# ANALYSIS OF BLADE RESISTANCE TO BIRD STRIKE USING DIFFERENT COMPUTATION MODELS

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The paper refers to comparative analysis of influence that the use of different models exerts upon evaluation of blade resistance to bird impact.

The analysis has shown that most models give qualitatively similar patterns of impact but quantitative estimations can considerably miss. To confirm reliability of blade resistance valuation to bird impact it is necessary to compare calculation results with control test data and obtain some empirical correlation factors referred to specific calculation model and software package.

## 1. Introduction

Modern requirements on a safety of flights include conditions that bird strike do not result in such dangerous consequences as breakage of the fan blade with punching the engine casing, inadmissible falling of draft and so forth. Direct check of those conditions by birds shot in the engine using different birds mass, their various orientations and arrangement is extremely expensive. The volume and terms of check can be essentially reduced at use of preliminary computation analysis of modeling blade damage at collision with birds.

Generally, for computation modeling of fan blade damage from bird's impact, 3D geometry and physically nonlinear statement of transient problems, and also elastic - plastic model of a blade material should be used. As the specified statement of the problem demands very great expenses of machine time even at use of modern high-speed computers, the most calculations are carried out in the simplified approach: without taking into accounts a pliability of a disk, for an elastic material with the approached recalculation of plastic deformations, without accounting of interaction with neighboring blades, etc. In view of uncertainty of a configuration of a bird body and impossibility of its exact description, the elementary geometrical forms of models are used, e.g., cylinder with plate or semispherical edges, parallelepiped, ellipsoid.

The most important mining refers to description of mechanical properties of a bird body. A strong heterogeneous and anisotropic bird body is simulated by some isotropic body with equivalent mean density and stiffness. A lot of such models are offered in the literature; however their reliability usually is not discussed.

In the paper, results of comparative analysis of influence which use of some models of a bird body material renders upon estimation of blade strike resistance are considered.

## 2. Calculated models of a bird body material

The model of an equivalent bird body material owes likely describe conditions of transfer an impulse and energy of bird movement to the blade during the impact, and also the blade deformation and destruction.

Most frequently the following mechanical models of a bird material are used:

a) elastic - plastic deformable body with low value of a yield point and small hardening;
b) hyperelastic (rubber-like) body that can be strongly elastically deformed without residual deformations;
c) jelly-like body, spreading over the blade at impact;
d) an area occupied with a liquid body, resisting only to compression; the body breaks up to separate particles at occurrence of tension;
e) an area occupied with particles of a solid body which completely transmit their impulse to blade at impact; so the body is collapsed under impulse loading; this approach corresponds to condition of inelastic impact and is justified by some supervision showing, that particles of a bird do not jump aside from blade after impact.

Basic difference of last ("impulse") model from the others consists that only the main characteristic of impact - an impulse transfer is used in it. Therefore, a need to involve any hypothetical representations about mechanical properties of a material, which rather remotely approximate a body of a real bird, disappears.

Earlier, authors successfully used the model e) in [1-2]. An "impulse" model f), analogous to e), is treated in Dytran package.

Average material density of a bird model is usually accepted close to water density. On the data [3], the average density of the bird body decreases a little with increase in its mass.

For the comparative analysis of influence of the bird body model upon estimation of blade strike resistance, the investigation was carried out in two stages: for impact on an equivalent plate and on real blade of a fan.

## 3. Impact of a bird model upon a plate

The calculations were carried out for the following data:

- A small bird in the form of a cube with the sides of 30mm and the mass of 27g strikes on a thin console titanic plate of the size of 300×100×10 mm.
- The bird runs against the top part of the plate with a speed of 100mps at an angle of 30 degrees to its plane.

An average dynamic pressure was 7.5 N/mm$^2$ and minimal contact duration at impact was $3{\cdot}10^{-4}$s. The model of a plate with

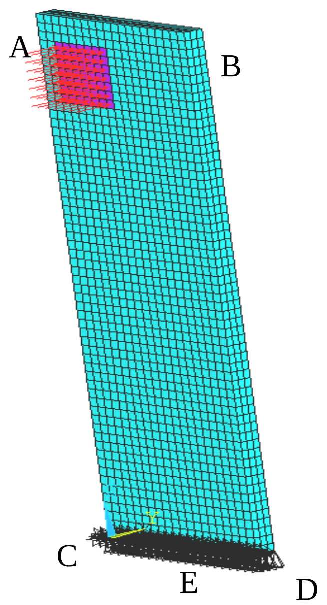


Fig.1. Model of the plate

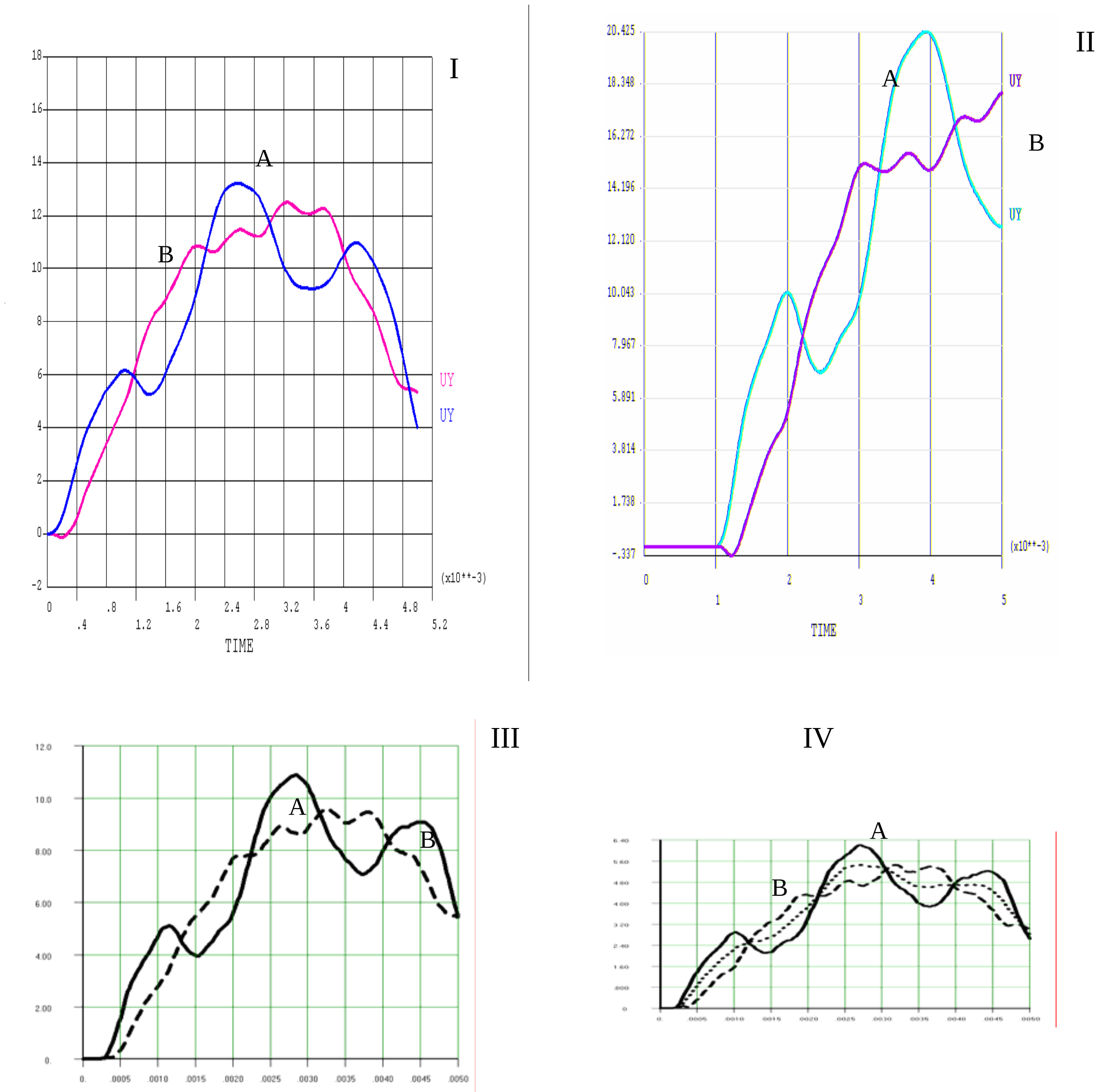


Fig.2. Displacement (mm) versus time (s) in characteristic points of a plate for different bird body models: I – completely destroyed, - e); II – hyper-elastic, - b); III – "impuls",- f) ; IV.-.jelly-like, - c)

the allocated loading area at impact and designations of characteristic points is shown in Figure 1.

Four models were considered: a hyperelastic body - b) using ANSYS package, jelly-like body - c) and "impulse" model – f) using Dytran package, and solid, completely collapsing body - e) using author's program.

Calculation results of displacement and equivalent stress vs time in characteristic points of a plate for the all material models are resulted in Figure 2 and 3, respectively.

The qualitative process pattern is described by all models enough close but quantitative evaluations show significant disagreement. The model of a hyper-elastic body b) gives the most "rigid" pattern of process, model of jelly-like body c) – the "softest" one, and calculation results referred to model of a solid, completely collapsing body e) and a modal of "impulse" loading f) settle down between corresponding results for models b) and c).

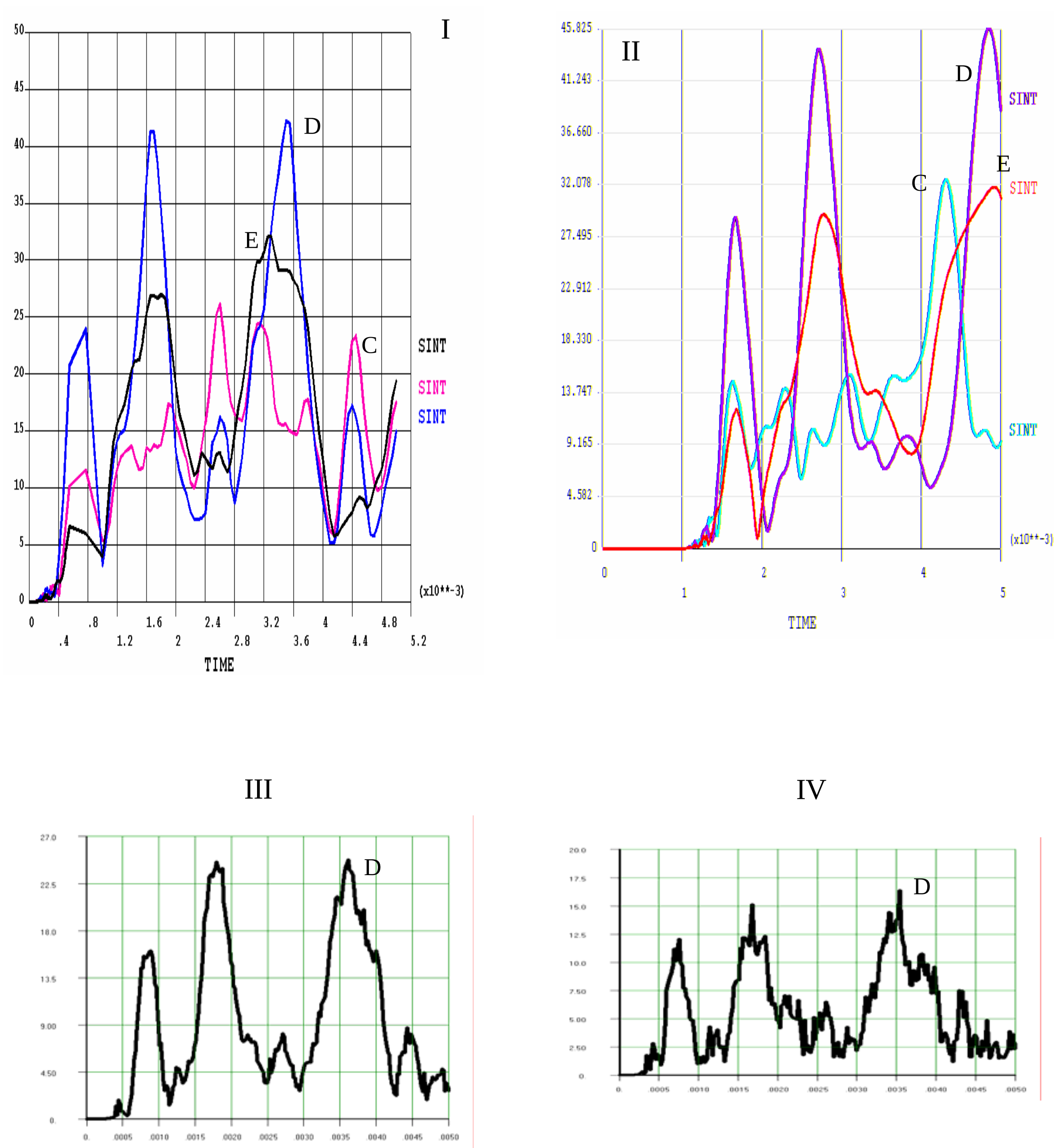


Fig.3. Equivalent stresses (kgf/mm$^2$) versus time (s) in characteristic points of a plate for different bird body models: I – completely/destroyed, - e); II – hyper-elastic, - b); III – “impuls”,- f); IV – jelly-like, - c)

## 4. Impact of a bird model upon a fan blade with an antivibrating shroud

A large bird with mass of 1.8kg strikes on overshroud part of a fan blade airfoil. A finite-element model of the blade is shown in Figure 4. Under the impact, the bird is cut by neighboring blades to two fragments. Axial speed of a bird is equal to the aircraft take-off speed about 90mps.

Calculations were carried out using two model configurations of a bird: as the cylinder with the relation of length to diameter equal to twain and a parallelepiped with the same relation of length to the basis sides. Two models of a bird body were considered: jelly-like c), spreading on the blade airfoil, and a solid, completely collapsing body e).

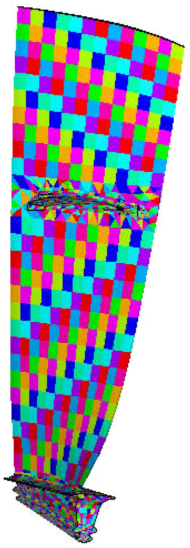

Fig.4. Blade finite-element model

Calculation of impact for jelly-like model was carried out on the base of the MSC-Dytran software package. A mixed statement of the problem including Lagrange grid for the blade model and Euler grid for the description of the bird model movement and destruction from collision with the blade was used.

In Figure 5 computation patterns of the bird spreading over the blade airfoil during the impact for different time instants are presented. (Dr. S.A.Sergievsky took part in the problem setting and calculations). Only upper part of the blade is shown.

Calculation of impact for solid, completely collapsing body (at impulse loading) was carried out with use of author's original algorithm.

All calculations were carried out in physically and geometry nonlinear statement, taking into account large displacements and elastic - plastic deformations of rotating blades at impact of one or several birds.

Calculated distribution of displacements and equivalent stresses over the blade pressure face at the impact termination for the model c) are shown in Figures 6a and 6b, respectively. Maximal stresses exceeding a material yield point arise in a zone of stress concentration at the domain of transition from the shroud to blade airfoil. Calculations for the model e) give qualitatively similar pattern.

Efficiency of models was estimated by comparison of computation results to the experimental pattern of blade damage at shot of the bird of the mentioned above mass, earlier executed by the engine's maker.

A maximal value of equivalent plastic deformation $\varepsilon_{cr}$ has been accepted as criterion of blade damage. Due to the specified criterion, a crack beginning was being expected at a forward edge of the overshroud part of the blade in a zone where the shroud passes in the airfoil.

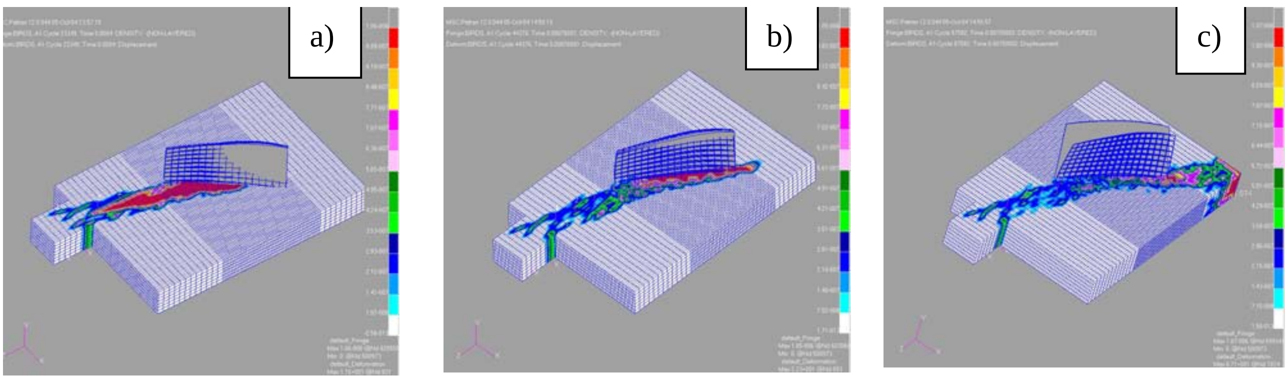


Fig.5.Time instants: a) t=0.0004s, b) t=0.0008s, c) t=0.015s

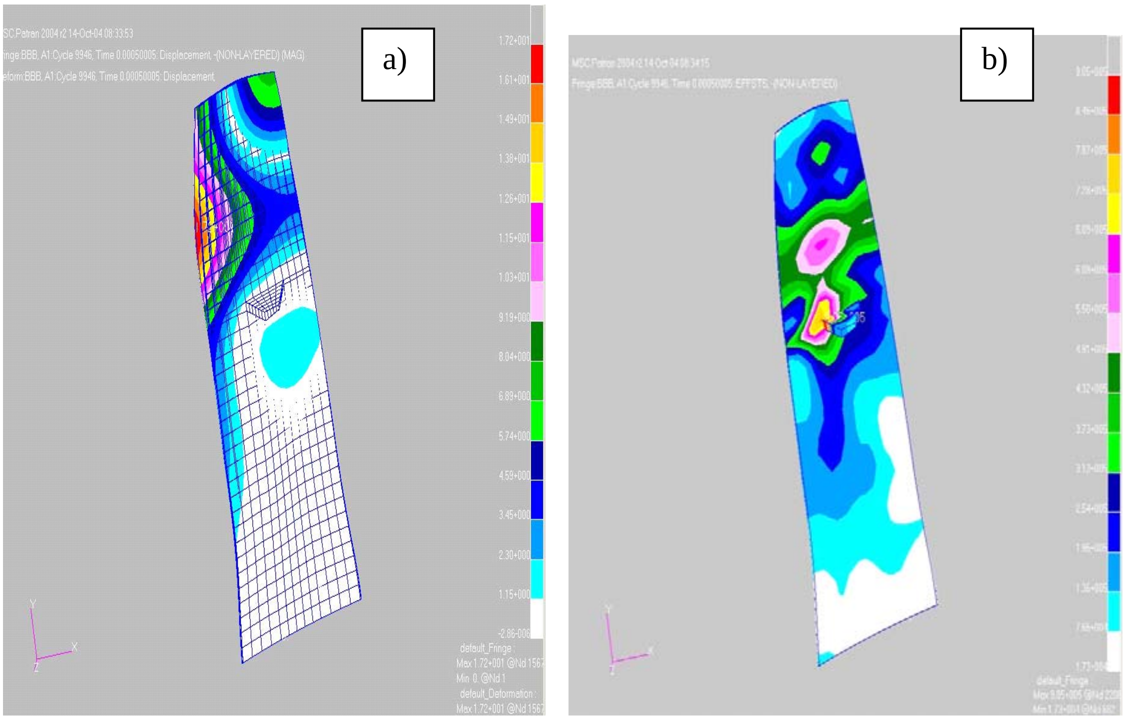


Fig.6. Displacements – a) and strsses – b) at the impact termination for the large bird

Predicted character of the blade damage has well coincided with an experimental picture of destruction. However, the values $\varepsilon_{cr}$ corresponding to the moment of the damage beginning are found various for each of considered model of a material and loading condition.

For more rigid model e) the value $\varepsilon_{cr}$ has been found as $\varepsilon_{cr}$ =7-8 % that is close enough to relative elongation of the blade material at a static tension. For softer model c) the analogous value appeared equal to $\varepsilon_{cr}$ =2-3 %.

## 5. Conclusion

At calculations of impact of a bird on a modeling plate and a real fan blade the considered various models of a bird body material have led to qualitatively close patterns of shock dynamic process development and occurrence of damages.

Quantitative magnitude of limiting plastic deformation $\varepsilon_{cr}$ at which there comes blade damage, for different models of a material and loading turns out various and can be found by comparison of calculations to experimental data under control birds shot into the operating engine.

The values $\varepsilon_{cr}$ obtained in such a way can be used for forecasting resistance of the blades of similar design to collision with birds of different mass in various operation conditions.

## References

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