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Analysis of catastrophic failure of axial fan blades exposed to high relative humidity and saline environment

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A R T I C L E I N F O

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A B S T R A C T

One blade of an axial fan that uses air from a marine atmosphere of high relative humidity for cooling a gas turbine failed, with catastrophic consequences for the system, the fracture type is brittle. Root cause analysis of the failure involved the application of non-destructive testing, chemical and mechanical characterization of the material of the blade, the fractographic analysis of fracture surfaces, the finite element modeling of the stress condition of the blade, the use of metallographic techniques for the identification of the manufacturing process of the component, and the nature of the interaction of the structural components of the blade with the surrounding environment. It was found that: (1) the alloy of the blade corresponds to Al-2024 without heat treatment, manufactured by directional solidification; (2) the fracture mechanism is low-cycle fatigue or high tensile stress, the initiation is in a inaccessible area and covered with corrosion products originated by a process of intergranular cracking of the alloy, as a consequence of saline products deposition from the marine atmosphere in the zone.

1. Introduction and background

Axial fans hold major importance at the industrial level, since they are an essential device for power generation; its main function is to allow proper cooling of the turbines and other generator systems. This explain the wide range of studies about them; from experimental evaluations about the effect of the thickness of the blades over the performance [1] to several investigations which use numerical simulations to analyze the behavior of the blades [2], as well as different topics related to study the axial fan blades [3–5,7].

Fatigue effects shall obviously be present on the blades, and this is the reason why fatigue crack growth has also been particularly studied [4], corrosion is an important failure factor as well because increases the likelihood of crack initiation [5]. The fractured blade belongs to electric power plant that uses thermal processes, based on natural gas turbines. The plant is located in Barranquilla, a city of northern Colombia (Caribbean coast), along the Magdalena River and near the mouth of the Caribbean Sea in an atmosphere which has RH >70%, where trade winds prevail during the northern hemisphere winter period, these trade winds blow from the sea to the city (river in between). The humidity effect on the blades has been studied previously in steel blades [6], showing the negative impact over their resistance. Axial fans that cool down the turbines directly capture this air without any filtering or pretreatment and it is moved by the aluminum alloy blades; one of these

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Table 1
Equivalent base operating hours (EBH) and equivalent starts (ES) in the combustion turbine.

Generation unit	Total EBH	Total ES	EBH since last maintenance	ES since last maintenance
Turbine	60,462.24	3533	3675.84	308

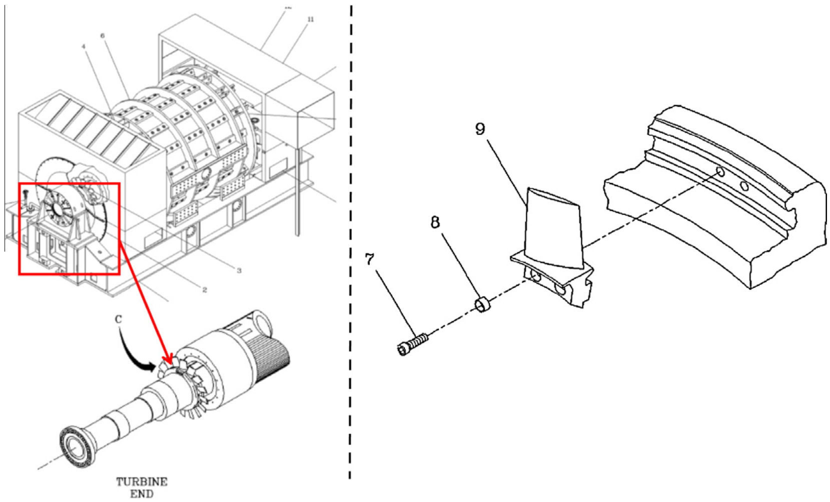

Fig. 1. Blower generator rotor and broken blade scheme with the security hardware.

Table 2
Chemical composition of the broken blade 4 (wt.%).

Sample	Al	Si	Fe	Cu	Mn	Mg	Cr	Ti	Ni	V	Sn
Blade 4	93.523	0.011	0.125	4.262	0.749	1.288	0.015	0.007	0.0042	0.001	0.006

Table 3
Mechanical properties of the fractured blade 4.

Mechanical Properties	M1 (HV)	M2 (HV)	M3 (HV)	M4 (HV)	M5 (HV)	M6 (HV)	M7 (HV)	M8 (HV)	M9 (HV)	Prom (HV)	Deviation (HV)
Aluminum blade	143.17	146.71	136.06	131.74	134.74	148.99	139.34	132.13	138.10	138.997	6.167

blades presented a catastrophically failure. This type of failure is unusual in these fans, since they are designed to have an extensive working life [7]; it is not desirable to experience machine stops in these power generation systems.

The aim of this study is to determine the possible causes of the failure, both based on different experimental techniques and simulation analysis. The methodology and obtained results of the analysis are described.

The failure occurred when the turbine and generator had the operational hours indicated in Table 1; its shows that the failure presented with less than 10% of the total normal operational hours.

Fig. 1 shows the fan installation with the blower of the generator rotor and a scheme of the broken blade. The failure was detected in of one of the 24 blades located in section C; all blades are identical as element 9 of the scheme.

2. Experimental

A set of three blades of a gas turbine were examined. Different studies were carried out, including chemical analysis; mechanical tests; visual inspection; stereo-microscopic; optical and scanning electron microscopy (SEM); optical metallographic analysis; fractography and stress analysis using finite element method (FEM).