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# CONSIDERATIONS ON THE USE OF MAINTENANCE PROGRAMS FOR NAVAL PROPULSION PLANTS WITH GAS TURBINES

**Ion Adrian GÎRBĂ[1]**
**Anastase PRUIU[2]**
**Beazit ALI[3]**
[1]Eng, PhD attendee Military Technical Academy, Bucharest
[2]Professor, PhD. Eng., "Mircea cel Batran" Naval Academy, Constanta
[3]Professor, PhD. Eng., "Mircea cel Batran" Naval Academy, Constanta

***Abstract:*** *The work has been done on the study of bibliography and experience in the operation of the doctoral students in the field of gas turbine power plants. The paper analyzed the main factors that require maintenance performed correctly, based on a schedule determined according to technical condition inspections, but on close monitoring of functional operation.*

## INTRODUCTION

***The gas turbine*** (GT) is a rotating machine inside which the potential energy of the fluid pressure and thermal fluid-gas engine produced by burning fuel is converted into mechanical energy in rotation movement.

In the naval domain the gas turbines are used increasingly more in the propulsion energetic systems.

At the beginning, despite the gas turbines advantages like the low ratio between mass and output power , simple, compact and reliable design, due to higher fuel used expensive compared to fossil diesel engines for marine use, the ship market prefer internal combustion engines propulsion systems. Thanks to technological developments in recent years in the construction of gas turbines and a drop in oil prices in the 80s and 90s convinced ship owners to reconsider the advantages of using marine gas turbine propulsion plants.[6]

***For the first time in naval domain****, the Metropolitan-Vickers company in 1947 succeed to engages one of the GT F2/3 jet aircraft propulsion used with a gas turbine power transforming motorized boat carrying guns (MGB 509) of the UK Royal Navy in the first vessel propelled by GT and in 1952 Rolls & Royce converts steam turbine propulsion of a military ship in one with GT and a year later built the first military ship propelled by gas turbine ;*[ 1 ]

*1951* ***first civilian ship*** *whose propulsion (tanker diesel-electric propulsion), is converted into propulsion TG*; [ 1 ]

Turbina cu gaze in naval propulsion plants has proven highly effective in propulsion systems combined cycle type, CODOG(COmbined Diesel Or Gas turbine), CODAG (COmbined Diesel And Gas turbine), CODELAG (COmbined Diesel-Eectric and Gas turbine ), COGOG (COmbined Gas Or Gas turbine), GOGAG (COmbined Gas And Gas turbine), COGAS (COmbined Gas And Steam turbine) and COGES (COmbined Gas Electrical Steam turbine). These naval propulsion systems were first used on military ships. Combined cycle propulsion system COGAS according to the analysis has the best performance, can reach up to 60% for full load. [7]

The advantages of the gas turbine to the internal combustion engine and the steam turbine in marine propulsion systems are:

- plant mass relative to the power developed is much less (11...14 kg/kW);
- low volume facility;
- due to the lack of reciprocating bodies during operation of the system the vibrations are not produced;
- low consumption of oil in comparison to the internal combustion engine;
- much simpler cooling subsystem;
- These plants are made far in powers ranging 5000...80000kW.

## NAVAL GAS TURBINE PROPULSION PLANT MAINTENANCE

The maintenance of gas turbines has a very important role in maintaining the reliability and extend the service life of the propulsion plant.

To ensure smooth operation of gas turbines in naval propulsion plants with gas turbines (NPPGT) are taken into account seven main elements:[3]

a. *The lubricating installation with a suitable lubricating oil* is critical in order to achieve the performance which has been developed a turbomachinery, as well as operation and maintenance corresponding to it. Thus, considering the basic conditions that must meet the lubrication system, the choice of lubricating oil, regular sampling and analysis of samples of oil, oil contamination, the choice of oil filters, cleaning and washing system and the lubrication of the couplings;
b. Analysis of the total high-speed rotating equipment gas turbines requires *a comprehensive and combined monitoring of the elements moving speeds and vibration* that may occur at these (gas generator and power turbine);
c. Dynamic balancing rotors is very important for the turbine can achieve maximum performance without vibration occur over highs admitted to running. Thus the following aspects are taken into account leading to gas turbine rotor imbalance asymmetry, inhomogeneity of the material, the appearance of eccentricity, misalignment rotor bearings, moving parts due to plastic deformation of rotor parts, hydraulic or aerodynamic imbalance and thermal gradient;
d. Couplings and turbine alignment are crucial to the functioning of;
e. The system's monitoring and control of gas turbine and hence the entire propulsion plant;
f. Testing and analysis of turbine performance continues as operating at high gas temperatures and their variations significantly affect the performance and service life of the gas turbine. Another performance parameter analyzed of the turbine is the compression ratio of the compressor. The turbines are very sensitive to backpressure exerted on them when used in combined cycle cogeneration energy systems. Testing and analysis of turbine permanent evolution is important because plants operating personnel contribute to :

- maintaining good working of installations;
- minimize degradation and maintain the plant operation performance which was designed;
- timely help diagnose technical issues that arise and to avoid major damage;
- extend the time periods between inspections and overhauls turbine, thereby reducing maintenance costs

In figure 2 we can follow the evolution of the main parameters that are monitored in a gas turbine.

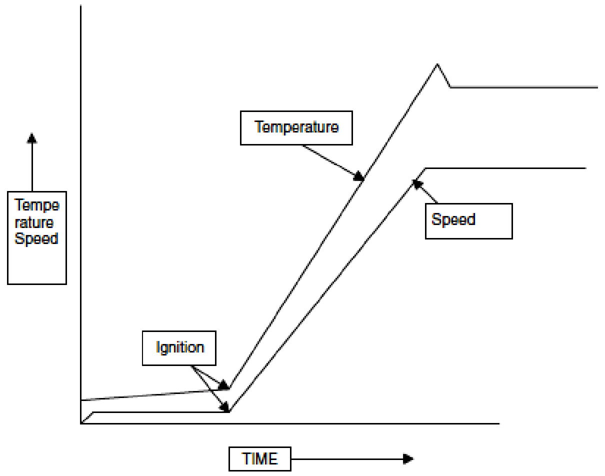


*Fig.2.- Startup characteristica of a gas turbine[3, p. 637]*

Follow the operating parameters during operation and to start or stop to avoid certain damages that may occur in both start and stop gas turbine sequences (fig.3 și fig.4)

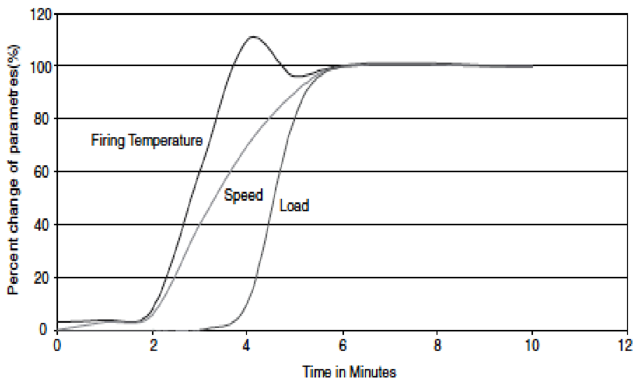


*Fig.3.- A typical startup curve for a gas turbine. [3, p. 641]*

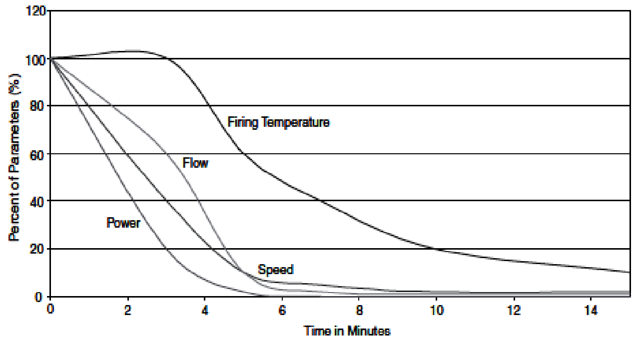


*Fig4. – A typical shutdown curve for a gas turbine. [3, p. 642]*

g. **Maintenance** defined as the most important activity which keeps the turbine operating parameters has been designed and lead to the extension of the operation being planned structured and strict inspection and repair operations substantiated by technical reports and reports on execution costs.

Maintenance is well structured and planned in advance, as a necessity to minimize the amount of time that NPPGT is decommissioned and have provided logistical support in advance. The main factors affecting the maintenance planning process can be seen in figure 5, and how it is operated facility will impact each of them. Some components require special attention being associated with the combustion process and exposed to high temperatures. These are called hot parts and are associated with: combustion chambers, flame tubes, caps, burner assembly, turbine pallets driven by combustion gas pressure.

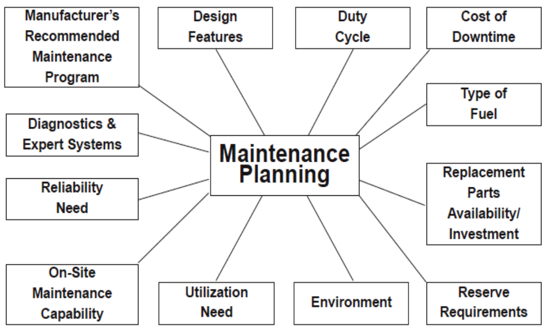


*Fig.5 – Key factors affecting maintenance planning. [4,p.1]*

To be made a proper maintenance, the designer takes into account several aspects that reduce costs, time and the complexity of maintenance operations, such as:

- turbine components and auxiliary aggregates are designed to serve allow dismantle, easy and safe installation in a short period of time;
- the turbine is equipped with a washing compressor palettes plant, maintenance operation that periodically according to designer;
- gas turbine design is provided endoscope (borescope) inspection access locations [Figure 6];
- the possibility of oil sampling for testing;
- possibility to verify the potential of metallic impurities in the oil to the bearings without the need to dismantle large parts of turbine without using special or complex tools rework;

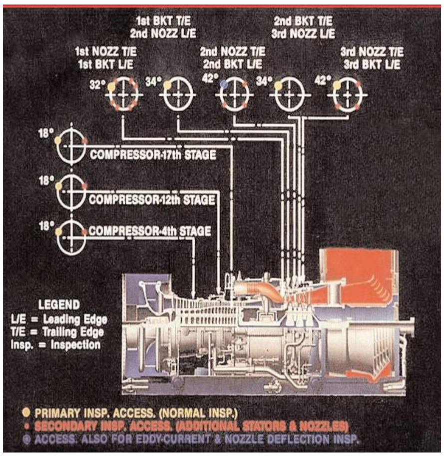


*Fig.6. – MS70001E gas turbine borescope inspection access locations. [4,p.4]*

Gas turbines equipping naval propulsion plants are basically derived from those used in aircraft propulsion, but given the marine environment and the global position of the ship sailing from one hemisphere to another, from the equator to the poles, new factors appear such as:

- depending on the destination of the vessel may appear very different operating regimes, but the naval vessels are the most varied and demanding, because those can have large variations in speed and load per unit of time;
- air humidity and salinity, and the risk of aspiration sand in some areas of navigation air intake manifolds, suppose the design of filters that meet filtering needs and withstand the high risk of pitting corrosion, environmental data;
- placing turbines on ships requires building large air intake galleries and discharge combustion gases to ensure the flow of fluids required;
- variety of fuels with different qualities and calorific powers and because of supply from various sources and standards in force in the world;
- very different atmospheric conditions due to operation of ships across oceans (the Arctic weather conditions in the equatorial)

By analyzing the evolution of these factors in each case, the major manufacturers of marine propulsion plants with gas turbines have developed strategies to reduce the cost of current repairs or overhaul. Other methods are to develop preventive and corrective maintenance programs to increase the time between two overhauls, combined with risk management to achieve these performance.[5, p.3]

Elements to be taken into account in the operations and maintenance during the operation of gas turbines are:

- starting and operating hours;
- evolution of functional parameters to specific tasks;
- fuel;
- combustion temperature;
- injection of steam / water where such facilities are available for controlling emissions;
- cyclical effects;
- hot items turbine (combustion chambers, injectors, etc.).
- rotor components;
- vibrations;
- air quality;
- mist inlet.

In figure 7 we can see the gas turbine components that impact on the length of time in service between two gas turbine overhauls.

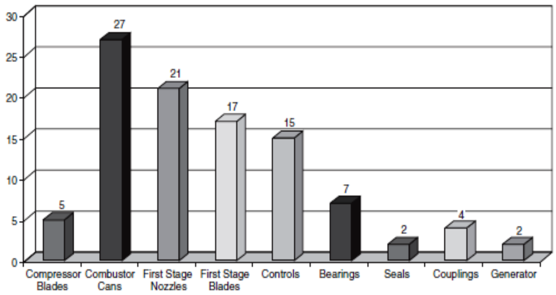


*Fig. 7. – Contributions of various major components to gas turbine down time.* [3, p.739]

Maintenance programs developed monitors and recommends certain maintenance operations on those elements that allow maintaining NPPGT (Naval Power Plants with Gas Turbines) in the area of reliability, durability and optimum operating performance.

An example of the study and development of maintenance program to extend the time between two repairs and increasing the length of time in service, was conducted by The UK Warship Support Agency (WSA). This case was studied evolution gas turbine propulsion plants (all TG are produced by Rolls & Royce) on military ships of four Navy that the UK, France, Belgium and the Netherlands, after 21 years of collaboration and experience of a total of 3 million hours. The results of this collaboration that they managed to increase the length of time between two overhauls service emerge from Table 1. [5, p.4]

Compared to other propulsion systems with internal combustion engines, the gas turbine have simplified maintenance operations do not require high cost between two overhauls, but the cost components that are replaced at overhaul are great because of production costs and resistant materials to high temperature variations.

*Tablel 1* [5, p.4]

| MOU Gas Turbine Intervals Between Overhaul | | | |
|---|---|---|---|
| **Engine Variant** | **RR Declared Overhaul Life** | **New Declared Overhaul Life** | **Remarks** |
| **Olympus** | 5000 hours or 10 year Calendar Life | Calendar Life 16 years | Subject to 2 yearly inspection after 10 years |
| | | Frigates & Destroyers : 5500 hours | Subject to periodic inspection |
| | | Carriers : 7000 hours | |
| **Tyne** | 5000 hours | 6500 hours | |
| **Spey SM1A** | 3000 hours (12.75MW) | 6000 hours | |
| **Spey SM1C** | 9000 hours (12.75MW) | 9000 hours | Lead engine currently at 2500 hours |

Most times maintenance is reduced to endoscopic inspection. In figure 7 we can see the effect of endoscope on planned maintenance maintenance costs.

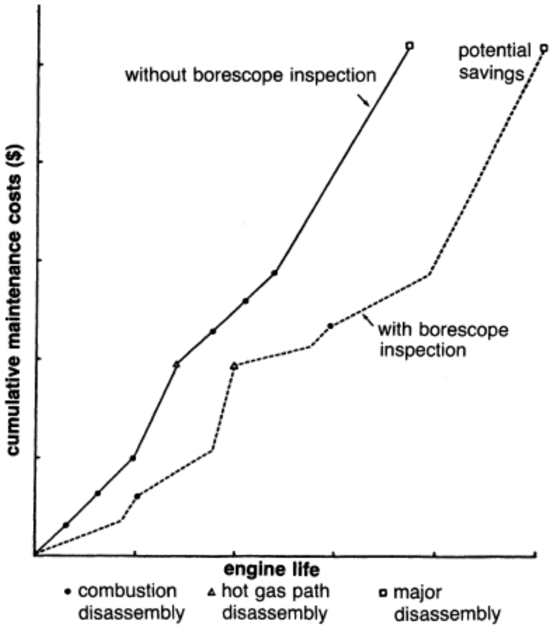


*Fig.7.- Effect on planed maintenance with usage of borescope*
[3, p. 748]

Endoscopic inspections are divided into three main types of inspections endoscopic inspection scheme which can be seen in Figure 8:

a. inspection of a combustion chamber;
b. turbine inspection;
c. major overhaul inspection

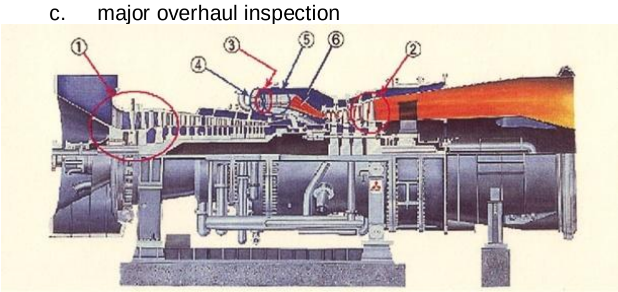

*Fig. 8.a –* Inspection of a combustion chamber [8];
*1– compressor inlet(1); 2- turbine blade row(1); 3- flame detector and igniter(2); 4- fuel nozzle(2) 5- combustor basket(2); 6- transition piece(2)*
*(1)- visual inspection;*
*(2)- roll-in&roll-out parts.*

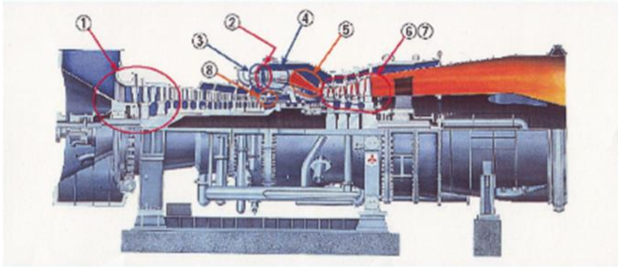

*Fig. 8.b – Inspecția turbinei* [8];
*1– compressor inlet(1); 2- flame detector and igniter(2); 3- fuel nozzle(2); 4- combustor basket(2); 5- transition piece(2); 6- turbine blade(2);7- turbine vane(2);8- compressor last row and OGV's blade and diaphragm(1)*
*(1)- visual inspection;*
*(2)- roll-in&roll-out parts.*

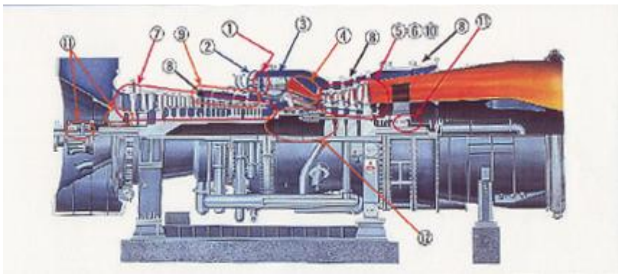

*Fig. 8.c – Major overhaul inspection* [8];
*1– flame detector and igniter(1); 2- fuel nozzle(1); 3- combustor basket(1); 4- transition piece(1); 5- turbine blade(2); 6- turbine vane(1); 7- compressor blade and diaphragm; 8- exhaust turbine and compressor casing; 9- compressor blade ring 10- turbine blade ring #1,#2,#3 and #4; Turbine journal brg and thrust brg;rotor(2).*

Due to saline environment, humidity or sea areas near land where weather phenomena can lead offshore sand on pallets compressor suction various deposits occur leading to imbalance manifested by its:

- increased vibration in the gas generator which can shorten the amount of time service components (bearings, pallets assembly, etc.);
- power losses occur;
- develop increased fuel consumption;
- turbine's hot start is manifested by increasing exhaust gas temperatures above the maximum permissible startup. These problems are remedied by washing operation using pallets compressor wash system specially designed to a period recommended by the designer and the manufacturer or as necessary (the emergence phenomena listed above). Maintenance costs are minimal, limited to the cost of detergent and wash system maintenance.

Washing can be *on-line* (with turbine operation) or *off-line* (with the turbine off). Washing type online is a relatively new procedure and results in lower maintenance costs, improved launch and increase the period of time between two washes off-line.

**CONCLUSIONS**

Naval propulsion plants with gas turbines generally have much lower maintenance costs than diesel power plants. Being a rotary machine and gasodynamic transmission between gas generator and power turbine, gas turbine has high reliability and simple maintenance operations.

In most cases the first phase maintenance inspection is limited to *that role more endoscopic diagnosis* by analyzing the pallets and other moving bodies, integrity combustion chambers. Following these inspections turbine can be included in one of the following cases:

- to operate until the next planned inspection without any specific intervention maintenance;

- can reduce the number of hours of operation until the next inspection endoscopic usually followed by maintenance operations to remove the fault found;
- the turbine is directly for two, ie to reveal certain mechanical deformation or cracks, shear require stopping the turbine into operation and repair as applicable to the board, or if it comes to pallets assembly or other moving parts that must be dynamically balanced be sent to specialized companies.

Other forms of diagnosis of deficiencies in naval gas turbines are:

- regular oil analysis chemically to determine whether signs of seizure bearings or oil and oil filters must be changed;
- oil analysis from the point of view of the amount of metal (scrap) existing in each camp to predict the traces of seizure;
- permanent monitoring of vibration gas generator and power turbine because if increased values may need washing pallets or endoscopic inspection early diagnostics;
- continuous monitoring of flue gas temperature, which has a maximum value at which the turbine can operate a maximum value at startup. Maximum values over these installations require adjusting operations startup, turbine load parameter reoptimization after again some maintenance operations that require cleaning / replacement of certain elements;
- compressor and turbine speed monitoring power operation and measure their rotation time since receptions STOP command to stop rotating wedge final, which reflects the state of the bearings.

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