# FATIGUE FRACTURE OF CYCLOSYMMETRIC SYSTEMS

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The mechanisms of variation for circumferential distribution of stresses of turbomachine impellers with initiation and development of fatigue cracks due to resource exhaustion from low-cycle fatigue are experimentally obtained; they are used as diagnostic criteria of a state by contactless laser measurements of amplitude-frequency characteristics of rotating rotors of turbomachines.

## INTRODUCTION

Requirements for simultaneous perfection of the basic parameters of turbomachines and resource increase make a problem of high reliability the most difficult to realize. So, state diagnostics systems, specially, availability of fatigue damages at impellers are very urgent. Such a system is based on contactless, e.g., laser methods and measuring facilities for amplitude-frequency characteristics of rotating rotors immediately during turbomachine operation.

Amplitude-frequency characteristics of cycle-symmetric systems to which turbomachine impellers are related, are known to be rather sensitive to violation of their symmetry as swown by Kirichenko et al(1). However, a level of development for theoretical methods of calculation of amplitude-frequency characteristics of impellers with cracks does not allow to obtain dependences on variation of circumferential spread of impeller stresses with resource exhaustion from low-cycle fatigue with accuracy sufficient to use in practical problems of diagnostics. resource exhaustion from low-cycle fatigue with accuracy sufficient to use in practical problems of diagnostics.

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The experiments which brought about diagnostic criteria, are to represent fatigue damages equivalent to operational ones at a fixed disc and measurement of circumferential distribution of stresses with resonance vibration of the impellers at amplitudes close to real ones.

## Electrohydraulic stand for multi-axis cyclic loading of turbomachine discs

Low-cycle tests of discs are performed on an electrohydraulic stand, a principal view of which is shown in Fig. 1. Structurally a stand consists of two support rings, along their perimeter the forced hydrocylinders are located. An effort from hydrocylinder rod is transfered via a two-member hinge joint to a blade simulator installed in intergrooved flange of a disc. Each hydrocylinder develops the effort equivalent to a field of centrifugal forces at rotation of the impeller under the corresponding operational conditions of the turbomachine. The electronic system of control allows to carry out a programming cyclic loading having simulated the operational cycle of the turbomachine. Periodically a disc is removed from the electrohydraulic stand, bladed and installed at electrodynamic vibration-testing machine where its resonance vibration is excited and a circumferential distribution of stresses is measured by using Laser Doppler Scanning Computer Vibration Meter (LDSCVM). In parallel to, a nondestructive control of disc state is performed by the known methods for nondestructive control. In case of cracks detection their parameters are measured. So, we manage to obtain a set of amplitude-frequency characteristics of one and the same impeller for different stages of development of fatigue cracks up to disc fracture which is accompanied by fragments separation (Fig. 2).

## Laser Doppler Scanning Computer Vibration Meter

LDSCVM allows to carry out contactless measurements for fields of displacements of large sections of vibrating constructions at any amplitude up to destructed ones (Kirichenko and Chmutin)(2). By using the extremal properties of spline-functions the fields of displacements are transformed into continuous fields of deformations . The problem has been analytically solved for any complex three-dimensional constructions e.g., of turbomachine blades by Kirichenko (3). In case when not all sections of the construction are accessible to be examined due to screening from probing laser beams (e.g., groove-type roots, intergroove flanges of a disc) the computer programs based on the finite element method adapted to operate with laser computer measuring systems are used by Kirichenko et al (4). Fields of displacements and deformations (stresses) of vibrating impellers measured by LDSCVM are shown as an example in Fig. 3,4.

## The basic peculiarities of procedure for experiments

During low-cycle tests at the electrohydraulic stand deformation fields in zones of intergroove flanges are measured by LDSCVM. The first several cycles of loading are accompanied by some variation of deformation fields with holding the cyclic symmetry. Then stabilization of deformation fields occurs at intergroove flange where the fatigue crack has been initiated. By a periodic blading of the disc under study the deformation field of each intergroove flange measured at the electrohydraulic stand is simulated by securing the blades of a special construction. The technological process of blading is carried out with a constant control of deformation field of each intergroove flange by LDSCVM. The bladed disc is mounted at electrodynamic vibration- testing machine stand and its resonance vibration is excited with consequent measuring circumferential distribution of stresses.

## Results of experiments

Variations of the circumferential distribution of stresses in case of fatigue damage of the impeller are sufficient to use them as the diagnostic criteria in the contactless diagnostics of the rotating impellers by LDSCVM.

Some practical peculiarities of application of diagnostic criteria at real turbomachines are considered.

## REFERENCES

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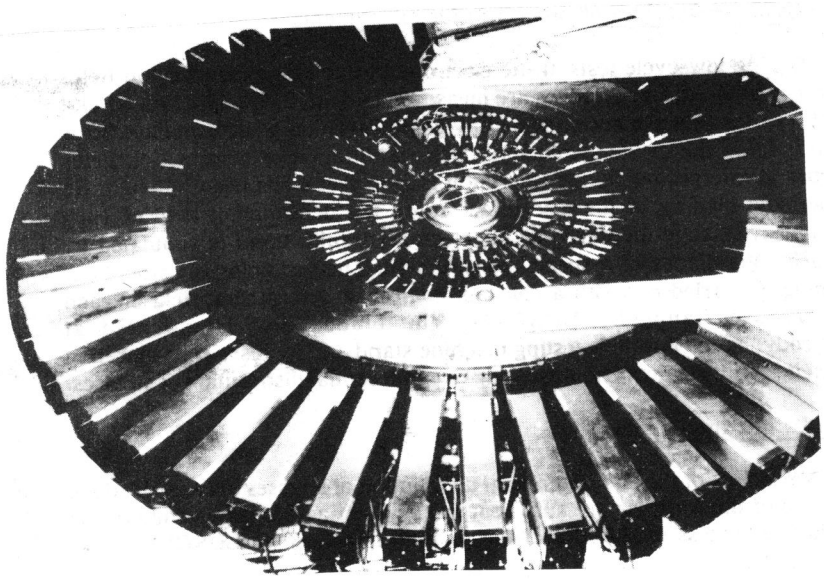

Figure 1 Electrohydraulic stand

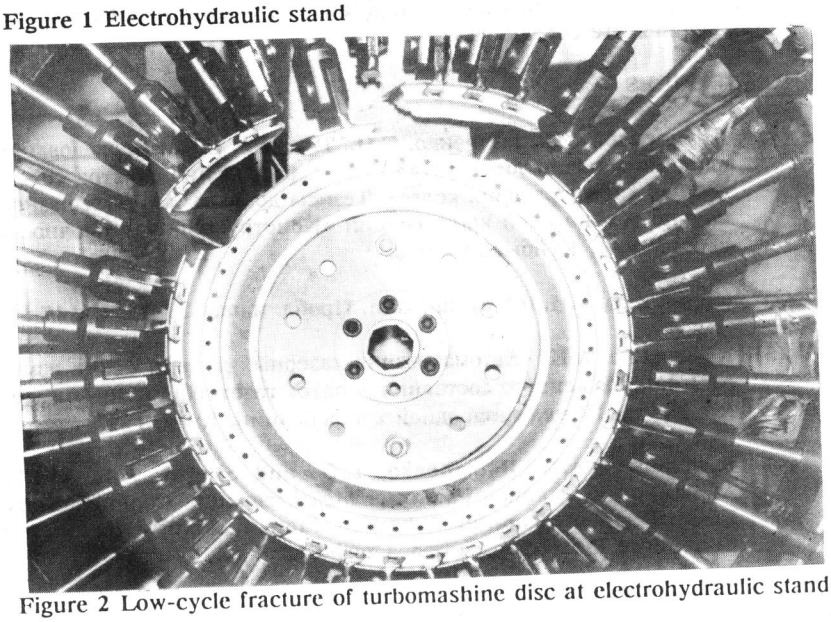

Figure 2 Low-cycle fracture of turbomashine disc at electrohydraulic stand

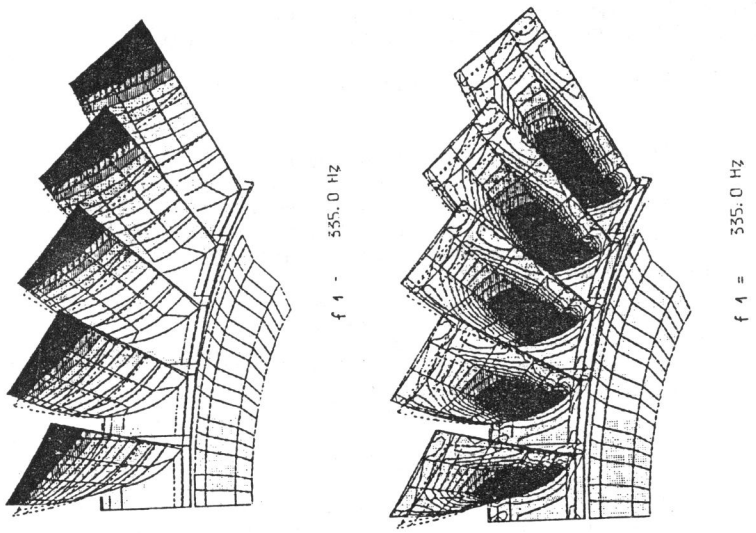


Figure 3 First vibration mode of turbomashine impeller ($f_1$ = 355 Hz)

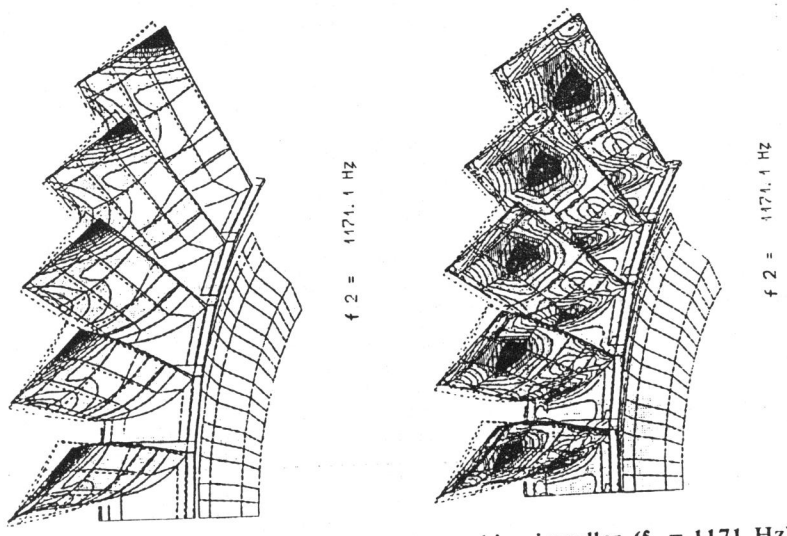


Figure 4 Second vibration mode of turbomashine impeller ($f_2$ = 1171 Hz)