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VERY HIGH CYCLE FATIGUE UNDER HIGH FREQUENCY VIBRATIONS OF GAS TURBINE ENGINE COMPRESSOR DISKS

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Disks of compressors of gas-turbine engines are exposed long-term low cycle loading (flight cycles: take-off-flight-landing) and very high cycle loading (vibrations of blades). The assessment of time of their safe operation represents considerable practical and theoretical interest [1].

For flight cycles (LCF - low-cyclic fatigue) in [2,3] calculated the strain-stress state (SSS) and estimates of fatigue durability of the rotating disk of variable thickness under the influence of centrifugal and loading in the disk and blades, contact interaction between disk and blades, aerodynamics pressure and blade vibrations are received. For an assessment of durability of a disk in flight cycles of loading known criteria of multiaxial fatigue failure of titanic alloys were used. On the basis of these criteria distributions of durability in a disk were received, dangerous zones of origin of fatigue damage in a disk are defined. It was shown that the fatigue durability of a titanic disk for characteristic frequencies of rotation is decreased to critical values $N \sim 10^4$ flight cycles (30000-50000 hours of safe operation) in the vicinity of a contact zone of blades and a rim of a disk.

Recently it is established [1,4] that the low-amplitude vibration loadings operating for a long time too can cause damage of stractures (VHCF – very high cycle fatigue). Stresses in disks caused by vibrations are significantly lower not only a limit of plasticity, but also fatigue strength for LCF mode, that is, on classical views of the theory of low-cyclic fatigue such vibration stresses shouldn't constitute danger at all. However, fractographic analysis of surfaces of a break of the disks destroyed in use showed that initial origin of fatigue microdamage in disks can happen in cyclic processes of both types (mechanisms): both LCF, and VHCF. Distinctive feature of destruction for the VHCF mechanism is that the center of origin of microcracks is under a design element surface, but doesn't adjoin it, as in case of cyclic process of LCF mechanism. This feature allows experimenters to distinguish these mechanisms at classification of primary reason of damage. We will note

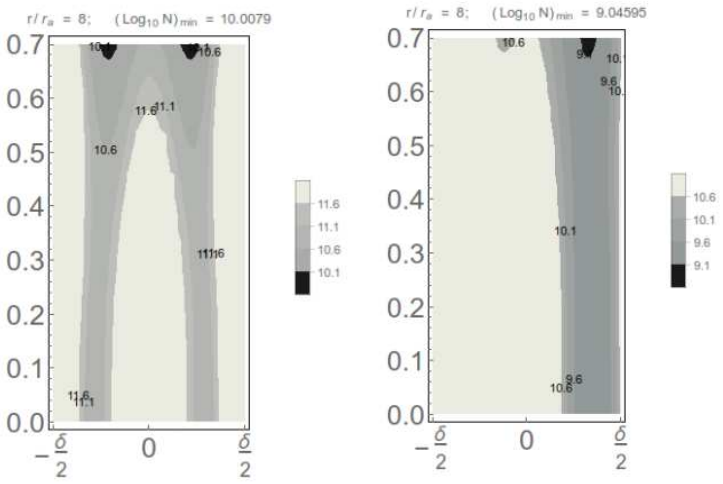
that further development of a fatigue crack, as a rule, happens in the mode of low-cyclic fatigue and is observed in the form of fatigue grooves on a break surface according to flight cycles of loading. From this it follows that LCF and VHCF mechanisms are alternative both often complementing and mutually strengthening each other. The review of pilot studies in this direction can be found in [1,4].

It is necessary to notice that the main loading of a disk is carried out in flight cycles under action on a disk and blades of centrifugal forces and aerodynamic pressure upon blades from the gas stream. On this power background vibration loading owing to tortional cyclic deflections of blades is imposed. In the accepted statement we don't consider the reason of vibrations, such as action of pulsations of pressure, excitement of own forms of vibrations of blades, transitional power setting and so on, and we consider vibrations as set. Data on amplitudes and frequencies of vibrations of disks and blades are provided in [1].

In this work the assessment of durability of a disk of variable thickness in VHCF process is carried out. The method of calculation of the three-dimensional SSS of elastic disks of variable thickness under the influence of cyclic loadings from tortional vibrations of blades is proposed.

Approximate representation of dependence of the stress-strain functions on coordinates along thickness of a disk and in the azimuthal direction is used. The coefficients of the formulas of this representation depend on radial coordinate and are calculated by solving the system of the differential equations using the implicit differential scheme.

Calculated SSS from vibrations was imposed on the SSS from flight cycles and then it is used for estimates of durability of operation and locations of damage in the considered disks on the basis of the generalized criterion of VHCF failure [5,6]. The decrease of durability on an external rim is revealed considerable (to $10^{9.5} – 10^{10}$ cycles) (in a zone of contact of a disk and blades). At vibrations the period of fluctuations has an order 0.01 seconds. Therefore real time before fatigue failure as a result of vibrations of blades can be of size 10 000 - 30 000 hours, quite achievable in usual operation practice.



a) *b)*

Fig. 1. Isolines of a logarithm of durability in rectangular section on an external rim of a disk (under a blade)

In Fig. 1 isolines of a logarithm of durability in rectangular section on an external rim of a disk (under a blade) for SSS of VHCF mode imposed on the main SSS of LCF mode without aerodynamic loads of blades (a) and taking into account these loadings (b) are visually shown. With dark color areas of the minimum durability which correspond to zones of origin and possible development of fatigue damage are shown. The right picture (b) looks more realistic because the arrangement of this failure zone corresponds to data the fractographic analysis of surfaces of a break of the disks destroyed in operation [1].

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