Analysis of different types of Coating of Gas Turbine Blade

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Article Info
Article history:
Received 25 September 2015
Received in revised form
20 October 2015
Accepted 28 November 2015
Available online 15 December 2015

Keywords: Gas turbine blade, Diffusion Coating, Overlay Coating, Smart coating and Thermal barrier coating

Abstract
In last few decades, the operating temperatures of gas turbine engines have been continually increased in order to achieve higher and higher power and efficiency. During the operation of power generation gas turbines, the blade and other components of hot gas path undergoes service induced degradation, which may be neutral or accelerated due to different causes. The degradation or damage may have a metallurgical or mechanical origin and results in reduction of equipment reliability and availability. It also increases risk of failure occurring. Also, due to blade material metallurgical deterioration, the material creep, fatigue, impact and corrosion properties decrease. There are different factors which influence blade lifetime as design and operation conditions but the latter are more critical.

1. Introduction

In First stage gas turbine blades, the most critical components of gas turbines, made from nickel-base super-alloys in various wrought and cast forms, have been singularly successful materials systems for the past 50 years. Nickel based alloys compositions have changed for improvement since 1965 and clearly shows that the chromium content has been drastically reduced from about 15 wt% to about 3 wt% and that aluminum contents have increased to about 5 wt%. These changes in composition are done in order to develop strengthening mechanisms in Ni-based alloys for optimum creep resistance at temperatures up to 1100^0C. The presence of these refractory elements in solid solution in the matrix gives rise to significant solid solution strengthening due to the strength of bonding to Ni. All of this development in alloy has been made in order to improve mechanical properties to facilitate higher component temperatures. However, the low content of chromium and aluminum means that these alloys do not have the necessary oxidation and corrosion resistance which is required for the long term gas turbine operation. Accordingly, coatings must be applied to gas turbine components for making them oxidation and corrosion resistant. In accordance to the demand to increase turbine inlet temperatures and thus cycle efficiencies, ceramic insulating coatings can be applied to decrease the temperature of the hottest parts of the turbine components by up to 170^0C.

Oxidation and corrosion resistant coatings which are applied to the gas turbine engine components are of two types. These are (1) Diffusion coating and (2) Overlay coating (3) Smart Coating (4) Thermal barrier coating (TBC).

2. Diffusion Coating

In diffusion coating, an inter diffusion zone is formed between the substrate and the coating. Diffusion coating is formed by diffusion of one or more elements into the surface of the metal to be protected. Typical diffusion coatings are simple aluminide and chromium or platinum modified aluminide coatings. They are more commonly referred to as diffusion coatings since their application involves inter diffusion between deposited Al or Cr and the substrate onto which they are coated. Several variants of these processes arise which includes pack, out of pack, CVD and Fluidised bed, CVD. With pack aluminizing or chromising components to be coated are placed in a ‘‘pack’’ of a diluents, typically alumina, a halide activator (e.g. ammonium fluoride) and metal powder e.g. Al or Cr and heat treated in argon [1]. For the out of pack process, the component is located downstream from the ‘‘pack’’ such that the metal halide gas produced by the pack impinges on the substrate and the metal is deposited on the surface where it undergoes inter diffusion with the substrate [2]. In the CVD process Al and HCl are reacted under controlled conditions and passed under a positive pressure into the coating part of the system where they enable aluminide formation [3]. The fluidised bed aluminizing process [4] involves the suspension of the component in a bed of inert particles (e.g. alumina) by a gas stream comprising the gases necessary for aluminizing in a carrier gas.

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3. Overlay Coating

In Overlay coating, no inter diffusion zone is formed between the substrate and the coating as formed in diffusion coating. Overlay coatings are basically coatings of specific composition applied directly on to the surface to be protected. These are deposited by using thermal spray like Ar shrouded plasma spray (APS) or Low pressure plasma spray (LPPS) or Electron beam physical vapour deposition (EBPVD). LPPS gives superior microstructure and mechanical properties but is expensive. Typical overlay coatings are MCrAlX type where M is usually nickel or cobalt; X is Y, Si, Ta, Hf, etc. which is mostly less than 1% by weight. Overlay coatings typically comprise β+γ’ aluminide in a γ matrix and typical composition consist of (Ni-Co) -15to28 % wt of Cr, 4–18 wt% Al, 0.5–0.8 wt% Y. Overlay coatings with 18–22% Cr and 8–12% Al are designed to withstand corrosion above 900^0C [5]. CoCrAlY alloy coatings with 17–22% Cr and 10–12% Al have the resistance to attack at high temperature, but not with most severe salt environment. CoCrAlY alloy with 25–35% chromium level is required for low temperature corrosion protection [6]. The application of MCrAlY coatings is limited to 1100^0C because of relatively thick oxide scales which are formed, followed by enhanced local spallation particularly when thermal cycling is encountered [7,8].

4. Smart Coating

In order that a single coating can operate successfully over a range of temperatures with different forms of corrosion attack – high temperature oxidation, type I and type II hot corrosion – it needs to respond to local temperature in such a way that it will form either an alumina or chromia protective layer as appropriate. High purity alumina scales offer the best protection under high temperature oxidation conditions, and this has been a major drive behind the development of platinum aluminide coating technology. Chromia scales form more readily at low to intermediate temperatures, are more resistant to salt fluxing and thus provide a rapid repair route under hot corrosion conditions.

In a “Smart overlay coating” these joint requirements are achieved through the use of a chemically-graded coating structure enriched in aluminium and chromium as shown in Fig. [1]. Here the basic coating is a standard MCrAlY (in this study either Co32Ni21Cr8Al0.5Y or Ni25Cr6Al0.4Y) that has been enriched at its outer surface in aluminium, sufficient to form □-NiAl. Before this aluminising treatment, the MCrAlY is pretreated to form an intermediate layer rich in chromium

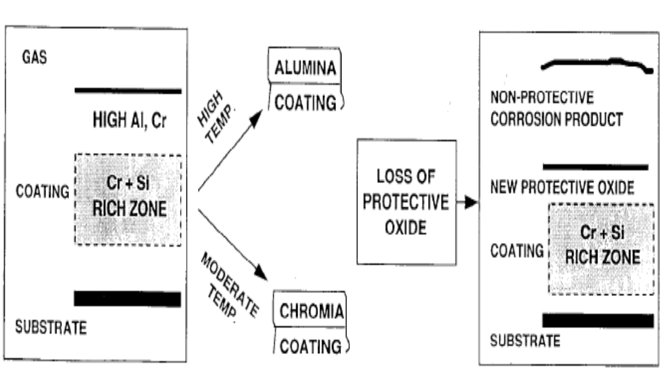

Fig 1 Concept of smart overlay coating

Nicholls et al.[10] has developed smart coating which is most recent technological advance in overlay coating technology. These coatings address the problems associated with the differences in temperature over the surface of an airfoil. Temperatures vary from a maximum of the order of 1100^0C at leading and trailing edges to about 650^0C in the centre of the airfoil surfaces and near airfoil roots. Because of this difference in temperature, the nature of environmental degradation varies from oxidation through Type I hot corrosion to Type II hot corrosion as indicated in Figure 4. Smart coating developed by Nicholls et al [10] comprises a commercial base coating (Co–32Ni–21Cr–8Al–0.5Y) adjacent to the substrate, a Cr enriched layer of variable composition from Ni–60Cr–20Al to Ni–35Cr–40Al and a surface layer of composition Ni–15Cr–32Al. These multi-layer coatings have been shown to outperform typical a commercial Pt modified aluminide and an Al enriched version of the base coat at 700^0C – 800^0C.This technology appears a step forward, with issues related to coating ductility and additional improvements with respect to corrosion resistance offered by cobalt.

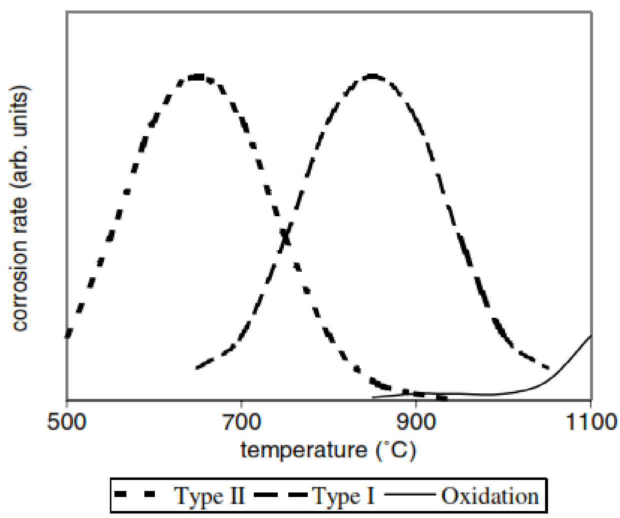

Fig.2 Schematic representation of rate-temperature curves for Type II hot corrosion, Type I hot corrosion andoxidation

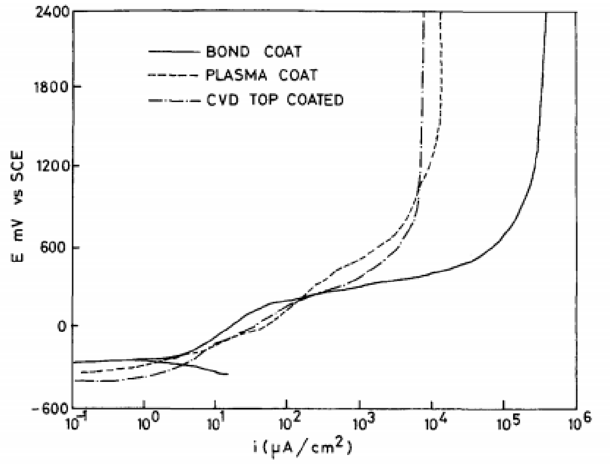

Fig. 3. Potentiodynamic polarization curves of (a) bond-coated substrate, (b) YSZ plasma sprayed onto bond-coated substrate and (c) CVD Zirconia on The plasma-sprayed sample

5. Thermal Barrier Coating

Thermal barrier coatings (TBCs) are two layer (duplex) coating systems which comprise of an oxidation and corrosion resistant inner layer caller ‘bond coat’ and an insulating ceramic outer layer called ‘top coat’. The bond coat serves two purposes: (1) it protects the metallic substrate from the ingression of hot gases and their attack on the substrate; (2) it serves as an intermittent layer that gives better adhesion between the substrate and the top coat.

Plasma spraying is a widely accepted technology to produce thermal barrier coatings for these applications. The porous nature of the coatings obtained by plasma spraying helps in accommodating the thermal stresses arising out of expansion coefficient mismatch between the base material and the ceramic coatings. However, these pores allow access for the corrosive environment to the underlying substrate or the bond coats. Furthermore, the porous structure of the coating is more susceptible to erosion.

In the light of the above limitations, it is worthwhile to develop a technique that can densify the surface of the porous plasma coating. Currently laser melting of the surface is being pursued for the surface densification; however, this process leads to micro cracks in the densified surface. Chemical vapour deposition (CVD) has been found to be a method which provides a dense overcoat without the undesirable micro cracks. It is envisaged that a process such as CVD should be amenable for densification of thermal barrier coatings on curved surfaces such as those of turbine blades. The duplex coatings thus obtained by plasma spraying followed by CVD should retain the buried porous structure to accommodate the thermal stresses and block the ingestion of hot corrosive gases at the surface itself [11-13].

Thermal Barrier Coating have a Thermally Grown Oxide (TGO) which is α- Al_2O_3 that forms between the bond coat and the top coat and provide protective layer on the bond coat to prevent the inner surface of it from further oxidation.

6. Conclusions

In the present study the analysis of different type of coatings in the gas turbine was done. The operation of power generation gas turbines, the blade and other components of hot gas path undergoes service induced degradation, which may be neutral or accelerated due to different causes. The degradation or damage may have a metallurgical or mechanical origin and results in reduction of equipment reliability and availability. It also increases risk of failure occurring. Also, due to blade material metallurgical deterioration, the material creep, fatigue, impact and corrosion properties decrease.

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