

DEVELOPMENT OF CONVENTIONAL AND NANO-STRUCTURED CORROSION RESISTANT COATINGS ON SUPER ALLOYS SUBSTRATES: A REVIEW

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ABSTRACT

Hot corrosion and erosion in boilers and related components are responsible for huge losses in power generation system. An understanding of these problems and thus to develop suitable protective system is essential for increase the life time of such components. These problems can be prevented by either changing the material of the boiler components or by separating the component surface from the environment. The unique processing variables in thermal spraying inevitably leads to superior mechanical properties like bonding strength, Young's modulus, higher erosion and wear resistance etc. among the other deposition techniques. Different composition of nanostructured coatings are widely used in gas turbine, steam turbine, aero-engine and power generation systems to improve the resistance to sliding, abrasive and erosive wear. In recent years, tremendous efforts have been made for fabricating coatings with different compositions as well as on the various kinds of superalloy substrates. In this review paper critical analysis of the available literature and comparison of different conventional and nanostructured coatings deposited by various thermal spray techniques has been made.

Keywords: *HVOF, Nanostructured coating, Hot corrosion*

I.INTRODUCTION

The structure and properties of coatings manufactured by thermal or cold-gas spraying depend strongly upon powder feedstock morphologies, injection of feedstock into the energetic flow, and spray operating conditions [1]. Most often, the degradation of a component during service, and its eventual failure, can be traced to material damage resulting from surface/environment interactions. Protective coatings are primarily sought to enhance the durability and/or performance of components employed in adverse operating conditions. Typically, these coatings are aimed at modifying the surface properties of critical components to provide enhanced resistance against deterioration due to mechanisms such as corrosion, oxidation, wear, or failure under an excessive heat load. In recent years, considerable advances in the field of coatings technology have accompanied the growing realization of the immense potential of surface engineering in the modern industrial world. Consequently, there are now available a number of methods for developing a wide variety of protective coatings [2]. Metal and alloys get oxidized when they are heated to elevated temperatures in air or highly oxidizing environments, such as a combustion gas with excess of air or oxygen. They often rely on the oxidation reaction to develop a

protective oxide scale to resist corrosion attack, such as sulphidation, carburization, ash/salt deposit corrosion etc. That is why oxidation is considered to be the most important high-temperature corrosion reaction. Further the rate of oxidation for metals and alloys increases with increasing temperature [3].

Super alloys are frequently used in high temperature applications such as gas turbine and energy conversion systems etc. During operation, blades and vanes of gas turbine are subjected to high thermal stresses and mechanical loads. In addition, they are also attacked chemically by oxidation and/or high temperature corrosion [3]. According to Eliaz et al. [4] the superalloys at gas turbine engines serve most of the time in an oxidizing environment. Therefore high temperature oxidation of superalloys has attracted the attention of many researchers in the past as well as in the recent times. Further, the superalloys are not able to meet both the high-temperature strength and the high-temperature corrosion/oxidation resistance simultaneously so protective coatings on superalloys are used to counter the latter. Thus, the oxidation behaviour is very important for high-temperature coatings. Although protective surface treatments are widely used at low temperature, the use of these at elevated temperature is relatively more recent. High temperature applications are limited largely to the aerospace industry. An enormous challenge exists to develop and apply these techniques to other high temperature applications [5]. Among the various coating methods, advanced plasma spray technique has many advantages such as high productivity for thick coating films of more than 100 μm and good applicability for a wide range of coating materials including ceramic powder. Furthermore, the process does not cause degradation of the mechanical properties of the alloy substrate [6]. Overlay coatings include a family of corrosion resistant alloys specially designed for high temperature surface protection. They are often referred to as MCrAlY coatings, where M is the alloy base metal (typically nickel, cobalt, or combination of these two). Furthermore MCrAlY overlays are also used bond coats in thermal barrier coatings and oxidation of the bond coat remains an important issue [7]. Various researchers have reported oxidation studies on thermal sprayed MCrAlY coatings at elevated temperatures in the recent past [8-14].

II. HOT CORROSION

Hot corrosion may be defined as an accelerated corrosion, resulting from the presence of salt contaminants such as Na_2SO_4 , NaCl , and V_2O_5 that combine to form molten deposits, which damage the protective surface oxides. Hot corrosion occurs when metals are heated in the temperature range 700°C – 900°C in the presence of sulphate deposits formed as a result of the reaction between sodium chloride and sulphur compounds in the gas phase surrounding the metals [15,16]. At higher temperatures, deposits of Na_2SO_4 are molten (m.p. 884°C) and can cause accelerated attack on Ni- and Co-based superalloys. This type of attack is commonly called ‘hot corrosion’. Accelerated corrosion can also be caused by other salts, viz. vanadates or sulphates– vanadate mixtures and in the presence of solid or gaseous salts such as chlorides [17]. Due to depletion of high-grade fuels and for economic reasons, use of residual fuel oil in energy generation systems is well known. Residual fuel oil contains sodium, vanadium and sulphur as impurities. Sodium and sulphur react to form Na_2SO_4 in the combustion system. During combustion of the fuel, vanadium reacts with oxygen to form an oxide V_2O_5 (m.p. 670°C). Thus V_2O_5 is a liquid at gas turbine operating temperature. These compounds, known as ash, deposit on the surface of materials and induce accelerated oxidation (hot corrosion) in energy generation systems. Corrosion occurs when these molten compounds dissolve the protective oxide layers, which naturally form on materials during gas turbine/boiler operation. Further, vanadate compounds are good oxidation catalysts and

allow oxygen and other gases in the combustion atmosphere to diffuse rapidly to the metal surface and cause further oxidation. As soon as the metal is oxidized, the cycle starts over again and high corrosion rates occur. Further, in coal-gasification processes, hot corrosion is expected to be a problem because the gas environment generally has large sulphur and low oxygen activities and also contains substantial amount of salts [18].

MCrAlYs (M represents Ni and/or Co) are among the most important range of protective coating materials to counteract hot corrosion and high-temperature oxidation. Like any coating designed to resist oxidative environment at high temperatures, MCrAlYs should be capable of providing a reservoir of uniformly distributed Al, Cr, and Y for developing a thermodynamically stable, slow growing and adherent scale. The final performance of the coating (till cracking and spallation) will depend on the virgin coating oxygen content as well as the oxidation and hot corrosion behavior of the coating in service. MCrAlYs are used in gas turbines as the main coat to provide oxidation and hot corrosion resistance or in combination with a thermal barrier coating as bond coat. MCrAlYs have evolved over time. FeCrAlY was among the early coating applications to nickel based super alloys.

This coating was not practically useful at high temperatures and was replaced by CoCrAlY. While this coating had useful hot corrosion and oxidation resistance it did not meet ductility requirements for airfoils in high-performance engines. Since NiCrAlY had limited hot corrosion resistance, a compromise was sought by adding Cobalt. This led to the CoNiCrAlY compositions, which had excellent combination of ductility and high-temperature oxidation and corrosion resistance [19]. One of the important considerations of the CoNiCrAlY main and bond coat for next generation of gas turbines, which have more demanding conditions and need to withstand ever increasing operating temperatures, is that they should possess very low oxygen content levels in the as-sprayed coating. Deposition of overlay coatings has been dominated by the vacuum plasma spray (VPS)/low-pressure plasma spray (LPPS) techniques [20-22] to avoid oxide forming in coatings particularly for the hottest stages in aero- and land-based gas turbines like buckets/blades.

Al₂O₃ scales are formed on the surface of MCrAlY coatings at high temperature, and these protect the Superalloy [23]. The microstructure of the coating depends on the coating components, manufacturing method and process used [24] MCrAlY coating can be prepared using vacuumplasm a spray (VPS) , electron-beamphysical vapour deposition (EBPVD) [25], magnetron sputtering and cathodic arc deposition[26]. Because of its higher deposition rate and good adherence to the base metal, these are benefits of using the arc ion plating (AIP) technique to deposit MCrAlY coatings. Commercially available NiCrAlY powder was mechanically cryomilled and HVOF sprayed onto Ni-based alloy to form a nanocrystalline bond coat [27].

III. CONCLUSION

The formation of the slow-growing, thermodynamically stable α -Al₂O₃ layer suggests that nanostructured HVOF coatings will exhibit improved oxidation behavior and that this technique could be an alternative to the conventional deposition methods of NiCrAlY bond coatings on super alloys. In the nanostructured HVOF NiCrAlY coating, the nucleation of the alumina layer seems to be faster than the coating made with as-received powder, and a homogeneous layer is rapidly formed on top of the bond coat. This behavior is believed to be due to increased aluminum diffusion through the grain boundaries of nanostructured coating, as well as to the preexisting Al₂O₃ oxide particles present in the powder after the cryomilling process, which favor the nucleation of the α -Al₂O₃ layer.

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