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Technical Note No.101

Subject: **Aircraft wing cutting steel post**

The wing of the Tu-154M airliner was modeled using the available external geometry, known material properties and the approximate design loads like those for the sister aircraft, Boeing 727-200. According to the official report on this Smolensk disaster, the point of impact was 10.8 m from the centerline of the fuselage.

The post model has 300 mm diameter, 8 mm wall thickness, is 12 m tall and is impacted at mid-height. According to the official reports, the fall of the aircraft was caused by a birch-tree cutting through the wing. The likely dimensions of the "suspect birch" are quoted below and the resulting shear strength is estimated to be about one-third that of the described post.

The view of the model is given in Fig.1. The outer (detachable) wing is modeled in detail, the inner wing is coarsely approximated as no impact load is directly involved there. The thin lines represent sizeable tubular members connecting the wing with the fuselage axis. The purpose of modeling these additional elements is to be able to approximate the inertia of the whole aircraft.

Effects of the collision is illustrated in Figs. 2-5. The change of forward velocity of the craft as well as that of the yaw were very small, almost imperceptible. The lift and the drag forces are applied to the wing during the event.

COMPARISON OF THE SHEAR STRENGTHS

Steel pole:
D = 300 mm, h = 8 mm, therefore section area A_1 = 7339 mm^2
Construction steel, F_y = 350 MPa, F_u = 430 MPa, e = 16%.
Shear strength, $F_{su} = 0.6\ F_u$ = 258 MPa
Section strength, single shear: $\mathbf{P_1} = A_1 F_{su}$ = 7339x258 = 1893.4 kN

Suspect birch:
D = 400 mm, therefore A_2 = 125,660 mm^2
Shear strength : F_{su} = 5 MPa
Section strength, single shear: $\mathbf{P_2} = A_2\ F_{su}$ = 125,660 x 5 = 628.3 kN
(Upper values were used here, but not the absolute maxima. It would be unreasonable for these circumstances to do otherwise.)

Strength ratio:
$\mathbf{P_1/P_2}$ = 1893.4/628.3 = **3.01**

The mass density of the pole is increased above that of steel, so that its mass per unit length is the same as for suspect birch. (Specific mass of the latter was assumed as 700 kg/m^3.)

FURTHER DETAILS
The material properties of the aluminum alloys used were
2024-T3: F_y = 293 MPa, F_u = 448 MPa and e = 16%
7075-T6: F_y = 493 MPa, F_u = 545 MPa and e = 9%   (Stringers only)

which are the averages of published data and which are similar to the original Russian alloys involved.

Structural properties near impact point: Main skin: 5 mm, front longeron wall: 4 mm, nose skin: 3 mm and rib 3 mm. The stringers are thick-wall I-beams which, in this region, have the section of 1010 mm^2. As there are 3 longerons, 6 of the stringers are used as caps.

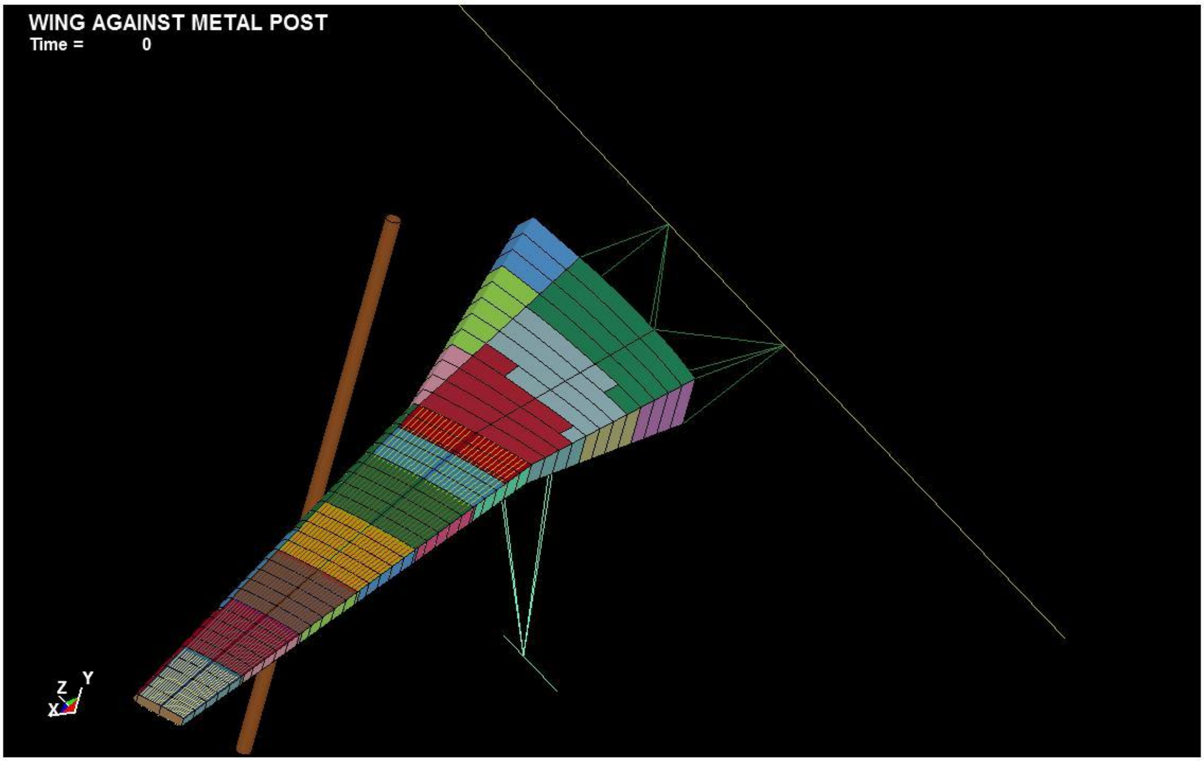

Fig.1. General view of the wing model. The long line disappearing near the top depicts the fuselage axis. The lines below the wing model the undercarriage (mostly for inertia). The post is at right angles to the wing axis.

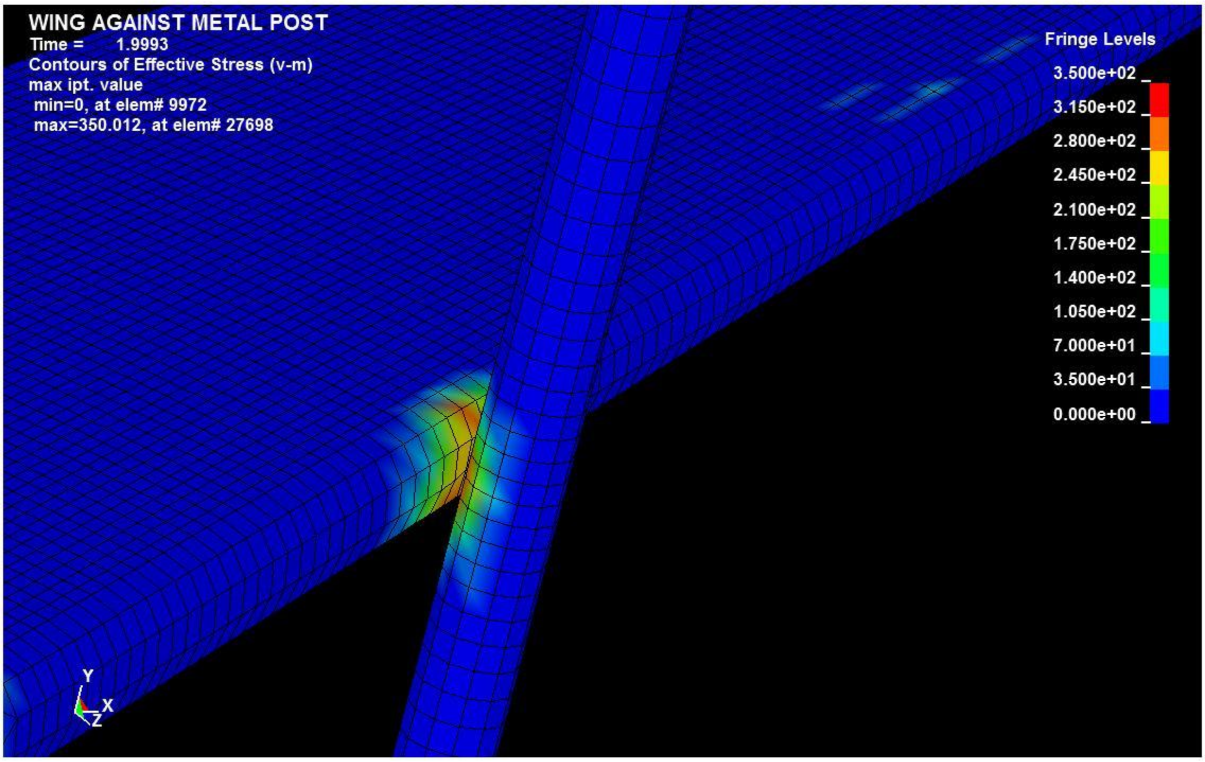

Fig.2. The initial contact of the wing and the pole. The relative speed of the two may be thought of as having two components: Across and along the leading edge. This will cause the damaged area of the nose to widen as the motion progresses.

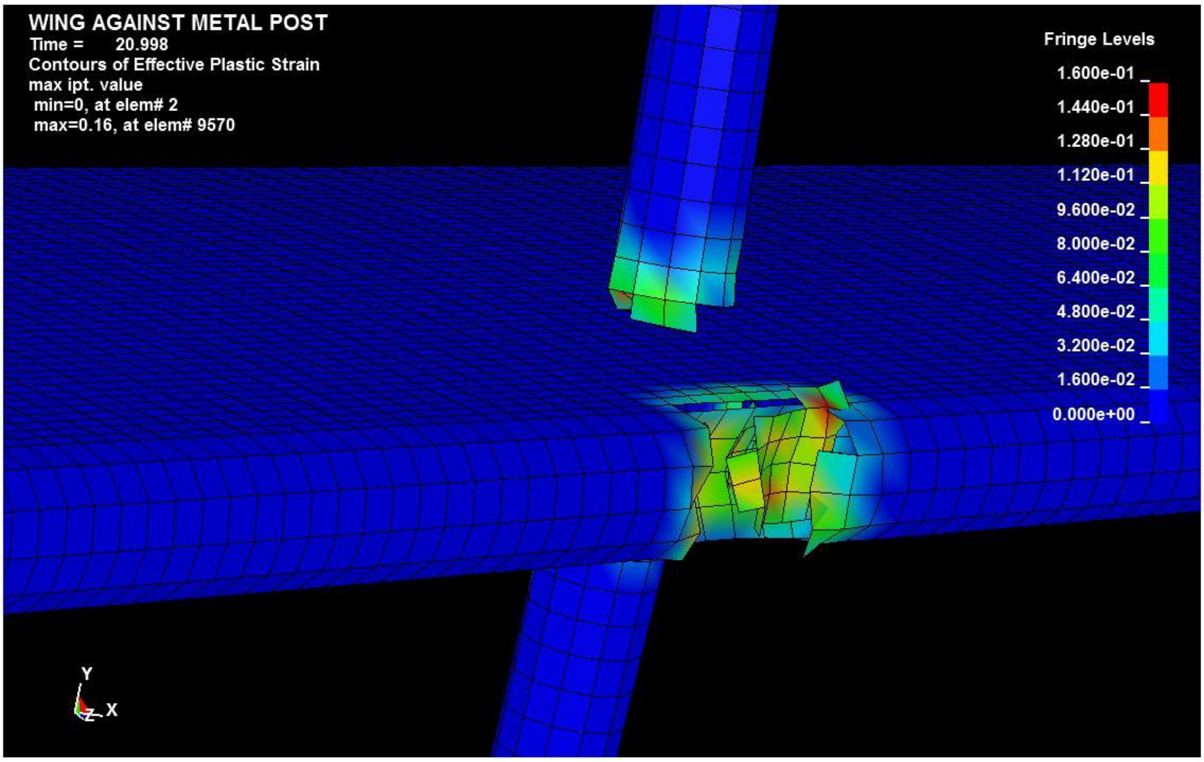

Fig.3. The pole breaks above and below the wing. The short segment between the two wing surfaces becomes lodged in the wing.

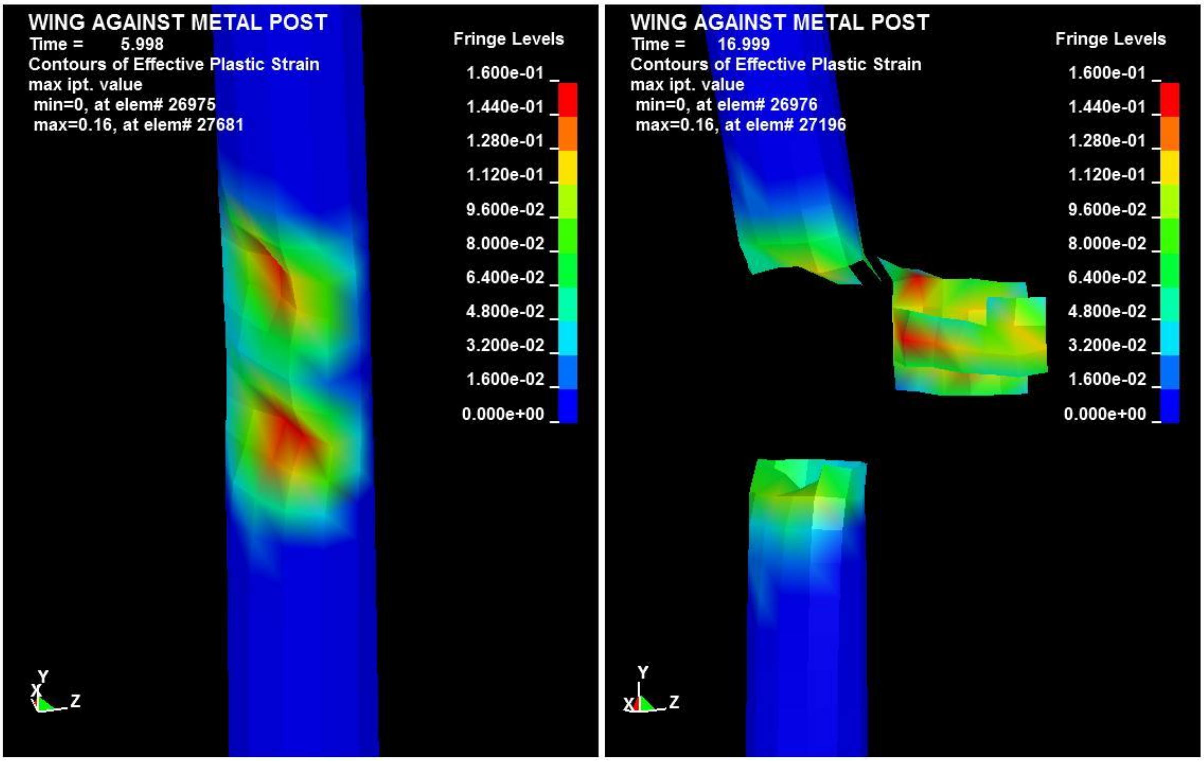

Fig.4. On the left the post is shown just after the initial contact. On the right the segment of the post removed by the wing is depicted.

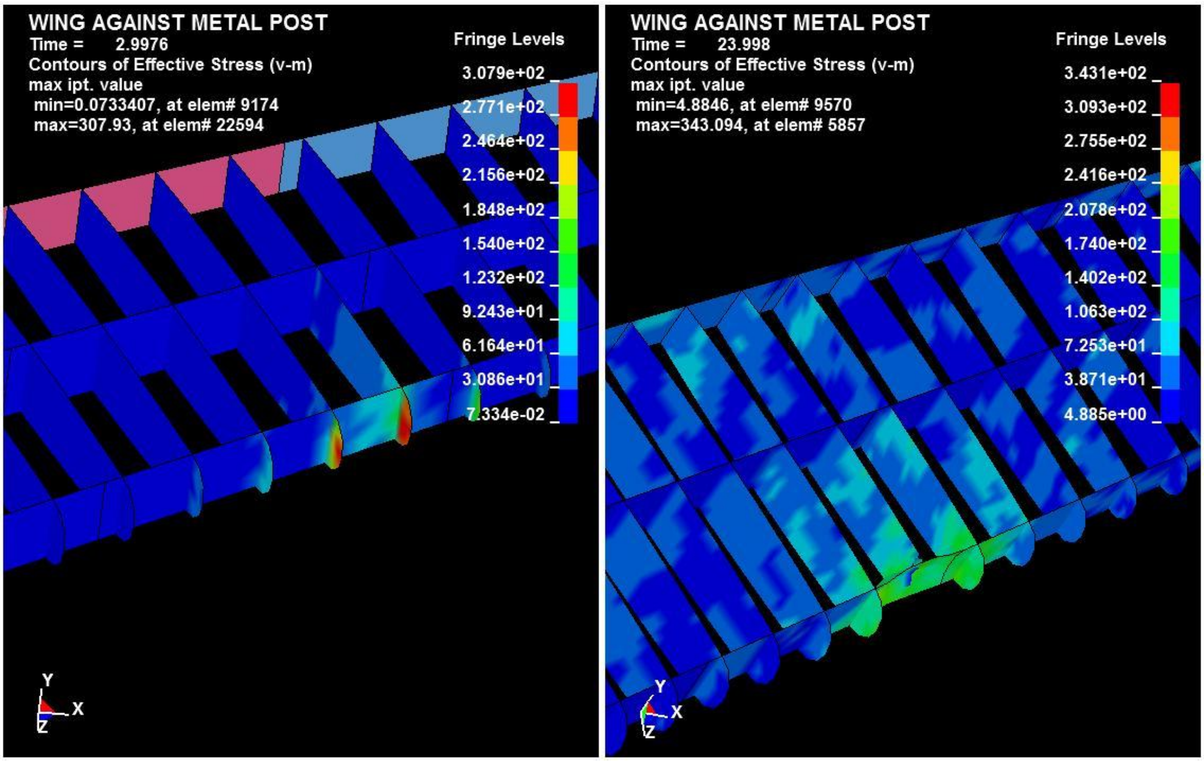

Fig.5. The extent of damage suffered by the wing is illustrated by comparing the state just after the first contact (left) and after breaking of the post (right). The nose rib is crushed and a short segment of the front longeron is bent-in.

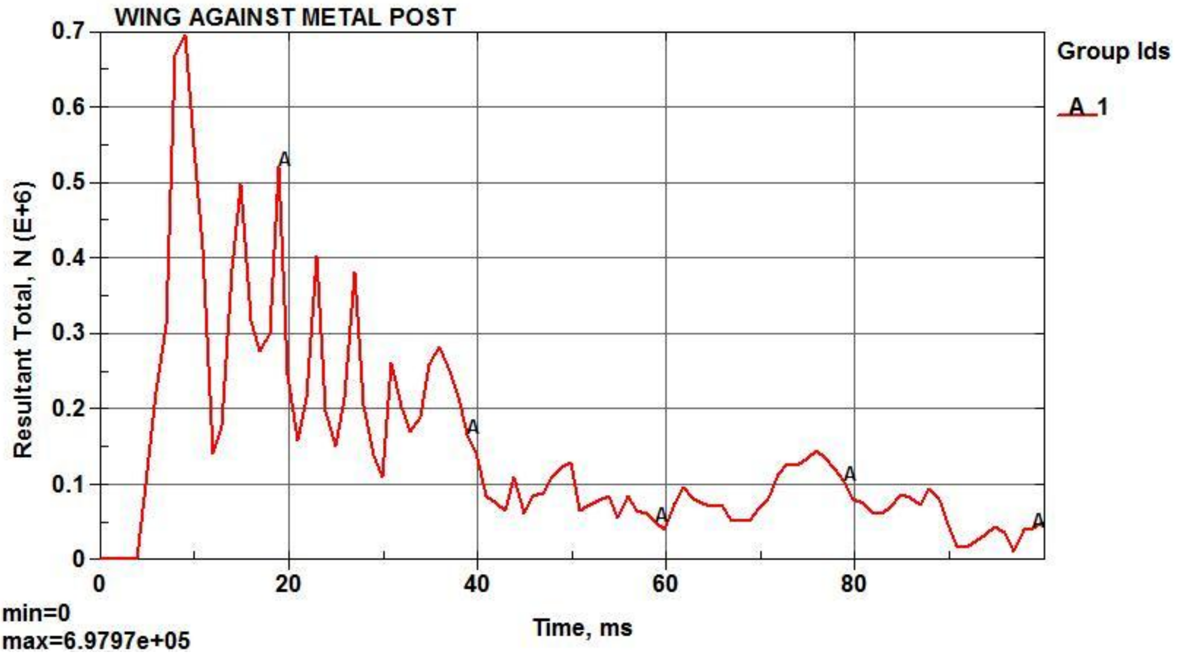

Fig.6. The resultant reaction force at the base of the post. Upon the impact, the post begins to vibrate, which shows itself in the magnitude of the base reaction.

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