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Feature of heavy-duty gas turbine compressor reengineering

In a paper the considered questions of a machine industry hard loaded responsible products resource saving at a stage of their repair, on an example of the heavy-duty gas-turbine compressors. A technique for safe disassembly of the element base of gas turbine compressors is proposed, taking into account the specific operating conditions and residual effects on the environment.

Keywords: *repair, selective disassembly, heavy-duty compressors, gas-turbine, resource saving.*

В статье рассмотренные вопросы сохранения ресурса тяжело нагруженных ответственных изделий машиностроения на этапе их ремонта, на примере газотурбинных компрессоров большой мощности. Предложена методика сохранной разборки элементной базы газотурбинных компрессоров с учетом специфики условий эксплуатации и остаточного влияния на окружающую среду.

Ключевые слова: *ремонт, частичная разборка, компрессора большой мощности, газовые турбины, сохранение ресурса.*

У статті розглянуті питання збереження ресурсу важко навантажених відповідальних виробів машинобудування на етапі їхнього ремонту, на прикладі газотурбінних компресорів великої потужності. Запропоновано методику ощадного розбирання елементної бази газотурбінних компресорів з урахуванням специфіки умов експлуатації та залишкового впливу на навколишнє середовище.

Ключові слова: *ремонт, часткове розбирання, компресора великої потужності, газові турбіни, збереження ресурсу.*

Introduction

In modern manufacture, in many areas of the industry heavy-duty gas turbine have found application (Fig. 1)[1].

Distinctive feature of such equipment is: - the big size; the big weight; - high cost of components; - increased requirements to manufacture, maintenance and repair of the equipment.

Maintenance costs and machine availability are two of the most important concerns to a heavy-duty gas turbine equipment owner. Therefore, a well thought out maintenance program that reduces the owner's costs while increasing equipment availability should be instituted. General Electric (GE) have Gas turbine maintenance program [2]. For this maintenance program to be effective, owners should develop a general understanding of the relationship between the operating plans and priorities for the plant, the skill level of operating and maintenance personnel, and all equipment manufacturer's recommendations regarding the number and types of inspections, spare parts planning, and other major factors affecting component life and proper operation of the equipment.

Advanced planning for maintenance is necessary for utility, industrial, independent power, and cogeneration plant operators in order to maintain reliability and availability. The correct implementation of planned maintenance and inspection provides direct benefits in the avoidance of forced outages, unscheduled repairs, and downtime. The primary factors that affect the mainte-
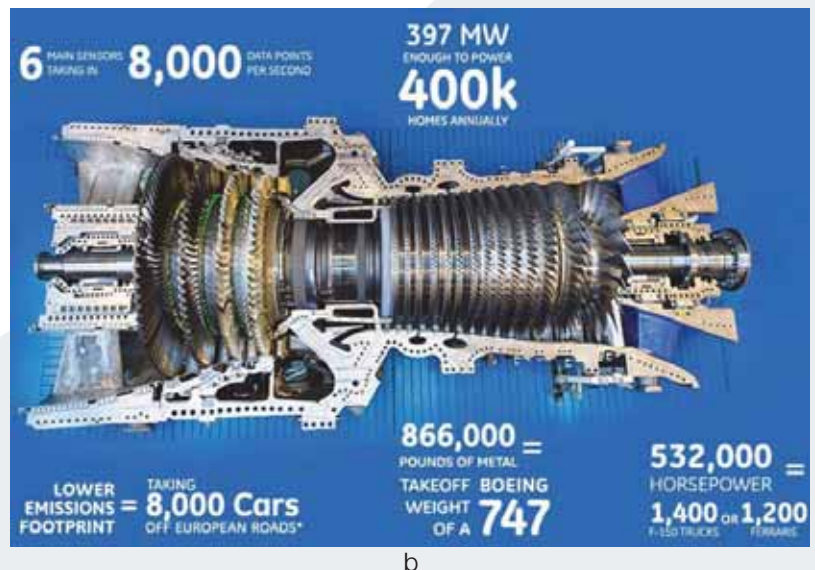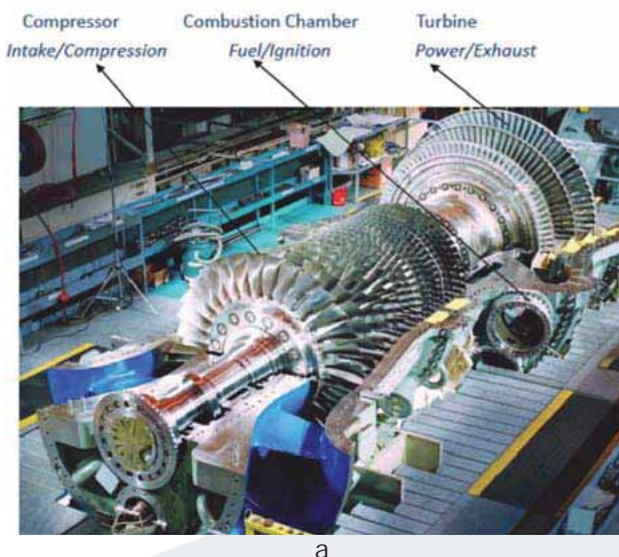

Fig.1. Heavy-duty gas turbine: *a - typical construction; b - heavy-duty parameters*

Fig.2. Key factors affecting maintenance planning

nance planning process are shown in Figure 2.

The owners' operating mode and practices will determine how each factor is weighted. Gas turbine parts requiring the most careful attention are those associated with the combustion process, together with those exposed to the hot gases discharged from the combustion system. These are called the combustion section and hot gas path parts, and they include combustion liners, end caps, fuel nozzle assemblies, crossfire tubes, transition pieces, turbine nozzles, turbine stationary shrouds, and turbine buckets.

Gas turbines wear differently in continuous duty application and cyclic duty application, as shown in Figure 3. Thermal mechanical fatigue is the dominant life limiter for peaking machines, while creep, oxidation, and corrosion are the dominant life limiters for continuous duty machines.

Fig.3. Causes of wear – hot gas path components [2]

Interactions of these mechanisms are considered in the GE design criteria but to a great extent are second-order effects. For that reason, GE bases gas turbine maintenance requirements on independent counts of starts and hours. Whichever criteria limit is first reached determines the maintenance interval.

Statement of the problem

At a stage of gas turbine maintenance and repair there is their necessity for disassembly for access to the failed detail or a unit. It is known, that full disassembly of the equipment at repair – one of undesirable operations as even at the most qualified safe disassembly interface of the worn-in details and a normal tightness in slots with motionless landings are disturbed. The part of details at disassembly is damaged (inflow, paws, flanges break, edges of bolts, nuts get off, rivets and etc.). Aggregates and the details which are not demanding repair, at all it is not recommended to remove from the equipment because of possible lowering working capacity of machines as a whole. Therefore before disassembly of the equip-

ment it is important to define objective necessity of execution of operations.

Modern direction in disassembly is Disassembly Wave Propagation method [3-6]. The disassembly analysis involves evaluating a disassembly sequence (order of component removals) from the geometric model of an assembly.

In real conditions of equipment maintenance can vary not only joints parts type going into it, but also a degree of their effect on an environment (chemical, radiological danger, etc.), that by all means leads to change of a set of the methods involved a disassembly (Figure 4) [7-10].

The object may come from out side and hit the component causing damage to the components and this type of damage is popularly known as Foreign Object damage (FOD). Or the object may be generated within the turbine and may hit the component causing damage to the components and this type of damage is known as Domestic Object damage (DOD). This is most common type of failure in gas turbine and takes place due to premature failure of gas turbine components. As mentioned above that the failure is due to impact and for impact failure, the material is to be hit by an object and this object may be external or internal, hence further investigation done on each and every stages of moving and stationary blades of compressor to identify the source of object. If the damage was due to foreign object, then the material has to travel from out side the Gas Turbine, and it has to be entered in to the Gas turbine Compressor through Compressor inlet air plenum air flow path only. As the probability of damage due to FOD has already been ruled out therefore, the damage has to be due to DOD, in order to find the source of Domestic Object, when the compressor mid casing was opened, it was found that all most all moving & stationary blades have failed from the root just above platform with massive deformations and failed surface are totally distorted (clockwise).

Therefore, though a moving & stationary blades have failed still question arises which has/have failed first and whether they have failed of their own (due to any reason) or they have also been hit by an object and this object has be generated with in compressor.

Research technique

Offered the new approach, which considers consequences of maintenance of the complex equipment, such as a gas turbine compressor [11]. The product, from the point of disassembly technique, view is represented as set of parts joints that going into it. Thus the period of product maintenance is represented as the function

$$E = f(t, u, v)$$

that depending from of some factors: t – time of maintenance; u – conditions of maintenance; v – degrees of residual effect on an environment.

The factor of time – for long time of parts maintenance even in normal conditions occurs change of an aspect of the connection, linked for example, to wear of pairs abrasion, change of parts physical properties being in contact (drying of rubber seals, contact surface magnetization and etc.). The maintenance conditions factor – effect of an excited environment, a dust content of a working area, effect of a heat, heavy loadings, maintenance in hard radiation conditions (heightened radiation), etc. The factor of a degree of residual effect on an environment – defines a degree of consequences of unfavorable maintenance conditions effect any product as a whole, and de-

tails going into it in particular (explosion hazard, residual radiation, biological danger, etc.).

All the above-stated factors influence, separately and in the set, not only on transformation of joints aspects, but also on generation of sequence of selective product disassembly up to the costing parts. Besides the choice of industrial conditions on repair shop and means of technological equipment also depends on a combination of their influence.

The set of decisions of the given problem at a qualitative level is described by the equation (a necessary condition):

$$\underset{\psi \in \Psi}{\forall} R_\psi = \{R \mid \gamma_R^{\min} \le \gamma_R \le \gamma_R^{\max}\},$$

i.e. for all existing candidate solutions of a problem (set of techniques) the included criteria on quality of process is in the field of acceptable values

$$\lambda_{P_0}^{\min} \le \lambda_{P_0} \le \lambda_{P_0}^{\max}.$$

The decision of a problem at a technological level (sufficient condition) (figure 5):

$$\underset{\xi \in \theta}{\exists} R_\xi = \bigcap_{\psi=1}^{\chi} R_\psi \vee \underset{\phi=1}{\overset{\varphi}{\exists}} M_\phi \vee \underset{\zeta=1}{\overset{\chi}{\exists}} STO_\zeta \vee \underset{\varepsilon=1}{\overset{\tau}{\exists}} TP_\varepsilon,$$

where $\underset{\xi \in \theta}{\exists} R_\xi$ – the existing candidate solution of a problem;

$\bigcap_{\psi=1}^{\chi} R_\psi$ – set of candidate solutions of the problem, satisfying to a necessary condition;

$\underset{\phi=1}{\overset{\varphi}{\exists}} M_\phi$ – presence of methods of the decision of a problem for each variant;

$\underset{\zeta=1}{\overset{\chi}{\exists}} STO_\zeta$ – presence of means of the technological equipment, capable to realize necessary methods;

$\underset{\varepsilon=1}{\overset{\tau}{\exists}} TP_\varepsilon$ – presence of necessary technological conditions for means of technological equipment under each method.

The results of research

In this case the set is shaped of technological cost prices of candidate solutions of a problem satisfying necessary and to a sufficient condition, according to expression:

$$\{C_{P_0}\} = \bigcup_{k \in X} \{C_{P_0}(k) \left| \begin{array}{l} \underset{\xi \in \theta}{\exists} R_\xi = \bigcap_{\psi=1}^{\chi} R_\psi \vee \underset{\phi=1}{\overset{\varphi}{\exists}} M_\phi \vee \underset{\zeta=1}{\overset{\chi}{\exists}} STO_\zeta \vee \underset{\varepsilon=1}{\overset{\tau}{\exists}} TP_\varepsilon, \\ \underset{\psi \in \Psi}{\forall} R_\psi = \{R \mid \gamma_R^{\min} \le \gamma_R \le \gamma_R^{\max}\} \end{array} \right.$$

The optimization problem by economic criteria (a minimum of the technological cost price) then is represented expression:
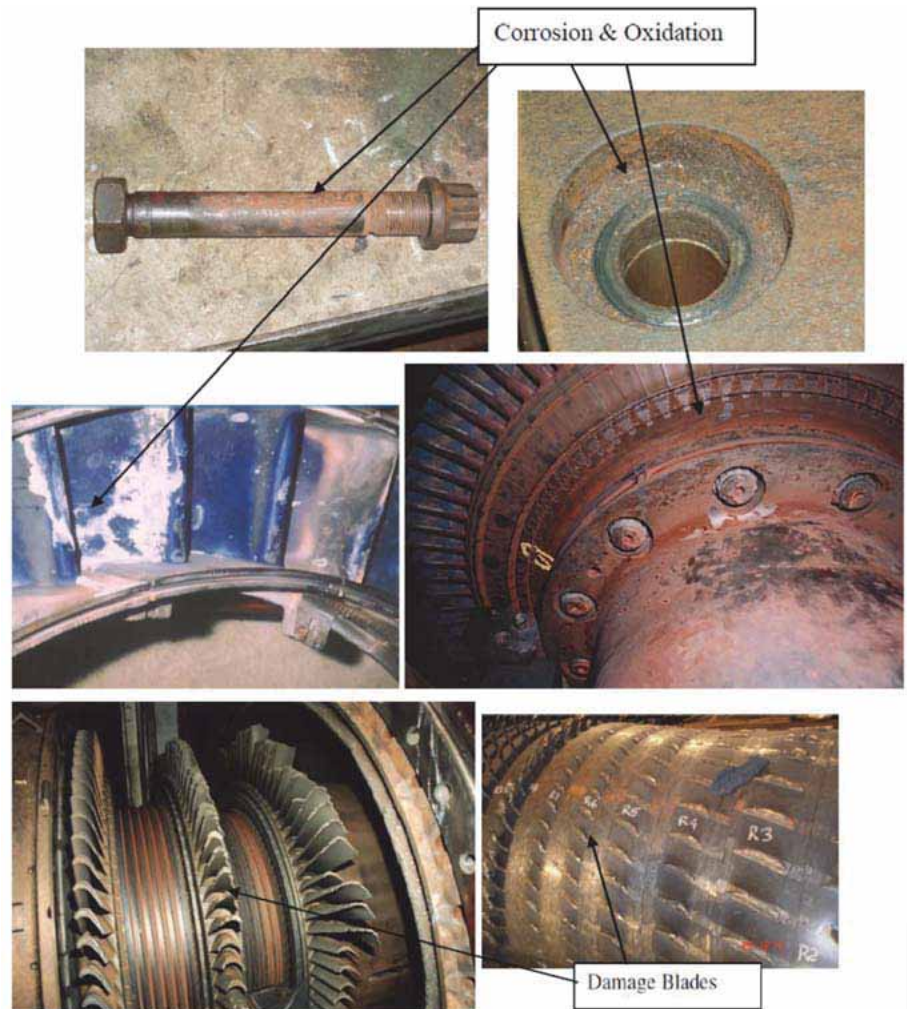

Fig.4. Gas turbine compressor damage cause and results

$$P_0^{opt} = \underset{C_{mex} \to \min}{\ell im} P_0 \big| C_{mex} \in \{C_{P_0}\}.$$

Conclusion

The basic idea of the concept resulted in operation consists in development of methodology of a system approach to projection of the highly effective technological systems applied at repair and modernizing of heavy duty gas turbine compressor. Practical application of the offered approach will allow to increase quality and safety of special assignment, and introduction of the formalized technique in conditions of real manufacture will allow increase in level of efficiency and the use of available means of complex technological equipment.

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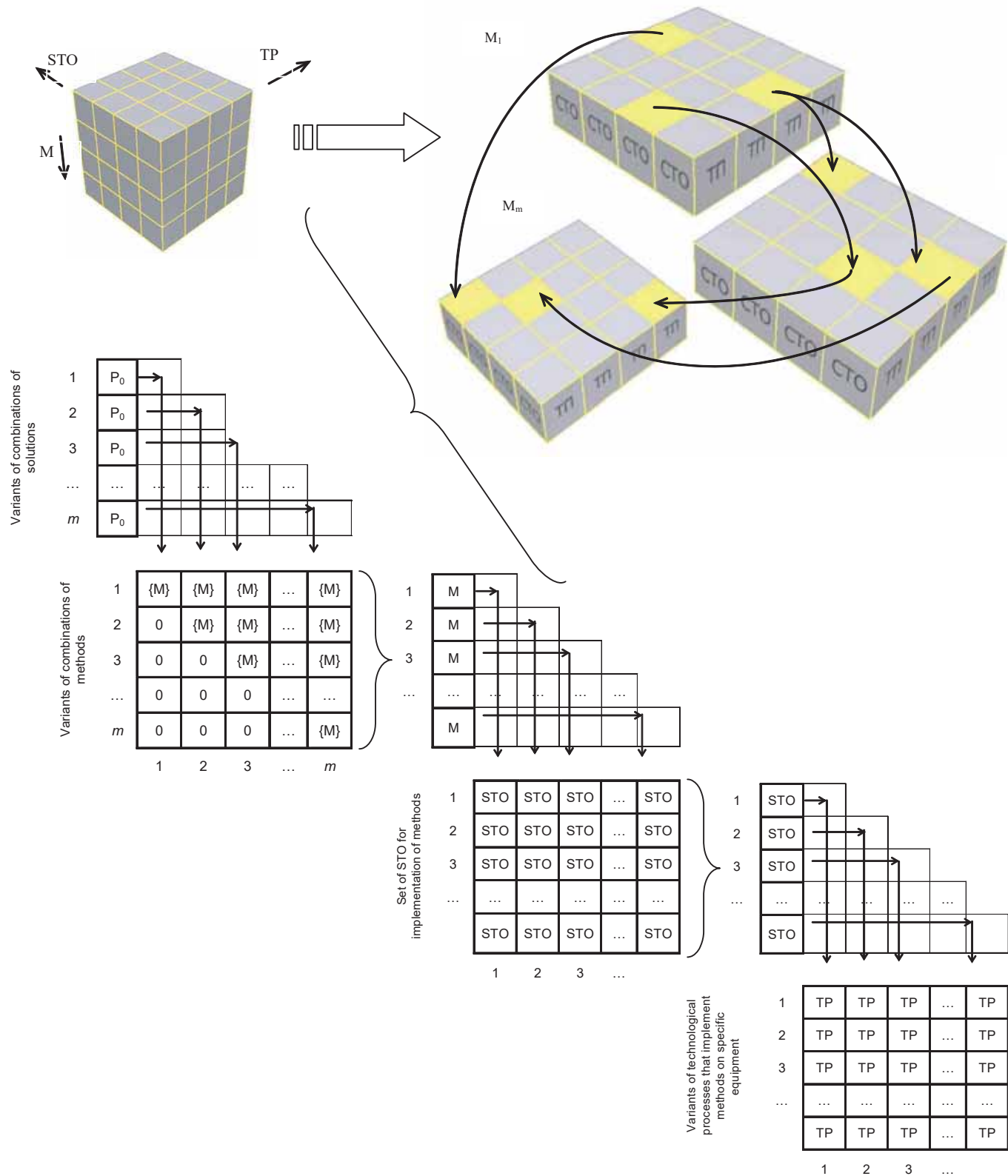
Fig. 5. Model of technology choice

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