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Coatings: A Review

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Abstract - To protect and safeguard a material from degradation, another material having better properties is applied on the base metal. The application of a coated material can propel the increase in life span, wear resistance or oxidation resistance of a material. Thermal spray coatings play an important role to protect the material from hot corrosion, erosion and wear. As it protects the material from this hazardous environment, it is helpful to increase service life of the material in any surrounding environment. This review paper presents the results of previous work done by different authors in the field of coating.
Keywords: **Hot Corrosion, Thermal Spraying**

I. INTRODUCTION

Coatings provide protection to any material from wear, hot corrosion and erosion in any surrounding environment. Coating material can be in any form like powder form, wire form, molten form and ceramic rod. Porosity of coating depends upon the sprayed material and condition of the spray. Mainly, there are three kinds of coating techniques i.e. thermal spraying, physical vapour deposition (PVD), chemical vapour deposition(CVD) But thermal spray coating techniques are widely used technique to coat any material. Some examples of thermal spray techniques are detonation gun technique, HVOF technique, plasma spray etc. Coatings also play precious role in medicine field as well as in industrial field. Coating tests are performed in both molten salt environment and in air environment. Some application of coatings are in automotive systems, boiler components, power generation equipments, aircraft engines, orthopedics and dental, ships, land-based and marine turbines [1].

II. STUDIES RELATED TO COATINGS

Fauchais *et al.* [2] Studied the thermal sprayed coatings used against corrosion and corrosion wear. He concluded that there were some reasons to use thick thermal sprayed coatings in industries. The reasons are as follows:1) It provided some beneficial properties to the substrate. 2) With low or no heat input, it could be applied to substrate. 3)Thermal sprayed coatings could be recoated the damaged or worn coatings without any changes in dimensions and properties. 4) Some of thermal processes could be used to spray big parts easily. He also concluded some negative points of this coating like. 1) It was impossible to coat deep cavities and small parts by this coating process. 2) It had pores and cracks which resulted degradation. Hence post-treatments like annealing, sealing, laser glazing etc. must to remove pores. These post-treatments increased the cost of coating.

Kaur *et al.* [3] investigated the high temp. Corrosion of HVOF sprayed Cr_3C_2-NiCr coating on SAE 347H boiler steel at 700°C. $Na_2SO_4 82Fe_2 (SO_4)_3$ solution was used as molten salt solution. She concluded that coating on 347 boiler steel by HVOF achieved great results and sprayed coating consisted irregular shaped splats which were interconnected. Corrosion loss for 347H steel in molten salt solution was high than corrosion loss in air and bare 347H steel in both environment suffered accelerated oxidation. Coated 347H steel showed better corrosion resistance in both environment than bare steel.

Kaur *et al.* [4] examined the surface engineering of D-gun sprayed Cr_3C_2–NiCr coating under high temp. Oxidation and Oxidation erosion environment. She concluded that coating on T22 boiler steel by D-gun achieved great results and coating had spongy structure. Higher weight loss occurred by bare specimen than coated at 700+10°C/700-10°C. Coated T22 steel resulted good oxidation erosion resistance than uncoated T22.

Arrieta *et al.* [5] determined the corrosion behavior of NiCr based coatings in simulated human body fluid environment. He concluded that NiCr coatings were high corrosion resistant or had low corrosion rate and pitting corrosion resistance .But by adding Cr_3C_2 in NiCr, corrosion resistance had increased more. NiCrAl coating had highest pitting potential value But Cr_3C_2 (NiCr) was most influenced to pitting type corrosion. Highest stable coating was Cr_3C_2 (NiCr).

Kaur *et al.* [6] examined the high temp. behavior of HVOF sprayed Cr_3C_2 (NiCr) coating. She concluded that no spallation was found during exposures. Therefore, coated T22 showed no cracks and spallation in both environment. Cross sectional analysis showed that penetration of oxygen was in margin, which was the sign of control of oxidation. Erosion-corrosion rate of steel was decreased by 35% after coating. In molten salt environment, Cr_2O_3 and $NiCr_2O_4$ acts as strong phases that resulted better result for high temperature corrosion resistance than in air environment.

Single *et al.* [7] determined characterization and corrosion resistance of plasma sprayed HA and HA-SiO_2 coatings on

Ti6Al4V. He concluded that after HA+10%SiO_2 coating on Ti6Al4V corrosion resistance increased as compared to HA coating and bare specimen. After immersion in ringer's solution, No cracks were observed on both coated surfaces. Before and after corrosion testing in ringer's solution, both the coatings showed HA+10%SiO_2 coating converts into irregular shaped particles and HA coating hold its morphology. Therefore, HA+10%SiO_2 coating became more corrosion resistant and less porous.

Kumar *et al.* [8] investigated the cyclic oxidation behavior of bare and Cr_3C_2-25 (NiCr) coated super alloy at elevated temperature He observed that coated sample weight gain was one –fourth of weight gain of bare specimen and for 100 cycles coating at 900^0C proved influenced. Parabolic rate constant(kp) for coated superni600 was 28 times less than bare .XRD analysis showed the presence of Cr_2O_3, $Cr_{23}C_6$, $NiCr_2O_4$ and Cr_7C_3 in scale after oxidation which made coated superni600 oxidation resistant. Coating with D-gun technique provided protection to substrate from hot corrosion.

Singh *et al.*[9] done investigations of plasma-sprayed hydroxyapatite-calcium phosphate coatings on 316L SS, in vitro corrosion. He investigated that HA+20%CaP was less crystalline than HA+10%CaP and HA coatings. After HA coating, corrosion resistance increased than uncoated, HA+20%CaP and HA+10%CaP. But no cracks were found on all the three coatings.

Mudgal *et al.* [10] investigated the hot corrosion behavior of some super alloys in a simulated incinerator in environment at 900^0C. She concluded that superni600 and superni718 showed less weight gain than superco605. In case of Ni-based alloys, a thin scale was observed but in case of cobalt-based alloys, scale was thick. In superco605 CoO, $NiWO_4$, $NiCr_2O_4$ and $CoCr_2O_4$ were formed and $NiCr_2O_4$ and Cr_2O_3 in superni600 and superni718. Ni- based alloys suitable for incinerator environment while Co-based alloys unsuitable for incinerator environment.

Rana *et al.* [11] examined the stepwise depletion of coating element as a result of hot corrosion of NiCrAlY coatings. She concluded that due to formation of Al_2O_3 layer at coating interface, NiCrAlY coating were observed as corrosion resistant. Al_3Y phase after 100 cycles, also increased the hot corrosion resistant and from 100 to 200 cycles, minimum corrosion was observed. Upto initial 5 cycles, NiV_2O_8 was formed .YVO_4 also formed when Y reacts with vanadium and at interface, Al rich layer was observed.

Mudgal *et al.* [12] investigated the corrosion behavior of bare, Cr_3C_2-25% NiCr+0.4%CeO_2 coated superni600 under molten salt at 900^0C. She concluded that bare superni600 corroded in Na_2So_4-25Nacl showed loss in weight due to some internal oxidation and had pores in scale, for 100 cycles at 900^0C. While coated specimens showed thick scale and weight gain. All the three cases had Cr_2O_3,$NiCr_2O_4$,$Cr_{23}C_6$,Na_2CrD_4 in both corroded coatings and CeO_2, CeS in Cr_3C_2-25(NiCr)+0.4CeO_2.

Rana *et al.* [13] done high temp. Oxidation and hot corrosion studies on NiCrAlY coatings deposited by flame spray technique. She concluded that NiCrAlY coatings successfully deposited by HVOF tech. On superni76 and superni76 coating provided high temp. Oxidation in both environments i.e. air and molten salt environment. Pre-oxidized region of coatings consisted alumina and unoxidized region consisted Ni and Cr which acts as air oxidation resistant. After 100 cycles of air oxidation, pre-oxidized region remained unaffected.

Shukla *et al.* [14] analysed the surface engineering analysis of HVOF sprayed Cr_3C_2-NiCr coating under high temp. Oxidation. He concluded that Cr_3C_2-NiCr coatings successfully deposited on 310S by HVOF tech. Upto 500 hours and coating had dense structure. Coating's microhardness was lies between 775-1014Hv. Presence of Cr and Ni oxides showed by coating oxide scale which provided good corrosion and wear resistance.

Grewal *et al.* [15] checked the effect of sliding velocity on wear behaviour of TiAlN coatings. He concluded that in nanostructured coating, formation of titanium oxides and aluminium oxides provided protection against high oxidation, wear and good thermal stability while in conventional coating, oxides breakaway & removed from the surface of the substrate. When sliding velocities were 0.5,1 and 2m/sec. with constant 10N load, Nanostructured TiAlN coating at 200^0C was best wear resistant than Nanostructured TiAlN coating at 500^0C, conventional TiAlN coating and bare AISI-304 boiler steel.

Rana *et al.* [16] studied the microstructural features and behavior of nano and conventional NiCrAlY coatings developed by LVOF process. She concluded that high interplay oxidation was the main cause of changes in oxidation mechanism of MC coatings and NC coatings .NC coatings hold the phases of the starting milled powder. The NC NiCrAlY coatings were better oxidation resistant than MC coatings.

Mudgal *et al.* [17] investigated the hot corrosion behavior of bare , Cr_3C_2-NiCr and, Cr_3C_2-(NiCr)+0.2 wt.%Zr coated superni718 at 900^0C. Cr_3C_2-NiCr coating provided great corrosion resistance to superni718 under (Na_2So_4 + K_2So_4 + NaCl + kCL) and Na_2So_4+NaCl salt environment. Zirconium addition in coating reduces the weight gain tendency. Cr_2O_3 and spinel of nickel and chromium protected the coating from corrosion.

III. DISCUSSION

Thermal sprayed coatings used against corrosion and corrosion wear. There were some reasons to use thick thermal sprayed coatings in industries. The reasons are as follows:

1. It provided some beneficial properties to the substrate.
2. With low or no heat input, it could be applied to substrate.
3. Thermal sprayed coatings could be recoated the damaged or worn coatings without any changes in dimensions and properties.
4. Some of thermal processes could be used to spray big parts easily.

There were also some negative points of this coating like.
1. It was impossible to coat deep cavities and small parts by this coating process.
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Hence post- treatments like annealing, sealing, laser glazing etc. must to remove pores. These post-treatments increased the cost of coating [2]. Coating on 347 boiler steel by HVOF achieved great results and sprayed coating consisted irregular shaped splats which were interconnected. Corrosion loss for 347H steel in molten salt solution was high than corrosion loss in air and bare 347H steel in both environment suffered accelerated oxidation .Coated 347H steel showed better corrosion resistance in both environment than bare steel [3]. Kaur *et al.* [4] examined the surface engineering of D-gun sprayed Cr_3C_2 –NiCr coating under high temp. Oxidation and Oxidation erosion environment. She concluded that coating on T22 boiler steel by D-gun achieved great results and coating had spongy structure. Higher weight loss occurred by bare specimen than coated at 700+10°C/700-10°C. Coated T22 steel resulting good oxidation erosion resistance than uncoated T22. NiCr coatings were high corrosion resistant or had low corrosion rate and pitting corrosion resistance .But by adding Cr_3C_2 in NiCr, corrosion resistance had increased more. NiCrAl coating had highest pitting potential value But Cr_3C_2 (NiCr) was most influenced to pitting type corrosion. Highest stable coating was Cr_3C_2 (NiCr)[5]. Kaur *et al.* [6] examined the high temperature behavior of HVOF sprayed Cr_3C_2 (NiCr) coating. She concluded that no spallation was found during exposures. Therefore, coated T22 showed no cracks and spallation in both environment. Cross sectional analysis showed that penetration of oxygen was in margin, which was the sign of control of oxidation.

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IV. CONCLUSION

Thermal spraying techniques are mostly used coating technique to enhance surface performance.

1. Ni-based alloys perform better than Co-based alloys.
2. Cr_3C_2 –NiCr show excellent results in the field of coatings.
3. Maximum corrosion attack occurs around 900^0C temperature.

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