BIRD STRIKE COMMITTEE EUROPE

BSCE22/WP82
Vienna, 29 August to 2 September 1994

NUMERICAL AND EXPERIMENTAL ANALYSIS OF THE BIRD STRIKE FAN RESISTANCE

Shorr B F, Inosemtzev A A, Rudavetz V A
Central Institute of Aviation Motors
Moscow-Per'm
Russia

ABSTRACT

Some results of numerical evaluation of the bird strike resistance of turbofan blades in comparison with experimental data are presented.

(Keywords: Bird, Blade, Calculation, Damage, Experiment, Fan, Strike)

Preliminary numerical evaluation of the bird strike resistance of blades allows to decrease the durability and the cost of engine tests on the injection of birds [1-3]. Such an approach has been used for the development of shrouded fan blades of the turbofan PS90-A.

The basic engine factors for the bird impact resistance are listed in Table 1 and in Figures 1-3. The reproduction of these factors in tests and possibilities of calculation of their influence are also shown.

The numerical method proposed is stated in [3]. But in contrast to this paper a blade is assumed to be a thin shell of variable thickness and arbitrary curvature of its midsurface.The displacements along the normal to the blade surface at shrouded points are assumed to be zero. The governing equations are formulated in the curvelinear coordinate system on the midsurface α_1 and α_2. The boundaries of the contact zone are calculated according to the kinematic conditions of intersection of the trajectories of a bird and a blade in their relative motion.

A variational approach is based on the use of given coordinate functions $\varphi(\alpha_1, \alpha_2)$. Fifst, from 15 to 20 eigenvalues and eigenfunctions are calculated with account of the influece of centrifuginal forces. Then the solution of the impact problem is sought for as a decomposition of displacements with respect to eigenfunctions

$$W_k = \sum_{i=1}^{n} R_i(t) W_{ki}(\alpha_1, \alpha_2); \quad k = 1, 2, 3. \qquad (1)$$

Here $\{R(t)\}$ is the vector of unknown functions R_i depending on time which is determined from the matrix equation

$$[a]\{\ddot{R}(t)\} + [c]\{R(t)\} = \{F(t)\}. \qquad (2)$$

In equation (2) $[a]$ is the mass matrix, $[c]$ is the generalized stiffness matrix which takes in account the influence of centrifugal forces, $\{F(t)\}$ is the vector of impact forces refered to eigenfunctions.

Both only impact and complete stresses and strains due to stationary centrifugal forces are determined. The stresses and displacements are calculated not only during the impact but also for any time after the impact when their values may take maximum.

As an example the calculated distribution of longitudinal stresses (the lines of the equal stresses) on the pression face (Figure 4a) and on the suction face (Figure 4b) of the blade are shown.

The following data are taken:
the bird mass m = 600g;
the bird velocity refered to the engine V = 69m/s;
the frequency of the fan rotation n = 4600rpm;
the time moment t = 408mks (the finish moment of the contact between the blade and the bird).
The direction of the bird-blade collision is shown by arrows.
The values of stresses (in MPa) are shown by numbers near the lines and the zones where the elastic stresses exceed the yield limit are shaded.

TABLE 1

Influence factors	Reproduction features on tests	Calculation possibilities
Rotational speed	Tests under atmospheric conditions do not always garantee maximum speed	Calculations at arbitrary speed
Bird axial velocity relatively engine	Equipment capabilities and its accuracy	Calaulations at different velocity
Normal component of relative velocity and its direction (V_n)	Limitation of the test number (see Figure 1)	Calaulations at different possible value of the velocity
Bird mass	Limitation of the test number	Calculations at different masses
Points of impact on circumference, radius, chord	Random or difficult for controlling of impact points (see Figure 2)	Calculations at arbitrary positions of impact points
Bird orientation relatively blade	Random (see Figure 3)	Calculations at different orientation
Non-uniformity of bird body due to bones	Effect depends on bird orientation; while using simulators it is neglected	Calculations at different orientation taking in account non-uniformity
Airfoil geometry (thickness, shroud sizes and position etc)	It is limited by made construction	Alternative calculations at design and development

At the upper part of the leading edge of the blade we can expect considerable local deformations and damages. The stresses at the central zone of the blade, especially under the shroud, are less. Therefore, the strength of the blade on the whole may be provided.
Analogic calculations for the collision with small birds (~60g) show that only light distortions may be expected.

The fan of the engine PS90-A was tested with success at a special plant (Figure 5). The character of blade damages after the collision with a medium bird for the conditions close to the above mentioned is shown in Figure 6.
There is respectively good coincidence between the numerical prediction and the experimental results.
The resistance of the blades after the collision with a flock of the little birds has been also confirmed by the tests.
The impact of a big bird acts on several shrouded blades. Therefore, the demages of the each blade are approximately the same as it has been shown.

All the de
after the

References
1.Storage
tal inves
J.Aircraf
2.Nicolas
Paper pre
15-19 Jun
3.Shorr B
action.-
Helsinki,

All the demands on the saving of the engine operating stability after the bird ingestion are satisfied.

References

1.Storage A.P.,Nimmer R.P.,Ravenhall R. Analitical and experimental investigation of bird impact of fan and compressor blading.- J.Aircraft, 1984, v.21,No.7, p.520-527.
2.Nicolas D.J. The wide-chord fan blade - a Rolls-Royce first.- Paper presented at VIII ISABE conference, Cincinatti, Ohio, USA, 15-19 June 1987.
3.Shorr B.F. Design of aviation engine elements for bord strike action.- BSCE, Working papers, 20th Meeting, Pasilan Valtimo, Helsinki, 1990, p. 556-562.

FIGURE 1

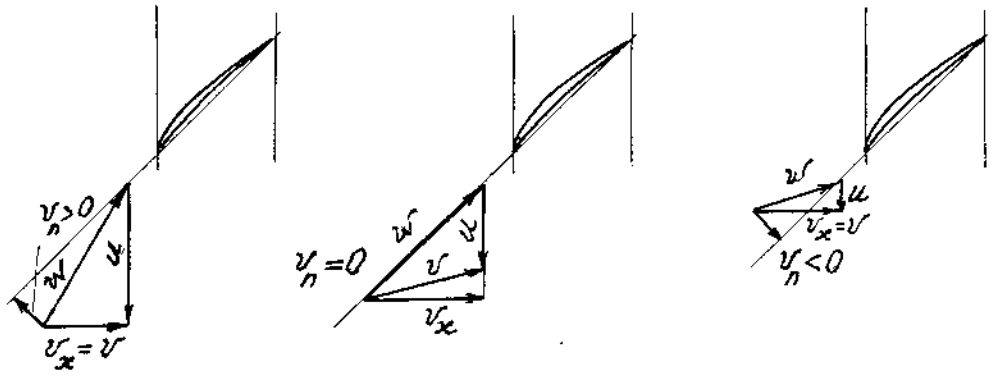


FIGURE 2

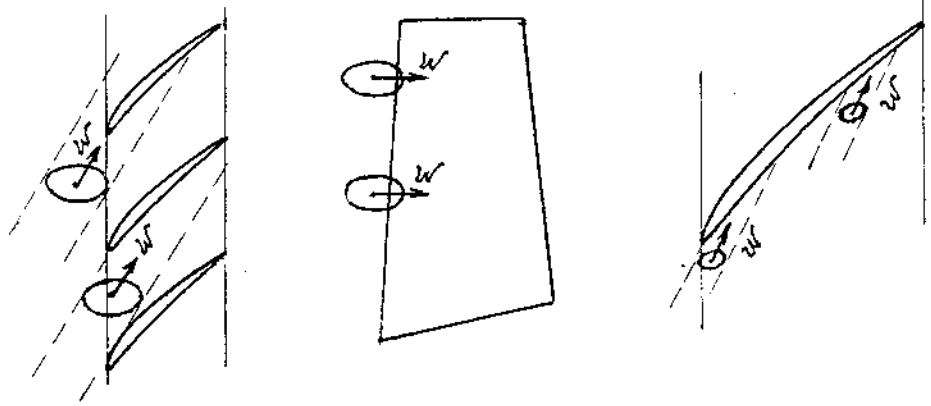
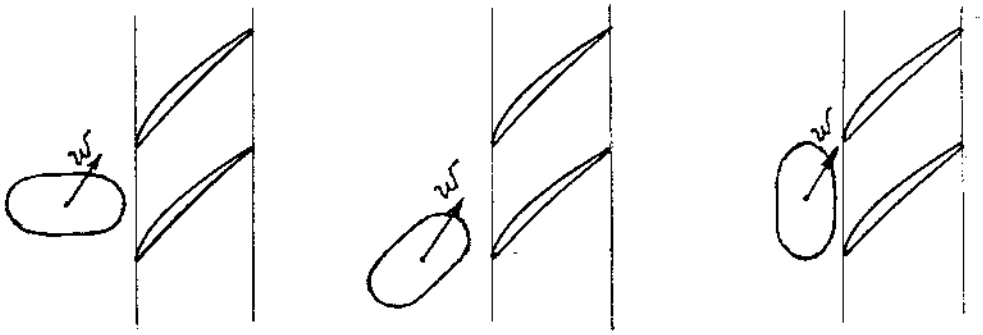


FIGURE 3



FIGURE

FIGURE 4

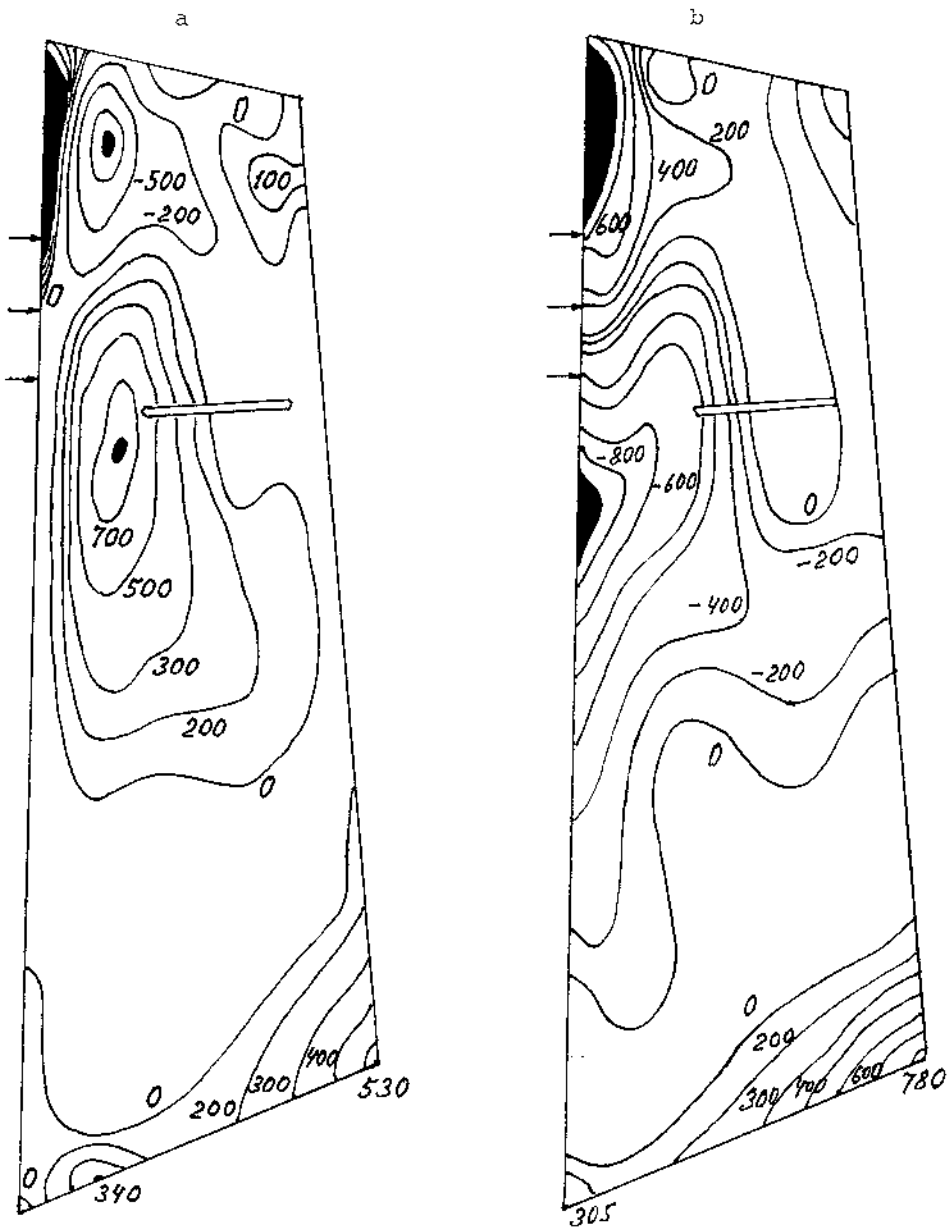

a
0
-500
100
-200
0
700
500
300
200
0
0
200
300
400
530
0
340
b
0
200
400
600
-800
600
0
-200
-400
-200
0
0
200
300
400
600
780
305

FIGURE 5

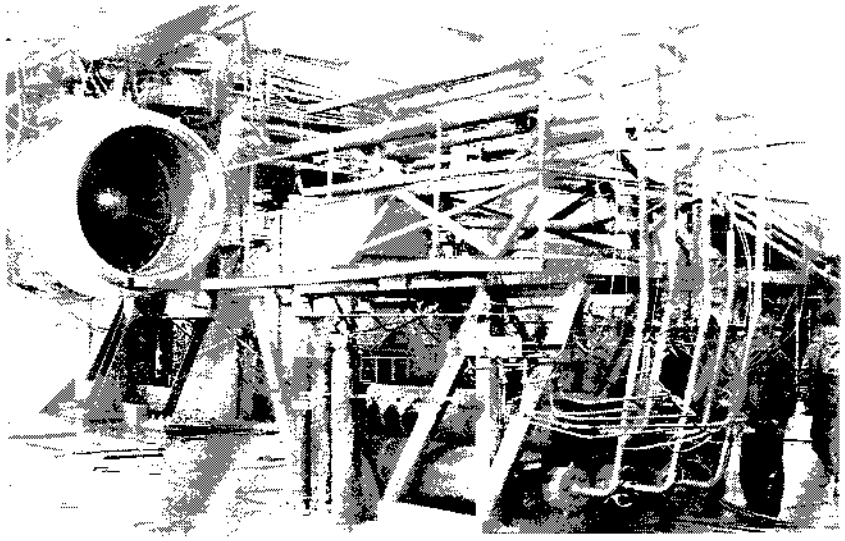


FIGURE 6