

Analytical Investigation and Comparison on Performance of Ss316, Ss440c and Titanium Alloy Tool Materials Used As Single Point Cutting Tool

Mr. Amaresh Kumar Dhadange¹, Dr. H.G. Hanumantharaju², Mr. Suresh³, Mr. Karthik K Kallur⁴, Mr. Anand S⁵

¹(Faculty, Department of Mechanical Engineering, Sri Venkateshwara College of Engineering, Bangalore-562157)

²(Faculty, Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore-560001)

³(Faculty, Department of Mechanical Engineering, Sri Venkateshwara College of Engineering, Bangalore-562157)

⁴(Student, Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore-560001)

⁵(Student, Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore-560001)

ABSTRACT

Theoretical analysis for performance studies of SS316, SS440C and Titanium Alloy used as a cutting tool is presented in this paper. Tool temperature, tools wear and life of the tool is investigated analytically. These theoretical values are compared with the experimental studies conducted by the author. The values obtained from experimental studies are comparable with analytical values and variation is the correlation between theoretical and experimental values is of the order of 15%.

I. INTRODUCTION

The tool used in a lathe is known as a single point cutting tool which has one cutting edge or point. The lathe tool shears the metal rather than cuts and it can only do so if there is relative motion between the tool and the work piece. For efficient cutting, a tool must have good strength, resistance to shock, hot hardness, resistance to wear and low coefficient of friction. Along with this, the tool material must be easily available and economical. Also, the materials used should have a wider range of application, preferably.

Some of the conventional tool materials like tungsten carbide, titanium carbide, cubic boron nitride (CBN) and diamond are expensive. Even for machining softer materials like aluminium, brass and copper expensive tools like TiC & WC are used. The range of cutting tool types is extensive. The selection of correct tool for a particular application depends especially on the tool geometry and the cutting tool material, if the operation is to be done in a cost-effective (i.e. productive) way.

The cutting parameters like cutting speed, feed and depth of cut affect different cutting forces exerted on the tool and work piece during any metal cutting action. These forces in turn derive the quality and the dimensional accuracies of the metal surface. Hence it is very important to accurately measure the cutting

forces and control them to obtain required degree of surface and / or dimensional accuracy on the surface, Electronic Dynamometers are used to measure these forces.

When the tool wear reaches an initially accepted level, there are two options - one is to sharpen the tool on a tool grinder and the other is to replace the tool with a new one. This second possibility applies only when the resource for tool sharpening is totally exhausted and /-or the tool does not allow for any further sharpening. Gradual wearing of certain regions of the face and flank of the cutting tool can terminate the life of a cutting tool, therefore the life of a cutting tool is determined by the amount of wear that has occurred on the tool profile and which reduces the efficiency of cutting to an unacceptable level, or eventually causes tool failure.

II. MATERIAL SELECTION

Tool materials selected based on hardness, toughness and wear properties. Below are few candidate materials that can substitute today's expensive tool material.

- SS440C
- SS316
- Titanium alloy (G5)
- Inconel
- Ferritic stainless steel 1.4003

- Invar 3

Among the above materials, the materials selected for our experimentations are SS440C, SS316 and Titanium alloy (G5) on the basis of required mechanical properties for the present work. The single point cutting tools are prepared according to the standard by using HSS tool as reference. Fig1 represent the final cutting tools obtained. The work piece materials used are as follows;

- a. Mild Steel (for HSS and SS440C)
- b. Aluminium (for SS316 and Titanium alloy)



Figure1. Test Specimens

After the preparations of the cutting tool, heat treatment processes were carried out for improving the hardness property of the material.

III. EXPERIMENTATION

Once the cutting tool is fabricated the next step is to subject these tools to various standard tests to determine the tool performance for the intended application on the tool samples which has been clearly discussed in the first paper “Investigation on SS316, SS440C and Titanium Alloy Grade-5 used as Single Point Cutting Tool”

FEA ANALYSIS

Ansys is a leading finite element tool used for mechanical design applications. In metal cutting Ansys can be used as a FEA tool for our purpose. Metal cutting can be considered as a large deformation transient analysis /explicit analysis for the analysis. Because explicit analysis will give better result in such conditions our project work metal cutting is done in ANSYS explicit analysis.

Using ANSYS as preprocessor geometrical FE model was created assuming the rake angle 7° , clearance angle 14° and edge radius 3° .

Boundary conditions of the FE model were as followed. The work piece was constrained in all 6 DOF, load of the type $U=f(t)$ (Displacement according to time) with the purpose of simulate cutting motion with respect to the cutting velocity.

The FEA geometric model constrained 35060 nodes & 31240 elements. For structural SOLID187 element were chosen as they are used in explicit

analysis assuming large deformation speed and non-linear contact for composition of geometric model. Work piece mesh sensitively study was performed.

For thermal analysis SOLID187 element were chosen as they are used in the thermal analysis. Couple field type transient analysis was done for the temperature distribution. With the help of temperature distribution and wear analysis theory we can find wear rate of the material. The wear rate of the material will directly influences the tool life of the investigated tool material.

For selection and specification dynamic constants by FEM the problem is interaction of deformable body and rigid body. Deformable body is work piece and defined as slave for contact search and chip separation in numerical analysis. A turning tool is a rigid body. Assuming tool dynamics and defined as a master for contact search in explicit numerical analysis.

A. INITIAL CHIP FORMATION:

By considering the cutting tool as a rigid model and work piece as a flexible material, boundary condition is applied for the tool-work piece arrangement. Feed is given for the tool and work piece is fixed with all degrees of freedom. Total load is divided to load steps for better convergence. At initial load steps tool will hit the work piece and it starts to cut the metal stress is recorded and stress variation is plotted.

B. CHIP GROWTH ANALYSIS:

As cutting tool advances cutting the stress distribution also varies and results are plotted for the same. Mechanical work done observed and simulation is done for the complete cycle. Max stress occurred during cutting is plotted.

Total mechanical work done is transferred to the heat and this heat generation is considered for the thermal analysis input. Transient thermal heat analysis is done in ANSYS APDL for the temperature distribution and results are plotted.

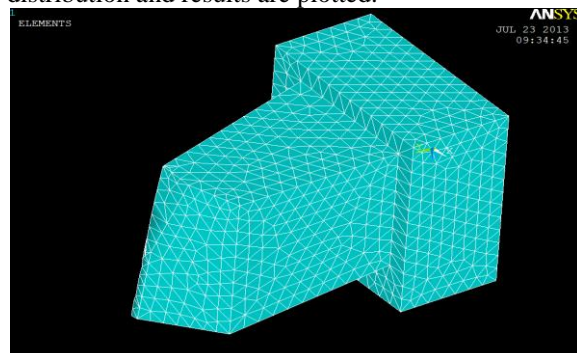


Fig 1: Tool Mesh Profile

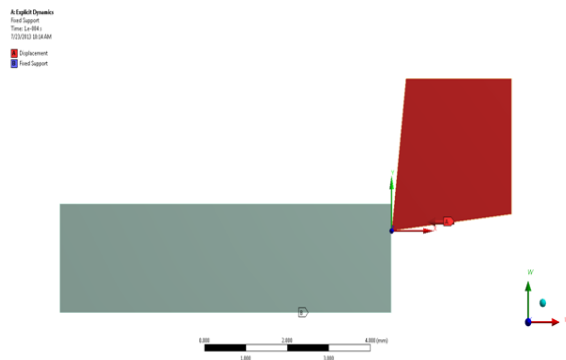


Fig 2: Tool and work piece solid model

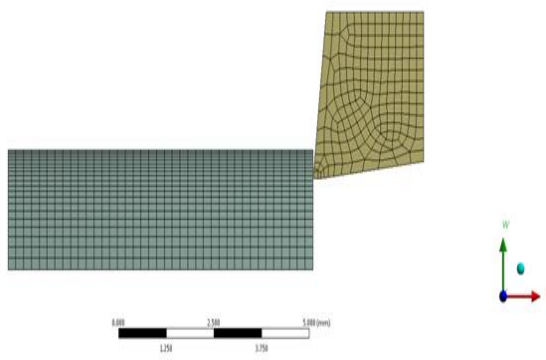


Fig 3: Tool and work piece mesh model

**c. MANUFACTURING SIMULATION BY FE A
 I) TOOL: HSS WORK PIECE: MILD STEEL
 (EN19)**

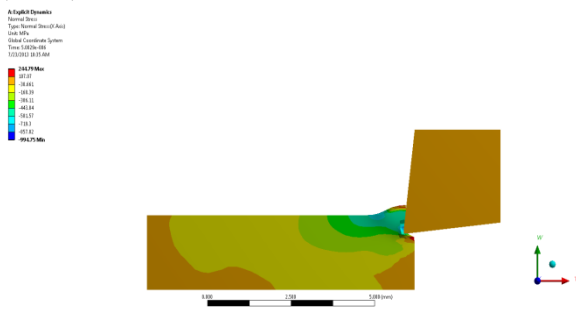


Fig 4: HSS Tool initial chip formation

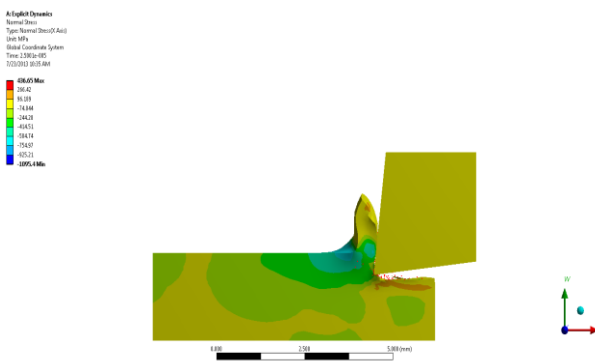


Fig 5 : HSS Tool initial chip growth formation

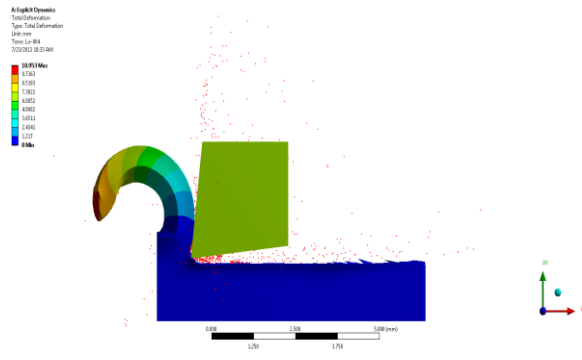


Fig 6: HSS Tool chip total deformation

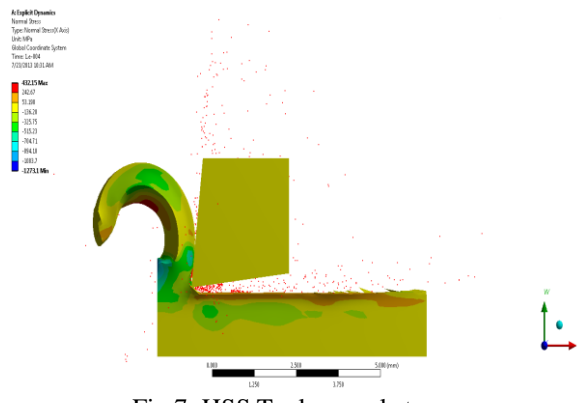


Fig 7: HSS Tool normal stress

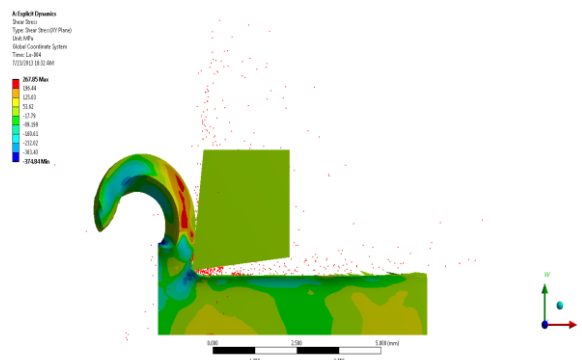


Fig 8: HSS Tool shear stress

II) Tool: SS440C Work piece: Mild Steel (EN19)

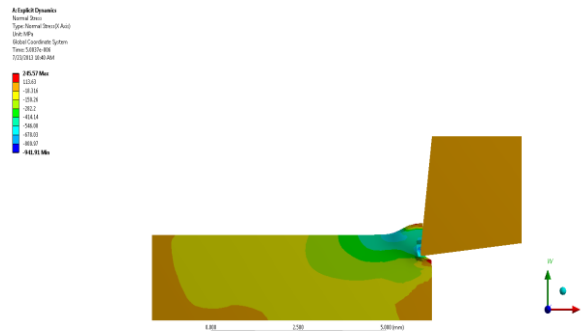


Fig 9: SS440C Initial Chip

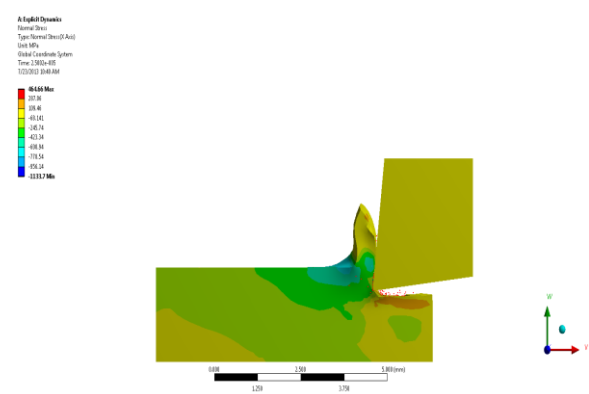


Fig 10: SS440C Tool Chip Growth

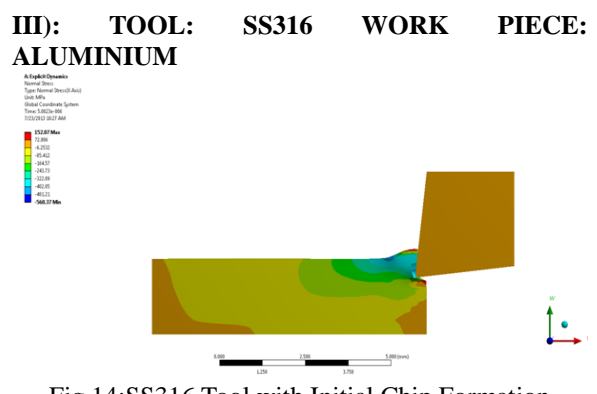


Fig.14:SS316 Tool with Initial Chip Formation

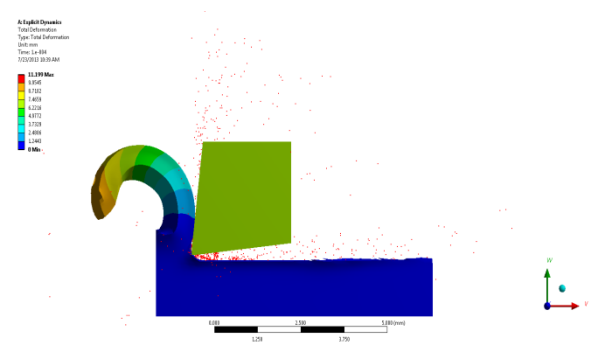


Fig 11: SS440C Tool Total Deform Chip

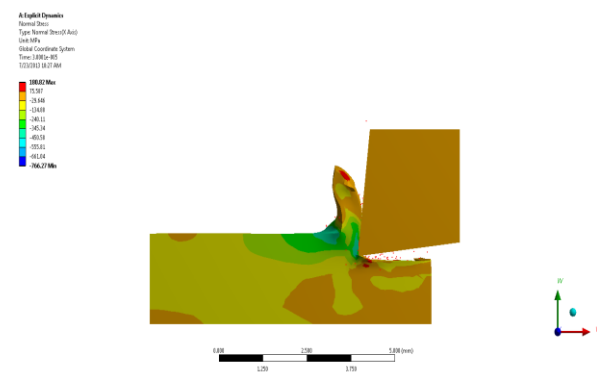


Fig. 15:SS316 Tool with Chip Growth

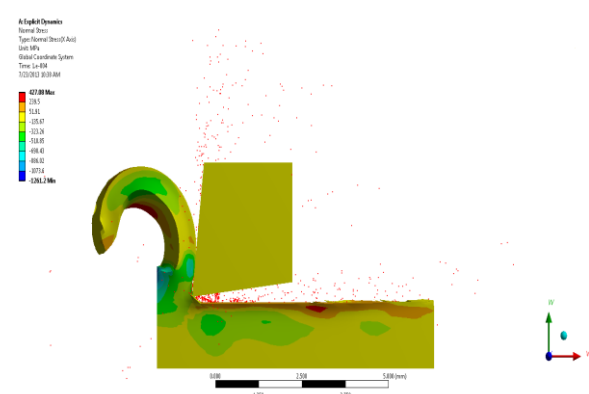


Fig 12: SS440C Tool Normal Stress Distribution

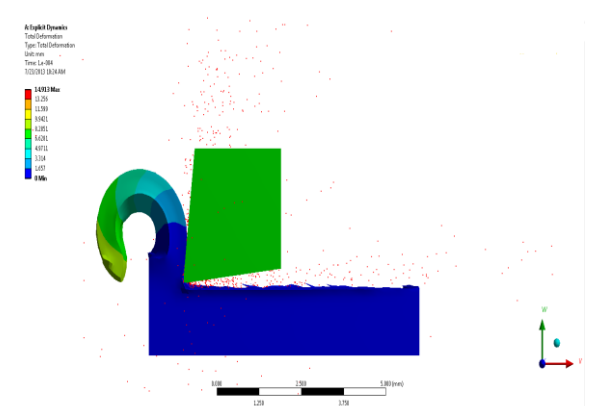


Fig.16:SS316 Tool with Total Chip Formation

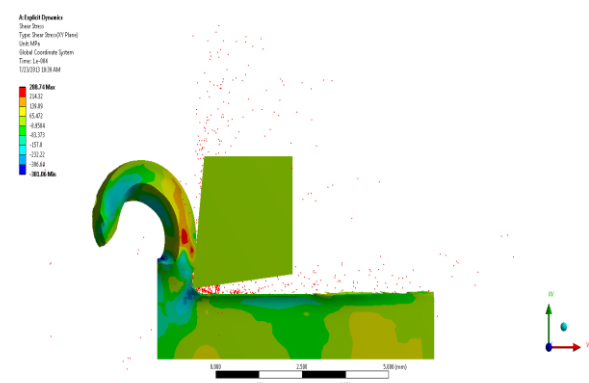


Fig 13: SS440C Tool Shear Stress Distribution

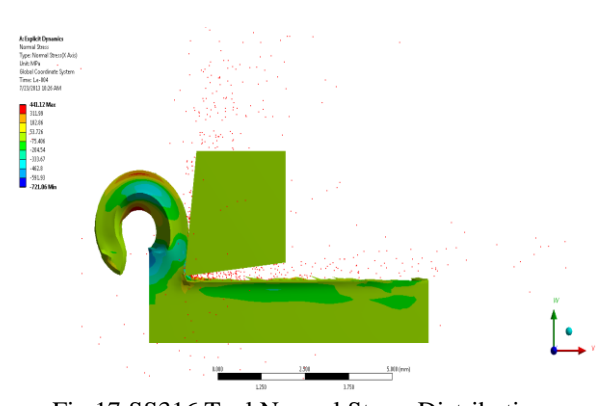


Fig.17:SS316 Tool Normal Stress Distribution

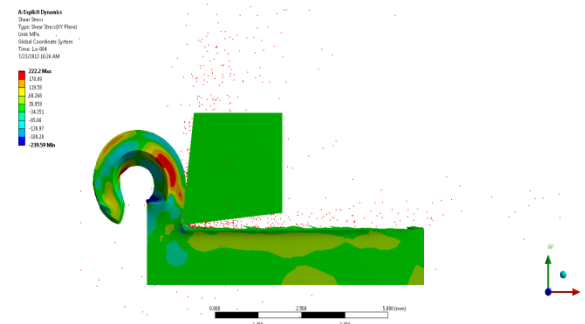


Fig.18:SS316 Tool Shear Stress Distribution

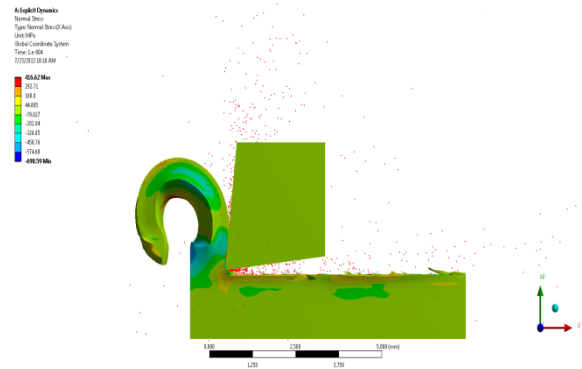


Fig.22: Titanium Alloy Tool Normal Stress Distribution

IV): TOOL: TITANIUM ALLOY WORK PIECE: ALUMINIUM

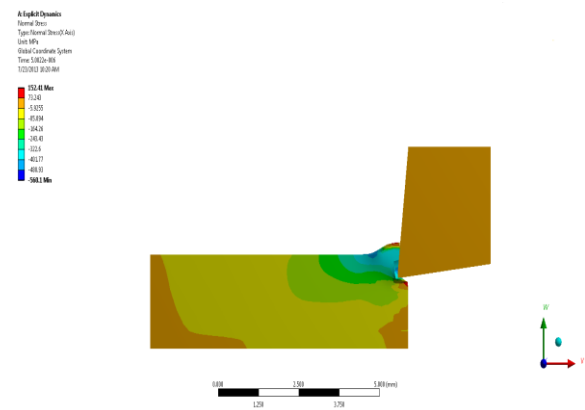


Fig.19: Titanium Alloy Tool with Initial Chip

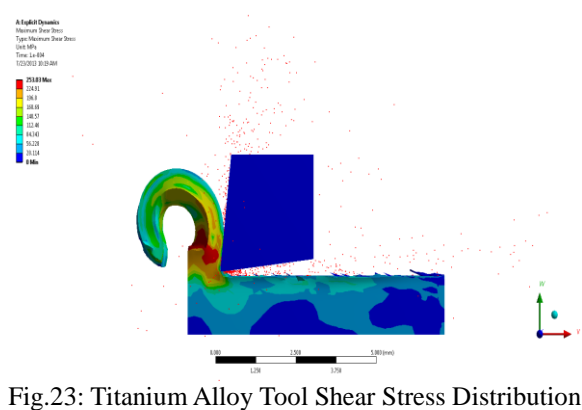


Fig.23: Titanium Alloy Tool Shear Stress Distribution

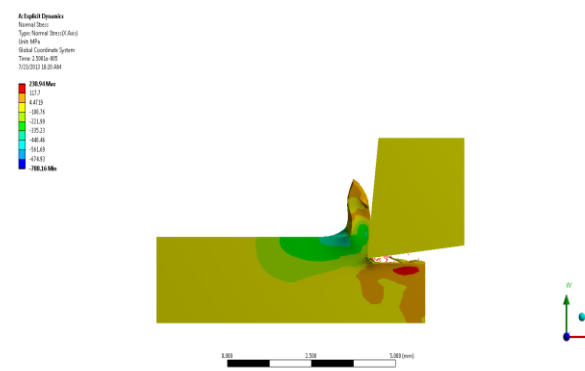


Fig.20: Titanium Alloy Tool with Chip Growth

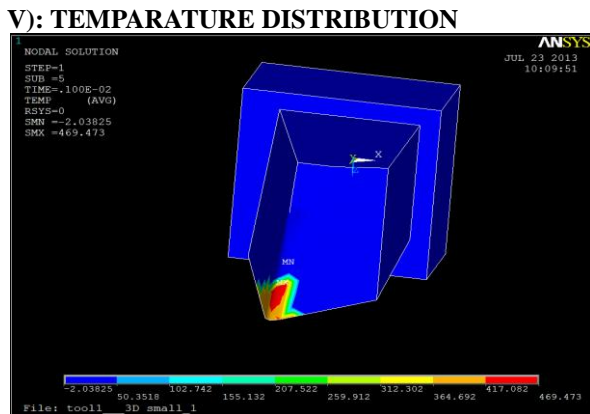


Fig.24: HSS tool temperature distribution

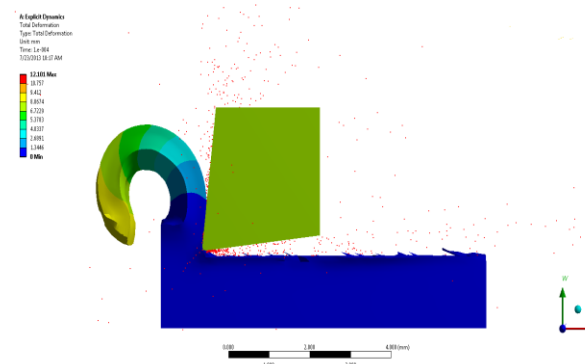


Fig. 21: Titanium Alloy Tool with Total Chip Formation

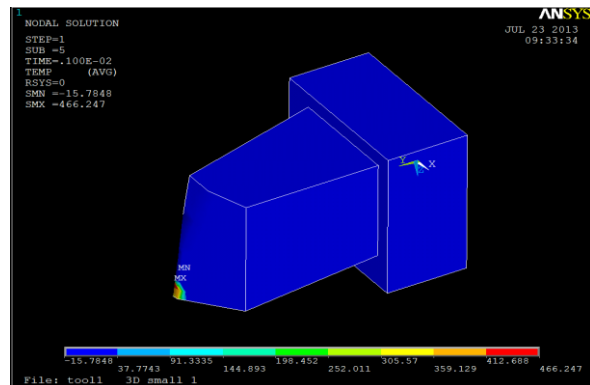


Fig.25: SS440C tool temperature distribution

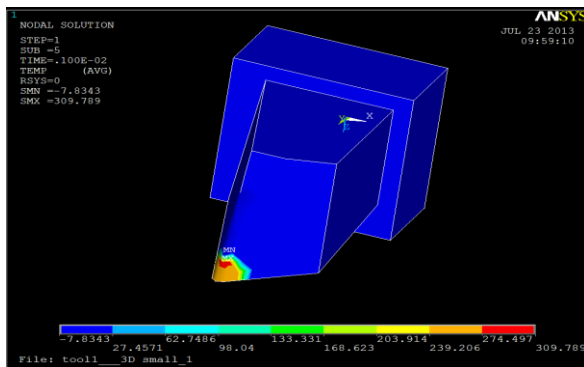


Fig.26: SS316 tool temperature distribution

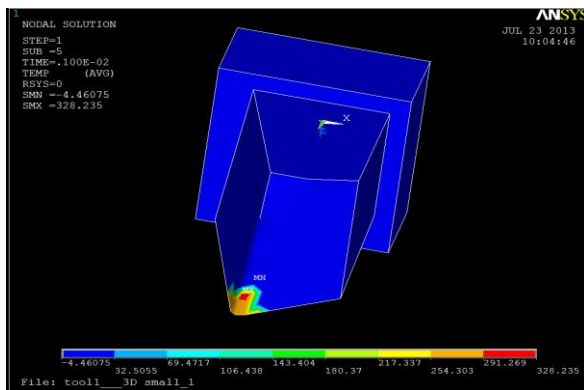
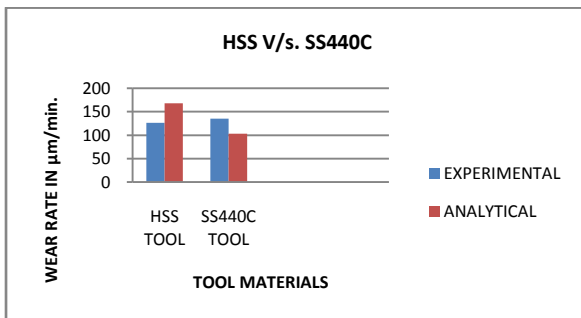


Fig.27: TITANIUM ALLOY tool temperature distribution

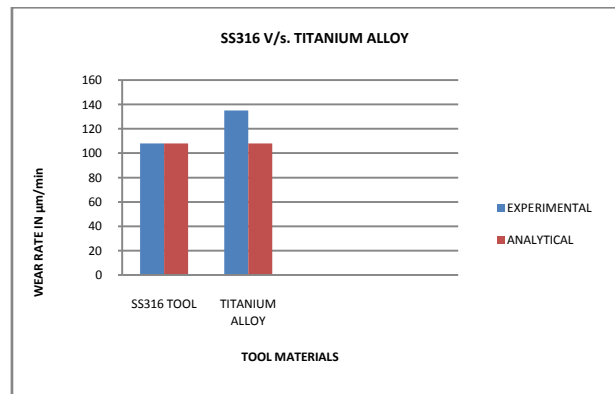
IV. WEAR ANALYSIS

TABLE: TOOL MATERIAL WEAR DETAILS

MATERIALS	EXPERIMENTAL IN $\mu\text{m}/\text{min}$	ANALYTICAL IN $\mu\text{m}/\text{min}$
HSS TOOL	126	168
SS440C TOOL	135	103
SS316 TOOL	108	108
TITANIUM ALLOY	135	108



Graph 6.10.HSS Tool V/S.SS440C Tool



Graph 6.11.SS316 Tool V/s. Titanium Alloy

V. RESULT AND DISCUSSIONS

The tool life of the selected cutting tools decreases with increase in cutting speed as shown in the Graph Nos. 6.6 to 6.9. Good surface finish was obtained for aluminium and MS work piece when machined with respective cutting tools at high cutting speeds which slightly reduces tool life. Due to hardening process carried out on respective tools, they can withstand mechanical vibrations at high speeds.

Heat generated between tool-work piece interface results in change in grain structure of the tool tip zone. At high temperature the material removed gets fused to the tool tip and thus results in poor surface finish. In order to remove the heat generated at tool tip the cutting fluids are used. By providing proper coatings the heat generated can be reduced and thus the tool life can be improved.

VI. CONCLUSIONS

1. For mild steel work piece material, SS440C materials were found to be cost effective, compared HSS material.
2. For aluminium work piece material, SS316 were found to be cost effective as compared to Titanium alloy(Ti-6Al-4V)
3. For mild steel work piece material, at low cutting speed the Shear force of the SS440C material is high as compared to the HSS tool.
4. For aluminium work piece material, at lower cutting speed SS316 has a greater Shear force than the Titanium alloy (Ti-6Al-4V), but at higher cutting speeds Titanium alloy (Ti-6Al-4V) were found to have higher Shear force than SS316.
5. For mild steel work piece material, at all cutting speeds tool life of HSS and SS440C were found to be relatively close.
6. For aluminium work piece material, at all speeds Titanium alloy (Ti-6Al-4V) were found to be having longer tool life than SS316.
7. SS440C tool can be replaced with HSS tool for mild steel work piece.

8. Instead of adopting high cost carbide tip tool for machining of soft materials like aluminum can be avoided by using SS316.
9. SS316 will produce low surface finish rather than the titanium alloy material.
10. Diffusion of material has occurred and deposited over the flank and creator on titanium alpha material deposited more on the rake face especially on the creator. This was due to high heat concentration by chips. This acted like shield & reduces further creator formation.

VII. SCOPE FOR FUTURE WORK:

1. Based on the materials survey this work concluded that, only martensitic stage materials are suitable for cutting tools.
2. Adopting different heat treatment process to further increase the hardness of the materials.
3. Adopting multiple coatings methods to reduce flank wear and increase tool life.
4. By changing the rake angles values how it influences on machining parameters.
5. By experimenting different stainless steel grades (SS grades) and adopting suitable heat treatment processes the results are compared.

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