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A MECHANICAL AND STATE ANALYSIS OF A GAS TURBINE

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ABSTRACT

At this study a mechanical and state analysis of a gas turbine under certain conditions is developed. Using functioning parameters, failures or quasi-failures we can know the real state of the gas turbine and the environment and use influence in it. It will be compared the evolution of various parameters along the functioning. Graphical and statistical techniques will be applied to treat the gas turbine data. It will be defined an inspection and maintenance plan according the results.

Keywords: gas turbine, functioning parameters, reliability, maintenance.

INTRODUCTION

The gas turbine hot parts work in an extreme environment and it will have an influence in maintenance cycle (Santos and Andrade, 2012). To define a gas turbine maintenance schedule it must be considered what kind of reparation it needs (Moritsuka, 2000), the substitution of the engine, the spare parts and adjustments.

The chosen fuel for gas turbine operation (Ghenai, 2010) and the environment in which it works has influence in its performance, its maintenance and life cycle (Rashidzadeh *et al.*, 2015). This study intends to show the correlation between readings of gas turbine sensors and it state facing the environment in which it is applied. A total of 30 samples were taken from the gas turbine sensors, and it was simulated 18 anomalies in a certain time interval.

RELIABILITY AND CONDITION BASED MAINTENANCE

The reliability knowledge allows to knowing the probability of a system failure in a certain time interval, allowing an action in time to correct an anomalous situation if it is needed.

A failure means that the functioning of a component or system had finished or it state is degraded, and the operating parameters are unsatisfactory. And probably low level of operability, high cost or risk to safety both material and personal exist.

Some techniques are presented to reliability and failure analysis.

Pareto Analysis

The Pareto analysis can be used when a reliability study begins. This methodology can group the failures accordingly the causes, so in this case, the number of failures is usually more than it causes. This analysis allows to eliminating failures with scarce economic resources, because it leads to the causes of failures. (O´Connor, 1991)

For the actual example we group four types of anomalies that the descriptive analysis can be found in the results of this article.

Weibull Probability Density Function

The Weibull Probability Density Function must derivate from equation:

$$R(t) = \exp\left\{-\left(\frac{t-\mu}{\delta}\right)^{\beta}\right\} \tag{1}$$

Where t is the time interval, μ is the mean, β, δ (δ =1/λ) are the form fator, and λ is the proportionnel factor. And in F(t)=1-R(t) the reliability R is the complement of the distribution F. (Dias, 2002)

Availability of a Reparable System

The availability of a reparable system is function of it failure rate, λ, and it repair or replacement. For a system with a stable failure rate, and a minimum reparable rate, μ, the availability in a stable state is:

$$A=\frac{\mu}{\lambda+\mu}=\frac{MTBF}{MTBF+MTTF} \tag{2}$$

Where MTBF is the Mean Time Between Failures, the MTTF is the Mean Time to Failure. For the systems with increasing failure rate, we propose improvements on the maintenance management.

For the systems which the failure rate is stable we calculate the MTBF using MTBF= *T/nf*, where T is the total functioning time for the system, where *nf* is the failure number.

Laplace Test

With a process i.i.d. (independent and identically distributed) the failures occurred accordingly a Homogenous Poisson Process.

Considering a time limited test:

$$Zo=\sqrt{12nf}\,x\left[\frac{\sum_{i=1}^{nf}\tau}{nfxT}-0{,}5\right] \tag{3}$$

nf is the number of components that fail, *T* is the interval of the test, τ_i the system age for a failure of *i* order, considering H_0 with stable failure rate, H_1 with non-stable failure rate, and α=0,05.

In a Homogeneous Poisson Process, if Zo> $\left|Z_{\frac{\alpha}{2}}\right|$ the H_0 is rejected. (Dias, 2002)

INSPECTION AND MAINTENANCE PLAN

Although the gas turbine has a preventive maintenance plan, we will develop a methodology to control the engine functioning and act in anomaly when the various conjugated parameters and factors shows us that necessity.

So the methodology we proposed is the following (Figure 1):

- Procced to online condition monitoring by continuous collection of the data;
- Collect data from vibration and temperature sensors;
- Calculate the reliability of the gas turbine;
- Calculate the MTBF;
- Apply the Laplace Test;
- Evaluate the results:
    - ✓ If the failure rate is increasing: evaluate with the sensors parameters to decide the intervention or substitution;
    - ✓ If the failure rate is decreasing: maintain the observation;
    - ✓ If the rate failure is stable: check if the obtained parameters are admissible, if not, decide when the intervention or substitution take place.

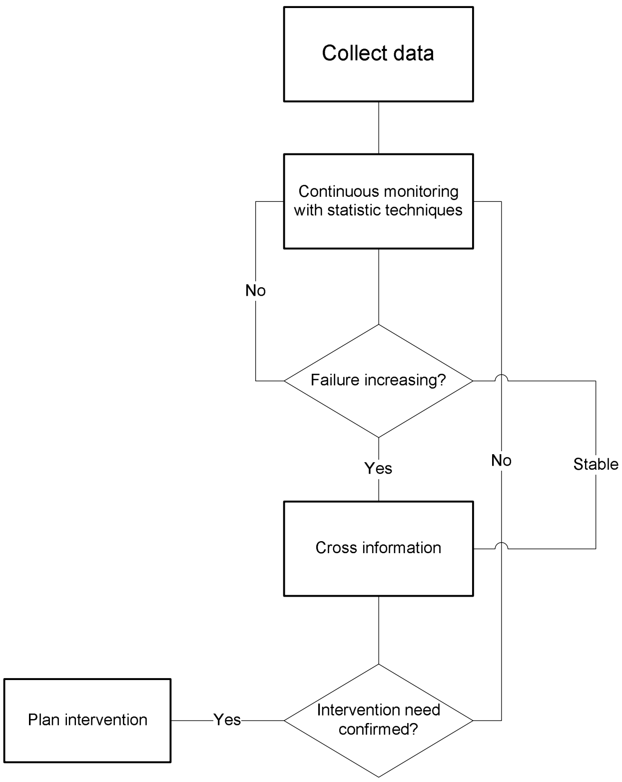

Fig. 1 - Methodology

RESULTS

The results of gas turbine data vibration sensors collection are shown in Figure 2 and scavenges temperatures in Figure 3. The SNV sensors represent vibrations and the SOT represent scavenge temperatures.

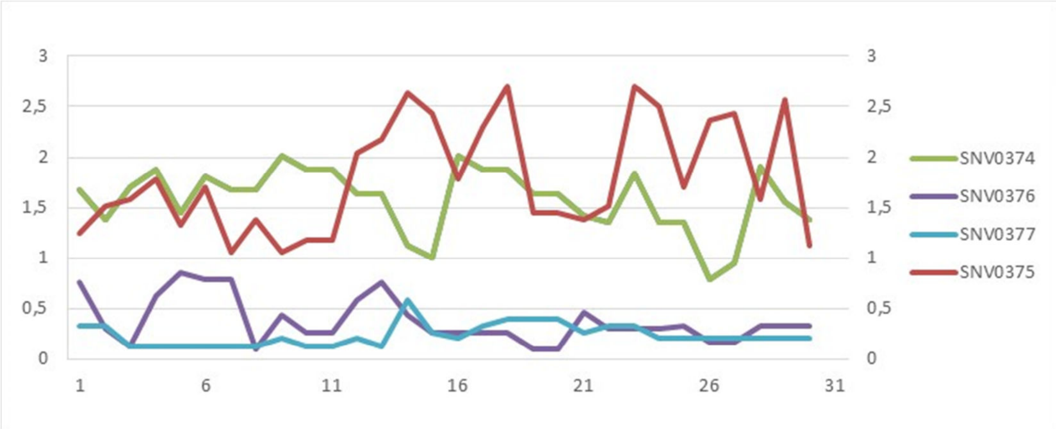

Fig. 2 - Vibrations

We can see that for the same moment the vibration on SNV0374 and SNV0375 that represent the self and induced vibration are higher than for the turbine. The SNV0376 and SNV0377 have lower values than the compressor sensors.

In Figure 3 we can see the temperature to descend along the observations, probably the engine had decreases its velocity, so the temperature decreases.

Fig. 3 - Scavange Temperatures

If we considered the environment temperature increasing, we may have all the temperature higher, so we simulate a 16ºC increasing in the temperature inlet on the gas turbine compressor, and we obtained:

Apparently, the scavenge temperatures had stabilized at higher temperatures, the results for the sensor SOT0369 is the result of sensor malfunction, it was substituted and the results had stabilize either. In other work the temperature in the power turbine of the gas turbine system should be analyzed together with the scavenge temperature, for this study this temperatures were not conclusive.

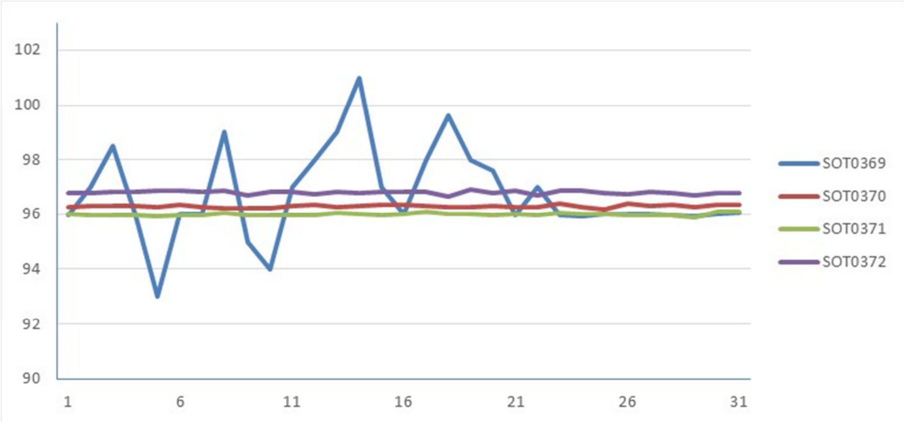

Fig. 4 - Scavenge Temperatures - higher inlet temperatures

For environment high temperatures levels there´s no evidence, in short time, of vibration increasing, so the vibration graphical data for higher seawater temperature is not present in this article. This happens because usually the power of gas turbine are reduced because of the exaust gas temperature.

The results show that the conjugation of various variables with statistical treatment can be more accurate to define a maintenance plan for the gas turbine.

The degradation of the gas turbine depends on the environment conditions and in which "power plant" or system it is applied.

This turbine shows high vibration on the compressor, this can reveal the need of equilibration on this system. By the collected data, this was a real situation, and the Gas Turbine had had an intervention maintenance, a mechanical balance on the compressor blades.

Pareto Analysis

In the evaluation of the system eighteen failures occurred on a 365 days period; we subdivided the failures in four types: compressed air system (A), fuel system (B), vibrations (C), and various components failures (D).

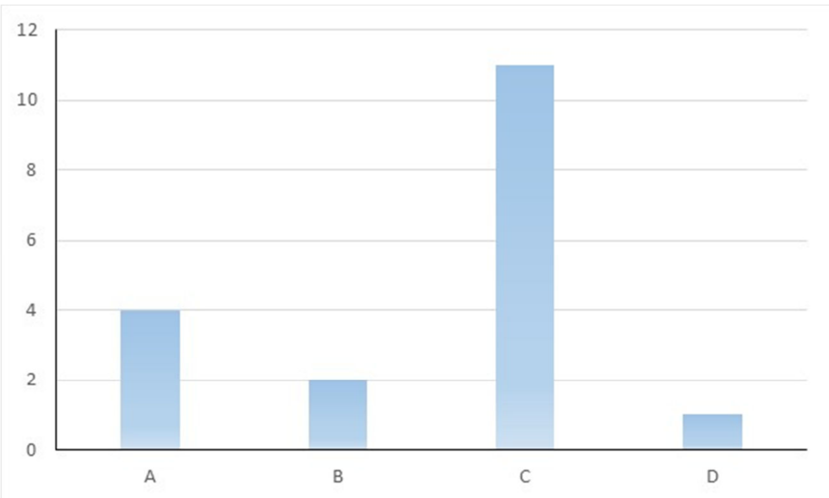

Fig. 5 - Pareto Analysis - Anomalies vs type occurrences

The compressed air system had 4 failures, the fuel system 2 failures, it was registered 11 vibrations alarms and 1 registered failure of other components. The vibration alarms were the highest type of occurrences, Figure 5.

Gas Turbine Reliability - Laplace test and MTBF

The time failure distribution is accordingly Figure 6:

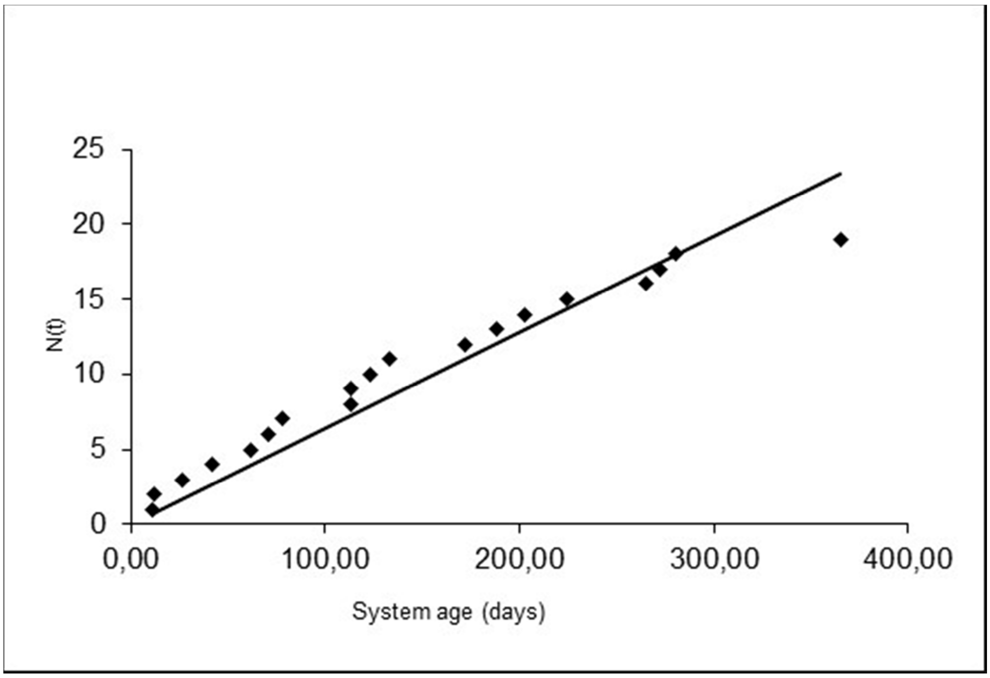

Fig. 6 - GT - Anomalies type occurrences

Only the last occurrence is way from the normal results, where the time between failures had increasing, but the last occurrence doesn´t exist, it is only the end of a cycle observation.

The failures sequence are accordingly the next figure (Figure 7), and although the representation is different, the results show similarity, and we can see there´s no occurrence on the 365 day.

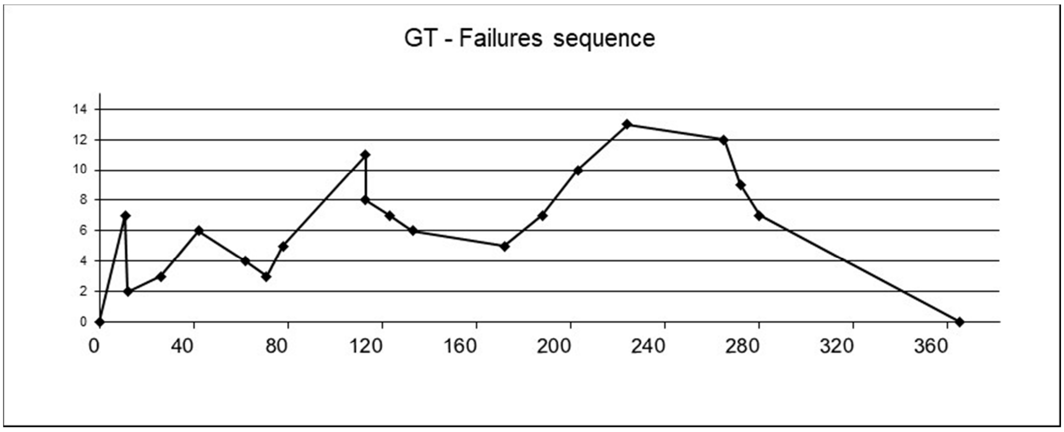

Fig. 7 - Anomalies type occurrences

Along one year, the gas turbine registered 18 anomalies. We applied the Laplace Test to define the gas turbine reliability, and calculate the MTBR.

For the Laplace test we have nf=18, for a 365 days of data collection, a $\sum \tau i=2753$, and a $Z_0=-1.1900717$ so the failure rate is constant for a confidence interval with α=5%, $]-1.96; 1.96[$.

With the Z_0 result, the H_0 is not rejected for a 5% significance level, and so, because the system have a constant failure rate, it is a Poisson Homogenous Process.

Studying the failures distribution, we obtain a MTBR of 20.28. In all the registered failure, none was catastrophic.

CONCLUSIONS

The Pareto analysis can initiate the reliability studies, allowing to group anomalies, highlighting the incidence of the subsystems anomalies.

We can calculate the gas turbine reliability having a continuous monitoring and anomalies historic registry and applying the Laplace Test.

Various statistical techniques can be conjugated to allow a mechanical system control.

Statistical control is essential for equipment performance monitoring and condition maintenance. This is also important when ships navigate on seawaters where it were not design.

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