Misguidance under the Polish Tu-154 Crash

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Abstract - The crash of Tu-154 has taken place in 10th April 2010 in Smolensk, USRR. The weather of that day was highly foggy, so the crew has been thrown back on the ground navigation facilities. These, in turn, have the obsolete instruments and present the extremely low standard of maintenance. In result, Tu-154 was directed to the woody area 1000x150 m aside the airport. Then, it collided with a tree and lost the large part of the left wing. This caused the plane to turn around its longitudinal axis. The process of turning is analyzed in detail via Newtonian differential model. The time of revolution on the back has taken merely 8 seconds. The plane hit next on the ground and produced thousands of small and large parts. The mean dispersion reached 300 meters. This process is modeled via parabolic equations under the assumption of 100% resiliency of the ground. Nobody of passengers survived. The final conclusion is as follows: the Tu-154 should not obtain the permission for 3 trials of lending in the extremely bad weather and much confusing maintenance from the ground station.

Keywords: Tu-154 crash, navigation/communications reasons, simulation of the overturn, Newtonian model

I. THE ESSENTIAL DATA OF PLANE

The Tu-154 is a three-engine medium range narrow-body air-linear designed in the mid-1960s and manufactured by *Tupolev* (1026 units). The data of modernized version Tu-154M is as follows: length 48 m, width 38 m, cabin 3.8 m, total mass 80 t; engine– jet, lending speed 230 km/h, capacity 96 persons. The number of accidents 110, including 71 crashes



Fig. 1. The front view of the Polish military jet Tu-145M under the take-off phase

II. THE PASSENGERS, THE AIRFIELD AND THE PROCESS OF LANDING

PLF101 took off from Warsaw at UTC 8.41 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. Cpt. Protasiuk has landed at Smlensk 3 days earlier in the same Tu-154M.

There was on the board the President of Poland - L. Kaczynski and his Chief Dignitaries, totally 89 persons plus 7 of crew. 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Airfield does not have the typical control tower and its infrastructure and the communications/navigations systems are outdated and do not meet the standards, e.g. there is a large hollow in front of the runway and close to it grow shrubberies and trees of the height up to 10 m. The accuracy of the approaching radar was merely $\sim 10^{0}$ [1-2]. Moreover, in the critical day many frontier lamps had the bulbs blown through, what - in dense fog - increased the threat. In this conditions the airfield should be closed. In the Russia report there are remarks on not fluent knowledge of the Russian language by Polish crew. This is not true: cpt. Protasiuk, who carried on the conversations knew the Russian fluently and had the proper certificates.

As the aircraft approached Smolensk airport, the weather conditions had rapidly deteriorated. The visibility in day light reached several hundred meters! So, the crew has

to support itself by the information from ground station. At 2 km to the runway this station informed the pilot (UTC 10:40:52): *You are in the curse and path!* The plain in that moment was merely 39 m over the runway level and 91 m over the local hallow. The descent rate was 6 m/s and the linear speed - 78 m/s. So, the required altitude should be 154 m! Hence, the error made is

$$(2000/78)*6=154 \text{ m } 154/39 \approx 400\%$$
 (1)

The ceiling of plane was then 4 times lower than required, hence an accident was unavoidable.

It, however, could be moderate if the curse of flight was towards the runway. Unfortunately, it was -10^{0} left the runway, Fig.2. So, the collisions with trees were unavoidable. The first one took place with a birch of thickness of ~40 cm and it caused the plane to overturn.

Next, there were still smaller collisions and the final ground crash took place 625 m further, see blue star 150.

It is still a big riddle: how it was possible to make such a coarse directional error?

IV. THE CRASH DISPERSIVE MODELS

The parts of crashed plane were scattered over the area of \sim 300x300 m. This gave rise to some suspicious theories of assassination. The question is, however, who and when arranged a plot and put some explosive material on the board? We will trust on the physical basis.

The plane presents the catalogue mass of M=80 ton. We will use 90 ton due to the additional fuel. The catalogue lending speed is v=230 km/h. However, because of the very strong angle of lending we will increased it to v=280 km/h.



Fig.2. The provisional front views (blue profiles) and the top views (green profiles) of the Tu-154M final flight.

(1a)

The blue data denote distances to the front- and left side of the runway

Hence, the kinetic energy is
$$E = M_1 r^2/2$$

$$E = MV/2 \qquad (1a)$$

where $M=90\ 000\ \text{kg}$, $v=280.000\ \text{km/h}\approx78\ \text{m/s}$. If the collision is **fully resilient** and it takes place along the **vertical line**

$$E = Mv^2/2g[\text{kgm}]$$
(1b)

where g – the ground acceleration, $g \approx 10 \text{ m/s}^2$.

Putting M, v and g into (1a) we obtain the energy

$$E=90.000*6000/20=27*10^6$$
 [kgm (1c)

If the collision is perpendicular to the ground, we can obtain the reflection distance via division of E by M. Hence we obtain the coarse assessment of the reflection distance of **300** m. The more detailed approach can be obtained via parabolic equations [3-4]

$$x = v * \cos(at); \quad y = v * \sin(at) - gt^{2}/2; y = x * tg\alpha - x^{2}g/2v^{2}\cos^{2}\alpha$$
(2abc)

where x,y- Cartesian coordinates, v- speed of a body, α - angle of throw, t- time, g- acceleration.

For $\alpha = \pi/4$ and $v_0 = 78$ m/s, the distance of throw is maximal and it equal

$$x_{\rm max} = (v_0^2 / g) \sin 2\alpha = 608 \ m$$
 (2d)

For more real $\alpha = 15^{\circ}$ we obtain x = 300 m.

This data relates the body as a one piece. Its smaller parts can obtain the longer distances.

V. THE TURNOVER MODEL

The plane's turnover is the critical point for the crash. We will use the Newtonian equations [3-4]. The angular frequency ω and the acceleration α of any moving body follow the equations

$$\omega = Frt / Mk^2; \quad \alpha = d\omega / dt = Fr / Mk^2 \quad (3-4)$$

where M – the mass of the body [kg], F – an outside force [kG], r – its arm [m], k – the special arm of inertia [m], ω - angular speed [degrees/s], t - the time starting with the force applied [s].



Fig. 3a. The approximation of mass distributions

We will approximate the distribution of masses of

the plane *Mdr* across the wings' line by the triangular and rectangular functions, Fig.3. Next, we will express them by an exponential function $m(r)\approx e^{-r}$. Hence, the important parameter, the arm of inertia is

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$$k = \int_{0}^{19} e^{-r} r^{2} dr = e^{-r} (-r^{2} - 2r - 2) \Big|_{0}^{19} \approx 2 m \quad (5)$$

Wing 1 Wing 2



F=0.1M



Fig.4. The speed and angle of the rotation process vs time: the plane reaches the angle $\Delta \approx 90^{\circ}$ nearly in 5 s

The force *F* appears as the effect of lost part of the wing and it is taken 10% of the total gravitation force, i.e. F=0.1*M. Hence, for r=13 m and $k^2=4$ m² we obtain the equation for the speed ω

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

It means that in 1 second the plane turns around by 0.33 of radian, i.e. $\sim 20^{\circ}$. All the process of rotation is illustrated in

Fig. 4 (blue curve) together with the hypothetical fall down curve (red curve). It is worth to note that the forward speed was ~280 km/h (~80 m/s), which responds to the falling down of a body from 30 m (10-floor building)! So, no one passenger could survive!

VI. CONCLUSIONS

The official report [1] states: the crash of Tu-154M was caused by its very steep descent: too high speed at too sharp path. This is formally true but not explains why the pilot made such a mortal manner? He did not see the airport and he was thrown back on the ground station. This in turn

informed him several times that all is OK, e.g. at some distance to airport: "the ceiling is 500 m", next "the curse is correct" and at 2 km to the airport: "you are in the proper curse and path". Meanwhile the plane found itself at course of -10^{0} instead 0^{0} and at the height of 91 m instead of 400 m! How it was possible to make such a coarse error? The only answer is: the instruments were completely out of order or the duty personnel was ill¹). A few seconds later the plane heat the tree at distance of 1050 m to the runway and 43 m aside it. In a result it lost a part of left wing (UTC 10:41:02, altitude 8 m). This accident could be taken insignificant from the forward run, but it affects much the horizontal stability of the plane and it caused the plane to turn upside down.

The main masses were located in the very center of the plane $(\pm 2 \text{ m})$, while the strange force appeared much outside (16 m).

This concentration of masses in the center and appearing the destructive force far outside, caused the plane to turn $\sim 180^{\circ}$ in few seconds and to kill all the passengers [5-6]. It is claimed that the airfield *Severnyj* should be closed for head visits because of poor instrumentation and/or irresponsible duty personnel.

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 $^{^{\}rm 1)} {\rm The}$ commend 'second ring' was then taken on by the crew but it was too late