



# WEAR RATE ANALYSIS OF NANO-COATED CUTTING TOOL

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## ABSTRACT

Drilling is one of the metal cutting operation that are widely used manufacturing technique in the industrial world. In this process, drill bits are the cutting tools that are used to create circular holes. The aim of the present work is to minimize the tool wear rate by nano-coating TiAlN on the tool surface. For that wear tests are conducted on the pin-on-disc apparatus under dry sliding condition. The surface morphology of the tools were studied by using Scanning Electron Microscopy (SEM). With the help of ANSYS Workbench 14.0 the frictional stress and contact pressure for both TiAlN coated and uncoated HSS pins were analysed for different varying loads. It was found that TiAlN nano-coated tool shows very less wear rate than HSS cutting tool.

## I. INTRODUCTION

A coating is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be decorative, functional, or both. The coating itself may be an all-over coating, completely covering the substrate, or it may only cover parts of the substrate. It is necessary to have an insight into the effect of TiAlN nano coating on the surface of the tool bit in order to investigate the wear on the surface during machining. Based on physical models used to calculate stress in the substrate and in various coating layers, it is possible to recommend PVD(Physical Vapour Deposition) and CVD(Chemical Vapour Deposition) coatings for interrupted cutting operations such as milling, parting, and drilling or in some cases also for continuous operations like turning and threading. The use of TiAlN coating has the advantage in dry and high-speed machining compared to the TiN and TiCN coatings. Here the commercially available PVD coating technique is used for nano coating the tool surface by TiAlN. Physical vapour deposition (PVD) describes a variety of vacuum deposition methods used to deposit thin films by the condensation of a vaporized form of the desired film material onto various work piece surfaces.

## II. EXPERIMENTAL METHOD

The wear analysis of TiAlN nano coated drill bit and HSS drill bit can be done using tribometer test. Here the experimental method includes the preparation on TiAlN nano coated pin and HSS pin and finally wear analysis is to be carried out using pin-on-disc experiment. For the preparation of the TiAlN nano coated pin, a 6mm dia and 20mm length HSS pin is to be Nano coated.

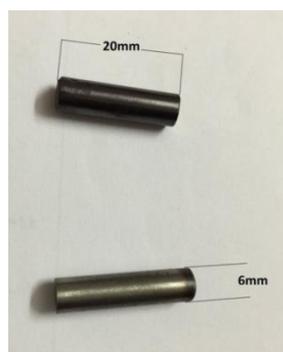


Fig. 1: TiAlN coated and HSS pin

### 2.1 Pin-On-Disc Experiment Parameters

A black emery sheet of 120 grade is used above the rotating disc during the testing. Tribometer test is done under normal environmental temperature in dry condition (without lubricant). The experiment was carried out for a time period [T] of 122 sec. During the process a 3kg ( $3 \times 9.81 = 29.43\text{N}$ ) weight is given to the pin. Rotating speed [N] of disc is maintained in 477rpm and Wear track dia (WTD) is 80mm.

Sliding Speed =  $\pi DN / 60 \times 1000$

$$= 1.998 \text{ m/s}$$

Sliding distance =  $\pi DNT / 60 \times 1000$

$$= 244.91 \text{ m}$$

Total time of experiment = 122 sec

[D=80mm, N=477 rpm, T=122 sec]

### III. EXPERIMENTAL RESULTS

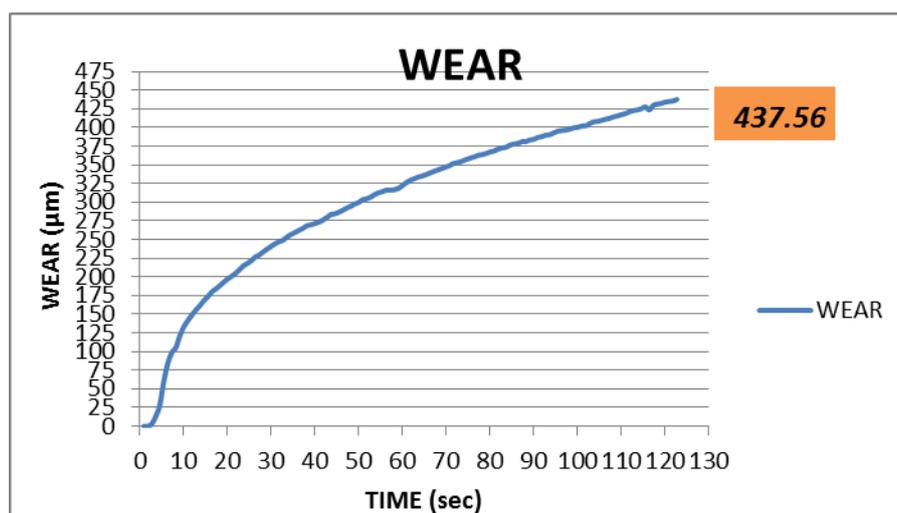
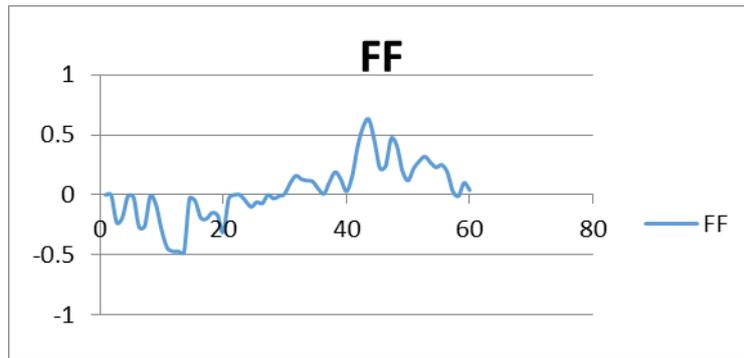


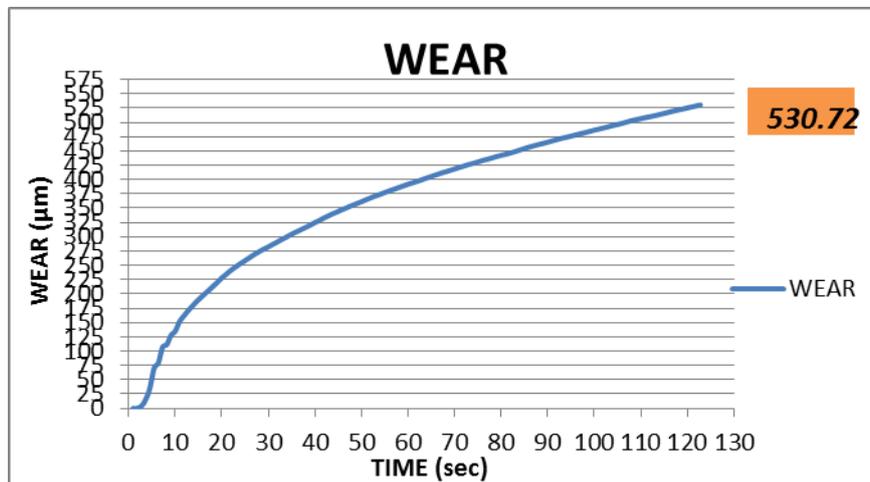
Fig. 2: Wear Vs Time (TiAlN Coated)

The cumulative volume loss of metal is lower in certain conditions and the wear rate of TiAlN coated metal are lower than that of the pure HSS. From the experiment, it is clear that the wear rate of the tools depends upon the coating provided on the surface. Here 30N load is provided for both the samples.

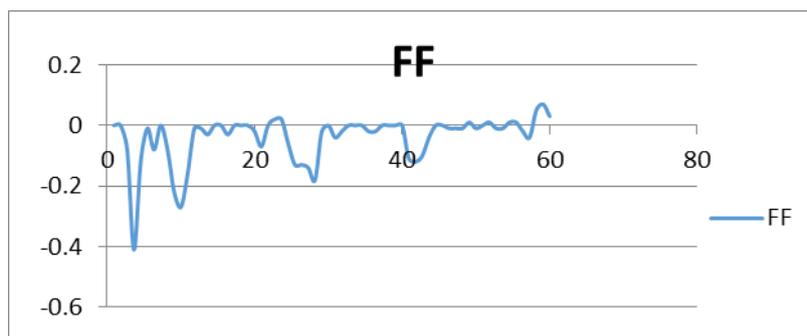


**Fig. 3: Frictional Force Vs Time(TiAlN coated)**

The cumulative volume loss of metal is higher in certain conditions and the wear rate of HSS metal are higher than that of the TiAlN coated metal. From the experiment, it is clear that the wear rate of the tools depends upon the coating provided on the surface. Here 30N load is provided for both the samples.



**Fig. 4: Wear Vs Time (HSS).**



**Fig. 5: Frictional force Vs Time(HSS).**

The figure below shows the wear happening on both TiAlN coated and uncoated pin was plotted with respect to time, where we can see that the wear rate is much more in uncoated pin and is reaching about 530.72µm after 122 sec where as for TiAlN coated pin undergoes 437.56µm.

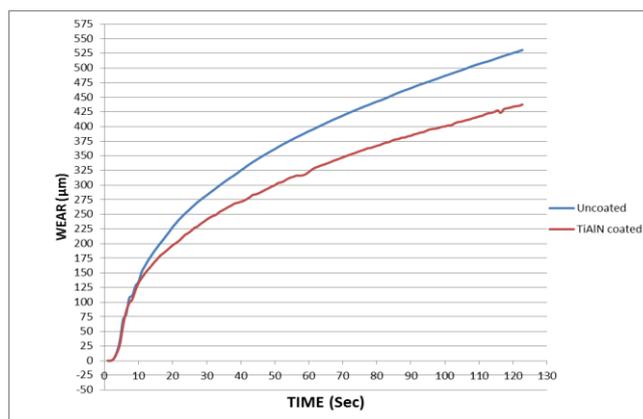


Fig. 6: Comparison of Wear V/s Time for Both Coated and Uncoated Pin.

#### IV. DRILL BITS

Drill bits are cutting tools used to create cylindrical holes, almost always of circular cross-section. In this work the standard drill bit of following specification are used. The Effective Length: 100mm, Overall Length: 160mm, Drill Bit Type: Twist / Jobber, Drill Point Angle: 118°, Drill Point Diameter: 6mm, External Diameter: 6mm, Material: High Speed Steel, Weight (kg): 0.038.



Fig. 7: HSS drill bit

#### 4.1 TiAlN Coating

Here Physical vapour deposition(PVD) technique is used for Nano coating on the surface of the HSS drill bit for wear analysis. TiAlN(Titanium Aluminium Nitride) is coated on the surface of the drill bit using PVD technique on the effective length of the drill bit. This coating has a greater hardness than TiN. A very thin film of Al<sub>2</sub>O<sub>3</sub> (Aluminium Oxide) is formed on the surface of the TiAlN which greatly increases the service life of the tool, withstanding higher temperatures especially when machining Cast Iron and tough steels.



Fig. 8: Coated drill bit and pin

### 4.2 Drilling

Using both HSS drill bit and TiAlN nano-coated drill bit drilling was made on a 10mm thick MS plate. 100 drilling was made by pillar drilling machine. The surface morphology of these drill bits after drilling were studied by SEM(Scanning Electron Microscopy) imaging.

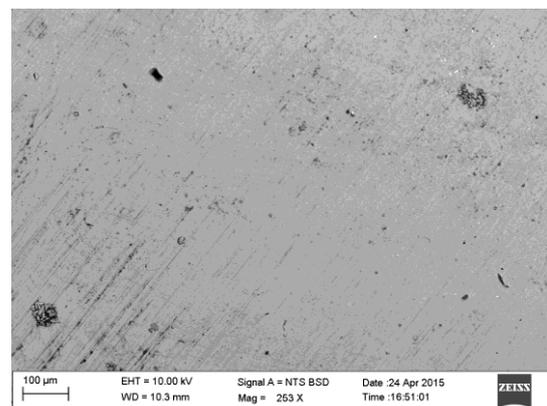
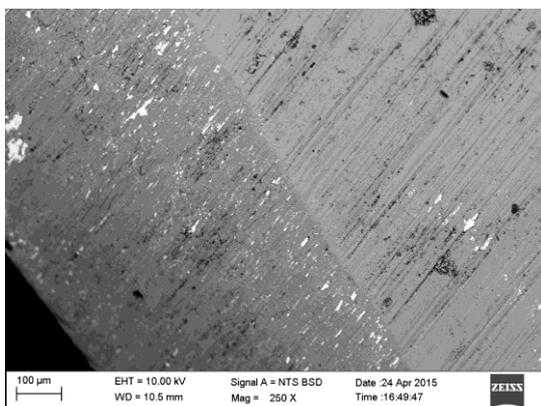
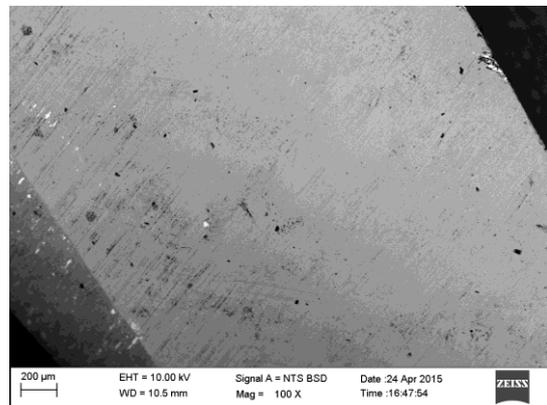
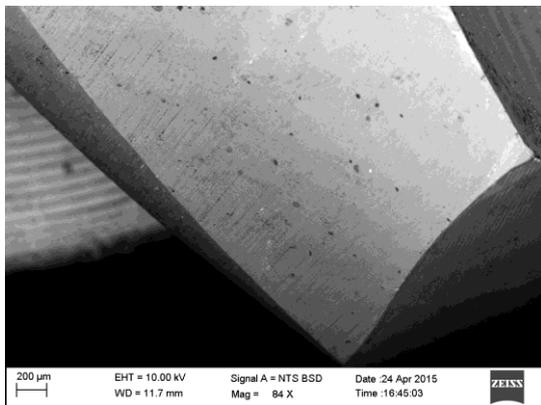


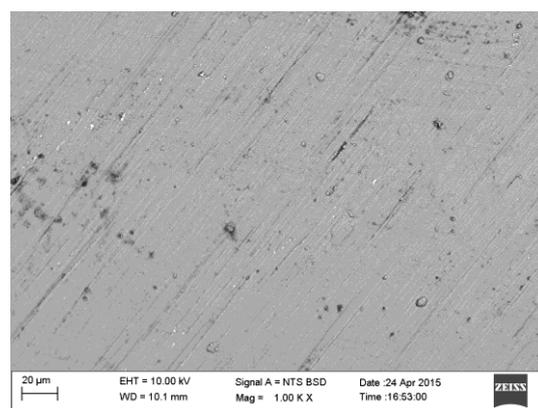
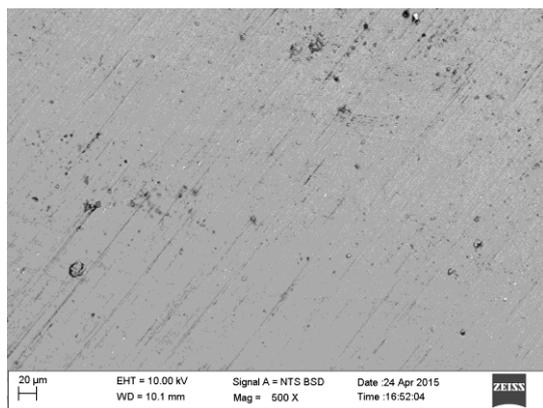
Fig. 9: MS Plate and drill bits

### V. SEM IMAGE

Here the SEM(Scanning Electron Microscopy) image of drill bit is taken in different dimensions. SEM image is taken on the surface of the drill bit. Image is taken for both TiAlN nano coated drill bit and uncoated HSS drill bit after 100 drilling process. Both the drill bits are machined(drilled) using same drilling machine on a MS plate of thickness 10mm.

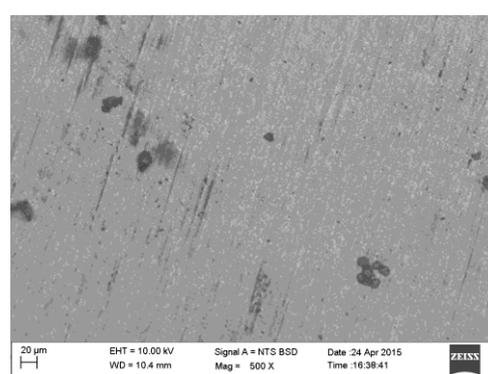
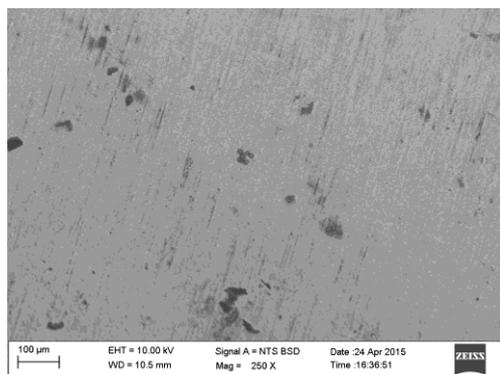
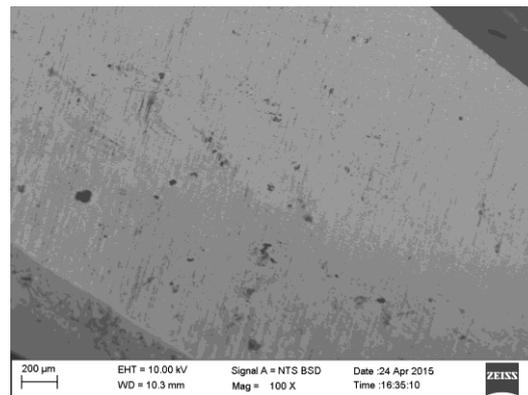
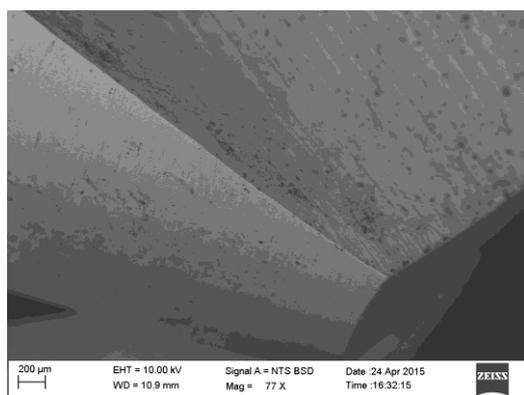
The SEM image of TiAlN nano coated drill bit after drilling process and it is seemed to be some particles are removed from the surfaces during drilling process but these removal rate is very less compared to the SEM image of uncoated drill bit.

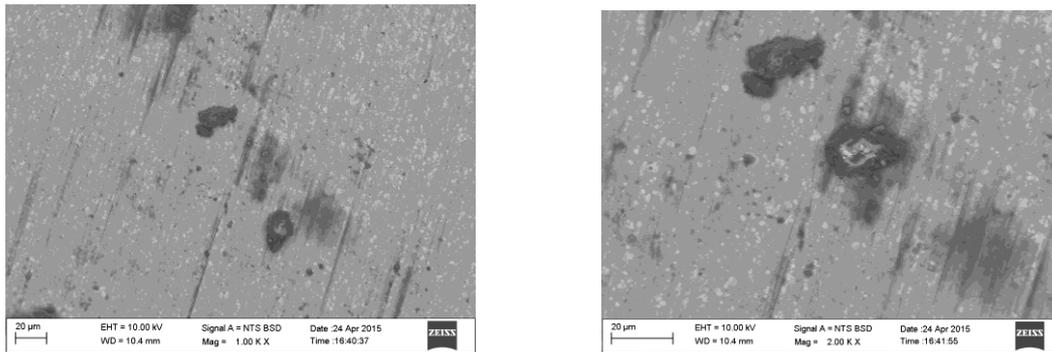




**Fig. 10: SEM image(TiAlN coated drill bit)**

Above figure shows the SEM image of the worn out surface of TiAlN Nano coated drill bit surface after 50 drilling process. The worn area of the drill bit investigated and find that the wear rate of the TiAlN Nano coated drill bit is less compared to that of the uncoated HSS drill bit. From this, it is clear that the TiAlN there by formed a strong bonding between the particles. These intermolecular bonding would leads to high wear resistant property to the tool surface and thus increases the tool life. Here the highest wear rate would experience in the HSS drill bit surfaces.





**Fig. 11: SEM image(Uncoated HSS drill bit).**

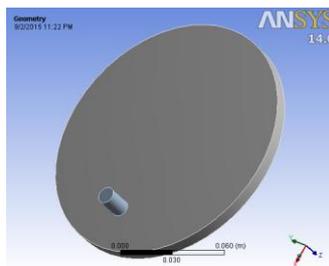
The above figure shows the SEM image of the worn out surface of uncoated HSS drill bit surface after 50 drilling process on MS plate. The worn area of the drill bit investigated and finds that the wear rate of the uncoated drill bit is much more compared to that of the coated drill bit and some more particles are thrown out from the surface during drilling which cause more wear and decreases the life time of the tool.

## VI. FINITE ELEMENT ANALYSIS

Finite Element Analysis was done on the ANSYS Workbench 14.0. Here both coated and uncoated pin were analysed. For uncoated pin HSS is taken and for coated pin TiAlN is taken for analysis.

### 6.1 Modelling Analysis

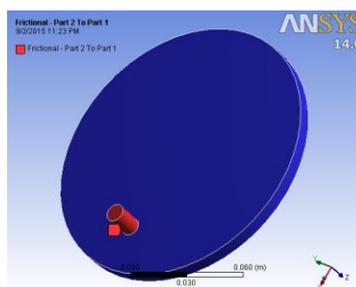
Modelling was done on ANSYS Design Modeler. A disc with diameter 165mm and thickness 10mm and a pin with 6mm diameter and 20mm thickness were modelled in ANSYS Design Modeler. Then they were assembled properly as shown below with a wear track radius 40mm from the centre of the disc.



**Fig. 12: Assembled model of Pin-On-Disc**

### 6.2 Connection

Frictional contact was made between the two parts (pin and disc). Frictional coefficient was given as 0.7.



**Fig. 13: Frictional contact between the Pin and the Disc.**

### 6.3 Mesh

The element used for meshing is Tetrahedron. It is the most simplest 3D element. Four noded tetrahedron element was used. Total number of nodes = 66126. Total number of elements = 41923

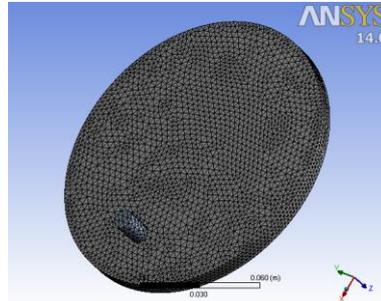


Fig. 14: Meshing.

### 6.4 Boundary Condition

Disc was made to rotate with a rotating speed of 477rpm about Z axis. Linear movements of the disc were arrested using ‘displacement support’ by giving a constant value of 0mm along X, Y and Z axis. And a force of 30N was exerted by the pin towards the disc along Z axis. Frictionless support was given to sides of pin for arresting its displacement in X and Y direction.

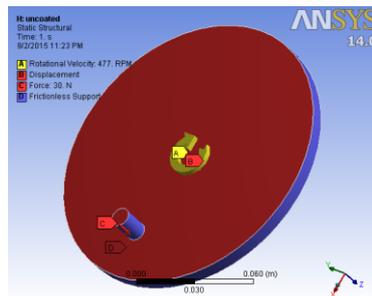


Fig. 15: Boundary condition

### 6.5 Solution

From the results obtained the maximum frictional stress occurs on the pin and the minimum for the disc. The below figure shows the frictional stress distribution of the uncoated pin and the disc. From the figure it is clear that the maximum value of frictional stress obtained is 23084 Pa.

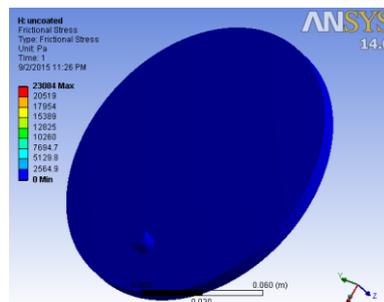
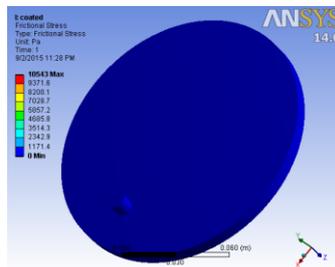


Fig. 16: Frictional Stress of uncoated pin.

The below figure shows the frictional stress distribution of the coated pin and the disc. From the figure it is clear that the maximum value of frictional stress obtained is 10543 Pa.



**Fig. 17: Frictional Stress of coated pin.**

The frictional stress experienced on uncoated pin was much more than that of TiAlN coated pin. The maximum frictional stress value of uncoated pin was 23084 Pa whereas the maximum frictional stress value of coated pin was 10543 Pa. Since wear is directly depended on the frictional stress, we can say that there exists low wear rate on TiAlN coated pin compared to uncoated pin. The Finite Element analysis shows that the frictional stress was more in uncoated pin thus we can say that wear will be more in uncoated pin compared to the TiAlN coated pin.

## VII. CONCLUSION

In this work, for a given load, the cumulative wear volumes of TiAlN Nano coated drill bit and uncoated HSS drill bit increases linearly with sliding distance under dry sliding. Wear rate would be maximum for the uncoated drill bit and wear rate would be minimum for the TiAlN Nano coated drill bit surfaces. The TiAlN coated on the surface will form a strong bonding between particles on the surface and a protective Oxides of Aluminium-(Al<sub>2</sub>O<sub>3</sub>)-Aluminium Oxide is formed on the surface of TiAlN which greatly increases the surface hardness. Surface smoothness for the TiAlN Nano coated drill bit would be greater and the HSS drill bit shows rough surface morphology. TiAlN Nano-coated specimen shows only very less volume loss on its surface during the experiment whereas the uncoated HSS specimen volume loss is more and during machining (drilling process) in MS plate by both drill bits they exhibits a different properties such as the easiness of machining increases and also the surface finishing of TiAlN Nano-coated drill bit tool is maintained much more which will increases the tool efficiency and tool life.

By analysing the surface morphology of tools surface after drilling process it may be stated that the twist or jobber type drill bit structure is unvaried for long time in TiAlN Nano-coated drill bit since the surface hardness is increased and only very less particles are removed from the surface of the tool. By analysing the SEM image of worn out specimen it can be noted that the TiAlN coated drill bit maintains a strong bonding between the atoms, and also the temperature and load experienced of the surface of drill bit during machining will not effects much on the tools surface when it is coated.

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