An Experimental Investigation of Metallurgical Properties of Thermally Coated Stainless Steel: A Review

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Abstract

Coating is one of the most important and basic feature of any components now a days. Because by applying the coating on the substrate material the performance of the components increases. The properties like as mechanical, optical, magnetic, optical & tribological properties very sharply. Physical vapour deposition (PVD) coating is one of good method of thermal coating. Physical vapour deposition (PVD) surface coatings make it possible to increase the surface hardness of treated components. Despite the good wear resistance of such coatings, the fatigue behaviour of the bulk material may be affected by changes in the residual stress field and microhardness. This research discuss characterize the thermal and mechanical properties of coated substrate. The analysis of PVD coating on different stainless steel has been carried out. The objective of the analysis is to check properties of coated substrate with the help of different experiment and using ansys software.

Keywords: PVD Coating, TiALN, Stainless Steel, Metallurgical Properties.

I. INTRODUCTION

Surface engineering is one of the most growing area of research because of the high industrial demands for friction control and wear resistance. Coating is a covering that is applied to the surface of an object. In many cases coatings are applied to improve surface finish. Nano coating refers to the act of covering a material with a layer on the nano meter scale. Nanocoating forms a nanocomposite that comprises a combination of two or more different substances of nanometer size, thereby producing a material that generally has enhanced or specific targeted properties due to the combined properties and/or structuring effects of the components. Now a day coating is characterized not only by its thickness of layer and its adhesion to substrate, but also evaluation of its mechanical properties, thermal properties, hardness, toughness, fatigue resistance. There are main three types of thermal coating which are:

1. Physical vapour deposition (PVD) coating,
2. Chemical vapour deposition (CVD) coating,
3. High velocity oxy fuel (HVOF) coating.

PVD method is based on separating atoms from surfaces and accumulating (atomic or ionic) them to sub-material surface to be coated by evaporating or sloping materials under vacuum. PVD method is carried out by three methods called as vacuum evaporation, sputter deposition and ion plating. Coating material in PVD method is transmitted to surface in atomic, molecular or ionic form, obtaining it not chemically but physically from solid, liquid and gas source. PVD coating is performed in relatively lower temperature. 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. There are different types of coating material use in now a day which are TiN, TiAIN, CrN, etc. Features of nitride, carbide, and oxides used in these coatings like hardness, lubricant and abrasion resistance have been known for long times. Sometimes two or more composite are use for coating for improving properties of substrate.

There are three step of formation of any deposition:
1. Transition from condensed phase (liquid or vapour) to vapour phase.
2. Transport of vapour from source to substrate.
3. Condensation of vapour followed by film nucleation and growth.

There are different types of PVD:-
1. Cathodic arc deposition,
2. Electron beam physical vapour deposition,
3. Pulsed laser deposition,
4. Sputter deposition.
II. LITERATURE REVIEW

In this paper few selected research paper related to coating. The studies carried out in these papers are mainly concerned with the different substrate and different coating material and how these affect the metallurgical and thermal properties.

S. Sween et al. [1] has studied that Scratch adhesion characteristics of PVD TiAlN deposited on high speed steel, cemented carbide and PCBN substrates. According to this paper the practical adhesion, as determined from the critical normal load, corresponding to substrate exposure, of the TiAlN coatings to the underlying substrate material increases in order PCBN – HSS – CC. The only coating/substrate composite showing major adhesive fracture is the TiAlN coated PCBN. Besides the type of interatomic bonding present at the coating/ substrate interface the critical normal load depends on factors such as the substrate load carrying capacity (hardness) and the cohesive strength of the substrate surface and sub-surface region. It is more important the effect of surface finish processes in pre treatment of hard substrate and the amount and type of damage they can create.

Samir K. Khrais et al. conducted [2] Wear mechanisms and tool performance of TiAlN PVD coated inserts during machining of AISI 4140 steel. The turning test was conducted with variable high cutting speeds ranging from 210 to 410 m/min. Here they used cemented carbide as tool insert with TiAlN coating for turning of hot rolled SAE 4140H steels. The upper limit speed for this process was 410 m/min and any other increase in premature failure. Micro-abrasion and micro-fatigue behaviors were the dominant kinds of wear mechanisms in higher cutting speeds under dry cutting. Dry cutting is better than wet cutting for TiAlN coating inserts under high cutting speed. The best performance of TiAlN coated tool inserts under study is under dry cutting with any cutting speeds less than 260 m/min.

G. Skordaris et al. [3] have checked the Brittleness and fatigue effect of mono- and multi-layer PVD films on the cutting performance of coated cemented carbide inserts. In this paper difference experiment are performed to check the brittleness, fatigue test, hardness and tool life. The brittleness and fatigue test is carried out by macro and nano impact test. Here they use cemented carbide as substrate and it was coated by TiAlN and TiN with mono and multi layer. Here they conclude that as coating layer increase hardness of substrate was improved. It is observed that in multilayer coating brittleness of substrate is better than monolayer coating because of good TiN layer resist the crack propagation, which are characterized by enhanced ductility compared to TiAlN films. Tool life is increases when it is introduce with multilayer PVD coating.

A.I. Fernandez-Abia et al. [4] conducted behaviors of PVD coatings in the turning of austenitic stainless steels. In this paper four coating materials AITiSiN, AlCrSiN, AITiN and TiAlCrN were tested. Here they analysed that nanocomposite AITiSiN coating present higher wear resistance at high temperatures. AITiN coating have high Al content (>67%) that confers high thermal resistance. AITiSiN and AITiN coatings have high chemical stability because of generation of protective layer of oxidation of aluminium. AITiSiN coating was superior to AITiN due to its nano crystalline structure. AlCrSiN and TiAlCrN provide protective layer of chromium oxide which is less stable than aluminium oxide layer. Roughness values were also lower for surface machined with AITiSiN and AITiN tool coating. AITiSiN and AITiN tool coating give best performance than other two coating in better tool flank wear, less tangential cutting force and less part roughness.

M. Antonov et al. [5] conducted investigations on the Assessment of gradient and nano gradient PVD coatings behaviour under erosive, abrasive and impact wear conditions. In this paper PVD coating by AITiN/Si₃N₄ on cemented carbide substrate. Here they also test other coating materials which are TiN, TiCN, TiAlN, AITiN. Erosive, abrasive and impact wear tests is conducted to obtain the insight into qualitative and quantitative aspects of PVD coatings resistance to wear. This coating possesses the highest hardness and proper microstructure of the nanometer sized AITiN particles distributed throughout tough Si₃N₄ matrix that provide the increase in impact resistance. The nano composite gradient super hard AITiSiN coating has better performance under wear conditions like erosive, abrasive and impact conditions than other coating tested. It was observed that at lower velocity and with less aggressive abrasive the performance of coating sufficiently increased. From relative material performance the order of wear resistance of different coatings are AITiSiN(nACo) -AITiN-G – TiAlN-ML – TiCN – TiN. It is important that TiN is best performance under erosive condition.

Mohammad Ahmed et al. performed [6] on Corrosion behaviors of nanocomposite TiSiN coatings on steel substrates. In this paper coating of TiSiN onto AISI M42 tool steel substrates by physical vapour deposition (PVD) using a reactive close-field unbalanced magnetron sputtering system was analysed. The effect of the coating microstructure and residual stress on the corrosion behaviour of TiSiN coated steels in acidic environments was investigated in this work. The microstructure of these coating have three sub layer, which are a nanocomposite TiSiN outer layer, a columnar-grained TiN transitional layer and a thin metallic Ti adhesion layer. All these three layers, while fulfilling their mechanical functions, also acted as physical barriers against potential corrosion attack on the steel substrates. Corrosion pitting was observed in TiSiN coating on steel substrate which originated from surface defect. Here thin oxidation layer of post deposition annealing process provide an overall protection of coated steel. Boundaries of columnar TiN grains reduce the compressive residual stress and maintain the structural integrity of TiSiN coated steel systems.

E.S Puchi-Cabrera et al. [7] carried out a study on The fatigue behavior of an AISI 316L stainless steel coated with a PVD TiN deposit. The effect of a TiN coating on the fatigue properties of an AISI 316L stainless steel has been investigated. The coating was approximately 1.4-μm thick and was deposited by means of filtered cathodic arc deposition. It has been determined that the application of such a coating to the steel substrate gives rise to a significant increase in both fatigue life and fatigue limit, in comparison with the uncoated steel. From the microscopic point of view, it has been observed that the coating remains well adhered to the substrate both in tension and during fatigue testing at low maximum alternating stresses (480 MPa). However, during fatigue testing at elevated maximum alternating stresses (510 MPa) the coating was observed to delaminate from the substrate. Also, it has
been determined that the fatigue fracture of the substrate-coating composite is dominated by the fracture of the TiN coating since fatigue cracks have been observed to form first at the surface of the coating and subsequently to propagate towards the substrate.

III. CONCLUSION

From all the above detailed literature review and analysis of various coating techniques, the following points have been observed.

- The steel have low corrosive resistance and it have poor surface tribology. By coating we can improve the tribological properties of stainless steel. By coating corrosive resistance also improve.
- TiAlN have better adhesion and thermal resistance than other coating material at high temperature and pressure. As increase the layers of TiAlN coating properties of material also improve.
- We denoted that at higher temperature the micro porosity in the structure gradually removed and the particles could be distributed on to the surface in the well dispersed Manner. Hence they form the dense & uniform, isotropic structure on the topographical substrate surface.
- Machine tools have better performance in coated tool. Tool life is increases when it is introduce with multilayer PVD coating. Coating gives reduce tool flank wear, less tangential cutting force and less part roughness.

REFERENCES