MODELING AND STATIC THERMAL ANALYSIS OF CUTTING TOOL USING VARIOUS MATERIAL WITH FEM

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ABSTRACT

Metal cutting is one of the processes to convert the raw material into finished goods. There are number of parameters which are mainly depend upon the tools and its geometry like the quality of cut, surface finish of cutting surface, power consumption of the machine etc. So the right design of the tool is very much important. At various operational cutting speed of lathe, temperature of the tool-chip interface is determined experimentally and modelled. Specifically, analysis is carried out at three different speeds- low, medium and high.Study and design of single point cutting tool is an important aspect of tool engineering. In this paper we have discussed the design aspect of shank, the tool geometries, the power required by the lathe and the stresses developed in the tool due to machining. Single point cutting tool is used for important operation in the lathe like facing and turning hence study of geometry of a single point cutting tool is very essential part of study required for manufacturing. The aim of the project is to design and analysis of Single point cutting tool using in catia v5 work bench. Perform the static and Thermal analysis using in Ansys software using the various materials like HSS,SiN,INCONEL 718, WC, H 30 Materials. Finally observed the which material is the best material based on the Von-misses stress, Total deformation, Shear stress, Strain, Total heat flux.

Key words: Single point cutting tool, static, thermal, catia, ansys, materials, stress, strain, Total deformation, heat flux.

INTRODUCTION OF CUTTING TOOL

Cutting tool or cutter is any tool that is used to remove material from the work piece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, planning and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. It is a body having teeth or cutting edges on it. Grinding tools are also multipoint tools.[1] Each grain of abrasive functions as a microscopic single-point cutting edge (although of high negative rake angle), and shears a tiny chip.

Cutting tool materials must be harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the work piece without the rest of the tool dragging on the work piece surface. The angle of the cutting face is also important, as is the flute width, number of flutes or teeth, and margin size. In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run.

Figure 1 Cutting tool

SINGLE POINT CUTTING TOOL:

A single point cutting tool consist Flank, face, cutting edge, nose, rack angle, clearance angle, cutting edge angle etc. All of these parts control the cutting condition, tool life and cutting speed of tool. These parts describe as follow.

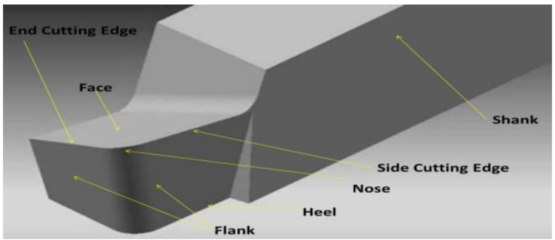


Figure 2Single point cutting tool Nomenclature

LITERATURE REVIEW

The main functions of a cutting fluid are lubricating and cooling the cutting tool. Jayal et al. [1] expanded this to include chip transport from the cutting zone, an increase from two to three functions of cutting fluids. In addition to this coolant provides temporary protection against oxidation and corrosion, which can be classed as an important secondary function. For these reasons it is apparent that coolant has an important role to play in metal cutting, and any alternative cooling method would need to provide the same properties. The ambition of this research is to prove that flood coolant can be replaced for many machining applications. Traditionally the only way to show that coolant may be replaced by alternative cooling methods was by carrying out robust testing of the machining operation. An easier and quicker method is to apply an appropriate computer analysis to determine best the cooling method. The mechanical energy consumed in a machining operation is converted into thermal energy [2] mainly by shearing the material, with a secondary heat being generated as a chip slides over the rake face of the tool tip. For this reason it is obvious that for whatever cooling method is used it is the effectiveness of dissipating the heat from the cutting zone that determines its usefulness. According to the National Institute for Occupational Safety and Health [3], metalworking fluids can be classified into four types: (a) straight oils (b) soluble oils (c) semi-synthetics and (d) synthetics Metalworking fluids often contain a mixture of other substances including biocides, corrosion inhibitors, metal fines, tramp oils, and biological contaminants [3].

Literature review identifies several health, safety, and environmental issues that should be addressed with regard to the application of cutting fluid: (a) toxicity of the fluid components, (b) flammability of the fluid, and (c) fluid disposal [4]. According to the Occupational Safety and Health Administration (OSHA) in the USA [4], metalworking cutting fluids can cause adverse health effects through skin contact with contaminated materials, spray, or mist, and through inhalation from breathing a mist or aerosol. These effects include skin disorders, respiratory diseases, and cancer. In recent years, the application of cutting fluids in machining operations has attracted also immense scrutiny due to its adverse effects on the environment. Consequently, a vast amount of research has been undertaken to reduce the application of cutting fluids [5].

Despite these efforts the problem remains unsolved because the research has shown that the effectiveness of the cutting fluid fluctuates on a case-by-case basis. According to Astakhov et al. [6], experimental studies in metal cutting are expensive and time consuming. In addition, the results are valid only for the specific experimental conditions used. The results also depend on the accuracy of the calibration of the experimental equipment. However, it is believed that the problem can be solved by developing a numerical model to help select the amount of cutting fluid in a scientific way, which minimises the amount of coolant needed for effective cooling of the tool tip. Computational Fluid Dynamics (CFD) was adopted to carry out the numerical analysis (this procedure is now relatively common place). Figure 1 shows a simple CFD model of an oblique cutting operation using flood cooling. Numerical methods have been applied for modelling machining operations. They can be applied in calculating the temperature distribution and thermal deformation in the tool, chip, and work piece: (a) Finite Difference Method (FDM) (b) Finite Element Method (FEM) (c) Boundary Element Method (BEM) The FEM is used to simulate the temperature distribution the tool insert, work piece etc. FEM is also used to simulate the thermal deformation.

OVER VIEW OF THE PROJECT

1. Have sufficient mechanical strength and stiffness of cutting tool due to the proper material

2. Can effectively block the heat reached the single point cutting tool

3. Select High temperature corrosion resistance material

4. Reduce the cracks, slags, porosity using proper coolants due to the over heat. The current experiment is to analysis the cooling of tool bit

5. The tool and the work piece must be held rigidly so as to allow the tool to penetrate the work piece when forces are applied.

6. The shank of the tool must be properly analyzed for strength and rigidity. The deflection of the tool must be within prescribed limit.

7. The tool must withstand forces encountered by it when it penetrates through the work piece.

8. Select the best materials the tool material must be harder than the work pieced. The tool material should be chemically inert. The material must be able to resist wear and tear. The material should be thermally stable. The material should have good thermal conductivity and less coefficient of thermal expansion.

9. Finally Observe the which material is best based on the Results

PROBLEM IDENTIFICATION:

Improper material leads to the failure In this project choose the right materials for the single point cutting tool. In the process of machining the hardness of the tool bit should be higher than the work peace in the time decrease the life of tools the cutting tool is very high cost, and also life span of the tool would be consistent for long time .in this project to increase its life span and we studied cooling process to avoid unconditioned effects like friction and thermal induction in to the tool bit ,those effects sometimes not only reduce life also they may damage the tool tip .to avoid these effects we must use proper coolants to improve tool life ,use low price coolants and naturally occurred materials used in this project.

METHODOLOGY

1. Journals: Study the different journals of the single point cutting tool consider the dimensions from previous Journals
2. Modelling: Modelling of Single point cutting tool is done by CATIA V5 R21 as per the geometrical considerations.
3. Meshing: Meshing is done by using ANSYS R15.0 workbench. It is necessary to understand how the structure is likely to behave and how elements are able to behave.
4. Material: Perform the static and Thermal analysis of single point cutting tool using various materials like HSS, SIN, INCONEL 718, WC, H 30.
5. Boundary conditions: Fixing the end face of the Single point cutting tool and applying force on the cutting edge.
6. Analysis: Analysis is done by using ANSYS R15.0 workbench and Comparison of results
7. Find out: Finally find out the which material is the suitable for the single point cutting tool based on the Von-misses stress, strain, deformation, shear stress, Total heat flux.

MATERIAL PROPERTIES:

- **HSS MATERIAL:**

  High-speed steels (HSS) are likely to continue to be used in the foreseeable future for many applications such as drilling, reaming, tapping and dieing, forming, broaching and milling due to the ease with which they can be shaped in both the soft and hardened state. Typically, they consist of carbon steel alloyed with tungsten or molybdenum, together with percentages of chromium, vanadium and cobalt.

  The alloying elements raise the temperature at which tempering occurs, allowing HSS to be used at temperatures up to about 650°C. Their hardness is limited to 750 HV, adequate for machining most of the common metals, including alloy steels in their unhardened forms.

- **INCONNEL 718 MATERIAL:**

  INCONEL alloy 718 is one of the many nickel-based super alloys supplied by Corrotherm. Its exceptional properties and technical specifications mean that it's used for lots of highly technical and essential industrial applications.

- **WC MATERIAL (TUNGSTEN CARBIDE):**

  Tungsten carbide is a chemical compound comprising equal parts of tungsten and carbon atoms. In its most simple form, tungsten carbide is a fine grey powder, but it can be pressed and shaped into shapes through a method called sintering for use in industrial equipment, cutting tools, abrasives, armour-piercing shells and jewellery. We have covered all of the important aspects of tungsten carbide in this article, including its description, tungsten carbide rings, applications, price, and properties. Wedding rings are often made of tungsten carbide. Tungsten carbide rings are much more durable than gold and silver rings. Tungsten rings are rated between 8 and 9 on the Mohs scale of hardness.

- **H 30 MATERIAL:**

  The high quality Sweden SS H30 material is one of the more steel grades we supply, Carbide for cutting tools. H30 is our main production grade, which has been approved by customers in many countries since its initial production, including our H30 round bars, flat bar, forgings, fasteners, tubes, wires, strips, sheets & Plates, as well as a variety of profiles, professional high precision auto-lathe processing manufacturer of clinching fasteners, axes, standoffs, screws, studs, nuts, bolt, OEM parts and special shaped turning parts the state of delivery includes quenched and tempered, annealed, machined semi-finished products, we also have strict management of the packaging, to avoid material damage from transportation. We are the best supplier of H30 materials, and we are willing to develop together with customers from all over the world.

- **SiN MATERIAL:**

  Silicon nitride components may be produced in dense form from a powder through the conventional sintering or hot-pressing routes. An interesting and important feature of the material, however, is that lower density (2300–2700 kgm^{-3}) components may be produced directly by the nitridation of compacted silicon powder—the reaction-bonding (or reaction-sintering) route.

MATERIAL PROPERTIES	Density(Kg/m^3)	Possions ratio(μ)	Young's Modulus (Mpa)	Ultimate Tensile strength (Mpa)	Thermal conductivity $(W/m.K)^{-1}$	SPECIFIC HEAT J/kg.K
HSS	7600	0.3	233000	1080	20.2	461
SIN	3000	0.27	207000	192	55	880
INCONEL 718	8190	0.28	200000	1250	11.4	435
WC	1570	0.31	550000	344	50	280
H 30	7750	0.3	220000	440	25	460

ANALYTICAL CALCULATION OF FORCES ON CUTTING TOOL

Analytical Calculation Of Forces On Cutting Tool

For d = 0.4 mm and f = 0.15 mm/rev $Fc = 5516 \times f^{0.85} \times d^{0.98}$ N

$Fc = 5516 \times 0.15^{0.85} \times 0.4^{0.98}$

Fc = 448.05 N

Where d = Depth of Cut f = Feed rate

Fc = Cutting Force

Average co-efficient of friction on the tool face, μ = 0.7

Rake angle, α = 12

$$\mu = \frac{Fc\tan\alpha + Ft}{Fc - Ft\tan\alpha}$$

Thrust Force, Ft = 190.11 N

Shear angle $\varphi = \frac{r\cos\alpha}{1 - r\sin\alpha}$

φ = 32.21°

Normal Force

$Fn = Fc \sin\emptyset + Ft \cos\emptyset$

Fn = 448.05 sin 32.21+190.11 cos 32.21

Fn = 399.67 N

MODELING DETAILS OF SINGLE POINT CUTTING TOOL:

Back rack angle: 2°
Side rack angle: 9°
End relief angle: 5°
Side relief angle: 5°
End cutting edge angle: 9°
Side cutting edge angle: 11°
Nose radius: 3mm

DESIGN PROCEDURE IN CATIA:

Go to the sketcher workbench create the rectangle as per dimensions after apply shaft again go to the part design create the plane now select create the circle as per dimensions cam width is 18mm after go to the apply pad option again go to the sketcher workbench create the camshaft diameter is28.6mm and journal diameter is 50mm and cam height is41.3mm create the lift is cam of total lift as shown below figure.

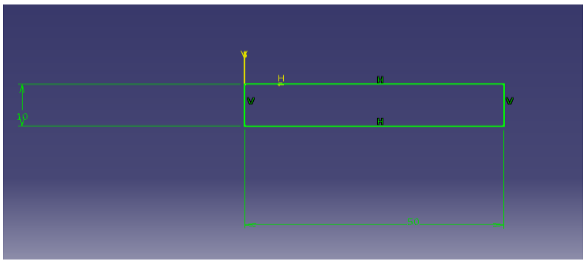


Figure 3 Rectangle created in sketcher workbench

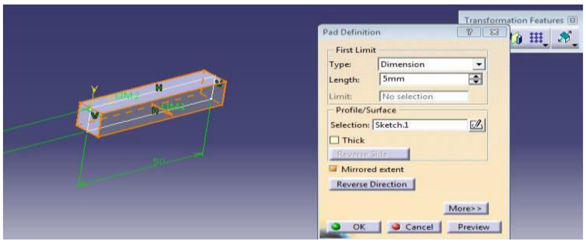


Figure 4 Apply pad in part design workbench

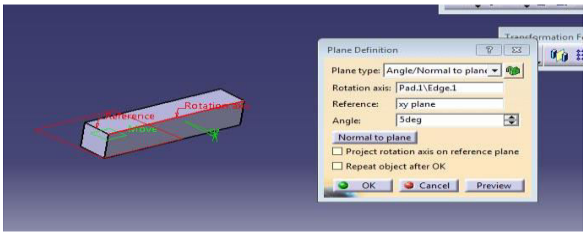


Figure 5 create the plane in part design workbench

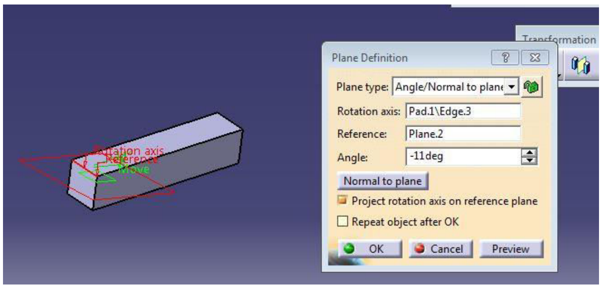


Figure 6 create the plane in part design workbench

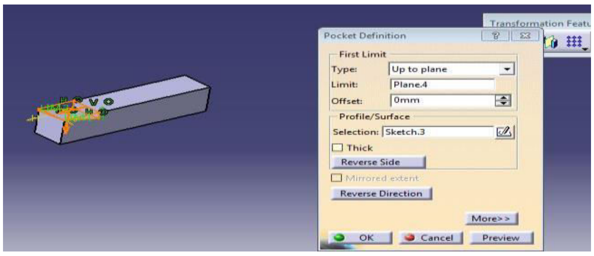


Figure 7 create the pocket in part design workbench

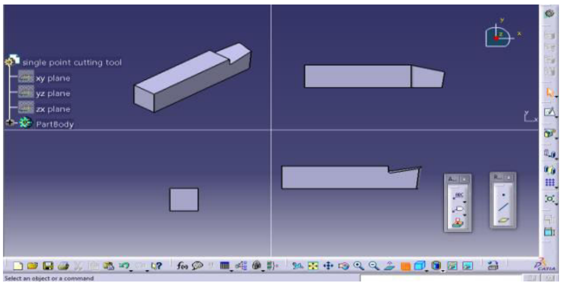


Figure 8 multiple view of single point cutting tool

THE BASIC STEPS INVOLVED IN FEA

- Discretization of the domain
- Application of Boundary conditions
- Assembling the system equations
- Solution for system equations
- Post processing the results.

STATIC STRUCTURAL ANALYSIS

The static structural analysis calculates the stresses, displacements, shear stress and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include:.

6.10 MESH AND BOUNDARY CONDITIONS:

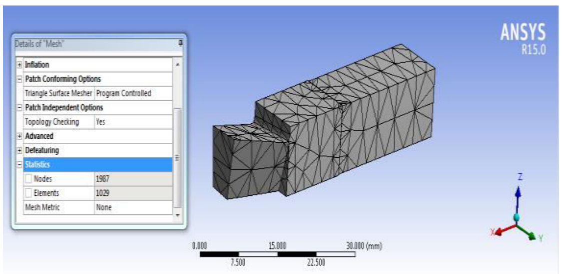


Figure 9 Mesh: Nodes: 1987 and Elements: 1029

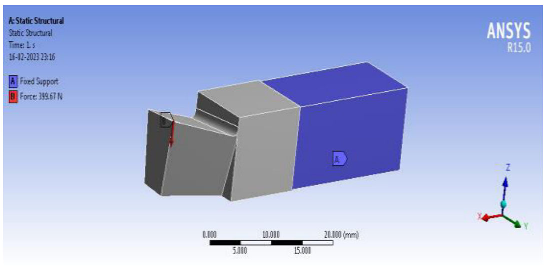


Figure 10 Boundary Conditions Force: 399.67 N

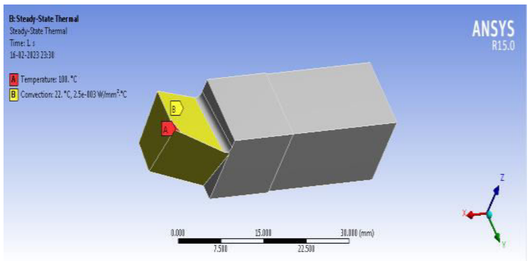


Figure 11 Thermal condition: Temp: 100°C, Convention: 22oc, 0.0025w/mm^2

RESULTS AND DISCUSSIONS

HSS MATERIAL:

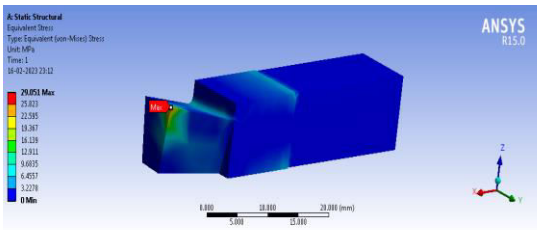


Figure 12 Von misses stress of HSS Material

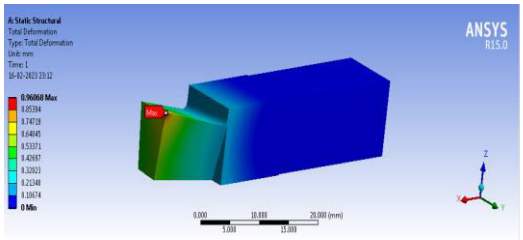


Figure 13 Total deformation of HSS Material

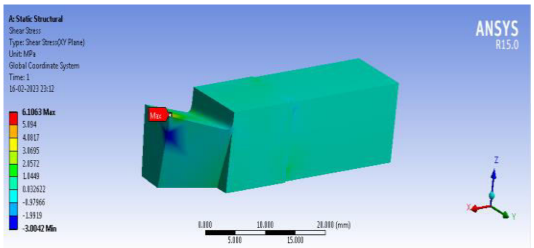


Figure 14 Shear stress of HSS Material

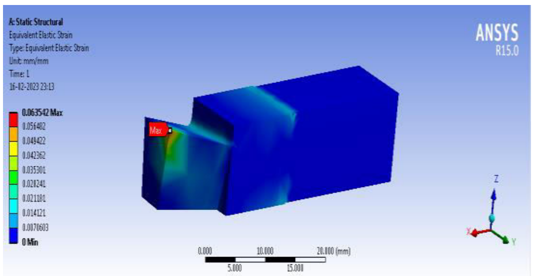


Figure 15 Strain of HSS Material

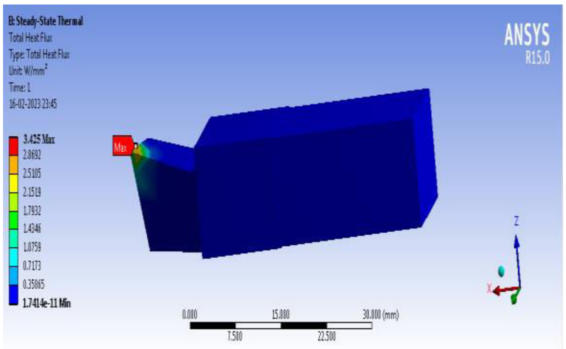
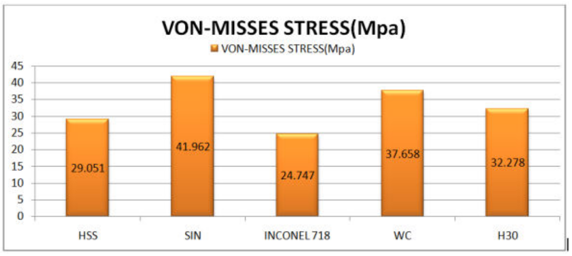


Figure 16 Total heat flux of HSS Material

Like the same way conducting analysis on HSS, SIN, INCONEL 718, WC, H 30

VONMISSES STRESSES GRAPH

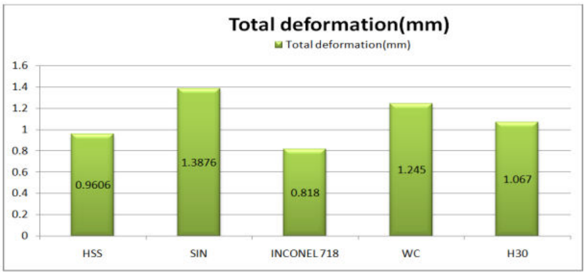
we can observe that in case of Equivalent von-mises stress, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Von-misses stress are SiN (41.962)Mpa material and least von-misses stress are Inconel 718 (24.747)Mpa compared to remaining materials as shown below graph



Graph 1 Von-misses stresses graph

TOTAL DEFORMATION GRAPH:

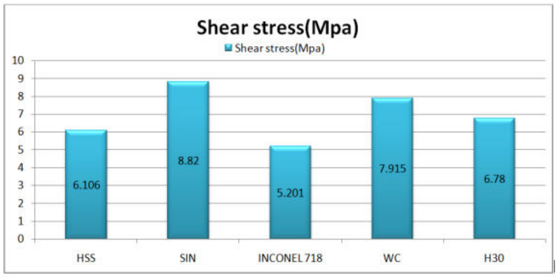
We can observe that in case of Total deformation, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Total deformation are SiN (1.3876)mm material and Total deformation are Inconel 718 (0.818)mm compared to remaining materials as shown below graph



Graph 2 Total deformation graph

SHEAR STRESS GRAPH:

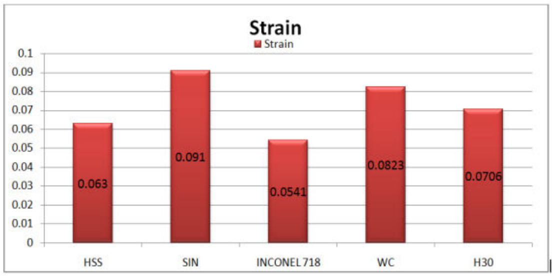
We can observe that in case of Shear stress, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher shear stress are SiN(8.82)Mpa material and low Total deformation are Inconel 718 (5.201)Mpa compared to remaining materials as shown below graph



Graph 3 Shear stress graph

STRAIN GRAPH

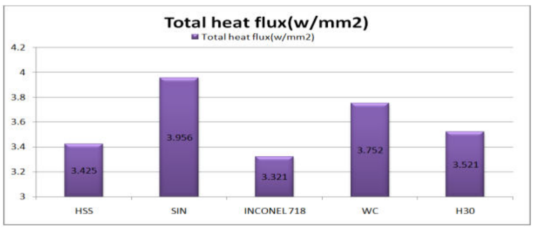
We can observe that in case of Strain, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Strain are SiN(0.091) material and low Total deformation are Inconel 718 (0.0541) compared to remaining materials as shown below graph



Graph 4 Strain graph

TOTAL HEAT FLUX GRAPH

We can observe that in case of Total heat flux, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Total heat flux are SiN(3.956) material and low Total heat flux are Inconel 718 (3.321) compared to remaining materials as shown below graph



Graph 5 Total heat flux graph

CONCLUSION

Modeling & Structural, Thermal Analysis is done on the single point cutting tool with different materials HSS, SiN, INCONEL 718, WC, H 30 to determine the von-misses stresses, deformation, shear stress ,temperature distribution & heat flux on the single point cutting tool using various materials of HSS, SiN, INCONEL 718, WC, H 30 . Metal cutting is one of the processes to convert the raw material into finished goods. There are number of parameters which are mainly depend upon the tools and its geometry like the quality of cut, surface finish of cutting surface, power consumption of the machine etc. So the right design of the tool is very much important. At various operational cutting speed of lathe, temperature of the tool-chip interface is determined experimentally and modelled. Specifically, analysis is carried out at three different speeds- low, medium and high.

1. Finally find out the we can observe that in case of Equivalent von-mises stress, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Von-misses stress are SiN (41.962)Mpa material and least von-misses stress are Inconel 718 (24.747)Mpa compared to remaining materials as shown below graph
2. We can observe that in case of Total deformation, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Total deformation are SiN (1.3876)mm material and Total deformation are Inconel 718 (0.818)mm compared to remaining materials as shown below graph
3. We can observe that in case of Shear stress, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher shear stress are SiN(8.82)Mpa material and low Total deformation are Inconel 718 (5.201)Mpa compared to remaining materials as shown below graph
4. We can observe that in case of Strain, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Strain are SiN(0.091) material and low Total deformation are Inconel 718 (0.0541) compared to remaining materials as shown below graph
5. We can observe that in case of Total heat flux, cutting tool is made up of HSS,SIN,INCONEL 718, WC, H 30 Materials Higher Total heat flux are SiN(3.956) material and low Total heat flux are Inconel 718 (3.321) compared to remaining materials as shown below graph
6. Finally concluded the inconel and 718,Hss, H30 are the best materials for the single point cutting tool.

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