SOME ASPECTS OF PROTECTION AGAINST CORROSION FOR THE GAS TURBINE STATOR

Sorin PAVEL*

*Corresponding author
SMG – STATUL MAJOR GENERAL,
Strada Izvor 3-5, Sector 5, Cod 050561, Bucureşti
pavel.sorin88@yahoo.com

DOI: 10.13111/2066-8201.2011.3.1.11

Abstract: *This paper continues the recent research of the author, considering the demands for turbines components.*
The turbine's destinations are taken into consideration during the design phase, but the technological, architectural requirements as well as the ones regarding the materials they are made of, set the limits for the turbine design.
The main determiner is the temperature.

Key Words: Corrosion protections of the stator gas turbine, the plasma spray coating, the fuel additives, heat-resistant coatings

1. INTRODUCTION

During operation most jet propulsion units are subject to a large number of ignitions and various working conditions, which leads to special design, execution and operation requirements.

2. CORROSION BEHAVIOUR OF THE GAS TURBINE STATOR BLADES

The temperature of the turbine stator blades grows at more than in all other jet engine components (excluding the fire tube and the gas collector). In contrast with the rotor blades, whose temperature is determined using the average temperature of the combustion gases, the stator blades may reach 50^0C, and in certain circumstances even $100\text{-}150^0$C above the average temperature of the combustion gases.

Since the section of stator blades are larger than the rotor blades, the gas temperature change that occurs during the startup, shutdown and different transient operation of the engine results in higher thermal stresses in stator blades than in rotor blades.

Depending on the structure, the blades are elongated due to the creep tension caused by the weight of the stationary elements, but mainly because of the stretching caused by the force produced by gases.

However tensions in the stator blades, usually are much smaller than the tensions of the rotor blades, which are subject to the action of centrifugal forces.

The most typical kinds of damage to the stator blades as a result of a long-term operation are:

- corrosive damage which leads to the thinning of the blade's leading and trailing edge, to corrosion stains and surface roughness , all of these diminishing the aerodynamic qualities (Fig. 1);

Fig. 1. Corosion stains and asperities on the stator blades

Fig. 2. Cracks in the blade's leading and trailing edge because of the thermal fatigue

- Thermal fatigue which leads to cracks in the blade's leading and trailing edge (Fig. 2);

Fig. 3 Cracks which lead to tearing of the material

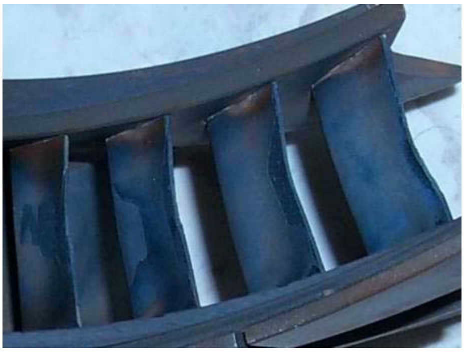

Fig. 4 Changes in their geometry

- Cracks which lead to tearing of the material affecting the other components (Fig.3);
- Changes in their geometry resulting in loss of blade resistance while being thermally loaded (Fig. 4);
- Superficial disruption of the blades made of materials less flexible because of different objects entering the jet propulsion unit (Fig. 5).

Fig. 5. Superficial disruption of the turbine's stator blades

Fig. 6. Curves of the leading and trailing edge

The impairment of the turbine's stator blades caused by corrosion is the result of the interaction between the materials of the blades, the gas surrounding them and deposits of ash which contain several combustion composites.

The corrosion process is more aggressive on the blades if the fuel contains vanadium and sulphur and if maritime salt enter the propulsion unit. Cracks which appear due to thermal fatigue are the most frequent phenomenon.

Their cause is the thermal load of the blades, blades which undergo thermal variation during the several stages of flight. During the ignition the temperature at the middle section of the blades is significantly higher than the temperature at the peripheries and when the blades are bandaged/hooped and do not elongate freely, curves of the leading and trailing edge may appear, lowering the director unit section and (Fig. 6) thus reducing the engine efficiency.

3. METHODS TO REDUCE CORROSION OF THE GAS TURBINES

Introducing the fuel additives that reduce significantly the corrosion of the blades is required as a first method in the reduction of corrosion made by products contained in the flue gas. It is recommended to add in fuel chromium acetylacetonate dissolved in benzene, izooctadecilsucsin chromium dioxide, chromium and manganese salts, oleic acid, stearic acid and other acids.

Chromium oxides (tin, Samaria, niobium) are interacting with sodium until the sodium sulfate sedimentation on the blade surfaces and form sodium chromate type compounds - Na2CrO4, which are more stable in comparison with sodium sulphates. Being a gas, the sodium chromate does not produce corrosion to materials.

Chromium content in the fuel must be a little higher than the content of sodium, which enters the sewerage turbine. The role of manganese compounds consists of decreasing the adhesion of deposits on the blades.

The corrosion speed, in presence of inhibitor conditions listed above may be reduced by about 30 times, [1].

For the gas turbine components, inorganic coatings are applied to protect from corrosion and erosion and to reduce mechanical wear.

To reduce the corrosion and erosion of the components, operating at temperatures near the combustion chamber, methods for applying coatings on plasma spray and also the detonation method are used. WC, Cr_3C_2, Al_2O_3, TiO_2 şi ZrO_2 are used as ceramic constituents. A very large use have the powder-based deposits, applied both in turbojet engines manufacturing and during their repairs.

In order to protect the gas turbine components against oxidation and sulfuric corrosion, different types of coatings are used: by diffusion; deposited by spray method, applied by immersion in bath of molten alloy and also by plating.

The method of applying coatings by diffusion is based on the saturation of the metal surface, with certain elements in quantities which are required by the type and speed of diffusion in refractory alloy, at the process temperatures and which depend on the activity of the environment - source.

The most widespread coatings in the construction of gas turbines are the alumina coatings and the chromium diffusion ones. Alumina coatings are effective against the oxidation of blades which are long-term operating at temperatures of 900^0C.

The addition of silicon increases the strength of Al2O3 formed oxides, partially replace the aluminum ions and reduce their rate of diffusion. The technology of superficial deposit of alumina powders containing 98% Al Fe (50%) Al and 2%NH_4Cl alloy at temperatures of 800 – 950^{0}C within 2-6 h is widely use to obtain layers of 20-60 μm, thickness [2].

A wide use has also the deposit method based on the application of paint coatings and special coatings (powder containing Al, Si, Nb, varnishes and thinners and other special items) using the spray and their annealing in neutral or argon environment. Alumina coatings, which contain no silicon, niobium, chromium, are very vulnerable to sulphide corrosion.

Protective layers formed by chromium diffusion in basic material provide a significantly greater protection to the blades both against sulfuric corrosion and erosion compared with the layers of alumina.

The features of the diffusion saturation process are the following:

1. Diffusion speed, comparatively lower than the aluminum one, requires a much higher temperature (1100 – 1200^{0}C), for the chromium process.
2. Much higher surface hardness and fragility of the coating significantly higher than aluminizing

In order to protect the turbine blades of high thermal oxidation (when T>900^{0}C) and particularly against the sulfuric corrosion, the condensed coatings of a different composition are successfully applied, settling down by the electron flow method. After sedimentation the diffusion annealing is performed.

During the annealing process and after a long -term operation, changes of the condensed shell structure and superficial layers of the support material are observed. Thus, after annealing at a temperature of 10000C, within 300 hours, of the alloy coated JC6K Co - Cr - Al-Y, Ni the content in the outer layers reaches 24-30% and the Al content is reduced to 3.5 to 6.5%, [3].

To prevent the diffusion processes in crystalline grain boundaries, which are normally oriented to the surface the micro globule processing and additional annealing are performed.

The system of Co-Cr-Al-Y containing 19-25% Cr, 12-15% Al, 0.1 to 0.5% Y. became lately the more widespread coating. High content of both aluminum and chromium oxide film ensures the formation of an Al_2O_3 and Cr_2O_3 cover on the basis of the substrate, and the presence of yttrium - training burns the upper layers of a compact and durable grip.

In order to achieve their intended destination, that is to reduce requirements for cooling system, the thermal protective coatings must have a low thermal conductivity, low density, and reflective capacity to stand the cyclic loading. The layers consisting in two and three-layer shells with a maximum thickness of 0.3 mm, whose outer layer is made of zirconium oxide, ZrO2 stabilized with different compositions, 12% Y_2O_3 + 3% MgO, ThO_2, CaO meet such requirements. As metallic substrate for coupling systems is used Ni - Cr - Al - Y, Ni - Cr - Fe - B - Si, Co - Cr - Al – Y. It stands out that oxysulphide Zr, Y, Th, Co, consisting of oxides of these metals, are barriers to sulfur diffusion. So Cr layer is applied as an interlayer. The arc spraying in plasma method is mainly used for the heat-resistant coatings.

Blades with heat-resistant coatings have been tested at the NASA experimental engines and on gaso-dynamic stands. it has been found a high fatigue strength and increased fatigue durability of the blades of alloy V - 1900 MAR - M - 200, MAR - M - 509 coated ZrO_2, established with with12% Y_2O_3,[4].

Stabilized zirconium powder with added calcium, magnesium and yttrium has performances in thermal corrosion protection when chemically uncontaminated fuel is used. It shows sensitivity to corrosive degradation if fuel is contaminated with sodium, sulfate, chloride and vanadate.

The primary goal of using new ceramic compositions is to increase resistance to fatigue and corrosion at high temperatures (above 1000°C) of jet engine components with lower thermal conductivity and coating performance predictable.

Fig. 7. Stator segment covered with ZrO2 stabilized plasma arc sprayed

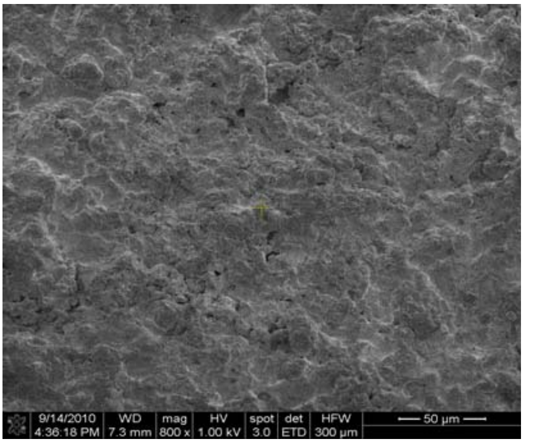

Fig. 8. Microscopic structure of thermal shell

Cerium yttrium-stabilized zirconium (CeO_2-Y_2O_3-ZrO_2) shows a significant resistance to thermal fatigue and cyclic thermal stresses while providing a low thermal conductivity at high temperatures.

The combination of outstanding thermal shock resistance, low thermal conductivity, corrosion resistance under high temperature enable the powder cerium yttrium-stabilized zirconium (CeO_2-Y_2O_3-ZrO_2) to provide advantages over most of the powders used in the process of plasma spray coating.

Fig. 7 presents the stator segment of the first stage of turbine engine VIPER 632-41equipping the IAR 99 aircraft, immediately after the plasma spray coating with cerium stabilized thermal zirconium - Yttrium (CeO_2-Y_2O_3-ZrO_2). Fig. 8 shows thermal skin.

4. CONCLUSIONS

Corrosive damage to the stator blades of the turbine is caused by the interaction of material, the surrounding gas and ash deposits of various compounds containing products of combustion. The corrosion process is more aggressive on the blades if used heavy fuels containing vanadium, sulfur and sea salt that enters the turbine. The fatigue (wear) cracks on the stator blades over the thermal borders, is observed most often. They are due to the high thermal loading of the blades, which unconditionally receive both the gas temperature changes during the power-up and variation of the engine operating modes and the temperature oscillations of the gases combustion flow.

After studying the functional behavior of turbine blade type parts the following conclusions can be drawn:

- turbine blades of both the stator and the rotor are subjected to complex applications and their surfaces bear very large surface (erosion, corrosion, vibration, thermal fatigue, etc.);
- the erosion phenomenon is evident in the gas turbine blades, when the gas temperature after the gas chamber is higher, when the aircraft takes off or lands on a

runway not very well cleaned,or is operating under saline, sandy and dusty environment, or do not use fuel additives with corrosion inhibitors .

- there is also a corrosive reaction of destruction on the blade surface. the corrosion (pitting) and the occurrence of crevasses and precipitates at the boundary between grains being evident;
- in the lack of protection, corrosion and erosion of the blades would cause premature removal from service of a too large number of turbojet engines;
- heat-resistant coatings on working surfaces at high temperatures both in the production and repair processes, should be a priority concern. Thus the service life of jet engines can be extended, in conditions of maximum security at a minimal cost.

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