**Tu-154: The Coup or Guerrilla**

*(Zamach, czy partyzantka)*

*Abstract.* The wrong guidance is considered as the main cause of the Polish Tu-154M crash on 10th April 2010 in Smolensk, USSR. At the distance of 2 km to destiny, the crew obtained the information that their course and path are correct. However 10 s later, the plane crashed at the point located ~1050 m before the runway and 43 m aside it, in a hostile woody area. These facts indicate on the navigation/communications faults and/or the negligence of the airfield duty service. The final overturn of the plane is the critical point in this crash. It is analyzed in detail via Newtonian inertial model. In conclusion the author claims that the airfield Severnyj should be closed that day because of the fatal weather and low standard of the control instruments/duty service.

The key words: Tu-154M crash, navigation/communications faults, Newtonian model, simulation of the overturn

1. The essential data of Tu-154M

Length 48 m; width 38 m; cabin 3.8 m, total mass 80 t; engine– jet, speed 230 km/h, carry- 96 prs.

![Fig. 1. The front view of the Polish military jet Tu-145M in the starting phase](image)

2. The passengers, the airfield and the process of landing

PLF101 took off from Warsaw at 9.27 Smolensk time after a delay of 27 minutes [1]. The cockpit crew consisted of pilot Captain Arkadiusz Protasiuk, co-pilot Major Robert Grzywna, navigator Lieutenant Ziętek and flight engineer WO2 Andrzej Michalak. Protasiuk has landed at Smolensk 3 days earlier in the same Tu-154M. There were on the board the President of Poland and his Chief Dignitaries, 89 persons plus 7 of crew.

As the aircraft approached Smolensk airport the conditions had rapidly deteriorated. The visibility in daylight reached merely 200 m! So, the crew during landing used the autopilot. At 2 km to the runway they obtained the information (UTC 10:40:52): *You are in the curse and path!* The plain in that moment was merely 39 m over the runway level, Fig.2. Taking the rate of fall down 6 m/s, the speed 73 m/s and the distance of 2 km one obtains the altitude:

\[(2000/73) \times 6 = 164 \text{ m}!\]

This is the fault of ~400%! The crash was then highly probable, but still moderate, if the direction of flight was proper. This, however, was 109 left the runway and caused a collision with a tree.
The collision took place 43 m apart the runway and the thickness of tree was ~40 cm, see blue star 43 m, Fig.2. Next, 625 m further the plane has overturned itself and crashed (see blue star 150 m). As we can see the main physical reason of the crash was too low altitude and the directional error of about 10° left the runway!

3. The state before the crash

The Smolensk North Airfield does not have the typical control tower and its infrastructure and the communications/navigations systems are outdated and do not meet the standards, e.g. the accuracy of the directional radar was merely ±10%, the terrain in vicinity of the airfield was too much uneven (±30 m) and covered by shrubberies and trees reaching 10 m [1-2]. Moreover, in the critical day many airfield lamps had the bulbs blown through, what, in dense fog, increased the danger of an accident. So, the airfield should be closed and the Russia responds for it.

The crew of the plane did not use fluently the Russian language, at least not all the members. The duty personnel at the guidance point was also not enough acquainted with the measuring instruments or these instruments were out of order. For example, the crew in approaching the airfield obtains the information: altitude 500 m and the course correct, while this altitude was only 200 m and the curse 10° left the runway. The evidence is on the black box.

If the duty service in the airfield point was at high level (personnel and instruments) the crash could be avoided. Also, if the crew in plane was better harmonious and the captain knew that barometric altimeter is the adequate instrument for the diversified terrain, the crash may be also avoided or at least the number of victims could be much less.

4. The explosive versions of the crash

The explosive versions are convincing from the viewpoint of the character of crash and losses. There is, however, the question: who and when put such material on the board? So, instead of suspicions versions, we prefer the analyze of the natural sources of the crash.
The plane presents the catalogue mass \( m = 80 \) ton, but taking the additional fuel we will use the value of 90 ton. The catalogue lending speed \( v = 230 \) km/h. However, because of very strong angle of lending we will use 280 km/h. The kinetic energy of the plane is

\[
E = \frac{mv^2}{2} = \frac{mv^2}{2}g \quad [\text{kgm}]
\]  

(1)

where \( g \) – the ground acceleration, \( g = 9.81 \text{ m/s}^2 \approx 10 \text{ m/s}^2 \); \( v = 280.000/3600 \text{ s} = 78 \text{ m/s} \)

Putting \( m \), \( v \) and \( g \) data into (1) we obtain the kinetic energy

\[
E = 90.000 \times 6000/20 \text{ kgm} = 27.000.000 \text{ kgm} \quad (2)
\]

This means that all the plane (90,000 kg) can be thrown away on \( 27000000/90000 = 300 \) m, and the 96 bodies each of 90 kg – still much farther! Such thrown is theoretically possible if the ground is 100% resilient. The frozen and forestry Smolensk ground was not much far of this assumption. The energy must have the estuary!

5. Modeling of the turnover

The turnover was the critical process from the viewpoint of large number of victims. We will use the Newtonian equations for modeling this process. The angular frequency and the acceleration of the any moving body are as follows [3, 4]

\[
\omega = \frac{Fr}{Mk^2}; \quad \alpha = \frac{d \omega}{dt} = \frac{Fr}{Mk^2}
\]  

(3-4)

where \( M \) – the mass under consideration [kg], \( F \) – an outside force [kG], \( r \) – its arm [m], \( k \) – the arm of inertia [m], \( \omega \) - angular speed [degrees/s], \( t \) - the running time.

The distribution of all masses \( Mdr \) of the airplane across the wings line is approximated by the triangular and rectangular functions and next replaced by the exponential function \( e^{-r} \). Hence, the arm of inertia is

\[
k = \int_0^1 e^{-r} r^2 dr = e^{-r} (r^2 - 2r - 2) \bigg|_0^1 \approx 2 \text{ m}
\]

(5)

Fig. 3. The cross balanced distribution of masses

Fig. 3a. The unbalance caused by a loss of wing part
Fig.4. The results of simulation of the final overturn of Tu-154M: the plane reaches the angle $\Delta = 90^0$ nearly in 4 s and it falls back still faster; the effect of the complete loss of left wing is not taken into account

Using the eq. (3-5) the simulation of turning the plane around the longitudinal axis has been carried out, Fig.4. The force $F$ representing the lost part of left wing is taken as 10% of the total gravitation force, eq.(1), i.e. $F = 0.1\times M$. Hence, for $r = 13$ m and $k^2 = 4$ m$^2$ we obtain

$$\omega = (F / M ) \times (r / k^2) t = (0.1) \times (13 / 4) t = 0.33 \times t \text{ [rad./s]} \tag{6}$$

It means that in 1 second the plane turned around by 0.33 of radian, i.e. $\sim 20^0$. All the process of rotation is illustrated in Fig.4 together with the hypothetical fall down. It is worth to note that the forward speed was $\sim 270$ km/h (78 m/s), which responds to the falling down of a body from $\sim 30$ m (10-floor building)! So, no one passenger could survive!

6. Conclusion

The official report [1] states: the crash of Tu-154M was caused by its too high speed on the line crossing the standardized path down. We claim that the speed was too high but the primary reason of crash was the false direction of flight: this error reached as much as $10^0$ relative to the proper curse on runway. The information “you are in the curse…” was repeated several times, including the last one at $\sim 20$ seconds before the crash (at altitude 91/39 m), Fig.2. The crew took a decision ‘second ring’ but it failed because of too low altitude. At distance of 1050 m to the runway and 43 m outside it, the plane hit the tree and lost a part of left wing (time 10:41:02, altitude 8 m). This loss could be taken insignificant from the forward run, but it affects much the horizontal stability of the plane and it caused it to turn over. The main masses of the plane were located in the very center ($\pm 2$ m), while the strange force appeared much outside of it (16 m). This concentration of masses and appearing the destructive force far outside the center might cause the plane to turn over in a few seconds and to kill all the passengers, Fig.4. The author claims that the airfield Severnyj should be closed that day because of the very poor instrumentation/personnel and the highly foggy weather. This may be a point for compensation and not a coup.

References