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Lifecycle costs for energy equipment FMECA for gas turbine

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Abstract

The procedure of reliability analysis for gas turbine unit (GTU) cogeneration-type SGT-800 is discussed. The example of creating a functional structure and categories of the failures criticality for GTU is provided. The qualitative matrix for GTU structural elements analysis is constructed and the criticality values are calculated.

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Keywords: gas turbine; functional structure; criticality of failure; the number of criticality; FMECA

1. Introduction

Modern engineering used a set of standardized methods and procedures for the analysis of industrial equipment failures named as Failure Mode Effect and Criticality Analysis (hereafter called FMECA). For example, NASA adopted this methodology primarily for military aircraft development. FMECA methodology is used for identifying, critical priorities and compensating actions to eliminate potential failures in a system, structure or process. An important point in FMECA is to identify the functions of equipment and structural elements, which required special attention in the design and operation of support. [2,3].

FMECA method must be planned and carried out simultaneously with the construction process. In ideal the analysis starts at the design stage during structure performance parameters and range of tasks definition. This "top-down" approach has a functional orientation. The biggest interest is FMECA application for the operated equipment where the critical failure analysis helps to build a rational system of maintenance and material supply.

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2. Experimental

The cogeneration heat and power gas turbine SGT-800 used at gas turbine power plants was chosen as a study subject [4]. For this type of gas turbine functional structure has been created that reflects the list of the main functions of the installation and the structural elements responsible for their implementation. First of all, it is necessary to identify all the components of the equipment which are relevant for the study. At this point it is necessary to identify all the basic functions of the turbine, starting from the most aggregated and finishing with the most detailed ones, and associate to every function the physical element which provides that function (Table 1).

Table 1. Association of all the functions to a single physical element.

1st level function	2nd level functions	3rd level functions	Elements of construction structure
Production of electrical energy	Translate thermal energy into mechanical energy	Address combustion products into turbine's blades	Compressor exit and exit of every pressure level of the turbine
		Cool working wheel	Air pipe from compressor to turbine, shape and inner structure of working wheel
		Control pressure after every step	Pressure sensors after every pressure step
		Fixation of working wheel	Ties of turbine
	Burn air and fuel (Exothermic reaction to create heat)	Fuel injection	Injector, fuel pump
		Air supply	Air addressing device
		Inflammation	Spark plugs
		Tubes' cooling	Air tubes
		Temperature control in the combustion chamber	Temperature sensors
		Maintaining stable combustion	Flue
	Translate mechanical energy into electrical energy with the necessary frequency	Translate mechanical energy into electricity	Generator
		Low the number of rounds until the necessary level	Speed reducer
		Providing connections from PTO to turbine shaft	Joint/Gasket
	Air compression	Providing connections from compressor shaft to turbine shaft	Compressor ties and wheel
		Air supply to the compressor	Inlet nozzle
		Address air to compressor's blades	Entrance to compressor and entrance of every pressure step
		Ensure a minimum free space between the rotor and the starter	Compressor's graphite sealing
		Pressure control after every pressure step	Pressure sensors after every step
	Warranty of safe work	Fuel filtering from particles	Fuel filter
		Construction fixation	Supports
		Clear air supply	Air filter
		Control of noize	Silencer

The procedure for the qualitative analysis of criticality is to appoint a functional failure with types of corrective actions depending on the priorities of the failure probability (Table 2) and the Degree of the Seriousness of the Failures (Table 3).

Table 2. Levels of failure probability and its descriptions.

Level of failure probability	Description
A	Frequent failure: it occurs more than 20% of the plant working time
B	Probable failure: it occurs between 10% and 20% of the plant working time
C	Possible failure: it occurs between 1% and 10% of the plant working time
D	Rare failure: it occurs between 0,1% and 1% of the plant working time
E	Unlikely failure: it occurs less than 0,1% of the plant working time

Table 3. Degree of the Seriousness of the Failures

Severity	Description
I	Catastrophic failure: it can cause equipment death or destruction.
II	Critical failure: it can cause serious damages to the equipment.
III	Medium failure: it can cause medium sized damages to the equipment
IV	Border line failure: it can cause minor priority injuries or damages to the equipment
V	Slight failure: does not cause injury, not inflicting damage and does not affect execution of the mission, but leading to the need for unscheduled maintenance or minor repairs the final product

For all of them the criticality of their impact and the probability of occurrence were identified (Table 4).

Table 4. Example of some elements characteristics.

Failure type	Occurrence probability	Severity
Filter clogging	B	III
Contamination of compressor's blades	C	III
Abrasion of graphite sealing	E	V
Pipe burning	A	I
Failure of fuel pump	D	IV
Abrasion of the bearing pads	E	V
Silencer burning	D	IV
Failure of reducer	C	IV
Failure of generator	C	IV
Contamination of cooling pipes	B	II
High-temperature corrosion	C	II

Having all this information, it is possible to create a matrix combining occurrence probability and criticality level of failures, as shown in Table 5, in order to choose the best maintenance strategies for all the groups.

Table 5. Matrix failure level - criticality level.

	Severity				
Level of failure probability	V	IV	III	II	I
>0.2					Pipe burning

0.1 – 0.2			Filter clogging	Contamination of cooling pipes	
0.01 – 0.1		Failure of reducer, failure of generator	Contamination of compressor blades	High-temperature corrosion	
0.001 – 0.01		Air filter, failure of fuel pump, silencer burning			Lubrication system
<0.001	Abrasion of graphite sealing, abrasion of the bearing pads, temperature sensors			Joint/Gaskets	

Then the criticality values of GTU elements are calculated by the following formula [1]:

$$C_r = \sum_{j=1}^{n} C_{mj} = \sum_{j=1}^{n} \lambda_i \cdot \alpha_j \cdot \beta_j \cdot t \qquad (1)$$

where C_{mj} is criticality value of the number j of the product; β_j is the conditional probability of the loose of the systematic mission when the product breaks down as model j; α_j is the percentage of failure displayed as model j (if all the failure models of a product are listed, the totality of α j would be 1.); λ_i is the failure probability of element i; t is equivalent hours of operating element i. As for a given degree of seriousness and a given phase of mission, C_r is the totality of C_{mj} under this degree of seriousness. The working time t can be calculated from the definition of the system. Generally, it is shown by the hours used to finish each mission or by the times of the working circle [1].

The destructive degrees of a GTU elements ordered by the degree of seriousness (Table 6) are calculated based on the manufacturer statistical data in the equivalent hours of operating time based on load factor and fuel ratio.

Table 6. The destructive degrees of a GTU elements ordered by the degree of seriousness.

Severity	Element	Probability of the failure effect occurrence	Percent age of failure	Failure probability (1/hour)	Equivalent hours of operating (hour)	Destructive degree of a product C_r
I	Flue	0.25	1	0.0000167	60 000	0.25
II	Turbocharger coolant supply tube	0.13	1	0.000033	30 000	0.13
	Turbine blades	0.005	1	0.00002	50 000	0.005
	Deflector	0.007	1	0.00002	50 000	0.007
III	Fuel filter	0.15	1	0.0001	10 000	0.15
	High-efficiency air filter	0.15	1	0.0001	10 000	0.15
	First stage air filter	0.15	1	0.000125	8 000	0.15
	Compressor ties and wheel	0.07	1	0.00011	9 000	0.07
IV	Generator	0.01	1	0.000033	30 000	0.01
	Speed reducer	0.01	1	0.000025	40 000	0.01
	Fuel pump	0.008	1	0.00005	20 000	0.008
	Silencer	0.01	1	0.000067	15 000	0.01
V	Compressor’s graphite sealing	0.001	1	0.000018	55 000	0.001
	Joint/Gasket	0.001	1	0.0000125	80 000	0.001

3. Conclusions

The calculated criticality values allow generating a list of items based on GTU failures priority (descending C_r values). The manufacturer in accordance with the actual data on the modes of operation and operating time of a particular installation by adjusting the intensity of failures can build up an individual GTU plan maintenance. This allows saving significantly on the support of the technical operation and material supply the gas turbine power plant. Thus, holding FMECA is necessary not only in the design and construction, but for active operation of the equipment for a long time.

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