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NUMERICAL SIMULATION TO STUDY THE INFLUENCE OF THE THICKNESS OF CANOPY AT A BIRD STRIKE

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Keywords: FEM, canopy, bird strike

1. Introduction

A canopy is a key component to directly ensure safety during flight. It should provide complete air tightness, good visibility and protection for a pilot against any impact of any small body, e.g. a bird. Aeroplane canopies can easily get damaged in the course of utilisation. Typical damages are cracks and scratches; also, loss of transparency due to surface micro-cracks. These damages can be removed. A repair procedure enables most of the scratches and micro-cracks to be removed; the canopy gets, however, thinner. Where is then a safety limit in the repair process? [Leski 2001]

This paper is intended to present some considerations on how to determine the relationship between thickness of an aircraft canopy and stress tension during a collision with a bird. Bird strikes prove to be a considerable hazard to flight safety. A reduction in the aircarft's canopy thickness in the course of repairs should not affect, however, the effects of a bird impact.

2. Numerical Model

A numerical finite element model was built using the MSC.Patran software. Because technical documentation was not available, taking measurements of the canopy's geometry proved to be a real need. To build a geometrical model of a canopy, reverse engineering method was applied. The canopy geometry was scanned using a manually operated 3D Microscribe scanner. Fig. 1 shows how the measurements of the canopy's geometry were taken.

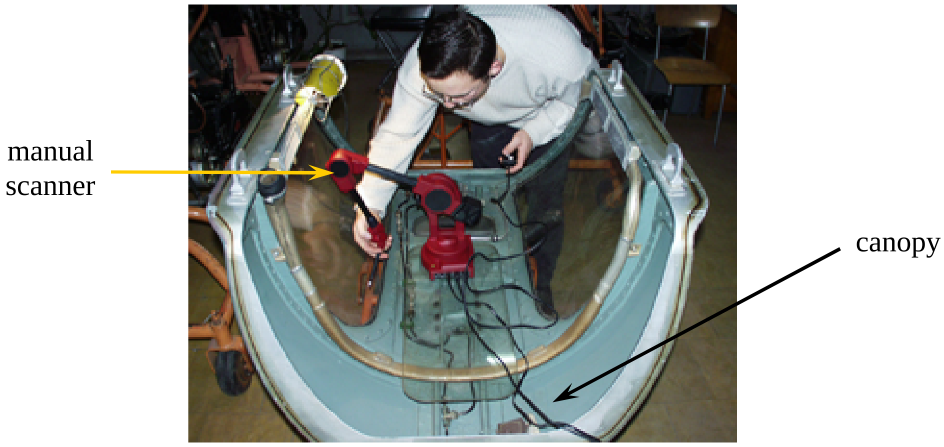

Figure 1. Measurements of the canopy's shape

The process of scanning consisted in loading the 3-D co-ordinates of points on the canopy surface into the computer memory. The number of scanned points remains unlimited. In the case the canopy shape is rather simple, e.g. the Su-22 canopy, feeding the co-ordinates of approximately 5000 points proves sufficient. Canopies of more complicated geometry, e.g. those of the MiG-29, need many more points to be fed. The measurements taken were then imported into the MSC.Patran software with the IGS format engaged.
While generating a model, it appeared that in the case of more complicated shapes of canopies there was a real need to take some additional measurements of the glass thickness. Those were taken using the ultrasonic techniques.
Numerical models were built using the solid finite elements. Shell elements cannot be easily used because there is no constant thickness of the material throughout the canopy structure. We are interested in the effects of reduction in the canopy thickness of approximately 1 mm order, or less. To obtain the relationship between a stress tensor and a thickness loss, it is necessary to build several numerical models. Each model takes different thickness of glass into account. Fig. 2 shows the FEM-generated model of the Su-22's canopy.

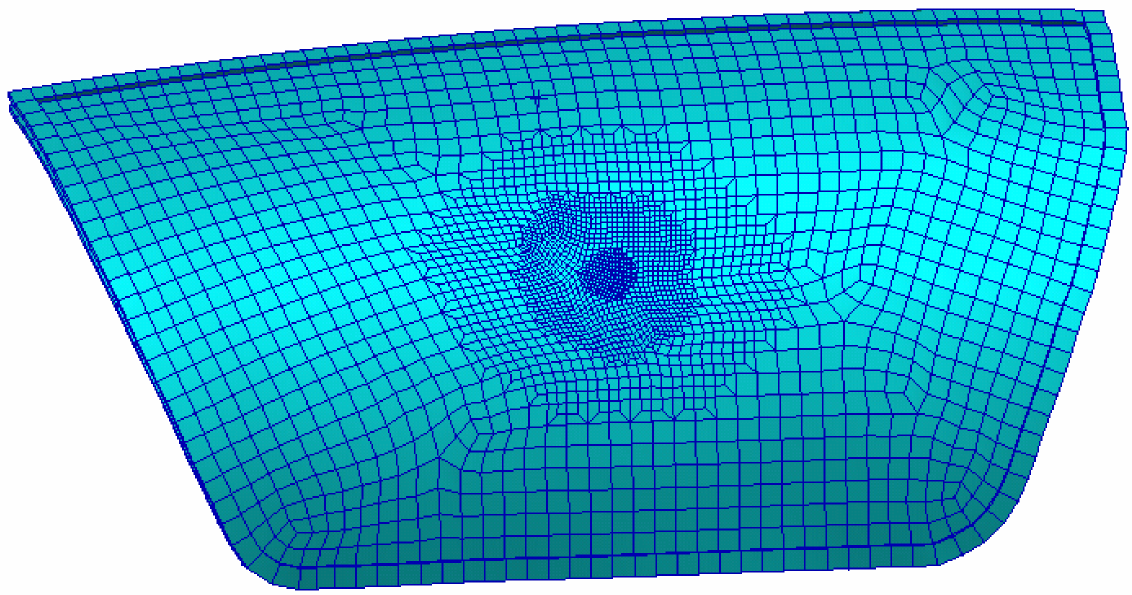

Figure 2. The FEM model

The finite element mesh was generated in such a way as to have the smallest elements within the simulated area of the collision with a bird. The technique improves accuracy of the FEM calculations.

3. Materials properties and boundary conditions

3.1 Materials properties

Materials tests were carried out to obtain materials properties. Samples of glass come from the Su-22 canopy. [Baraniecki and Leski 2001] The following properties were determined in the course of these tests: the material density, the stress-strain curves $\sigma(\varepsilon)$, the elastic modulus, the Poisson ratio. The tests were carried out for the temperature range $-40^0C<t<+60^0C$. Fig. 3 shows exemplary stress-strain curves $\sigma(\varepsilon)$ determined in the course of the materials tests.

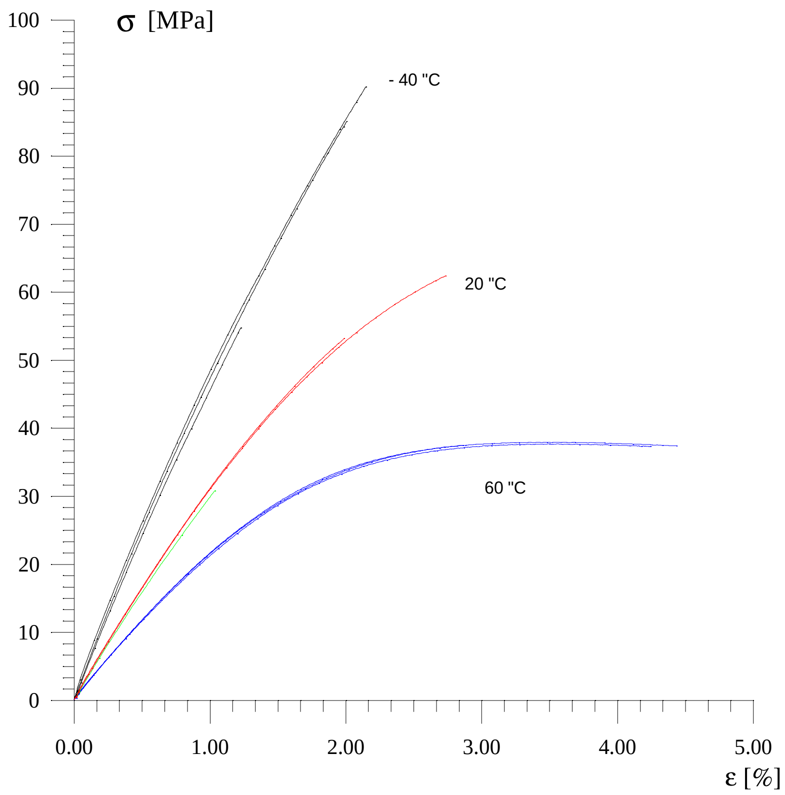

Figure 3. Results of materials tests

3.2 Boundary conditions

The way of fixing a real glass panel to the canopy frame is rather complicated. It enables only slight movement of the glass against the canopy frame, but still provides the required air tightness. While generating the FEM model, complete modelling of the mechanism of fixing the glass fairing was neglected. An actual fixing system was reduced solely to the sealing layer fastened to the glass fairing along one edge while the other edge of the sealing remained restrained (displacement equals zero). Fig. 4 illustrates the fact.

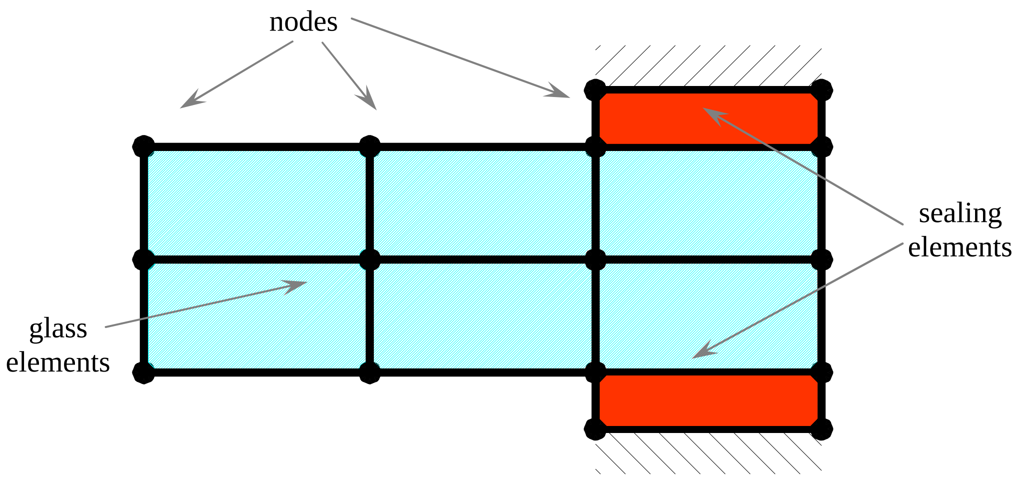

Figure 4. Fix of bounder

3.3 A pressure during bird strike

The problem of a bird strike against the aircraft canopy has been paid much attention and careful analytical handling at many research centres. Two approaches to the modelling of the phenomenon are possible. The first one consists in modelling the canopy and the bird, whereas the second one allows the bird effect upon the canopy to be replaced with the pressure against it. Great difficulty in applying the first approach consists in both defining the phenomenon of two bodies in contact, and describing mechanical properties of the bird's body. The other approach is divested of these problems; however, there is a problem of the form the function of pressure takes. In the past, some experiments used to be conducted to determine distribution of pressure affecting the canopy's glass surface. The experiments were carried out for different rates of bird's movement, different masses of birds, and different angles of impact [Ito 1976, Sanders 1973].

The following form of the function of pressure has been assumed on the grounds of the literature data:

$$P(r,t) = P(r)P(t) \tag{1}$$

Fig. 5 illustrates the course of changes of the P(t) function.

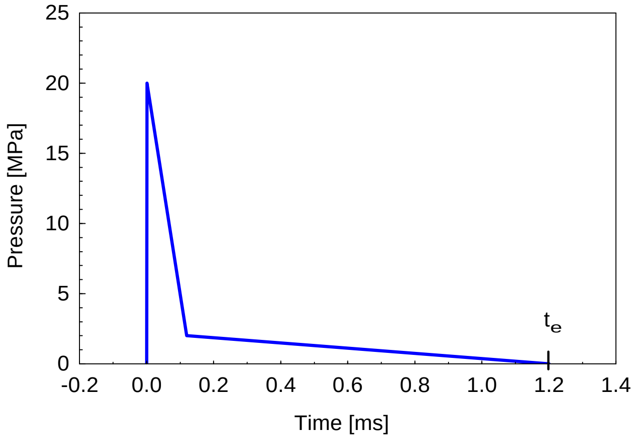

Figure 5. Pressure against time, the P(t) function

Fig. 6 shows the P(r) function, where r - distance to the central point.

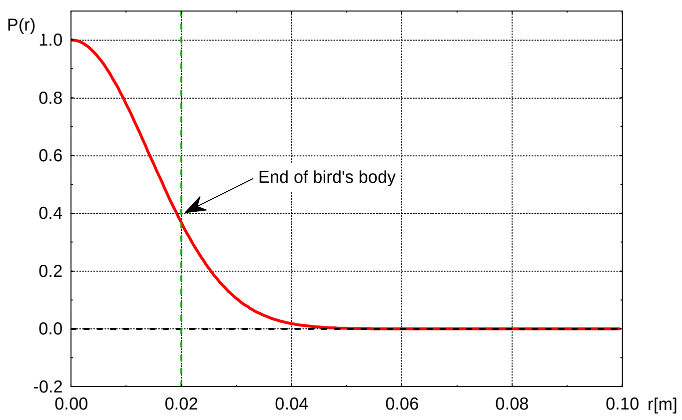

Figure 6. Pressure distribution on the glass fairing's surface

The assumed values correspond to a small bird's (8 cm long, of 2 cm radius) impact - at the angle of 30^0 - against the canopy of an aircraft flying at the velocity of 500 km/h.

4. Findings

Calculations were made using the MSC.Nastran and the MSC.Mark software (the Implicit methods). Dynamic analyses were conducted for times 0<t<120% t_e. Calculations were made for seven models of different glass thickness. What was tested was the effect of the glass thickness of max. 2 mm. The solutions arrived at didn't differ in quality.

Fig. 7 shows the dependence of the maximum material effort (Mises) within the canopy upon the changes in glass thickness. The interpolation formula refers to the parabola (red solid line).

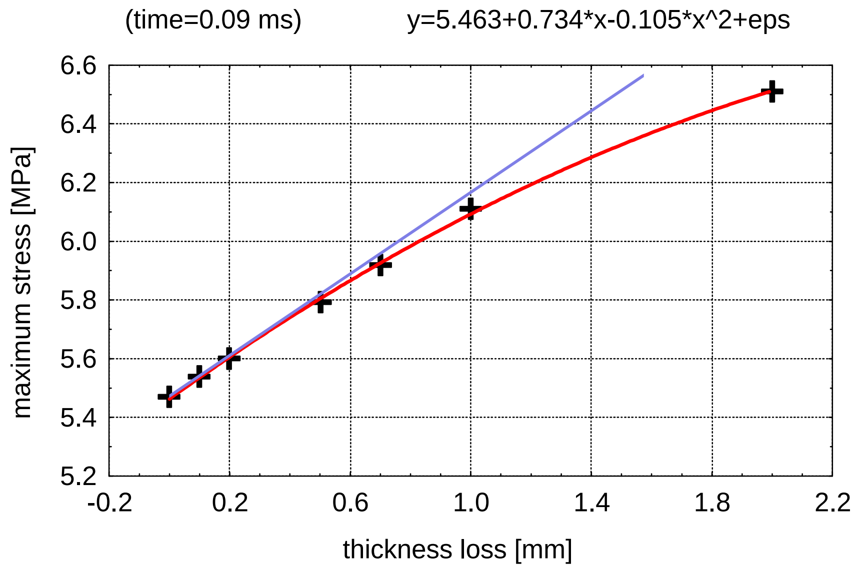

Figure 7. Maximum material effort (Mises) against changes in glass thickness

Fig. 8 shows displacement of the central point at the impact. Results of calculations for three models taking account of different degrees of reduction in glass thickness.

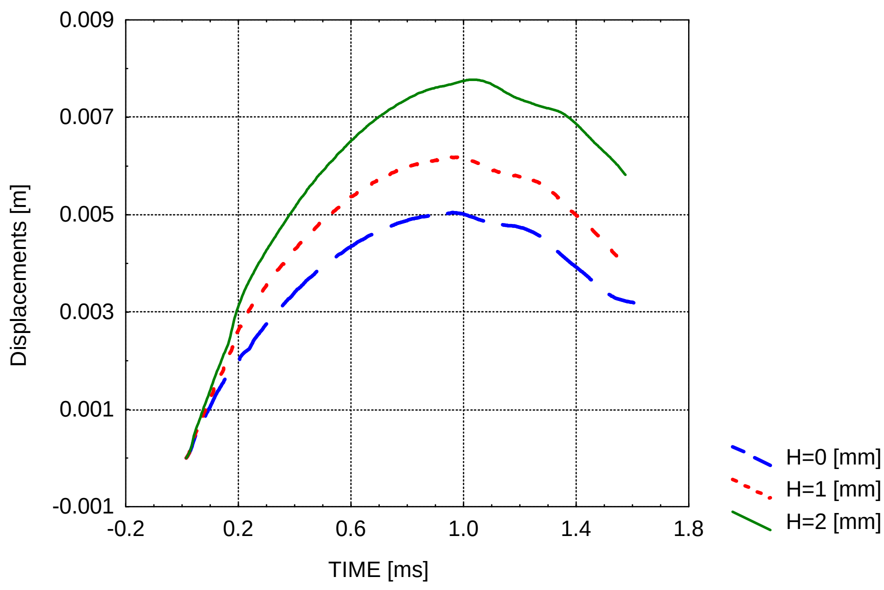

Figure 8. The central point displacement

Fig. 9 illustrates courses of stress in the central point as calculated for both a model with no changes in glass thickness (H=0 mm) and a model with the reduced thickness of glass (H=2 mm).

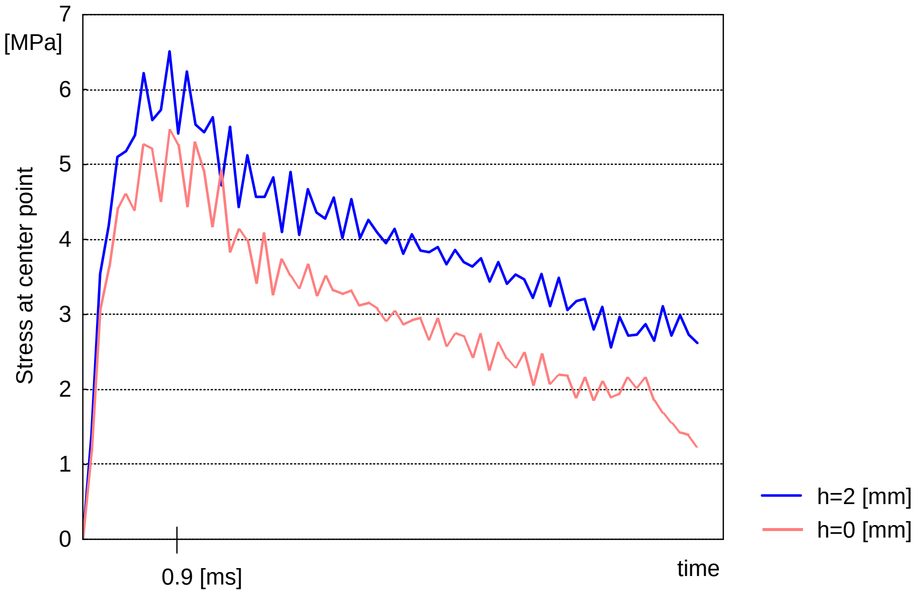

Figure 9. Material effort (Mises) in the central point

5. Conclusions

The level of stress found corresponds to the assumed airspeed of an aircraft and the size of a bird, both being factors decisive to the effects of impact. The computer-based simulation revealed that the relationship between the loss in glass thickness and the maximum stress (Fig. 7) for only slight changes in the thickness of the fairing glass proved to be nearly linear. Since there are no generally accepted safety rates that describe the aircraft glass fairing, it is difficult to determine the limit of allowable changes in the glass thickness. If we assume that the level of stresses within the glass at the moment of a bird strike is the safety rate, then we have proved that safety changes follow a linear pattern along with the reduction in glass thickness. In the case of only slight changes in the thickness of glass, any change of 0.1 mm results in the stress increase of 1%. Most of operation-induced damages can be removed (repaired) by grinding which reduces the thickness by 0.3 - 0.5 mm, usually. The safety rate will therefore change by less than 5%. Hence, with high cost of a new canopy in view, it seems quite reasonable to prolong service life of a canopy already in use by means of simply repairing it. From the viewpoint of the above-presented findings, the rules and regulations in force up to the present turn out to be groundless as they mention the number and locations of failures/damages instead of the thickness of glass in the damaged areas as a criterion of permitting the canopy to be repaired.

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