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Research Article

Characterization of TiAlN and TiN Coating on High Speed Steel using Ion Beam and Cathodic Arc Deposition Techniques

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Abstract

This paper deals with the characterization of TiAlN and TiN thin film coating over the high speed steel substrate. TiAlN and TiN coatings were done using two different processes in an effort to compare the coating properties of the two processes. The two processes employed are cathodic arc evaporation technique and the ion beam deposition technique. The coated material was subjected to different types of tests to determine their properties. The thickness of TiAlN coated over high speed steel found to be 1.4 microns and the thickness of TiN was found to be 2.9 microns. The microstructure of the coated and uncoated material were studied, it was evident that the substrate contains large and small particles of carbide in a matrix of tempered martensite. The scratch test was conducted in order to determine the maximum scratch load the coating can withstand, the value of TiAlN was found to be 4 kg and the value of scratch load the TiN coating withstood was 3.8kg. This proves that the TiAlN coating is more resistant to scratches.

***Keywords**: Coating, Ion beam, Cathodic Ion Deposition etc.*

1. Introduction

Research organization addressing with the tool materials problems exert much effort for many years to fabricate the better tool material, characteristics of the high ductility, resistance to dynamical loads, and high abrasion wear resistance. Fabricating such tool, in spite of its high price would cut significantly manufacturing costs of engineering materials connected with the machining, replacement of worn out tool. Fabricating a tool in such properties is merged like the relatively high ductility and abrasion wear resistance has become possible by the technologies of coatings onto the finished tools with the PVD and CVD methods . High Speed Tool Steel and their requirements are defined by The American Society for Testing and Materials in Specification A600-79 as follows: High-speed tool steels are so named primarily because of their ability to machine materials at high cutting speeds. They have the highest toughness and good cutting ability, but they possess the lowest hot hardness and wear resistance of all the high-speed tool steels . Cryogenic treatment on HSS will result in the conversion of retained austenite into martensite. This results in an increase in hardness of HSS drill bit due to increase in density of dislocation and gaps. Plasma nitridation of high speed steel is studied using a microwave assisted electron cyclotron resonance plasma source; plasma nitridation on HSS shows the increase in hardness. The Titanium based coatings have a wide range of applications, because the coating increases the hardness of the base material.

The goal of this work was to investigate the influence of deposition of TiN and TiAlN over high speed steel using two different techniques that is Cathodic arc and Ion beam assisted deposition.

2. Experimental Details

HSS raw material of the dimension 156mm×12mm (length × breadth) and a cylinder of 20mm×116mm (diameter × length) were procured. The HSS cuboidal raw material was cut into two segments each of 76×12 (mm) and the cylindrical raw material was cut into two segments each of 20×56 (mm) by parting operation. Grinding operation was carried out to machine the ends and the surface of the two cuboidal segments and the two cylindrical segments, in order to provide a high surface finish for the coating process.

2.1 HSS-Specimen Preparation

The following steps were undertaken for the initial stage of receiving the HSS specimens till its quality check.

- High Speed Steel substrate was first subjected to visual inspection with the aid of magnifying lens in order to identify any physical damages such as scratches or burn marks which would have occurred post machining or due to wrong handling.

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- Pre Cleaning is a method employed in the industry post visual inspection to remove the dirt accumulated on the surface of the substrate such as grease, oil, grime etc. in cleaning equipment using cleaning solutions.
- The process of micro-abrasive blasting involves mixing a finely graded abrasive media with a compressed stream of air and forcing it through a small nozzle. The un-coated substrates were subjected to Micro-Abrasive Blasting to obtain scratch free clean surface.
- HSS substrate was subjected to ultrasonic cleaning post micro-abrasive blasting. The substrates were cleaned using this equipment in the 9 baths and then dried in the sub-sequent 3 baths. This cleaning using ultrasonic equipment ensures proper removal of all the dirt adhered to the substrate. These are the important and final stage of cleaning the substrates, work piece needs to handle carefully after cleaning.

2.2 Cathodic Arc Deposition

Cathodic arc deposition is employed to coat TiAlN onto the HSS substrate; the coated specimens are shown in figure 3.3. In this process, Inert gas such as argon and reactive gas nitrogen is used for reaction purpose, due to high current and low voltage, ionization of inert gas occurs leading to formation of an arc, and this arc reacts with the cathode (TiAl) to evaporate its constituents which in turn will react with nitrogen leading to deposition of a thin layer of TiAlN onto the substrate.

Figure 2.1 TiAlN coated HSS

2.3 ION Beam Deposition

Ion plating is employed for the coating of TiN (Titanium Nitride) onto the substrate HSS; the coated specimens are shown in figure 3.4. Ion plating is a PVD process involving reactive electron beam evaporation. For the coating of HSS by TiN an inert gas argon and a reactive gas nitrogen are employed. The metallic component for ion plating is evaporated by a low-voltage arc. A metal plate is bombarded with argon atoms to generate the coating material. Ti reacts with nitrogen leading to the deposition of a thin layer of TiN onto the substrate. The metallic component for ion plating is evaporated by a low-voltage arc.

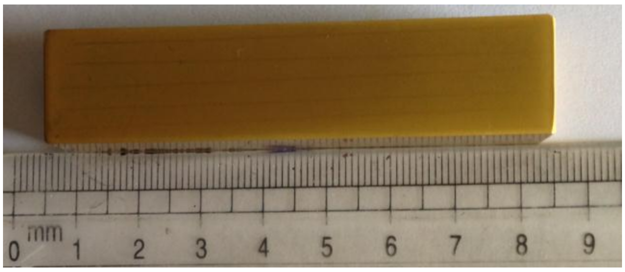

Figure 2.2 TiN coated HSS

3. Results and Discussion

3.1 Coating Composition And Thickness

SEM in combination with EDX (Energy Dispersive X-ray spectroscopy) was used to find out composition at different region of samples. We used JEOL-JSM 6380 (LA) SEM is shown in figure 3.1 to find out the composition of the HSS tool and also the composition of the two thin films- TiN and TiAlN. The chemical composition test for the TiN and TiAlN Coatings were done. Figure 3.1 and 3.2 shows the percentage composition of TiAlN and TiN respectively.

Figure 3.1 Scanning Electron Microscope

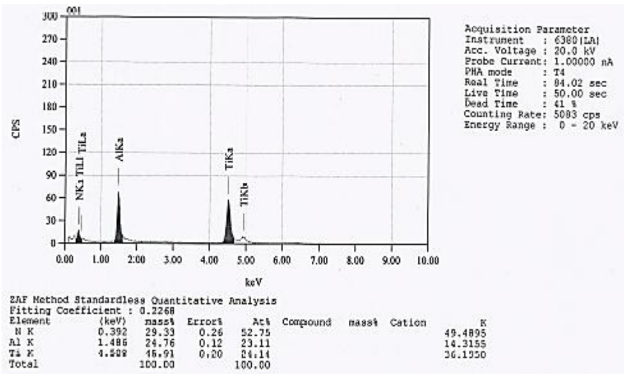

Figure 3.2 Composition analyses for TiAlN

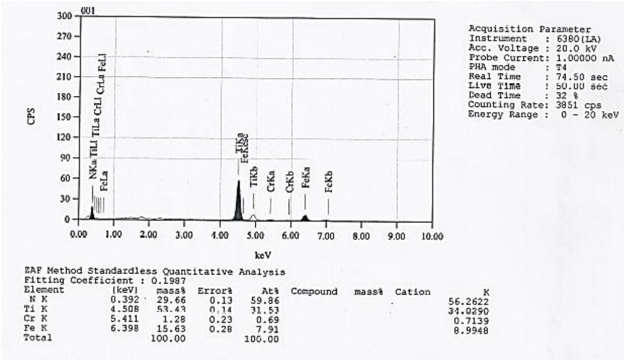

Figure 3.3 Composition analyses for TiN

The thickness of deposit material was determined using laboratory microscope and at a magnification of 500X. The average thickness of TiN shown in Figure 3.3 was found to be 2.9 microns and the average thickness of TiAlN shown in Figure 3.4 was found to be 1.4 microns. This indicates that the coating in fact was a thin film coating by definition.

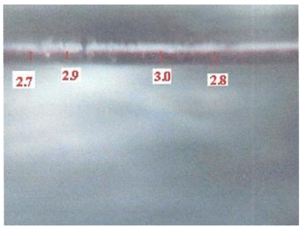

Figure 3.4 Thickness of TiN coating

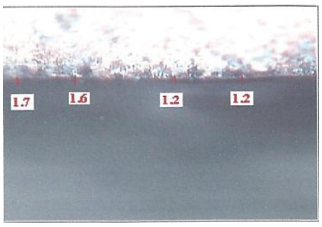

Figure 3.5 Thickness of TiAlN coating

3.2 Scratch Test

Figure 3.6 Automatic Scratch tester

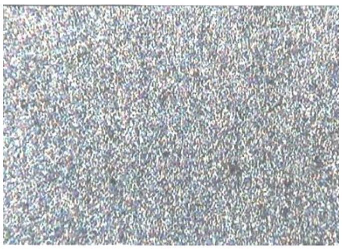

Figure 3.7 Microstructure of TiN before scratch test (500X)

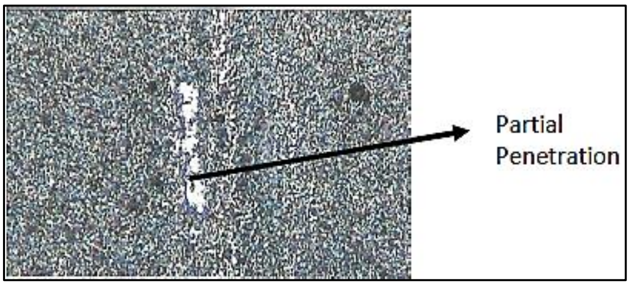

Figure 3.8 Microstructure image of TiN upon 3.5kg load of scratch (500X)

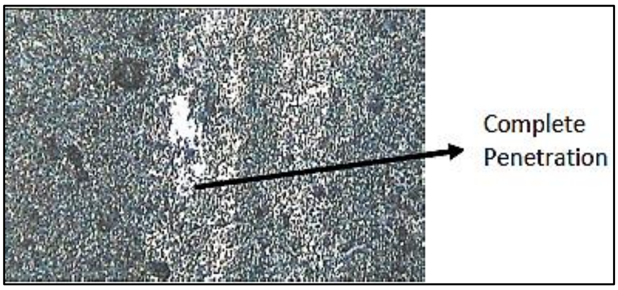

Figure 3.9 Microstructure image of TiN upon 3.8kg load of scratch (500X)

Automatic scratch tester shown in Figure 3.7 is an ideal instrument for characterizing the surface mechanical properties of thin films and coatings, e.g. adhesion, fracture and deformation. The same device was used to determine the scratch resistance and the penetration point of scratch load that the coated material can withstand.

From the scratch test it was observed that when 3.5 Kg load was applied, the needle started penetrating the coating material. AT 3.8 Kg load, the needle completely penetrated the coating.

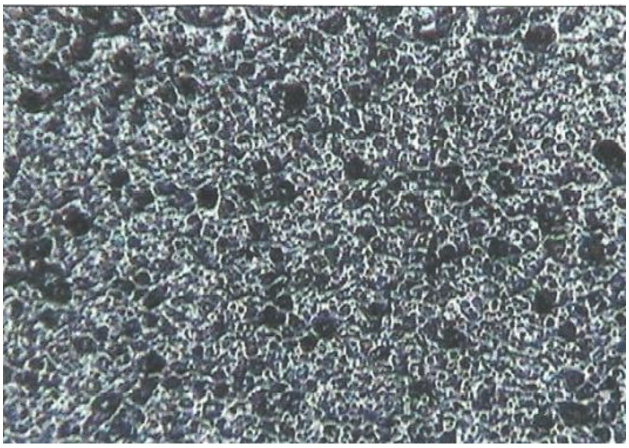

Figure 3.10 Microstructure of TiAlN before scratch test (500X)

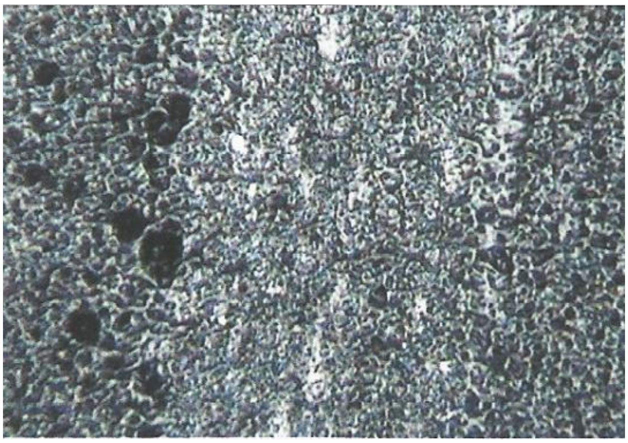

Figure 3.11 Microstructure image of TiAlN upon 3.8 kg load of scratch (500X)

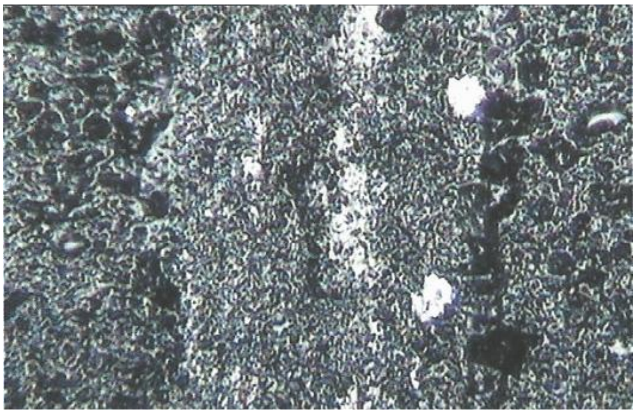

Figure 3.12 Microstructure image of TiAlN upon 4.0 kg load of scratch (500X)

From the scratch test it was observed that when 3.8 Kg load was applied, the needle started penetrating the coating material. At 4.0 Kg load, the needle completely penetrated the coating.

3.2 Hardness Test

Hardness of the substrates made of high speed steel was 7.48 - 7.75 GPa measured by using a vicker hardness tester shown in figure 3.11. Ion beam coating of TiN onto the substrates lead to the increase of hardness of the coated surfaces to the values from 26 GPa to 31 GPa which is a fourfold increase in hardness compared to the substrate itself. Cathodic arc coating of TiAlN onto the substrates lead to the increase of hardness of the coated surfaces to the values from 26.5 GPa to 29 GPa which is also a fourfold increase in hardness compared to the substrate. The values of the roughness of TiN and TiAl coatings were equal to 0.71 µm and 0.33 µm respectively.

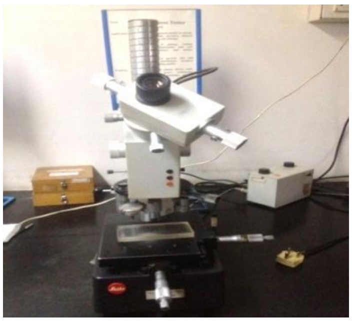

Figure 3.13 Vicker hardness tester

4. Conclusions

In this present work, the process of thin film coating has been understood and the coating of Titanium Aluminium Nitride (TiAlN) and Titanium Nitride (TiN) has been carried out on High Speed Steel (HSS) substrate. The TiAlN and TiN coatings were done using two different processes in an effort to compare the coating properties of the two processes. The two processes employed are cathodic arc evaporation technique and the Ion beam deposition technique, TiAlN coating was carried out on HSS substrate using the cathodic arc technique and the TiN coating was carried out using the Ion beam deposition technique. The coatings were successfully developed and they were subjected to thickness test, scratch test, microstructure analysis and chemical composition test. The thickness was determined using Laboratory microscope and at a magnification of 500X, the thickness of TiAlN was found to be 1.4 microns and the thickness of TiN was found to be 2.9 microns. The scratch test was conducted in order to determine the maximum scratch load the coating can withstand, the value for TiAlN was found to be 4 kg and the value of scratch load the TiN coating withstood was 3.8 kg. This means that the TiAlN coating is more resistant to scratches. It can be understood from the results of the scratch test and the thickness test that cathodic arc deposition is a better coating process in comparison to Ion beam deposition coating process as it provides a more resistant coating at a lower film thickness.

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