Improvement of gas turbines performance through erosion resistant nanocoatings and exergy analysis

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Contaminants met during marine transportation erode air compressor blades of the gas turbine; the result of this process is sein in the decrement of the performance and the increment of fuel need.

Also, there is an energy degradation during the operation of the gas turbines, being required an exergy analysis which is able to provide a plan for this power plant performance enhancement.

This is why are formulated exergy destructions for these components. According to the results of this analysis, it can be stated that the least inefficient component of the gas turbine system is the compressor, followed by the gas turbine itself. The object of this study is a 4,1 MW gas turbine with ceramic matrix composites nanocoating, operating at different loads (60%, 80%, 100%).

1. INTRODUCTION

- Gas turbines are an other type of internal combustion engines, in which the mixture air-fuel produces burning gases flowing continuously through this equipment;
- A real challenge is combating corrosion since it causes degradation and accidents in the system.
- Erosion produced by solid particles and liquid droplets leads to damages of the turbine elements and efficiency decrement, with negative effects on business of power plants owners. A method used in the prevention of this process is the coating of blades with a strong and light layer which impedes the erosion, by the use of nanotechnology.
- Nowadays, by the help of nanotechnology, it is possible to provide new materials for the coating, with specific properties (strength, durability, etc), the result being sein in an improved erosion resistance. Nanomaterials are materials having minimum one of their morphological characteristics (for example the size of a particle) given in nanoscale.
- Due to their very small dimensions they show better thermal, mechanical, physical or chemical features.

- In the actual framework, when energy efficiency and fuel savings are priorities.
- This paper focuses on two means of improving energy efficiency of marine gas turbines.
- One mean is the inclusion of erosion resistant nanocoatings in the structure of marine gas turbines. More specifically, it is about ceramic matrix composites-used as layers to enable the erosion prevention to compressor air foils. The second mean taken into discussion is the exergy analysis of the performance – since energy analysis leads to overestimate the performance. From this paper will result which is the most inefficient component part of the considered plant.

2. ABOUT THE NANOMATERIAL

Ceramic matrix composites show important benefit due to their characteristics such as: small weight, very good resistance, high temperature capabilities and low failure under loading. A very good option is the use of ceramic matrix with silicon carbide. In order to ensure operation under high temperature conditions, iron, nickel and cobalt base super alloys are used.

The coatings are applied through a vaporization coating process during which a solid coat, presenting a very good purity, is evaporated using high vacuum technique and subsequently attaches onto the substrate material on a nano level.

The analysis of the dependence (cumulative weight loss – time) indicates the effectiveness of the nanocoating.

The resistance to the fluid erosion shown by the protected sample is superior than the unprotected one. The unprotected sample loses five time more weight than the protected one, after only one hour of running.

3. EXERGY ANALYSIS OF THE GAS TURBINE

Other method of gas turbines performance enhancement, except erosion resistant nanocoating is exergy analysis. This is due to the fact that exergy is a tool of analysis more complex than the one based on energy analysis.

The assessment of energy inefficiencies of a thermal process plays a major role in the design and improvement of power systems.

The main source of inefficiency in a system is given by the amount of irreversibility (the exergy destruction); so, in gas turbines, the location, the quantity and the cause of inefficiencies is found by the use of exergy analysis, through out exergy destruction within the main component parts.

- The results of the analysis were obtained for a 4,1 MW gas turbine, with ceramic matrix composites nanocoating; the environment is featured by 10.13 bar and 24^{o}C. The load variation is considered to be in the range (60%–100%).
- In Figure 2, 4, 5, 6, and 8 are shown important dependencies.

Figure 2 – Influence of load variation on the exergy destruction rate in the compressor

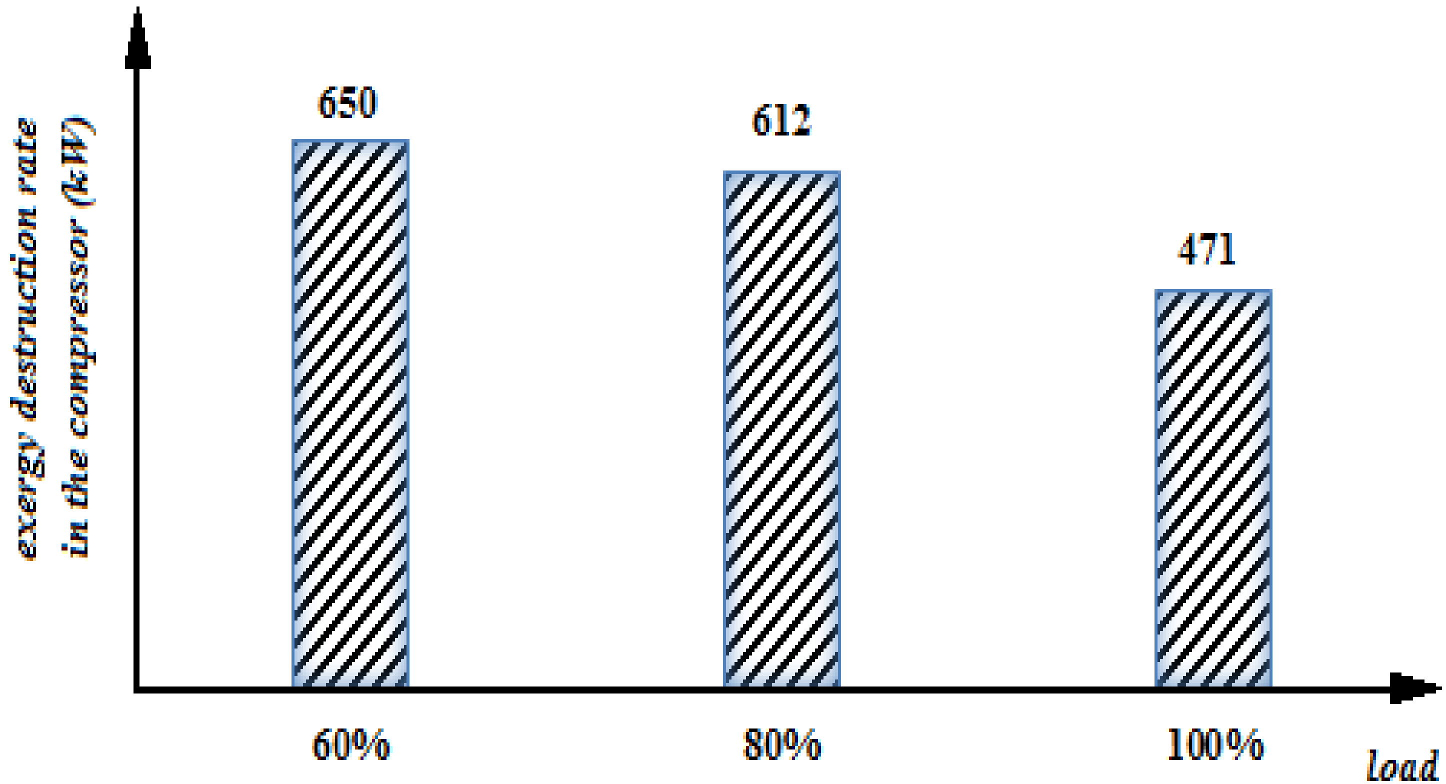


Figure 4 – Influence of load variation on the exergy destruction rate in the combustor

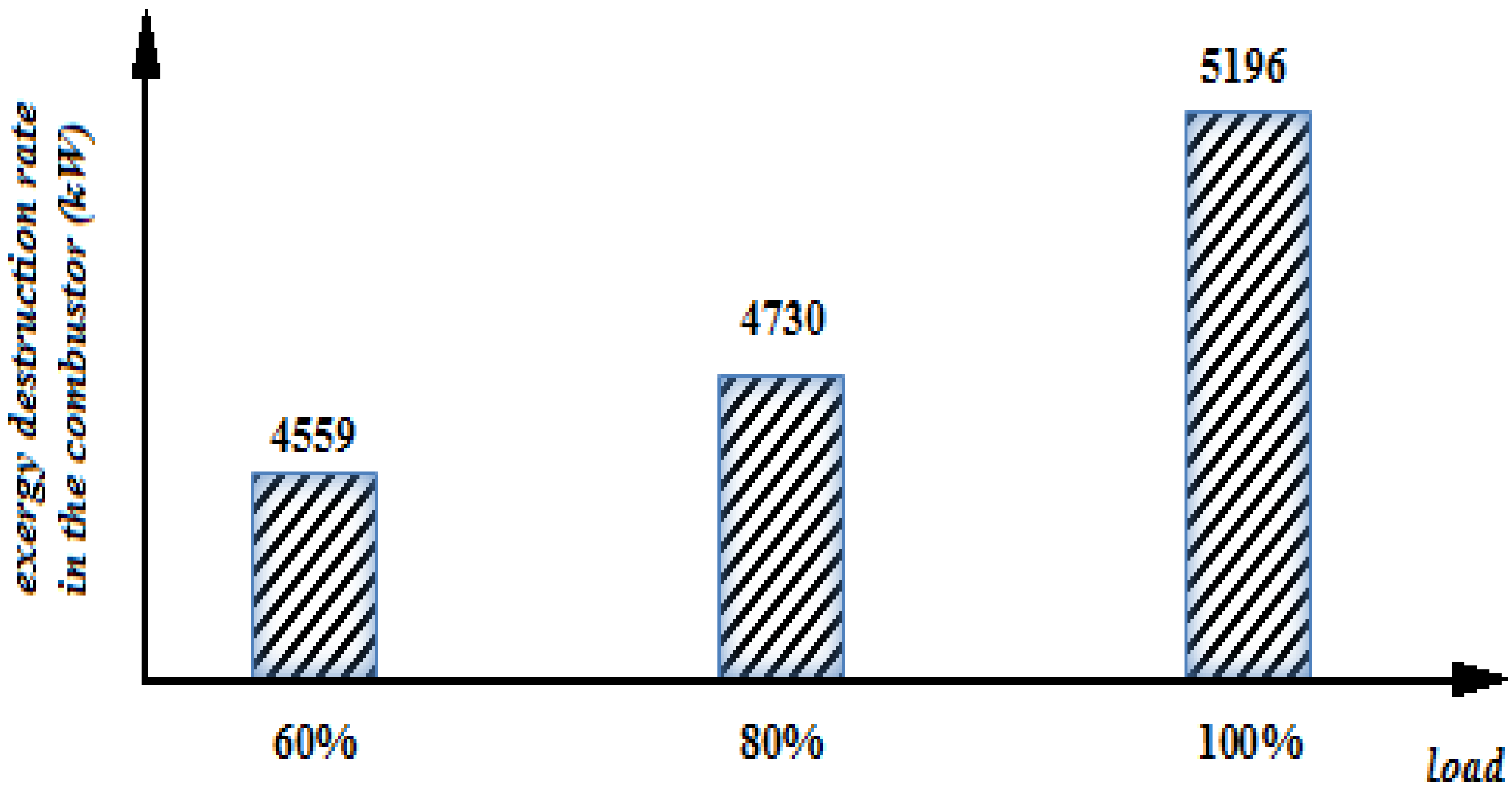


Figure 5 – Influence of load variation on the combustor efficiency

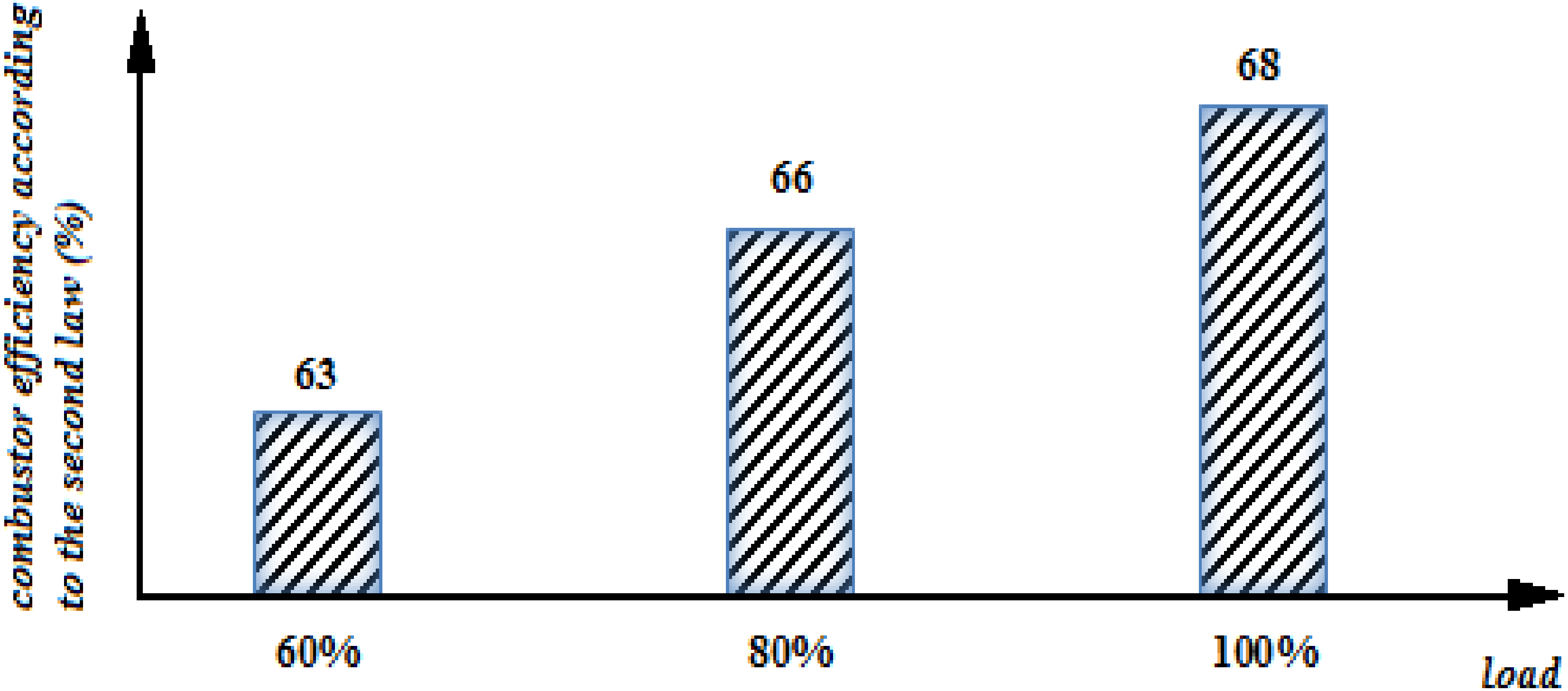


Figure 6 – Influence of load variation on the exergy destruction rate in the gas turbine

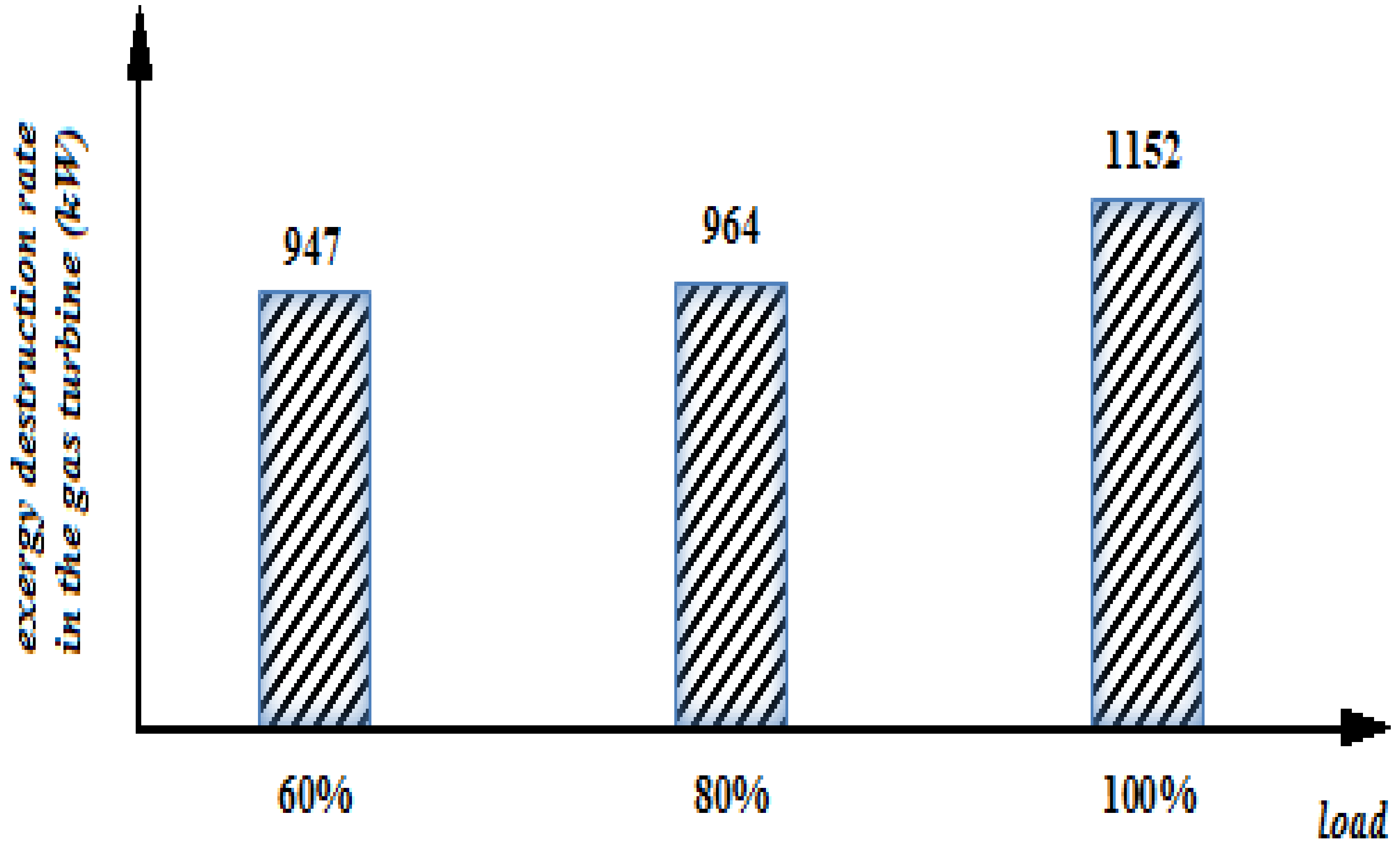
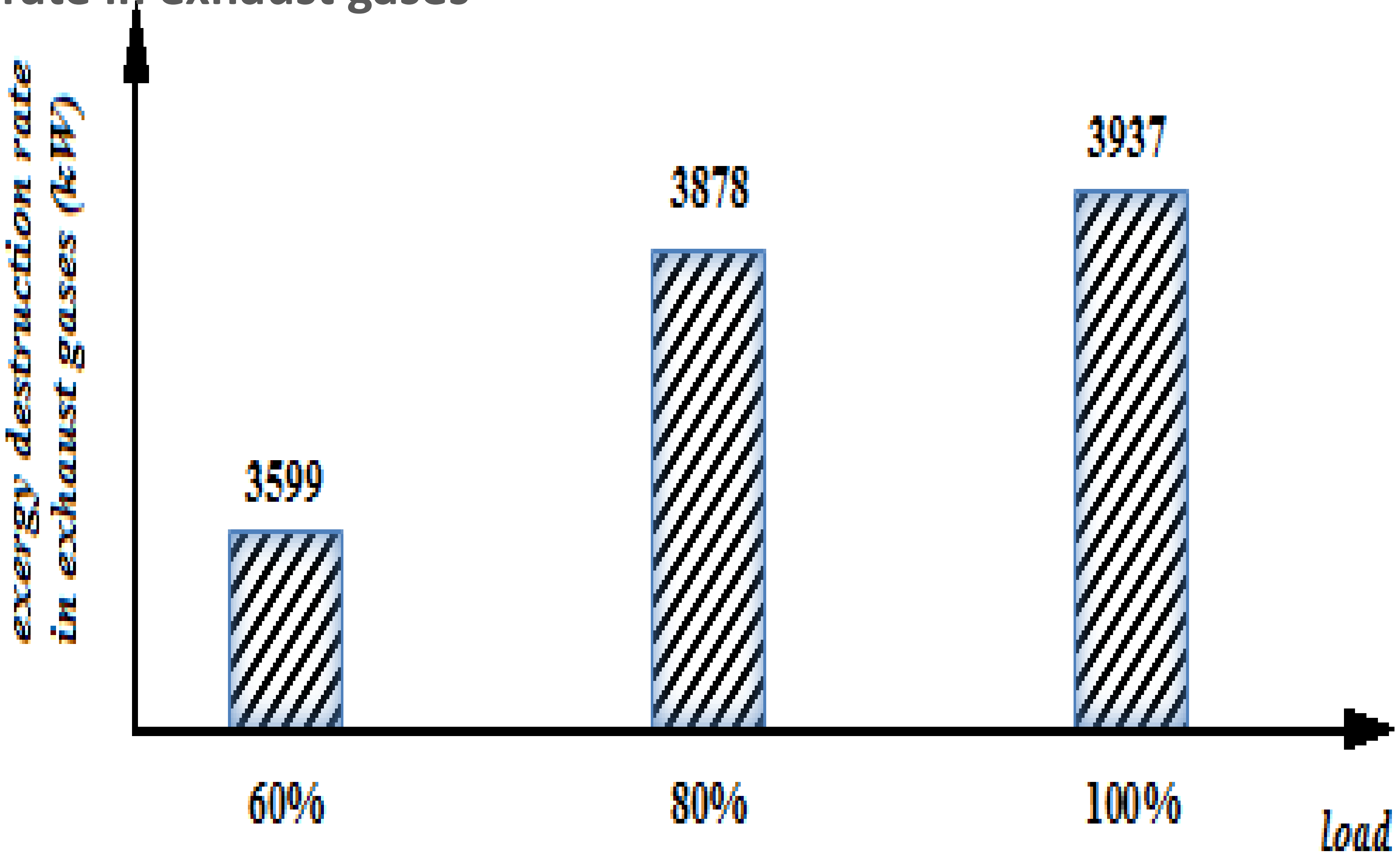


Figure 8 – Influence of load variation on the exergy destruction rate in exhaust gases



4. CONCLUSIONS

- The current context related to marine gas turbines asks for studies focusing on the merit enhancement of this systems. In this paper, this issues is approached from two directions: erosion lowering by the use of nanotechnology and exergy analysis.
- It was shown that by the help of ceramic matrix composites, included in the structure of gas turbines, might be reached long term and high temperature corrosion resistance. A protected sample do not lose weight after 60 min of running, in contrast to the unprotected one. After 3 operating hours, an unprotected sample loses about 14 times more weight (in mg) than the protected. As well after 4 operating hours.
- On the other hand, for the discussed turbine, at full load, the exergy destruction is high in the combustor (5196 kW) and in the exhaust gases (3937 kW), because of the operating temperatures. The exergy analysis carried on offers an image on the inefficiencies of the component parts. In this hierarchy, the less inefficient component is the compressor (with an exergy destruction rate of 471 kW – at full load), being followed by the gas turbine (presenting an exergy destruction rate of 1152 kW – at full load). The combination of these two approaches will ensure the more effective improvement of marine gas turbines.