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Construction diagnostics of the aircraft parts on the basis of the energy method and the stress-state stiffness criterion

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Abstract

The analysis of the stress-strain state on the basis of equivalent stress and the theories of durability is used for diagnostics of parts at present moment in the typical strength calculations. However a lot of basic aviation parts work at cyclically repeated loadings and they are exposed to loadings and deformation in the field of low and high cycle fatigue. In this case there is necessity of deformation condition calculations or the stress-strain type which significantly influences on the cyclic durability of the parts. For increasing of reliability and cyclic durability of the parts the research purpose is to develop a way and criteria of the analysis and assessment of the stress-strain state for the identification of the most loaded areas of the parts limiting its fatigue. It is offered to consider the stress-strain type on the basis of coefficient of stiffness K_S calculated through the main tensions. In this case it is recommended to determine the most subjected to cracking initiating areas of the parts by the largest size of parameter $K = K_S K_U$. The research of the finite element analysis of the stress-strain state for the low pressure turbine shaft and high pressure compressor disks of D-30 series gas turbine engine was made according to this parameter. On the basis of this parameter the finite element analysis of the stress-strain state for the low pressure turbine shaft and high pressure compressor disks of the gas-turbine engine of D-30 series is researched in this work.

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Keywords: Diagnostics of parts; Coefficient of stiffness; Specific energy; Cyclic durability; Tension

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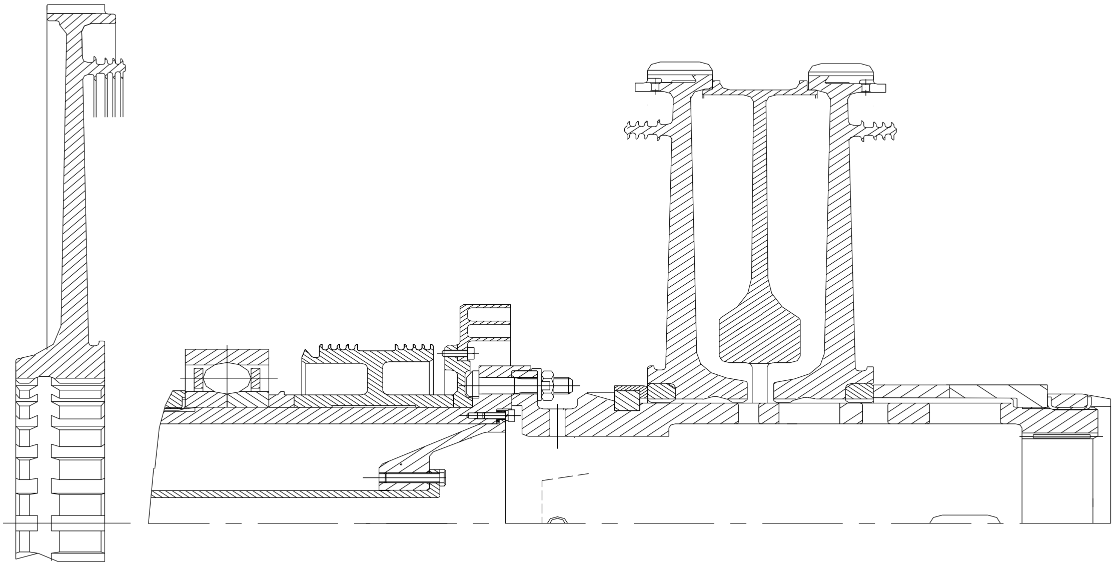
The stress strain state (SSS) analysis which is based on equivalent stress according to one of theories of durability is used to diagnose the working capacity of the parts. However the primary aviation parts of a gas turbine – shafts, disks, pawl coupling blade-disk work under conditions of cyclically repeated loadings. In this way the stress-strain state with the high stress gradient arises in the elastic range of stress and beyond its borders. In this case arises necessity of objective diagnostic of the parts condition including deformation conditions and stress-strain state type which significally affects on cyclic durability and life time of the basic gas turbine parts. For example with the basic overhaul time of engine D-30KP/KU-154 2310 cycles (~5000 hours) the service life limit of the 11-stage high pressure compressor (HPC) disk (Fig. 1, a) equal to ~3550 cycles. As a result those disks serve the purpose of one time use without working out its recourse. The reason for this is faulty for double usage low-cycle fatigue of disc hub splines as evidenced by the bench test results. At the JSC "NPO "Saturn" was implemented the complex of computational and experimental works [1, 2] for the enhancement of disc durability. The efficiency estimation of developed arrangements concerned with labour required and high-cost testing on the bench UIR-2 the scheme of which is shown in figure 1, b. Therefore the development of the computational methodology of work efficiency estimating for construction optimization of the gas turbine parts and technological repair procedure development are important research issues.



a b

Fig. 1 a – 11 stage high pressure compressor disk; b – element of bench test UIR-2 with the disks installed for cyclic testing on low-cycle fatigue

1. Research methodology

Usually the analysis of the stress-strain state of parts is carried out on the basis of equivalent tension according to the energy hypothesis of Guber – Mises (Huber M.T., Mises R.) the analytical expression of which is identical with the stress intensity ($\sigma_{equiv} = \sigma_i$)

$$\sigma_i = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2} \ . \tag{1}$$