JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 19, 2020

CHARACTERIZATION OF ZIRCONIA COATED HSS BUTT WELDFLASH CUTTING TOOL

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ABSTRACT;

Various surface techniques have been developed to improve the wear, corrosion resistance of cutting tool materials. One of the most effective methods is to deposit a protective coating on the cutting tool surface. Coating increases life and efficiency of cuttingtool. Coating of the tool will enhance the properties of like physical, mechanical, thermal and chemical properties. The operation of removing the flash metal from the base metal is called flash trimming. Many researches have been carried out regarding cutting tool coating where the base metal is at room temperature. But it is needed to study and characterize the coating tool material when the base metal is in elevated temperature. Hence it is proposed to conduct the experiments with a Zirconium coated HSS flash cutting tool coated using Electron Beam Evaporation and analyzing for the improvement in the performance of cutting tool.The various testing methodology like pin on disc apparatus to measure the friction and wear properties and Scratch Testers to characterize the surface mechanical properties of thin films and coatings, e.g. adhesion, fracture and deformation thicknesses of thin films. This study aimed at the analysis of the wear, thermal and friction of cutting tools using various parameters. The experiment results will be analyzed for the suitability of the coated tool for the improved flash removal operation and tool life.

Keywords: HSS butt weld, Zirconia, Flashcutting tool

INTRODUCTION;

Flash butt welding is one of the resistance welding processes employed to join metals. In flash butt welding process, the ends of the piece to be welded are connected to the secondary circuit of a transformer, whileone piece is held firmly by a clamping device attached to a stationary platen; the other piece is clamped to a movable platen. The surfaces to be welded are allowed to touch when heavy currents pass through the peaks or asperities ofthe edges providing resistive heat to the edges. These asperities start melting and, at greater velocities, the molten bridges are broken and thrown off as flash particles from joint.

Steps involved in flash butt welding process
Clamping
Retraction
Apply current & flashing
Upset & current cut off
Declamping

In butt welding the joints are heated near to the melting temperature of the material and a heavy pressure is applied to fuse the edges together. The metal near to the joint willbe in plastic stage. So during upsetting themetal oxides & plastic metal which is near to the weld joint is squeezed out of the base metal and projects outside base metal.

Widely used materials and compositions cutting tool:

Tool steels - low end of scale. Used to make some drills, taps, reamers, etc. Low cost equals low tool life

High speed steel (HSS) - can withstand cuttingtemperatures up to 900 Kused to manufacture drills, reamers, single point tool bits, milling cutters, etc.
Cobalt - one step above HSS, cutting speeds are generally 25% higher.
Carbides - Most widely used cutting tool today. Basic composition is tungsten carbide with a cobalt binder.
Ceramics - Contain pure aluminum oxide and can cut at two to three times faster than carbides.
Cubic Boron Nitride(CBN) - This tool material maintains its hardness and resistance to wear at elevated temperatures and has a lowchemical reactivity to the chip/tool interface. Itis typically used to machine hard aerospace materials. Industrial Diamonds - diamonds areused to produce smooth surface finishes such as mirrored surfaces.

Factors influencing the characteristics of coated cutting tool

Hardness
Wear Resistance
Surface Lubricity
Oxidation Temperature
Anti-Seizure

Currently used coating materials over HSS:

- WC/C coatings by physical vapour deposition (PVD) on high speed-steel (HSS)
- TiAlN coatings on high-speed steel (HSS) drill bits, silicon and mild steel substrates using a four-cathode reactive direct current (DC) unbalanced magnetron sputtering system.
- Titanium nitride (TiN) films on high- speed steel (HSS) by using cathodic arc physical vapour deposition (CAPVD) technique.
- Chromium aluminium nitride (Cr–Al– N), titanium nitride (Ti–N), titanium aluminium nitride (Ti–Al–N) and chromium nitride (Cr–N) coatings on
  6.35 mm HSS drills

- PVD TiN/TaN multilayer coatingswith three different multilayer periods (thickness of one TiN lamella together with one TaN lamella) of 10, 50 and 200 nm thickness on high speed steel substrates.
- carbide phase in a new high-speed steel (HSS) substrate and coatings deposited by a physical vapourdeposition (PVD) method.

All the above techniques have been carried outregarding cutting tool coating where the base metal is at room temperature.

Proposed Coating material and technique:ZIRCONIA

Zirconia is an extremely refractory material. It offers chemical and corrosion inertness to temperatures well above the melting point of alumina. The material has low thermal conductivity. It is electrically conductive above 873 K and is used in oxygensensor cells and as the susceptor (heater) in high temperature induction furnaces. With the attachment of platinum leads, nernst glowers used in spectrometers can be made as a light emitting filament which operates in air.

Pure zirconia exists in three crystal phases at different temperatures. At very high temperatures (>2643 K) the material has a cubic structure. At intermediate temperatures (1443 to 2643 K) it has a tetragonal structure. At low temperatures (below 1443 K) the material transforms to the monoclinic structure. The transformation from tetragonal to monoclinic is rapid and is accompanied by a 3 to 5 percent volume increase that causes extensive cracking in the material. This behavior destroys the mechanical properties offabricated components during cooling and makes pure zirconia useless for any structural or mechanical application. Several oxideswhich dissolve in the zirconia crystal structure can slow down or eliminate these crystal structure changes. Commonly used effective additives are MgO, CaO, and Y_2O_3. With sufficient amounts added, the high temperature

cubic structure can be maintained to roomtemperature.

Thermal Conductivity (W/m.K)	1.8-2.2	1.7	0.69-2.4
Specific Heat (J/Kg.K))	400	502	

Key Properties of Zirconium Oxide:

Use temperatures up to 2673 K.
High density
Low thermal conductivity (20% thatof alumina)
Chemical inertness
Resistance to molten metals
Ionic electrical conduction
Wear resistance
High fracture toughness
High hardness

Table 1: Mechanical properties of zirconia

	Partially stabilised	Fully Stabilised	Partially stabilised (plasma sprayed)
Density ($g.cm^{-3}$)	5.7 - 5.75	5.56 - 6.1	5.6-5.7
Hardness - Knoop (GPa)	10-11	10-15	
Modulus of Rupture (MPa)	700	245	6-80
Fracture Toughness ($MPa.m^{-1/2}$)	8	2.8	1.3-3.2
Youngs modulus (GPa)	205	100 -200	48
Poissons ratio	0.23	0.23-0.32	0.25
Thermal expansion (10^{-6}/K)	8-10.6	13.5	7.6-10.5

Typical Uses of ZrO2:

- Precision ball valve balls and seats
- High density ball and pebble millgrinding media
- Rollers and guides for metal tubeforming
- Thread and wire guides
- Hot metal extrusion dies
- Deep well down-hole valves and seats
- Powder compacting dies
- Oxygen sensors
- High temperature induction furnacesusceptors
- Electric furnace heaters over 2273 Kin oxidizing atmospheres

PHYSICAL VAPOUR DEPOSITION -ELECTRON BEAM EVAPORATION

Metal vapor plasma is produced by melting the desired metal in a crucible using a focused electron beam source. The coating is produced when the metal vapor ions react in a low pressure gas. The electron beam source allows for electron heating of the substrate material when a positive potential is applied. The electron beam can be used to ionize argon gas to enhance sputter etching of the substrate when a negative charge is applied.

The EB-PVD process takes place in a vacuum chamber consisting of a vacuum-pumping system, horizontal manipulator, a water-cooled crucible containing a ceramic ingot to be evaporated, an electron-beam gun, and the work piece being coated . The electronbeam gun produces electrons, which directly impinge on the top surface on the ceramic coating, located in the crucible, and bring the surface to a crucible.

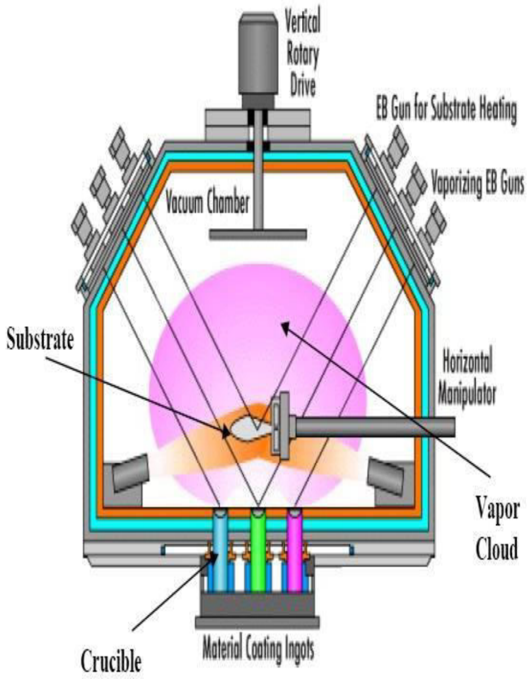

Fig 1: Electron Beam Evaporation

Vapor Cloud Substrate temperature high enough that vapor steam is produced. Thevapor steam produces a vapor cloud, which condenses on the substrate and thus forms a coating. The substrate is held in the middle of vapor cloud by a horizontal manipulator that allows for height variation in the chamber. During the coating process, oxygen or other gases may be bled into the vapor cloud in order to promote a stoichiometric reaction of ceramic material.An .over source. heater or an electron beam gun may be used for substrate heating, which keeps the substrate at a desired temperature.

The primary control variables for the coating process are the ingot feed rate, ingot size, gun current, and over source heater power . The feed rate and size controls how much mass is to be evaporated by the gun current. The gun current controls how much power is transmitted to the melt pool, and thus controls melt pool temperature for the evaporation rate and deposition rate. The maximum gun currentis limited by the stability of the ingot melt surface. Too high a current overheats the ingot

surface causing spattering, thus loosing mass evaporated. The melt pool is a major source of heat energy for the substrate as well as substrate heating if used. The substrate temperature is important because it controls many of the deposited coatings material properties.
A source of substrate heating that is uncontrollable is the time in the coater. As parts are coated, ceramic coating builds up on the chamber walls changing the heat dynamics of the chamber, thus effecting substrate temperature. Therefore, chamber temperature varies depending on when the coating chamber was last cleaned. Overall, substrate temperature is hard to control in the coating process .The coating operator must control the primary variables involved in the coating process, as well as beam sweep frequency and rotation rate, which are set prior to the coating process. Beam sweep frequency refers to the irregular scanning pattern the electron beam gun makes on the ingot surface.

TESTING;

Pin on disc tester

The pin on disc tester measures the friction and sliding wear properties of dry or lubricated surfaces of a variety of bulk materials and coatings. The pin on disc tester consists of a rotating disc of the material to be tested against a stationary sphere, usually made of cemented carbide, referred to as the pin. Most pin on disc testers are computer controlled and store the measured friction versus time or distance plots for future reference.

Scratch tester

Scratch Testers are dedicated instruments for characterizing the surface mechanicalproperties of thin films and coatings, e.g. adhesion, fracture and deformation.

Dilatometer

It is an instrument that measures coefficient of thermal expansion ie dimension variations of a specimen heated at temperatures that generallyrange from 25 to 1673 K.

Nanoindentation

Indentation tests, sometimes called Hardnesstests the most commonly applied means oftesting the mechanical properties of materials. **Scanning electron microscope (SEM)**
The scanning electron microscope (SEM) is a
type of electron microscope that images the sample surface by scanning it with a high- energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals thatcontain information about the sample's surface topography, composition and other properties such as electrical conductivity.

Transmission electron microscope (TEM) Transmission electron microscopy (TEM) is a microscopy technique whereby a beam ofelectrons is transmitted through an ultra thin specimen, interacting with the specimen as itpasses through. An image is formed from the interaction of the electrons transmitted throughthe specimen; the image is magnified andfocused onto an imaging device, such as afluorescent screen, on a layer of photographicfilm, or to be detected by a sensor such as aCCD camera.TEMs are capable of imaging ata significantly higher resolution than lightmicroscopes, owing to the small de Brogliewavelength of electrons. This enables theinstrument's user to examine fine detail—evenas small as a single column of atoms, which istens of thousands times smaller than thesmallestresolvable object in a lightmicroscope.

Experimental Results and Analysis:

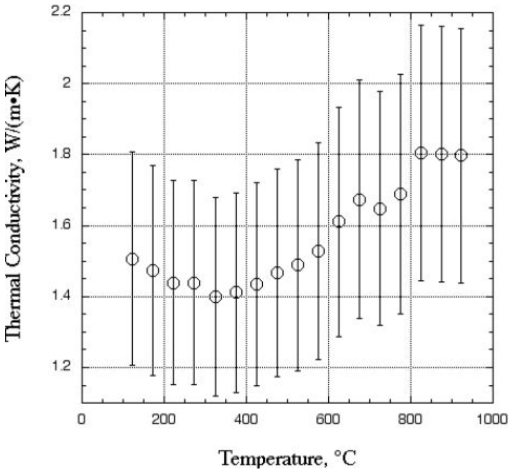

Figure 1 Thermal conductivity of the coating

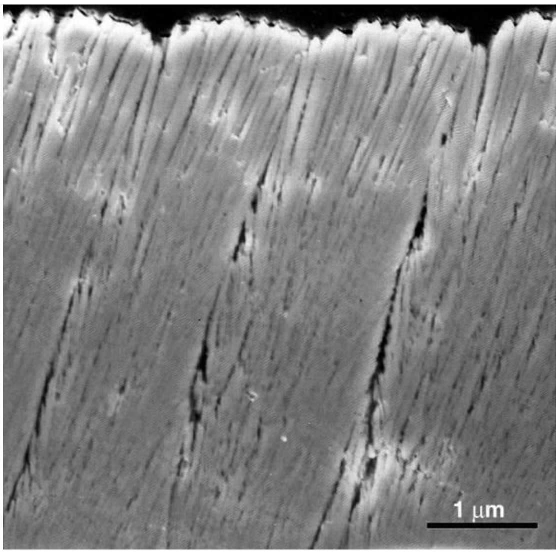

Figure. 2. SEM image of an electron-beam directed-vapor-deposition coating showing microstructure similar to the EB-PVD coating measured here

Figure 1 shows data for the average thermal conductivity of all six coated specimens. The uncertainty bars shown are for a 20 % relative standard uncertainty. The combined standard uncertainty of the apparatus is 5 % . However, the apparatus was designed for measuring monolithic ceramic materials of greater thickness. Due to the inherent interfacial thermal resistance between the sensor plates and the specimen, the reliability of the measurement is influenced by the ratio of the thermal resistance due to the specimen and the thermal resistance of the contact between the specimen and sensor plates. In general, the thermal resistance due to the specimen should be at least four times greater than that of the interfacial thermal resistance between the specimen and sensor plates. However, the small thicknesses of some of the specimens results in a low thermal resistance of the coatings relative to that of the specimen/sensor-plate interface. This factor significantly increases the uncertainty of the measurement of thermal conductivity of thecoating vs temperature.

Conclusion and Future work:

The average thermal conductivity was measured over temperatures ranging fromapproximately 100 ºC to 900 ºC. The measured results vary from 1.5 W·m–1·K–1 to 1.7 W·m–1·K–1 with a relative uncertainty range of 20 % at each temperature. The results are relatively independent of temperature. Due to the fine microstructure and pororosity of yttria-stabilized EB-PVD coatings, the thermal conductivity is expected to be independent of temperature. Even though EB-PVD coatings grow in a directional manner, resulting in a high degree of texture, they do not exhibit thermal behavior normally associated with texture. Figure 2 is an SEM image of an EB- PVD coating showing fine structure, which promotes geometric scattering of phonons. Measurements on similar coatings show a three-level structure of porosity that can result in significant reduction of thermal conductivity from that of sintered polycrystalline material. The large amount of scattering due to the disorder of the stabilized zirconia lattice, combined with the geometric scattering due to a large population of other defects causes these coatings to have a lattice thermal conductivity that is not sensitive to temperature.

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