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Changes in the Engineering Products Performance during Operation

I.A. Krivosheev[a], D.G. Kozhinov[a], K.E. Rozhkov[a,*]

[a] *Ufa State Aviation Technical University, 12, K. Marksa, Ufa, 450008, Russia*

Abstract

This paper presents the change of indicators characterizing the efficiency and condition (or health) of mechanical engineering products (such as aircraft engines, gas turbines, etc.) during their operation (over time). Employing the method of phase portraits used in automatic control theory (ACT), is proposed. A method for direct measurement of power, generated by gas turbine unit (GTU) is suggested. The algorithms able to predict changes in the technical condition of engineering objects over their operation time are developed. These algorithms do not require measuring the efficiency indicators derivatives.

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Keywords: technical condition; diagnostics; prediction; operation; phase portrait.

1. Introduction

Currently, in operation of mechanical engineering products, a maintenance based on actual technical condition is used instead of operating time resource assignment. Thus, algorithms for diagnosis and prediction of changes in the technical condition of the objects are necessary. This allows individual planning of shutdowns for every product to conduct preventive maintenance, repair and decommissioning.

1.1. Relevance and scientific significance of the matter with a brief narrative review

The task monitoring, diagnosis and prognosis of changes in the technical condition at operating time is particularly relevant for aircraft engines and gas turbine units, which are used in power generation and gas transportation. This matter is the subject of many works, such as [1-4].

* Corresponding author. Tel.: +7-905-006-1991.
E-mail address: rke85@mail.ru

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1.2. Statement of the problem

Currently, in operation of mechanical engineering products, only a limited set of parameters is monitored. This allows avoiding a large number of expensive devices and sensors, which otherwise would interfere with normal object workflow. Therefore, to assess the effectiveness (and operability) of products, estimation is based on parameters which are monitored without large expenditures. In this paper we propose a method for direct control of parameters that characterize the effectiveness and operability of aircraft engine (AE) and GTU in operation. Furthermore, a new data processing algorithm is proposed, which allows to predict changes in the state of GTU over time and schedule shutdowns for preventive maintenance, repair and decommissioning (individually for each product). The algorithm does not require any changes in the existing technology of GTU thermal tests.

1.3. Construction of references

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2. Theoretical part

Currently, for example in AE operation, a periodic or continuous measurement of thrust is not practiced. The same applies to measurement of turbine power in GTU exploitation. However, the values of these parameters characterize the state of the object with high degree of reliability when the parameters are reduced to some base operating mode and standard atmospheric conditions (SAC).

It is known that in gas transportation appliances, fairly complex equipment is used for measuring torque on the drive shaft of a centrifugal supercharger. In contrast, the authors suggest measuring the torque as a torque on the stator of GTU. For this purpose it is suggested to measure the additional axial force occurring in one of the two mounting pillars (the loaded one). This axial force increases with increasing the load on the rotor.

This allows determining torque as (1), and monitoring turbine power output as (2). In our case the torque value reaches 30000 Newton-meters.

$$T = FL \tag{1}$$

Where T – torque; F – axial force; and L – distance between mounting pillars.

$$P_t = \pi n_t T \tag{2}$$

Where P_t – turbine power; n_t - turbine speed; T – torque.

Currently, in the energy sector and gas transportation industry, the reference operating mode is the mode at which GTU (at SAC) has a predetermined value of the turbine power. Here, said power is considered as efficient and reduced to the SAC and to the reference operating mode P_{ref} (e.g. P_{ref} = 16 MW). Thus on a new product during acceptance tests (AT) a value of n_{red_lpr} is detected (a reduced low pressure rotor speed), or a value of T_{full_lpt} (full temperature at the outlet of the low pressure turbine) – at SAC at the GTU inlet. The authors suggested the contrary – determining the value of n_{red_lpr} or T_{full_lpt} for a given value of P_{ref} (e.g. P_{ref} = 14.5 MW) for setting the reference mode at AT. For example, it may reach T_{full_lpt} = 640°C in our case.

Similarly, in the aviation industry is not difficult to arrange direct periodic (or continuous) measurement of aircraft engine thrust. It this case a reduced thrust should be considered, reduced to SAC and reference operating mode, that is effective thrust. The mode can also be determined by the value of n_{red_lpr} or T_{full_lpt}.