Analysis of Coated Single Point Cutting Tool

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Abstract – This study presents tool wear characterization of single point cutting tool inserts coated with titanium nitride (Tin) and Al_2O_3.The single point cutting tool of material SAE-AISI 1037 carbon steel is selected. The coated tools exhibited superior wear resistance over the uncoated tool. The Al_2O_3/Tin coated tool had the lowest flank wear due to the high abrasive resistance. The coating is done according to the boundary conditions of the existing cutting tool as we selected, More than one layer are coated. The analysis of coated cutting tool is reported. Modeling of a cutting tool is designed by existing dimension. Feed force and cutting force are Analysis induced in the coated tool material.. Then the Finite element analysis is done to determine the total deformation in the existing Single point cutting tool for the given loading conditions using Finite Element Analysis software ANSYS WORKBENCH. In the first part of the study, the static loads acting on the cutting tool. The material of maximum Efficiency of single point cutting tool.

Index Terms – Titanium nitride (TIN), Aluminum Oxide (Al_2O_3)**, coating of tool, Carbon 1037.**

1. INTRODUCTION

The majority of inserts presently used in various metal cutting operations are cemented carbide tools coated with a material consisting of nitrides, oxides (e.g. Tin and Alumina).Coating cemented nitrate with Tin and Al_2O_3 dramatically reduces the rate of flank wear. High hardness is beneficial in resisting the abrasive wear. Retention of hardness even at higher temperatures is very important since the tool bit experiences a temperature in the range of 300-1000°C depending on the machining parameters and the materials to be machined. They all exhibit a decrease with an increase of temperature, and the decrease of hardness was much more pronounced in the case of TiN. Interestingly, the micro hardness of Al_2O_3 was significantly lower than TiN at room temperature but retained almost 40 % of its room temperature hardness at 1000 °C.

Thus, having a coating layer of Al_2O_3 over an under layer of Carbon help decrease the wear at the coating layer. This enhances the performance of the cutting tool, by including the Tin layer with a low wear rate and protecting it with a layer of Al_2O_3 to decrease the effect of diffusion/dissolution wear. The softer Tin outer layer helps in reducing the propagation of cracks into the inner coating layers, in addition to decreasing the welding of the chips to the cutting tool. Another reason for having the Tin as an outer layer, as opposed to inner layer, is that at higher temperatures of oxidation, under layer may affect the performance of the protective alumina over layer of the oxide

2. LITERATURE REVIEW

Rogério Fernandes Brito et al.[1],

The thermal properties of three layers of titanium carbide, (TiC), aluminum oxide (Al_2O_3), and titanium nitride (TiN) were analyzed, both individually and in group, considering a layer with equivalent thermal properties. Coated and uncoated cutting tools, titanium aluminum nitride (TiAlN) and aluminum chromium nitride (AlCrN), were used in the turning of AISI 4340 steel.

C. Chim1 et al. [2]

TiN, CrN, TiAlN and CrAlN coatings were deposited by vacuum arc. Their thermal stability and oxidation resistance were investigated after annealing in air at different temperatures (500°C-1000°C). TiAlN and CrAlN showed better oxidation resistance than their binary counter parts TiN and CrN. Cr-based coatings exhibited much better oxidation resistance than Ti-based coatings.

Audy J et al. [3]

The use of coated tools has advanced to the stage when surface coatings of increasing complexity are being routinely deposited on HSS tools. It is generally accepted by industry that popular TiN and Ti(C, N) coatings are now under increasing competition from TiAlN, TiAlCrN and more complex coatings based on TiN/TiAlN and or TiAlCrYN. These coatings are claimed firstly to increase the tool life due to improved tool wear resistance, and secondly to reduce the forces, power and tool temperature due to improved tool surface roughness and its resistance to built-up-edge formation and reduced friction at the tool-chip interface.

Mubarak et al. [4].

Titanium nitride (TiN) widely used as hard coating material, was coated on tool steels, namely on high-speed steel (HSS) and D2 tool steel by physical vapor deposition method. The study concentrated on cathodic arc physical vapor deposition (CAPVD), a technique used for the deposition of hard coatings for tooling applications, and which has many advantages. It is used to analyze and quantify the properties.

Nickel et al.[5]

The nature and the underlying wear mechanisms of TiN-coated tools and the role of TiN in improving wear resistance and increasing tool life have been the subject of many investigations. For example, the wear modes of TiN-coated HSS, from the results of sliding pin-on-disc wear tests, were found to include adhesive and abrasive wear of the coating w12,13x. TiN-coating fragments were found to be the dominant wear mechanisms in actual machining tests w8x. The latter wear mechanism was attributed to insufficient adhesion.

Abdul Kareem Jaleel et al. [6]

Hard coating such as TiN, TiC and Al_2O_3 have been used. High-speed machining is constantly increasing in importance. These new techniques can be applied in place of conventional machining methods for manufacturing of various components at low cost or even making entirely new type products, e. g. machined from brittle materials.

K. Aslantas et al.[7]

Research in coated mixed ceramic tool, the thermal conductivity value of TiN coating material increases with increases in temperature. Therefore, the heat flow to the cutting tool increases and the temperature at the tool–chip interface decreases. The temperature difference between the upper and lower sides of the chip decreases and the chip up-curl radius increases.

Cem Karacal et al.[8]

Advanced coating technology has significantly improved the tool life expectancy. Titanium Nitride (TiN), Titanium Carbo-Nitride (TiCN), Titanium Aluminum Nitride (TiAlN or AlTiN), Chromium Nitride (CrN), and Diamond coatings can increase overall tool life, decrease cycle time, and promoted better surface finish.

S. PalDey [9]

In this paper, deposition of (Ti,Al)N coatings using different PVD techniques have been reviewed. The effects of deposition variables on coating microstructure and film properties were analyzed. (Ti,Al)N exhibited superior performance in many applications as compared with the other commercially available Ti based coatings. Based on a simple TiN coating, various strategies were developed in order to improve or adapt hard coatings.

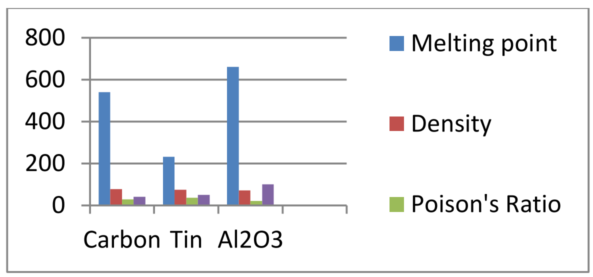
Weiguang Zhu [10]

The use of Tin-coated tools causes a reduction in heat partition into the cutting tool compared with the uncoated tool about 17 percent at conventional cutting speed and 60 percent in the HSM region. It may be concluded that, compared with uncoated carbide tools, TiN coatings significantly improve the

tribological phenomena by reducing the tool chip contact area, providing a lower thermal conductivity for the tooling systems, and ultimately reducing heat partition into the cutting tool.

3. PROPERTIES

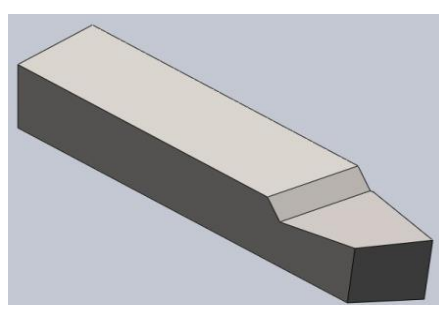
Type	**Melting p oint**°C	**Density** g/cm3	**Young's modulus** Gpa	**Shear modulus** Gpa	**Bulk modulus** Gpa	**Poisson ratio**
1037C	540	7.79	40	14	64	0.29
TIN	505.08	7.36 5	50	180	58	0.36
Al_2O_3	660	7.0	100	124	172	0.21



4. MODELING

Solidworks

Solidworks uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies. When designing a model using Solidworks, you can visualize it in three dimensions, the way the model exists once it is manufactured.

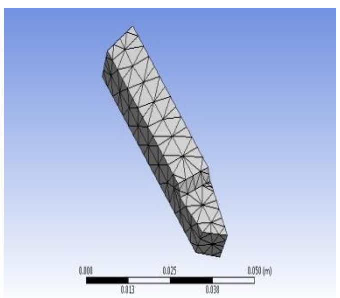


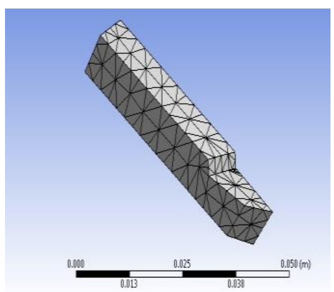
5. ANALYSIS

ANSYS Mechanical provides solutions for many types of analyses including structural, thermal, modal, linear buckling and shape optimization studies. ANSYS Mechanical is an intuitive mechanical analysis tool that allows geometry to be imported from a number of different CAD systems. It can be used to verify product performance and integrity from the concept phase through the various product design and development phases. The use of ANSYS Mechanical accelerates product development by providing rapid feedback on multiple design scenarios, which reduces the need for multiple prototypes and product testing iterations.

5.1. Meshing

Mesh generation is the practice of generating polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen or for physical simulation such as finite element analysis or computational fluid dynamics..



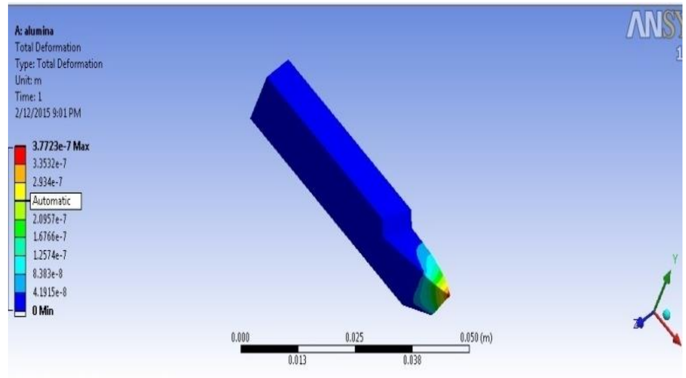


Tin **Al_2O_3**

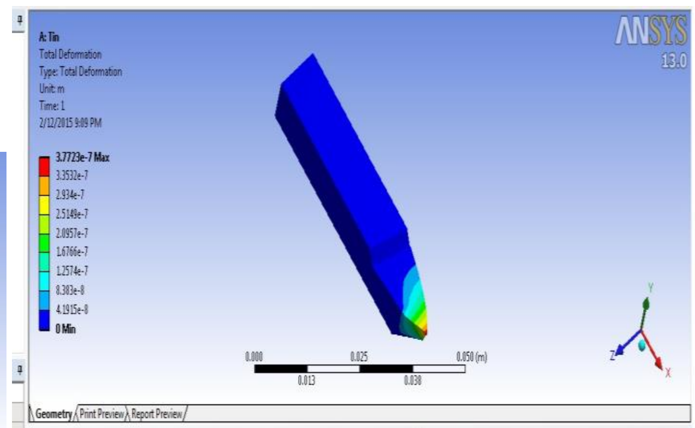
In materials science, deformation refers to any changes in the shape or size of an object due to-an applied force (the deformation energy in this case is transferred through work) ore change in temperature (the deformation energy in this case is transferred through heat).the first case in the form of tensile, compressive, shear and bending forces.

5.2. Total Deformation

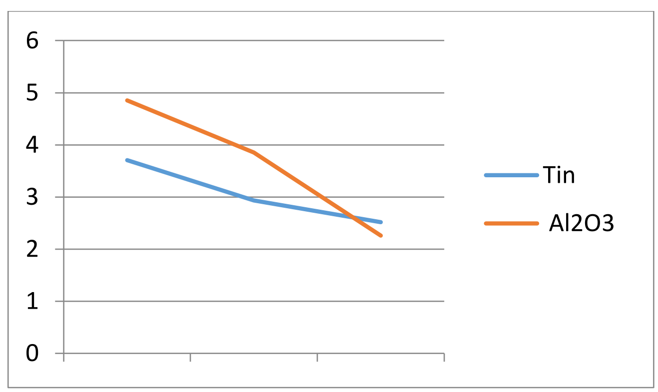
In the second case, the most significant factor, which is determined by the temperature, is the mobility of the structural defects such as grain boundaries, point vacancies, line and screw dislocations, stacking faults and twins in both crystalline and non-crystalline solids. The movement or displacement of such mobile defects is thermally activated, and thus limited by the rate of atomic diffusion



Tin



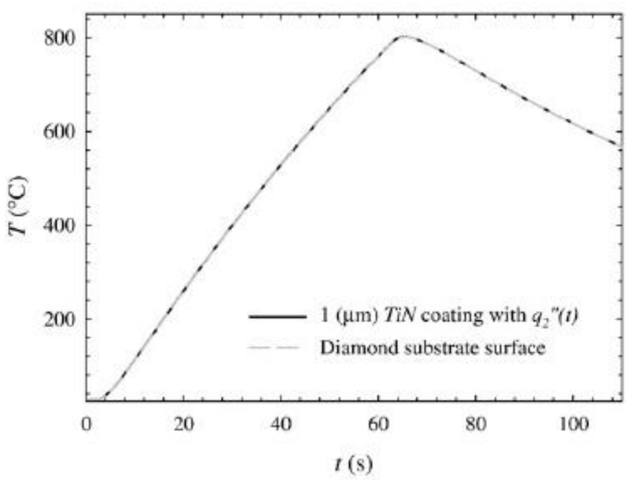
Al_2O_3

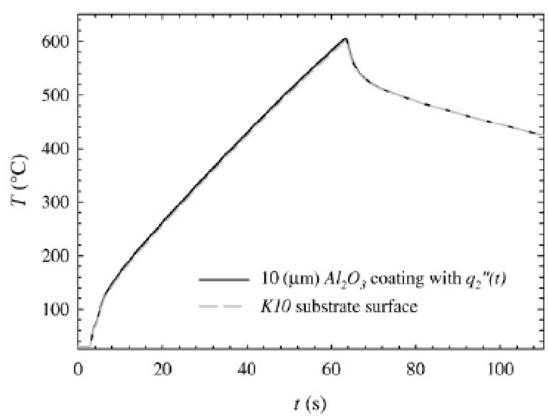


5.3. Principle stress

From elasticity theory, an infinitesimal volume of material at an arbitrary point on or inside the solid body can be rotated such that only normal stresses remain and all shear stresses are zero. The three normal stresses that remain are called the principal stresses.

6. NUMERICAL VALIDATION





7. RESULT AND DISCUSSION

The characteristics of both substrate and coatings are presented in graph 1. As can be seen, the highest percentage of carbon corresponds to the TIN & Al_2O_3 coating. According to earlier studies, coatings of (TIN)N with less than 70%Al have a cubic B1 structure which is the same structure as pure Tin.

It shows the total deformation corresponding to the morphology of the fractured surfaces of the coatings. As can be observed, all the coatings possess a fine grained, as expected from carbon 1037, is obtained.

Tin :

Minimum	Maximum	Young's Modulus Pa
0. m	3.7723e-007 m	2.e+011
0. m/m	2.7553e-005	1.6667e+011

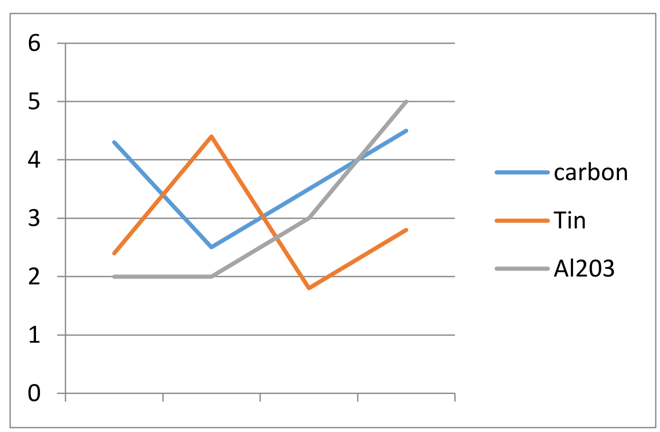
	m/m	
3.1923e+006 Pa	1.0994e+006 Pa	7.6923e+010

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

Al_2O_3:

Minimum	Maximum	Young's Modulus Pa
0. m	3.7723e-007 m	2.e+011
-3.1923e+006 Pa	1.0994e+006 Pa	2.6667e+011
5.5941e-012 Pa	1.0696e+007 Pa	6.8723e+010

Density	8850 kg m^-3
Coefficient of Thermal Expansion	3.2e-005 C^-1
Specific Heat	725 J kg^-1 C^-1
Thermal Conductivity	120.5 W m^-1 C^-1
Resistivity	2.7e-007 ohm m



8. CONCLUSION

In the present work the performance of coated tools in machining hardening steel under dry conditions is studied. The results shows that the Tin coated tool perform better as compared to uncoated cutting tool. The effect of cutting is to reduce wear and tear of tool tip point as well as more heat dissipation to surrounding hence the increase in tool life and surface finish of the product to be machine. With increase in depth of cut the surface roughness is increased. Here experimental results shows by selecting the proper cutting parameters the coated tools are suitable to produce fine surface finished components.

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