Erosion Resistant Coatings A Review

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Abstract- Erosion is severe tribulations in boilers related components are responsible for massive losses, together direct and indirect, in power production. A considerate of these troubles and thus to develop a suitable protective system is essential for maximizing the utilization of such apparatus. These troubles can be prohibited by also changing the material or by separating the component's surface from the environment. Erosion prevention by the use of coating for separating material from the environment is in advance significance in surface engineering.

Keywords – Erosion, Physical Vapour Deposition (PVD), Chemical Vapour Deposition (CVD), Laser Cladding.

I. INTRODUCTION

Solid particle erosion (SPE) is a serious problem for the electric power production, costing a projected US$150 million a year in lost efficiency, forced outages, and repair costs [1]. Erosive, high temperature wear of heat exchanger tubes and other structural materials in boilers are recognized as being the main cause of downtime at power-generating plants, which could account for 50-75% of their total seize time. Safeguarding costs for replacing out of order tubes in the same installations are also very high, and can be estimated at up to 54% of the total production costs. High temperature oxidation and erosion by the impact of fly ashes and unburned carbon particles are the main problems to be solved in these applications. Therefore, the increase of wear and high temperature oxidation protection systems in industrial boilers is a very important topic from both engineering and an economic perspective [2].

II. EROSION RESISTANT COATINGS

A. *Thermal Spraying –*

Thermal spraying is one of the most versatile hard facing techniques available for the application of coating materials used to guard components from abrasive wear, adhesive wear, erosive wear or surface fatigue and corrosion (such as that caused by oxidation or seawater) . Generally, any material which does not decompose, vaporize, sublimate, or separate on heating, can be thermally sprayed. Consequently a large class of metallic and nonmetallic materials (metals, alloys, ceramics, cermets, and polymers) can be deposited by thermal spraying. Heath et al (1997) [3] has summarized the thermal spray processes that have been considered to deposit the coatings, are enlisted below:
(1) Flame spraying with a powder or wire, (2) Electric arc wire spraying, (3) Plasma spraying, (4) Spray and fuse , (5) High Velocity Oxy-fuel (HVOF) spraying, (6) Detonation Gun.

The technique of thermal spraying has developed at a fast pace due to progress in the advancement of materials and modern coating tool. Plasma-sprayed ceramic coatings are used to protect metallic structural components from corrosion, wear and erosion, and to provide lubrication and thermal insulation [4]. In particular, coatings made of Al_2O_3 containing 13 wt% TiO_2 (Al_2O_3-13 wt% TiO_2) are commonly used to improve the wear-corrosion and erosion resistance of steel. In conservative plasma-spray processing of Al_2O_3-13 wt% TiO_2 coatings, powder particles are injected into a plasma jet, cause them to melt into droplets that are propelled towards the substrate [4]. Solidification of the droplets stream onto the substrate as “splats” results into the buildup of the coating, normally 100-300μm thick. In order to obtain chemical homogeneity in the coating, the processing is performed at “hot” plasma conditions which ensure complete melting of the powder particles [5]. Plasma sprayed zirconium coatings as thermal barrier coatings have been applied to hot section components of gas engines to increase temperature capability Ni-base super alloys [6]

Buta Singh Sidhu et al. [7], while studying Ni3Al coatings on boiler tube steels through plasma spray process (where Ni-Cr-Al-Y was used as a bond coat before applying Ni3Al coatings) observed that the Ni3Al coating was very effective in decreasing the corrosion rate in air and molten salt at 9000C in case of ASTM-SA210-Grade A1 and ASTM-SA213-T-11 type of steel where as the coating was least effective for ASTM-SA213-T-22 type of steel. Uncoated ASTMSA213- T-22 type of steel had shown very poor resistance to hot corrosion in molten salt environment and also indicated spalling of oxide level. T.S. Sidhu et. al. [8] have evaluated the hot corrosion performance of high velocity oxy-fuel (HVOF) sprayed Ni-20Cr wire coating on a Ni-based super alloy for 1000hrs at 900oC under cyclic conditions in a coal-fired boiler. The HVOF sprayed Ni-20Cr coating was found to be effective in imparting hot corrosion resistance to Superni 75 in the actual working environment of a coal fired boiler as compared to the uncoated super alloy.

S.B. Mishra et. al. [9] have investigated plasma sprayed metallic coating of nickel-aluminide deposited on Fe-based super alloy. The coating had shown better erosion resistance as compared to the uncoated samples. H.Singh et. al. [10] have studied high temperature oxidation behavior of plasma sprayed Ni3Al coating. In their investigation, Ni3Al powder was prepared by mechanical mixing of pure nickel and aluminium powders in a ball mill. Subsequently Ni3Al powder was deposited on three Ni-base superalloys: Superni 600, Superni 601 and Superni 718 and, one Fe-base super alloy, Superfer 800H by shrouded plasma spray method. Oxidation studies were conducted on the coated superalloys in air at 900 ◦C under cyclic conditions for 50 cycles. Each cycle consisted of 1 h heating followed by 20 min of cooling in air. The thermogravimetric method was used to approximate the kinetics of oxidation. All the coated super alloys nearly followed parabolic rate law of oxidation. X-ray diffraction, SEM/EDAX and EPMA technique were used to analyze the oxidation products. The Ni3Al coating was found to be successful in maintaining its adherence to the super alloy substrates in all the cases. The oxide scales created on the oxidized coated superalloys were found to be intact and spallation-free.

B.Physical Vapor Deposition (PVD) Process

In physical vapor deposition (PVD) process, the coating is deposited in vacuum by condensation from a flux of neutral or ionized atoms of metals [11]. Several PVD techniques are available for deposition of hard coatings. Among them, cathodic arc vapor (plasma or arc ion plating) deposition, magnetron sputtering (or sputter ion plate), and combined magnetron and arc processes are most widely used techniques to deposit titanium-aluminum based coatings.

PVD process is carried out in high vacuum at temperature between 150 and 500°C. The high purity solid coating material (metals such as titanium, chromium & aluminum) is either evaporated by heat or by bombardment with ions (sputtering). At the same time, a reactive gas (e.g. nitrogen or a gas containing carbon) is introduced; it forms a compound with the metal vapors and is deposited on the tools or components as a thin, extremely adherent coating. In order to obtain a uniform coating thickness, the parts are rotated at the same speed about several axes. The PVD techniques are widely used nowadays for improvement of the mechanical and other properties, of a broad range of engineering materials. Employing the PVD techniques for the deposition of coatings (namely multilayer coatings) ensures high corrosion and wears resistance. Further, the ceramic nitrides, carbides present interesting colors which allow them to be used indecorative components (e.g., golden or a polished brass-like) [12].

In. S. Choi et.al. [13] have studied the corrosion behavior of TiAlN coatings prepared by PVD in a hydrofluoric gas atmosphere. TiAlN coating has one of the highest working temperature (800oC) due to the surface being covered with a stable and passive aluminum oxide layer. When TiAlN is exposed to a HF gas atmosphere in working situation, it reacts with HF and forms aluminum fluoride (AlF3), which is chemically very stable to various corrosives like acid, alkaline, alcohol and even HF. The process was quite successful and the coating exhibit better corrosion resistance. Sugehis Liscano et al. [14] have studied corrosion performance of duplex treatments based on plasma nitriding and PAPVD (Plasma Assisted physical vapour deposition) TiAlN coating. The plasma nitrided substrates were coated commercially with BALINIT FUTURA NANO (TiAlN) coatings (Balzers, Inc., USA). The nanograined TiAlN coating has shown better results then the conventional counterpart.

C.Chemical Vapor Deposition (CVD)

Chemical Vapor Deposition (CVD) process is a versatile process that can be used to deposit nearly any metal as well as non metal such as carbon or silicon [15]. The first step is the production of metal vapours. some chemical reactions can be used: thermal decay, pyrolysis, reduction, oxidation, nitridation etc. The main reaction is carry out in a separate reactor. The vapors thus formed are transferred to the coating chamber where the sample is mounted and maintained at high temperature. One of the limits of the CVD is the high substrate temperature, which in several cases changes the microstructure of the substrate, and another is the size of specimens, often minor parts are used due to limitation of chamber size.

S. Tsipas et. al. [16] have studied Al–Mn CVD-FBR protective coatings for hot corrosion application. In this study, new Al–Mn protective coatings were deposited by CVD-FBR on two ferritic steels (P-92 and HCM12). The CVD-FBR has been exposed to be a powerful and effective technique to obtain Mn-containing aluminide coatings on ferritic steels. These coatings could be potential candidates for steam oxidation protection of ferritic steels.

F.J. P´ereza et. al. [17] have studied adhesion properties of aluminide coatings deposited via CVD in fluidised bed reactors_CVD-FBR/on AISI 304 stainless steel. The CVD-FBR method has been shown to be a very interesting surface modification technology because aluminum diffusion coatings can be produced at lower temperatures and shorter times than by conventional pack cementation. Generally, the heat-treated aluminum coated AISI 304 specimens may find an application due to the combination of their toughness and the potential good corrosion properties.

D. Laser cladding process

One such technique to improve the surface properties is laser cladding. Laser composite surfacing is a process where a high-power laser beam is used as a source of heat to melt the metallic substrate and simultaneous feeding of the ceramic particles (in the form of powder) in the molten surface. This is the invention of a surface layer of particulate (ceramics such as WC, TiC, SiC, ZrO2 or Al2O3) reinforced metal matrix (any of the feasible metal such as Ni, Fe, etc) composites on metallic materials [18-23]. Ability to deliver a large power/energy density (103–105 W/cm2), high heating/cooling rate (103–105 K/s) and solidification velocities (1–30 m/s) are the notable advantages associated with laser-assisted composite surfacing [24-26]. This leads to development of wide variety of micro-structures with novel properties that cannot be achieved by conventional processing technique that are more traditional and involve the deposition of films and coatings from solid, liquids and vapour sources [27]. Moreover, these coatings are metallurgically bonded providing a sound and adherent interface between the coating and substrate.
Laser cladding is a method that has brought tremendous interest in a number of industries, as the process can be used to enhance material surface properties for corrosion and wear resistance, repair of worn parts, and forming of near net-shaped structures, as well as customisation of material and mechanical properties through functionally graded materials [28].

III.CONCLUSION

This paper reviews all major types of erosion resistant coatings, Thermal Spraying, Physical Vapor Deposition (PVD) Process, Chemical Vapor Deposition (CVD), and Laser cladding process. The relevant properties and preparation methods of the various coatings are summarized.

REFERENCES

[1] Kevin J. Stein, Brian S. Schorr, Arnold R. Marder, "Erosion of thermal spray MCr-Cr C cermet coatings", *Wear, Vol. 224, pp 153-159, 1999.*

[2] V. Higuera Hidalgo, J. Belzunce Verela, A. Carriles Menendez, S. Poveda Martinez, "High temperature erosion wear of flame and plasma sprayed nickel-chromium coatings under similated coal-fired boiler atmospheres*", Wear, VOl.247, pp 214-222, 2001.*

[3] R. Heath, P. Heimgartner, G. Irons, R. Miller, and S. Gustafsson, *Material Science Forum, Vol. 251-54, pp 809-816, 1997.*

[4] P.Bansal, N. P. Padture, A. Vasiliev, " *Improved interfacial properties of Al2O3-13wt%TiO2 plasma sprayed coatings derived from nanocrytalline powders", Acta Materialia, Vol.51, pp.2959-2970, 2003*.

[5] N. Priyantha, P. Jayaweera, A. Sanjurjo, K. Lau, K. Krish, "Corrosion-resistant metallic coatings for applications in highly aggressive environment*", Surface & Coating Technology, Vol. 163-164, 31-36, 2003.*

[6] B. liang, C. Ding, "Thermal shock resistance of nano-structured and conventional zirconia coatings deposited by atmospheric spraying", *Surface & Coating Technology journal,Vol.197,pp.85-192,2005*.

[7] Buta singh Sidhu, S. Prakash ., "Evaluation of the corrosion behaviour of plasma sprayed Ni3Al coatings on steel in oxidation and molten salt environments at 9000C", *Surface &coatings technology*, 166, Vol, pp. 89-100,2003.

[8] T.S. Sidhu, S. Prakash and R.D. Agrawal, "Hot corrosion performance of a NiCr coated Ni-based alloy", *Scripta Materialia*, Vol.55, pp.179-182, 2006.

[9] S.B. Mishra, K. Chandra, S. Prakash, B. Venkataraman, "Characterization and erosion behaviour of a plasma sprayed Ni3Al coating on a Fe-based superalloy", *Materials Letters*, Vol.59, pp. 3694-3698, 2005.

[10] H. Singh , S. Prakash , D. Puri, "Some observations on the high temperature oxidation behaviour of plasma sprayed Ni3Al coating",*Materials Science & Engineering*, Vol…..,2006, PP……

[11] S. Paldey, S. C. Deevi, "Single layer and multilayer wear resistant coatings of (Ti,Al): a review", *Materials Science & Engineering*, Vol: A 342, pp 58-79, 2003.

[12] L.A. Dobrzanski, K. Lukaszkowicz, A. Zarychta, L. Cunha, "Corrosion resistance of multilayer coatings deposited by PVD techniques onto the brass substrate", *Journal ofMaterials Processing Technology*, Vol. 164-165, pp 816-821, 2005.

[13] In S. Choi, Jong C. Park, "The corrosion behavior of TiAlN coatings prepared by PVD in*a* hydrofluoric gas atmosphere*", Surface Coatings & Technology*, Vol. 131, pp.383-385, 2000.

[14] Sugehis Liscano, Linda Gil, O.A. Leon, Marlon Cruz, Mariana H. Staia, "Corrosionperformance of duplex treatments based on plasma nitriding and PAPVD TiAlN coating *", Surface Coatings & Technology*, Vol. 201, 4419-4423, 2006.

[15] A.S. Khanna, "Introduction to high temperature oxidation and corrosion", ASM International, ISBN 0-87170-762-4, SAN: 204-7586, pp 1-322, 2002.

[16] S. Tsipas, J.M. Brossard, M.P. Hierro, J.A. Trilleros, L. Sánchez, F.J. Bolívar, F.J. Pérez,"Al–Mn CVD-FBR protective coatings for hot corrosion application", *Surface &Coatings Technology*, Vol. 201, pp.4489–4495, 2007.

[17] F.J. P´ereza,U, F. Pedrazaa, M.P. Hierroa, P.Y. Hou, "*Adhesion properties of aluminide*coatings deposited via CVD in fluidised bed reactors CVD-FBR/on AISI 304 stainless steel*", Surface and Coatings Technology*, Vol. 133-134, pp..338-343, 2000.

[18] Y.Q. Yang and H.C. Man , *Surface Coating Technology*, Vol.130 (6), pp.132, 2000.

[19] A. Hidouci, J.M. Pelletier, F. Ducoin, D. Dezert and R. El Guerjouma , "Microstructural and mechanical characteristics of laser coatings", *surface and coatings technology*, Vol.123, pp. 17-23 ,2000.

[20] P.H. Chong, H.C. Man and T.M. Yue ," Laser fabrication of Mo-TiC MMC on AA6061 aluminum alloy surface*", Surface and Coating Technology*, Vol.154 (2-3), pp.268-275,2002.

[21] Y. Herrera, I.C. Grigorescu , J. Ramirez , C. Di Rauso and M.H. Staia , "Microstructural characterization of vanadium carbide laser clad coatings", *Surface Coating Technology* , Vol. 308 (11), pp.108–109,1998.

[22] A. Mchimann , S.F. Dirnfeld and I. Minkoff , *Surface Coating Technology*, Vol.42, pp.275–81,1990.

[23] T.C. Lei, J.H. Quyang, Y.T. Pei, T.C. Lei and Y. Zhou , "Tribological behaviour of laser clad TiCp composite coating*", Wear*, Vol.185, pp.167-172,1995.

[24] .L.E. Rehn, S.T. Picraux, H. Wiedersich (Eds.), "*Surface alloying by ion, electron and laser beam*s", ASM, Metals Park, OH , p. 1 ,1987.

[25] R.W. Cahn, P. Haasan and E.J. Kramer , "Laser processing of materials", *materials science and technology*, Vol.15, pp. 111–136,1993.

[26] J.D. Majumdar, J, I. Manna , "Laser processing of materials", *Sadhana*, Vol.28, pp. 4,2003.

[27] A.Y. Fasai, M. Pon, C. Tassin, A. Galerie , "Laser surface melting of mild steel with submicronic titanium carbide powders", *journal of material science*, Vol.29, pp.5121-5126 ,1994.

[28] J. S. Lim, K. L. Ng and K. M. Teh , "Development of laser cladding and its application to mould repair", SIM Tech technical report, vol.9, pp.142,2008.