used to solve displacement problems, while the mesh is repositioned and Eulerian step is used to solve velocity problems. Eulerian approach is used for modeling the tool tip area where cutting process occurs. Hence, without using remeshing, severe element distortion is avoided. Lagrangian approach is used for the unconstrained material flow at free boundaries. Method involved in the design of a cutter includes:

1. Creation of cross-sectional profile of the tool and helix generation
a. Flute creation using slot operation
b. Creation of back surface of the tool
c. Cutting edge generation
2. Parameters involved in generating the cross sectional profiles are:
a. Rake angle of the tool
b. Relief angle of the tool
c. Tool diameter
3. Parameters involved in modeling the helix are:
a. Height of the tool
b. Diameter of the tool
c. Pitch of the helix

The three dimensional CATIA model of milling cutter was produced by performing Ansys work bench 14.0.

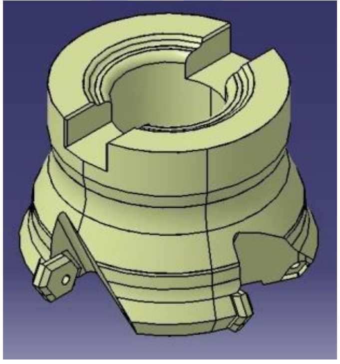


Fig. 7 CATIA model of milling cutter with inserts

Material Description

Cemented Carbide

Density	1.525e-005 kg mm^-3

Cemented Carbide > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
6.e+005	0.2	3.3333e+005	2.5e+005

Results;

After applying the force of 2000 N and rotation velocity if 125.66rad/sec we find the following results:

Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Force*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	2 Faces	1 Face
Definition		
Type	Fixed Support	Force
Suppressed	No	
Define By		Vector
Magnitude		2000. N (ramped)
Direction		Defined

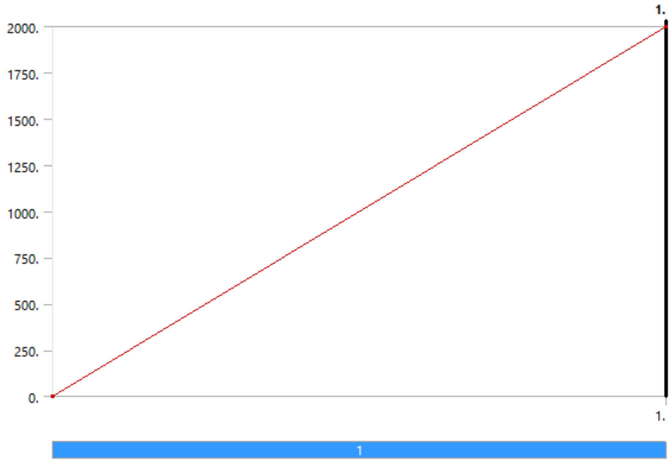


Fig 8: Model (A4) > Static Structural (A5) > Force

Model (A4) > Static Structural (A5) > Rotations

Object Name	*Rotational Velocity*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	

Define By	Vector
Magnitude	125.66 rad/s (ramped)
Axis	Defined
Suppressed	No

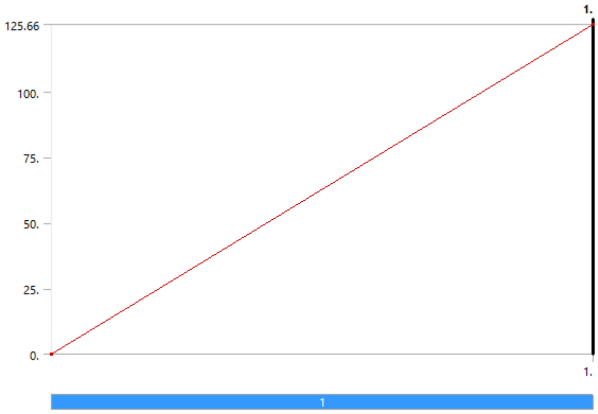


Fig 9: Model (A4) > Static Structural (A5) > Rotational Velocity

Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

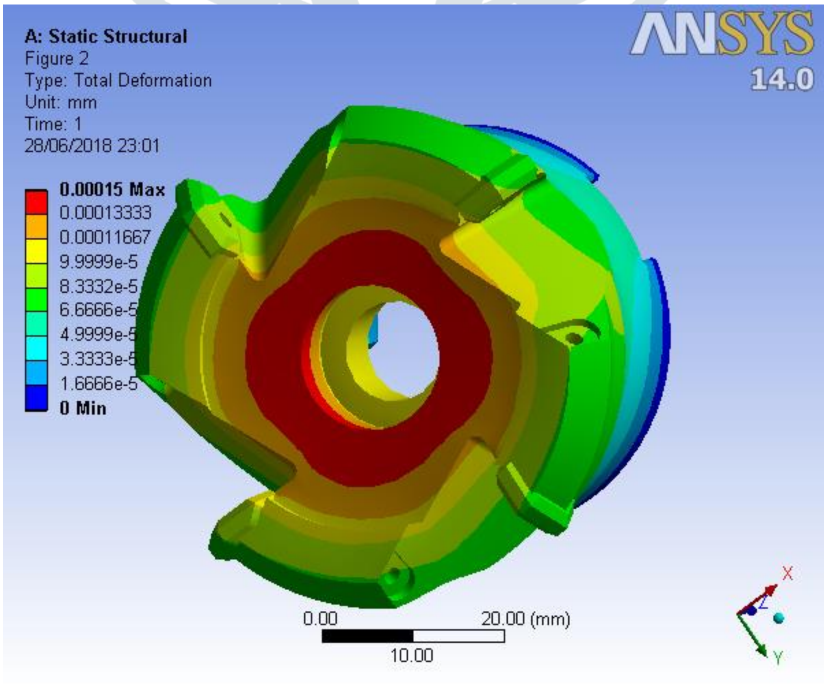
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

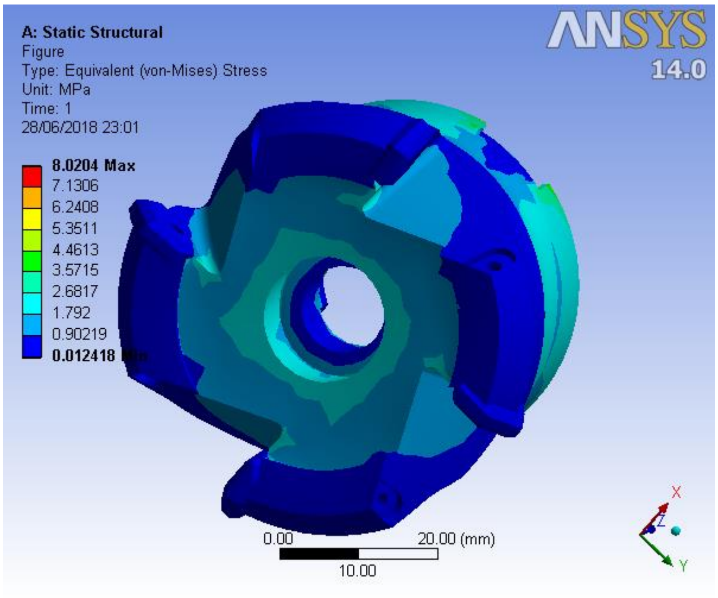
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Equivalent Stress*	*Strain Energy*	*Equivalent Elastic Strain*
State	Solved			
Scope				
Scoping Method	Geometry Selection			
Geometry	All Bodies			
Definition				
Type	Total Deformation	Equivalent (von-Mises) Stress	Strain Energy	Equivalent Elastic Strain
By	Time			
Display Time	0.21196 s	Last		
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Results				
Minimum	0. mm	1.2418e-002 MPa	1.0306e-012 mJ	3.1506e-008 mm/mm
Maximum	1.5e-004 mm	8.0204 MPa	2.8395e-004 mJ	1.5789e-005 mm/mm
Information				
Time	1. s			
Load Step	1			
Substep	1			
Iteration Number	1			
Integration Point Results				
Display Option		Averaged		Averaged

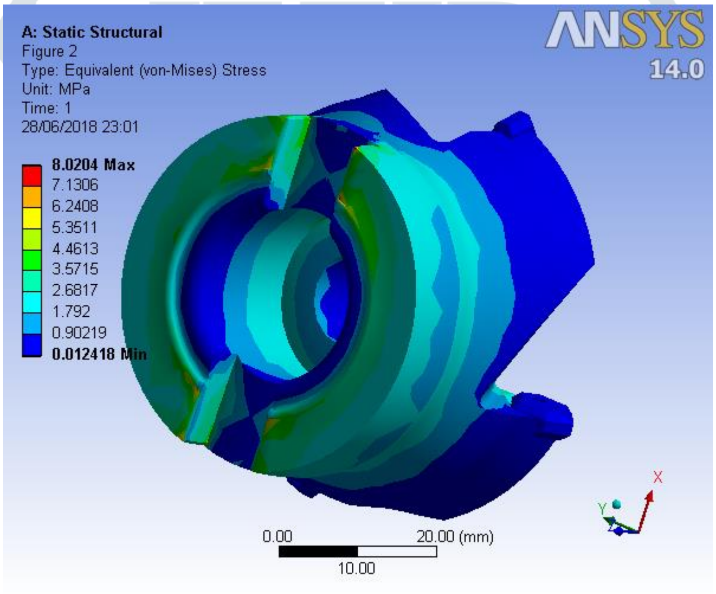
Total Deformation



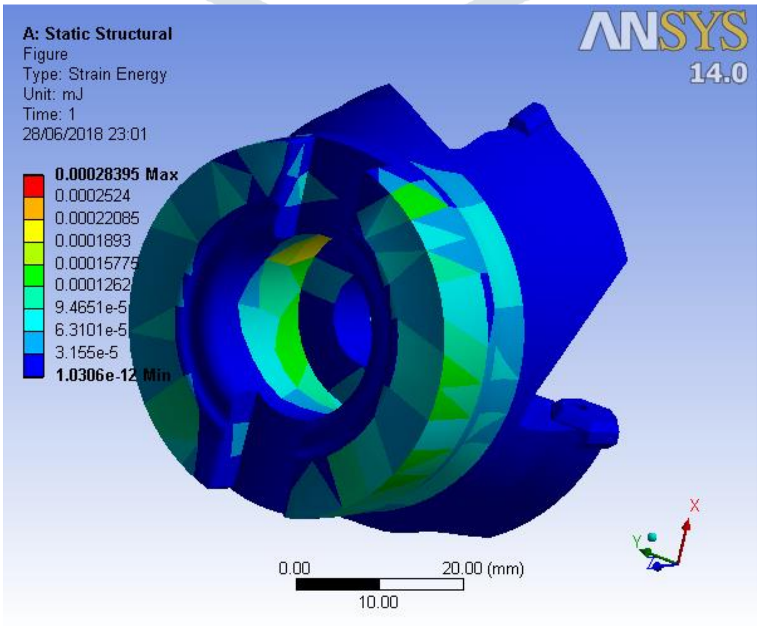
Equivalent Stress 1



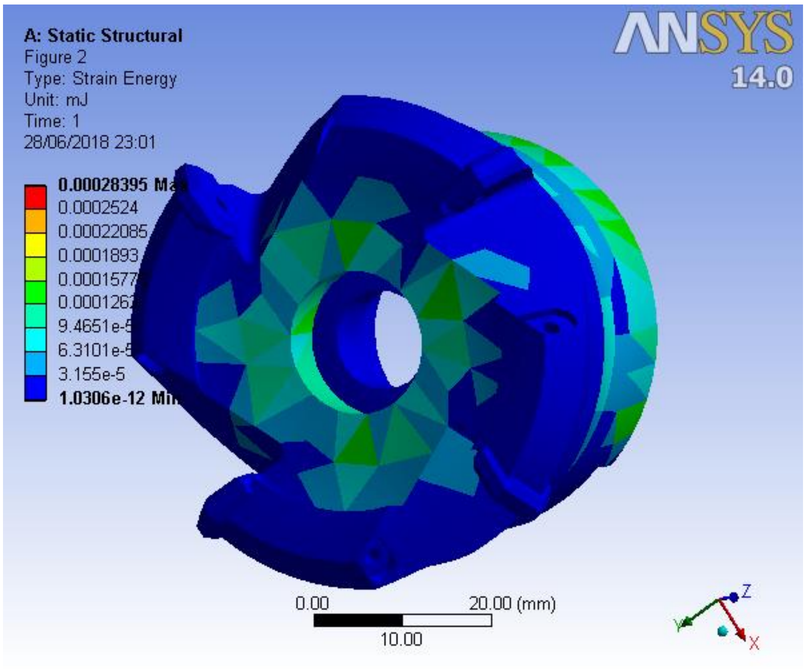
Equivalent Stress 2



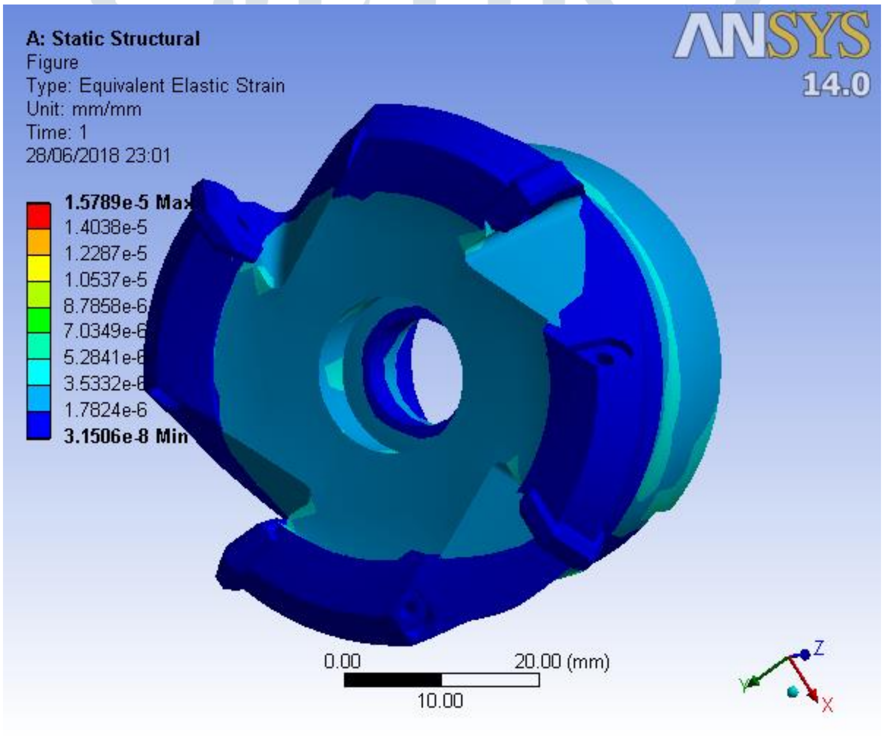
Strain Energy1



Strain energy 2



Equivalent elastic Strain



Conclusion

From the results obtained in ANSYS it can be observed that the equivalent stress for high feed face mill cutter is less than HSS face mill cutter by approximately 4.42% and strain energy is less than by 67% .This is due to the high feed.

- From the results the fail safe condition for the tool has been established by comparing with the practical data.
- At high cutting speed the wear rate is higher and at low cutting speed wear rate is lower on all the tool materials.

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