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A Review on Hard Coating by Means of Thermal Spray Process

K N Balan[1], N.Prakash[2], U Yashvanth[2] ,S Jenoris Muthiya[2], Cheri V Dinesh kumar[3],KanuriDundivinayaka sai[4], CH Sai Abhishek[4].

[1&2] *Faculty, Department of Automobile Engineering, Hindustan Institute of Technology and Science (Deemed To Be University).*

[3&4] *Students, Department of Automobile Engineering, Hindustan Institute of Technology and Science (Deemed To Be University).*

k.n.balan22@gmail.com

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Abstract:
Thermal spray coating is a method of enhancing the properties of surfaces by means of making them better sustainable in working conditions. This paper gives an insight on the various researches carried out in the field of thermal spraying. The gap between the various research outcomes of thermal spraying was found. This also suggests various combinations of base materials and coating materials which will give the optimum outcomes. It also briefs on the various tests carried out for the testing of the coated materials and it was identified that very limited reaches had been conducted in the field of improving impact strength for the application of defense field

Keywords:*BALLISTIC TEST, HARD COATING, THERMAL SPRAY COATING.*

I. INTRODUCTION

Thermal spraying process is one of the surface enhancement technique. This is a very diverse process which consists of different types of coatings and process.The types are HVAF (High Velocity Air Fuel),HVOF (High Velocity Oxy Fuel),Cold spraying,Pulse plasma nitriding, C V D (Chemical Vapour Deposition),Magnetron sputtered deposition and PVD(Physical Vapour Deposition) .Reactive magnetron sputtered deposition and Hot filament, Detonation gun coating, Reactive plasma spraying, Laser surface texturing & Thermal spraying. This process has wide range of applications used inturbines, piston rings, extruders, ball valves, valve seats, electrical insulators, valve seats, components of pump, and chemical sealing, automatic machinery components, automotive parts, petrochemical and oil & gas industries ,drilling tools and oil and gas valves to gas turbine engines, internal parts of the pump, sleeves of mud pump , hydraulic rams and directional drilling tools, plastic films, electro-optical elements, and lenses,aircraft turbines, milling cutter and hobbing tool, screw extruder and screw injection moulding machines, etc.This review paper deals with the different types of coatings on different types of base metals or materials/substrates with different types of metals or materials. This paper projects the advantages and disadvantages of this process.The advantages are: HVAF is better than HVOF on stainless steel by WC-CO-CR, HVOF and Detonation gun coating have good bond strength & adhesion strength, HVAF increasesthe wear resistance, Tungsten carbide improves hardness, Metco 68 F-Ns-1 exhibit higher impact strength. The disadvantages are debonding of the coating in case of flame spraying(due to higher thickness), Nitride coated tool steel reduces Hardness and stress gradiant, Plasma sputtering results in low surface hardness and adhesion.This review paper consists of the elobarateddetails of these coatings and coating powder.

January-February 2020
ISSN: 0193-4120 Page No. 7078 - 7086

II. LATEST RESEARCH TRENDS IN HARD COATING

2.1 HVOF (HIGH VELOCITY OXY-FUEL COATING)

2.1.1 Lutz-michaelberger[11] (2014) investigated on the application of thermal spray coatings of hard materials like Wc (or)Cr_3C_2 on the substrate by using HVOF and HVAF.The thickness is 100-500 μm. The micro hardness, corrosion resistance were studied and it was identified that the properties were enhanced by means of the post coating process of heat treatment .

2.1.2 K. Bobzinetal[6] (2017) investigated on impact wear of an hvof sprayed Cr_3C_2- NiCr coating on carbon steel by using HVOF technique . Cemented carbide ball during test is conducted on the coating to study the impact wear of coating .by the test it was proven that at f=330N, f=500N and f=800N , coatings are subjected to deformation without failure . under f=1000N loading , failure occurs between the coating and substrate .it shows that impact testing can be successfully applied on thermally sprayed coatings to evaluate their impact wear . it also mention that coating can with stand load up to its level after that it will deform along with substrate cr3c2-nicr coatings are applicable at high operating temperature of more than t=850 degrees.

2.1.3 Nuriacincaetal [2](2012) investigated the coating powder of iron, nickel titanium aluminizes on any required substrate and thermal treatment and oxidation are done over the coated surfaces . It was found that 80 percentage of oxygen is required in oxy-fuel ratio to get good results in bond strength. In addition that it was found that powder particle size should be in between 15 μm and 45 μm for good improvement in fatigue , creep and wear .these coatings with iron, nickel and titanium aluminizes are used in area where we have to reduce wear and increase creep and fatigue of substrate which is coated with coating powder

2.1.4 P.g. Thiemetal [7](2017) studied the properties like microstructure and adhesion strength bymeans of plasma flame and HVOF. Iron aluminide powder is used as coating material . Alsi10mg and Alsi12cunimg are the substrates. Tensile adhesion test and heat treatment test was done for both substrate coated with three different methods (flame spray ,plasma spray and HVOF). it was found that feo re arrange in to fe3o4 during heat treatment to provide additional strength to the coat and adhesion test (tensile test) determine the bond strength between substrate to tensile force offered by the test .in additional to that it was proved that 500 μm coating thickness can be achieved by using aps and hvof but it does not exceed 250 μm by flame spray process. Higher thickness resulted in de bonding of the coatings in case of flame spray

2.1.5 Avnishkumaretal (2016) investigated on Erosion charcteristics of WC-10Co-4Cr Coated on 23-8-N Nitronic Steel by HVOF .WC-10Co-4Cr is used as coatind material and is coated on nitronic steel substrates by HVOF with nominal particle size (-45 to + 15 μm)

The coating thickness was kept 350±20 μm. Erosion test is done on the coating .test conducted at various angle (30, 60, 90 degree)and it was found that Coated 23-8-N nitronic steel showed high erosion resistance at different impact angles. It is due to the hardness of coating and high fracture toughness together with optimum mechanical properties of the coated material.By this we can know the erosion properties of WC-10Co-4Cr Coated on 23-8-N Nitronic Steel by HVOF . Besides the coating, mechanical properties of the substrate is also an very important characteristic to enhance the erosion resistance of the coating. It is mostly applicable in hydro turbine

2.1.6 R.K.Kumaretal (2017) investigated on practical approach and quantitative assessment of silt erosion characteristics of HVOF and HVAF for WC-CoCr coatings and $16Cr_5Ni$ steel for hydro turbine applications. WC-CoCr hard

January-February 2020
ISSN: 0193-4120 Page No. 7078 - 7086

composite is coated on hydro turbine steels (stainless steel) by using HVAF and HVOF with WC size of 1.2 μm was used and thickness of coat is 410 μm. Erosion test is done on coating. Thereforethe resistance towards wear of the coating is found .

The valued erodent mass factor for impact angles 15°, 30°, 45° and 60° are 0.26, 0.5, 0.71 and 0.86 correspondingly. Erosion mechanisms are investigated in detail using SEM and laser scanning confocal microscopy. Compared to all the WC–CoCr coatings, the HVAF coating sprayed at highest spray velocity has shown high erosion resistance compared to HVOF coatings. It is applicable for offshore structures, cryogenics, chemical industries ,water pumps and hydro turbines

2.2HVAF(HIGH VELOCITY AIR FUEL COATING)

2.2.1 Giovani etal[9] (2015) investigated that impact and wear behavior of HVAF . In this alumina (Al_2O_3) is used as coating material on substrate (nickel, cobalt and nicrbsi) by using high velocity air - fuel spray with the thickness of 1mm with porosity level of 10.0+ 2 and 3.0+0.6 percentage respectively for apss and dgs the average thickness of aps coating is 3.0 + 0.5 μm after coating dry sliding wear test is done to study the impact and wear behavior of HVAF coating it was found that at 700 degree centigrade sliding wear rates are leveled and it also proven that at 700 c wear is higher because of severe abrasive grooving when compare to room temperature. Its given a final result that coating with HVAF is efficient in terms of wear resistance than any other type of thermal coatings

2.2.2 Robert j.k wood etal[10] (2017) formed a critical review of the tribo corrosion of cemented and thermal sprayed tungsten carbide . In this tungsten carbide is used as coating material on the substrate with high velocity air fuel spray. It was shown the improvement in hardness by coating substrate with tungsten carbide tungsten .carbide coatings are used on drilling tools and oil and gas valves to gas turbine engines valve trim, pump internal sleeves and directional drilling tools

2.2.3 Lutz-michaelberger[11] (2014) investigated on the method of using of hard metals as thermal spray coatings . Wc (or) cr3c2 are used as coating materials on the substrate by using HVOF AND HVAF. This coatings have a typical thickness of 100-500 μm .The micro hardness, corrosion resistance were studied and it was identified that the properties were enhanced by means of the post coating process of heat treatment .These are used in wires and suspensions etc.

2.3 COLD SPRAYING

2.3.1 Nuriacincaetal [2](2012) investigated the coating powder of iron, nickel titanium aluminizes on any required substrate and thermal treatment and oxidation are done over the coated surfaces . It was found that 80 percentage of oxygen is required in oxy-fuel ratio to get good results in bond strength. In addition that it was found that powder particle size should be in between 15 μm and 45 μm for good improvement in fatigue , creep and wear .these coatings with iron, nickel and titanium aluminizes are used in area where we have to reduce wear and increase creep and fatigue of substrate which is coated with coating powder

2.3.2 P.cavaliereetal[5](2017) investigated on micro structural and fatigue behavior of cold sprayed ni - based super alloy coating on carbon steel substrate with thickness of coat of 50-80 μm fatigue test is done on the substrate which is coated with ni -based super alloy . By the test it is easy to study the fatigue behavior of cold spray ni based super alloy coatings. It also found that good adhesion bond between substrate and coating materials can offer good resistance for loads (fatigue loads) on the substrate coated by coating material. It also indicates the application of ni - based super alloy in the field of industry for repair of cracked steel sheets.

January-February 2020
ISSN: 0193-4120 Page No. 7078 - 7086

2.4 ATMOSPHERE PLASMA SPRAY PROCESS

2.4.1 Natanetal[3](2017) investigated spray particle filling qualities bond of NI- based coating on cast iron and steel by using atmosphere plasma spray technology XRD diffraction and Nano indentation tests were used to measure the residual stress of substrate after laser treatment. by the tests it was found that the bond strength valve depends up on the thickness of spray and filling quality i.e. if the coating material is correctly atomized and spray on substrate it creates good bond than the coat formed with larger size particles of coating powder. by this it was proven the importance of filling quality as well as adhesion strength during coating . in addition it was found that improvement of surface contact area results in correct bond between substrate and coating material.

2.4.2Shakhovaetal [8](2017) investigated on the thermo electrical properties of alumina coatings deposited by different thermal spray technologies . Alumina is deposited on steel substrate by using atmospheric plasma spray, vacuum plasma spray and detonation gun spraying. Alumina of feedstock powder composition of fe-28al-5cr and particle size of 45 μm to 75 μm is used, after coating vicker test is done to investigate properties of alumina coatings it was found that aps and dgs give the hardness value of 783+55 hv and 973+68hv respectively. It also give information about thermal electrical properties of the alumina coatings deposited by different thermal spraying technology

2.4.3Helong yunetal [20] (2013) investigated on sliding and bonding wear behaviors of the plasma sprayed NiCrBSi coating. NiCrBSi coatings is used as coating material and is coated on steel substrates. By using APS (Atmospheric plasma spray) .Coating is done with particle size of 25–45 μm. Wear test is done after coating. From the worn surfaces we come to know the wear properties, abrasive wear mechanism and fatigue abrasive mechanism of plasma spray Ni based alloy coatings. These types of coatings are applicable where the wear resistance is needed.

2.5 PULSE PLASMA NITRIDING

2.5.1 K.hock et al [16] (1995) investigated on Technical matters of the properties and production of PVD hard- coated and combined plasma-nitridedhigh alloy tool steels. TIN is coated on the nitrided high alloy steel by using pulse plasma nitriding. The depth of coating varies between 15 and 50 μm. The investigations were done to determine the adhesion, hardness, tribological behavior and residual stress, as a function of the process parameters and first stage process. It is used as tool steel. Stress gradients and the hardness between the substrate and coating are reduced by nitride tool steels. The hard coating can be supported by higher strength of nitrided tool steels.

2.5.2 Hyeon-GyunIm et al [14]l(2017) investigated on A transparent protective hard-coating material byphysico chemically-incorporated silica nanoparticles and organic siloxanes . Silica Nano particle is sprayed on substrate by using pulse plasma nitriding. By this investigation they introduce synthetic steps of the Nano composite and discuss the optical, morphological, thermal and mechanical properties of the composite. Nano particle coatings is applicable in flexible electronics, hard coatings for functional plastic films, electro-optical elements and lenses

2.5.3 B.buekenaetal[12] (1994) investigated on mixing of PVD hard coatings and plasma nitriding by a continuous method. Titanium carbonitride (ticn) is used as coating material which is deposited on steel substrates by using continuous process plasma nitriding .The results obtained during plasma nitriding in the modified cold wall reactor and hot wall reactor are compared . The wear resistance and hardness increases in hard coatings materials which are deposited by using plasma nitriding. The adhesion is increased by the deposition of Ti intermediate layer due to hard coating of the nitrided substrates.

January-February 2020
ISSN: 0193-4120 Page No. 7078 - 7086

This type of coatings is mostly used in the complex stressed tools and machine components.

2.6 PLASMA ENHANCED MAGNETRON SPUTTERED DEPOSITION

2.6.1 Ronghuawei et al[17] (2002) investigated on plasma-enhanced magnetron-sputtered deposition of hard coatings on cutting tools. TiN, TiCN, Ti Al N are used as coating material. Tool steel is used as substrate .coating material is deposited on substrate by using PMD. The very fine microstructure (average grain sized approx. 60 nm) are shown by the TiN coatings formed using the PMD process. It was found that substrate coated with arc-evaporation and unbalanced magnetron sputtering processes have less improved life compared to coating TiN using the PMD process. It is applicable in tools such as milling cutter and hobbing tool.

2.7 PHYSICAL AND CHEMICAL VAPOUR DEPOSITION

2.7.1 M. Heinze[19] (1997) investigated on resistance to Wear of hard coatings in plastics processing. Aluminium titanium nitride is used as coating material on special st

eel substrate. It is found that a high micro resistance against polymer melt is obtained by Hard coatings with a dense structure. By the corrosion inhibition the improvement was achieved. Hard coatings on plastics processing are applicable for screw injection and screw extruder molding machinery.

2.7.2 H.j. Spies etal [18](1993) investigated on PVD coatings on prenitrided low alloy steel. TiN hard coating is done on low alloy steel. This low alloy steel is being tempered and hardened by using magnetron sputtering and ion plating. This coating having thickness nearly 2-4 μm. That the iron nitriding by decomposition during the plasma sputter cleaning to the compound layer will result to the lowering the surface hardness and adherence of TiN. Low alloy steel have been PVD hard coated and is applicable in machine parts.

2.8 REACTIVE MAGNETRON SPUTTERING

2.8.1 Muhammad Boot et al [15](2012) investigated on nickel-based single-crystal super alloy for suitable hard coatings . Aluminium titanium nitride (Al TiN) is used as coating material on nickel based super alloy substrate by using reactive magnetron sputtering and HFCVD. The coated films were characterized with respect to mechanical properties, film adhesion, surface morphology and microstructure. It was found aluminium titanium nitride is suitable for coat on nickel based super alloy substrate which is used for aircraft turbines

2.9 DETONATION GUN COATING

2.9.1 Shakhovaetal [8](2017) investigated on the thermo electrical properties of alumina coatings deposited by different thermal spray technologies . Alumina is deposited on steel substrate by using atmospheric plasma spray, vacuum plasma spray and detonation gun spraying. Alumina of feedstock powder composition of fe-28al-5cr and particle size of 45 μm to 75 μm is used, after coating vicker test is done to investigate properties of alumina coatings it was found that aps and dgs give the hardness value of 783+55 hv and 973+68hv respectively. It also give information about thermal electrical properties of the alumina coatings deposited by different thermal spraying technology.

2.9.2 Amardeepetal (2017) investigated on Effect of thermal spray coatings on wear behavior of high tensile steel applicable for tiller blades. WC-Co-Cr and Cr3C2-NiCr are coating powders used to coat on high tensile steel substrate by using D- gun thermal spraying with coating thicknesses for the both coatings were between 100 -150 μm. Wear test is done on the coating .Improved sliding wear resistance and hardness of the Wc-Co- Cr based coatings was observed reason for better wear resistance is : WC-Co-Cr coating did not have any un-melted particle. Wc - co- cr coating provide good adhesion than the

January-February 2020
ISSN: 0193-4120 Page No. 7078 - 7086

cr3c2-nicr. This study shows that resistance for wear of Wc-Co-Cr coating is more compared to Cr3C2-NiCr.Therefore less number of Wc grains are fractured due to the higher hardness of WC grains.This type of coating is applicable in industrial components working at high temperature.

2.9.3 Sanjeetkumaretal (2017) investigated on ceria doped alumina coatings and thermally sprayed alumina coatings on AZ91 Mg alloy.AL2o3 doped with ceo2 is coated on Mg alloy substrate by using d gun spraying with Particle size ranges between 15µm to 45µm And small percentage of particles ≥50µm. The coating properties and other results are recorded by using scanning electron microscopy,Nano intender, x-ray diffraction and energy dispersive. It was found that the nano hardness and elastic modulus of CeO_2 doped alumina coating was increased to 13% to 53% respectively.when compared to aluminia coating Under high velocity and high load conditions. The specific wear rate is also reduced 40% due to decrease in friction between sliding parts. The alumina and alumina doped with ceria coatings on mg alloy are developed by using D-gun thermal spray coating. The mechanical characteristics of coating substrate interface is improved by doping with CeO_2. Such as wear resistance etc.

2.10 REACTIVE PLASMA SPRAYING

2.10.1 Yanfangqinelat[4] (2017) studied about effect of powder injection distance on mechanical properties and microstructure of reactive plasma spray TICN coated on stainless steel substrate .titanium carbonitride coated material was tested by un lubricated sliding wear on block on ring tribometer. From the test it was found that as the increase in distance may decrease wear resistance of the coat .it also found that the number of unwell spread particles increases due to increase of powder injection distance. Due to increase in distance ,coat surface may be un even, pores are formed around these particles. By this we can understand the importance of power injection distance which effects the mechanical properties andmicrostructure of coat.

2.10.2 N.Krishnamurthyetal (2011) investigated on solid particle erosion behavior and Characterization of plasma sprayed alumina and calcia-stabilized zirconia coatings on Al-6061 substrate.Metco 201NS (TC2) ,Metco 446 (BC1),Metco105SFP (TC1) and Metco 410NS (BC2) are used to coated on Al-6061 substrate by using plasma sprayed coating technic with top coat thickness :300-400µm, bond coat thickness : 50µm. erosion test was conducted on coated substrate .It was observed that at 45◦ angle of impact the volume erosion is more and shows the behavior is in between brittle and ductile. It is observed that the erosion rates are affected by variousfactors impingement variables,particle variables and material variables. Therefore for Al-6061 substrate two types of plasma sprayed coating systems were developed. For every system a microstructural study was done to understand the changes caused after spraying. Some mechanical properties like density, hardness of coatings and adhesion strength were determined. This also deals with the mechanism involved in erosion wear of plasma coating. This type of coating is applicable in combustion engines , Thermal power plants.

2.11 LASER SURFACE TEXTURING, THERMAL SPRAYING

2.11.1 R.kromeretal[1](2017) investigated the important factors of Laser surface texturing to enhance good adhesion in the coating like atmospheric plasma spraying ,cold spraying and wire arc spraying . It was found that laser at nominal wave length of 1.06µm, max- power of 20w and frequency between 20 to 100 Hz are identical to improve the bond strength and adhesion of coating. By laser texturing it is easy to study the particle impact and spreading mechanisms .at finally it was concluded that laser is good technology available to get good adhesion

January-February 2020
ISSN: 0193-4120 Page No. 7078 - 7086

bond strength in coating deposition fields. It is applicable to check the coat used for coating the commercial and military gas engines.

2.12 BALLESTIC TEST PROPERTIES

2.12.1 Evren et al (2010)[21] investigated the coated surface at Metco68f-n1-1 powder (Cobalt52%,Molybedenum28%,Chromium17%,Silicon3%) and Metco 201ns(Zirconium oxide93%, calcium oxide5%, Aluminum oxide0.5%,Silicon oxide0.4%, balance other oxides) powder on aluminum plates . These coated specimen and uncoated aluminum substrates were subjected to ballistic test and it was found that Metco 68 F-Ns-1 exhibit higher strength in terms of penetration depth and bulging[30-32].

III. CONCLUSION

- This review paper has concluded with the different types of coatings on different types of substrates with different type of metals or materials and has a wide range of applications and a detailed way of choosing a coating, substrates, coating powder with detailed specification.
- The characteristics of coated surfaces are tested by means of wear properties; Corrosion in elevated temperature, Bond strength, Adhesion strength, Thermal expansion, Micro hardness, Ballestic test etc.
- Wc-Co-Cr is better than Cr_3c_2-NiCr to with stand high temperature and HVAF is better than HVOF in Wc-Co-Cr on stainless steel.
- Al_2o_3dopped with CeO_2 on Mg alloy improves mechanical properties, Cold sprayed Ni-based super alloy coating&nickel aluminides on Mg alloy will increase good adhession and bond strength.
- Tungsten carbide on any substrate will improve hardness.
- HVAF&Reactive plasma sprayed process improves wear resistance,Metco 68 F-Ns-1 exhibit higher strength in terms of penetration depth and bulging.

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