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Main Causes of Hard Landings

Soviet study covers 10 years of accidents and incidents.

by
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One of the most specific types of hazards that occur in the landing phase of flight is a hard landing, which is characterized by the exceedance of acceptable values of vertical acceleration on landing.

Statistical analysis of hard landings involving different types of Soviet aircraft, during a 10-year period, shows that hard landings are rather frequent events with a relatively high probability of serious accidents resulting from them. From 1978 to 1987 we had 164 hard landings on our main types of aircraft: Tupolev Tu-154 and 134; Ilyshin Il-62 and IL-86; Antonov An-24, An-26 and An-30; and Yakovlev Yak-40. These hard landings resulted in 17 cases of serious structural damage to the aircraft, four full hull losses and one fatal accident.

The rates of hard landings per 100,000 flights are as follows: Il-62, 2.0; Tu-154, 1.47; Tu-134, 1.24; An-24/26/30, 0.35; and Yak-40, 0.064. (For An-24/26/30 aircraft, one in three hard landings results in an accident; for Tu-154 aircraft, the figure is one in 18).

The main causal factors of hard landings, identified by the investigation commission, are: incorrect landing flare (50-55 percent of occurrences); exceedances of vertical rate of descent (V_y) on the final approach (40-45 percent of occurrences); insufficient crew coordination (50 percent of occurrences); and special meteorological conditions (20 percent of occurrences).

Often, several main factors occur in combination: incorrect landing flare and exceedance of V_y occur together in 25 percent of the events; exceedance of V_y and insufficient crew coordination occurred together in nearly 25 percent of the hard landings.

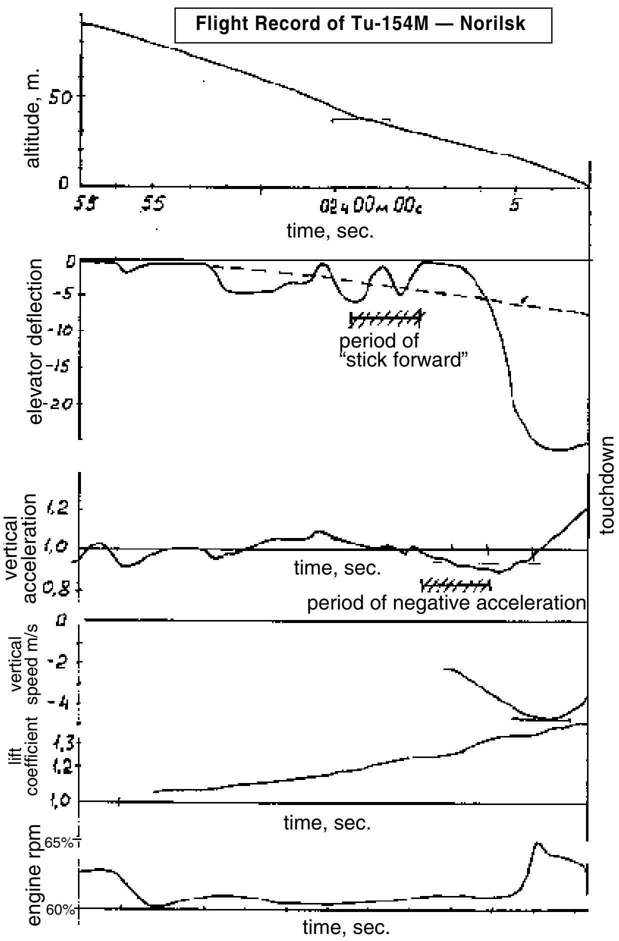
The majority of hard landings (approximately 55 percent) are performed by captains with fewer than 1,000 hours flying experience in the given type of aircraft. Hard landings at night are four to seven times more frequent than in the daytime, a statistic which illustrates that nighttime conditions have a significant effect on landing performance.

Pilots with little flying experience exceed acceptable vertical rates of descent (V_y) 10 to 30 times more frequently than pilots having more than 1,000 hours of flying experience in the given type of aircraft.

Pilots often believe that a hard landing results from low landing speed, and that the increase of this speed is a reliable guarantee against a hard landing. After an analysis of all hard landings of Tu-154/134 airplanes, distributions of values of deviations of actual landing speeds from recommended speeds were plotted, taking into account the landing weights. It was found that the distribution of these values in cases of hard landings correspond closely to the distributions of values of the deviation of landing speeds from those recommended for normal landings:

Normal landings: Differential V_{avg} = 12-13 km/h (19-21 mph); rate of descent (V_y) = 8-9 km/h (435-495 fpm)

Hard landings: Differential V_{avg} = 10-11 km/h (16-18 mph); rate of descent (V_y) = 10 km/h (550 fpm)



In other words, the analysis indicated that high rates of descent, and the resultant hard landings, generally occurred when airspeeds exceeded normal speeds. Therefore, safety recommendations that suggest higher approach speeds will prevent hard landings are not supported by the facts.

Some typical hard landings that occurred in the U.S.S.R. during 1988 illustrate the effects of last-minute pitch and power adjustments, or so-called "duck-under" maneuvers, prior to touchdown.

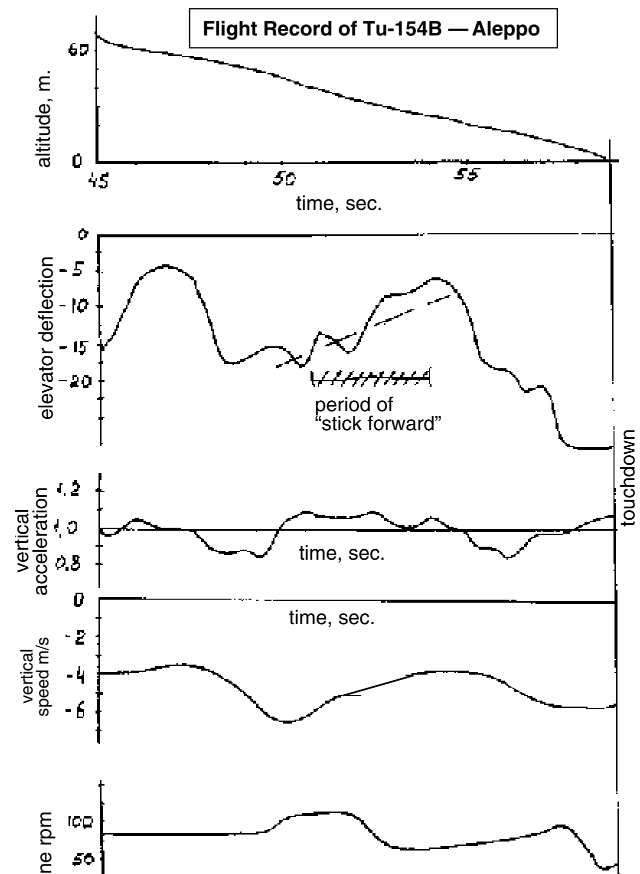
Two accidents, caused by hard landings of Tu-154 aircraft, took place on the same day. One was at the Norilsk airport, resulting in serious structural damage, and the other at the Aleppo airport (Syria), resulting in full hull loss. Other examples occurred at Krasnovodsk and Volgograd.

Norilsk, Tu-154M aircraft. The aircraft was flying an approach on the glidepath down to 150 meters (500 feet) with an indicated airspeed of 275 km/h (170 mph), which is 10 km/hr (6 mph) higher than prescribed. After an insignificant increase in thrust beyond the value necessary for continuing the descent on the glidepath, the speed gradually increased, and crossing the inner marker, the airspeed reached 290 km/h (180 mph). The pilot adjusted the throttles twice to decrease the thrust to near idle. Further along the approach from the inner marker to the touchdown point, the indicated airspeed decreased until it reached 255 km/h (158 mph) at touchdown, instead of the normal 265 km/h (164 mph).

All of these power and airspeed changes made piloting the airplane more difficult, since it was necessary to change the elevator trim but, in general, there were no obvious signs of a developing hazardous situation down to the altitude of 30 meters (100 feet). At this height, the control wheel was pushed and the elevator was applied seven degrees down. The vertical acceleration decreased to 0.9 g and stayed so for three seconds, which led to an increase in the vertical rate of descent to more than five meters per second (m/s), or 975 feet per minute (fpm). The crew failed to identify this tendency and it was not until 1.5 seconds before touchdown that the pilot, pulling the control wheel back, applied full-up elevator.

Just prior to touchdown, the vertical acceleration increased to 1.2 g, but the vertical rate of descent within a limited period of time decreased insignificantly, and at the moment of touchdown, it had become 3.9 m/s (769 fpm), which resulted in a hard landing with a vertical acceleration of 3.15 g.

Aleppo, Tu-154B aircraft. The events in this case devel-

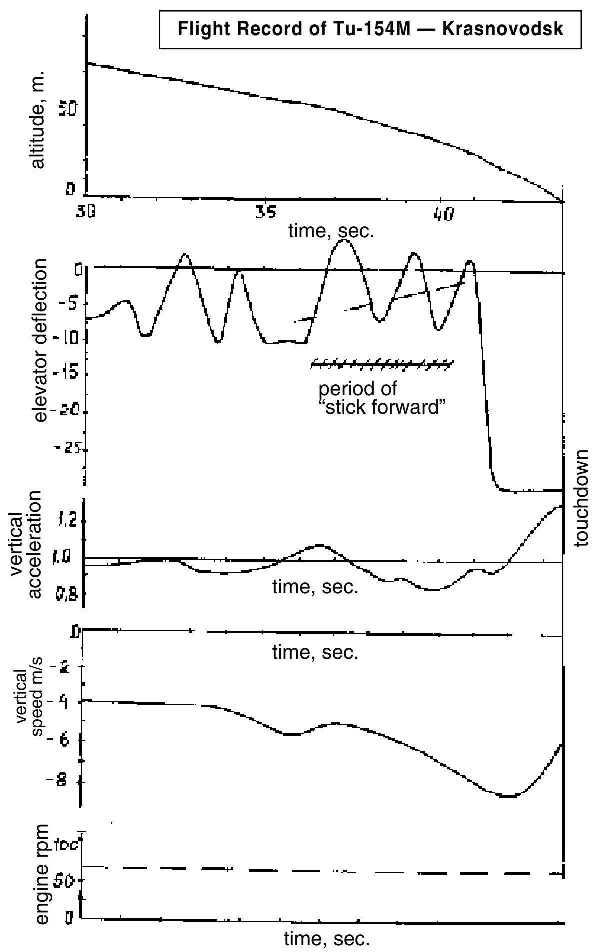


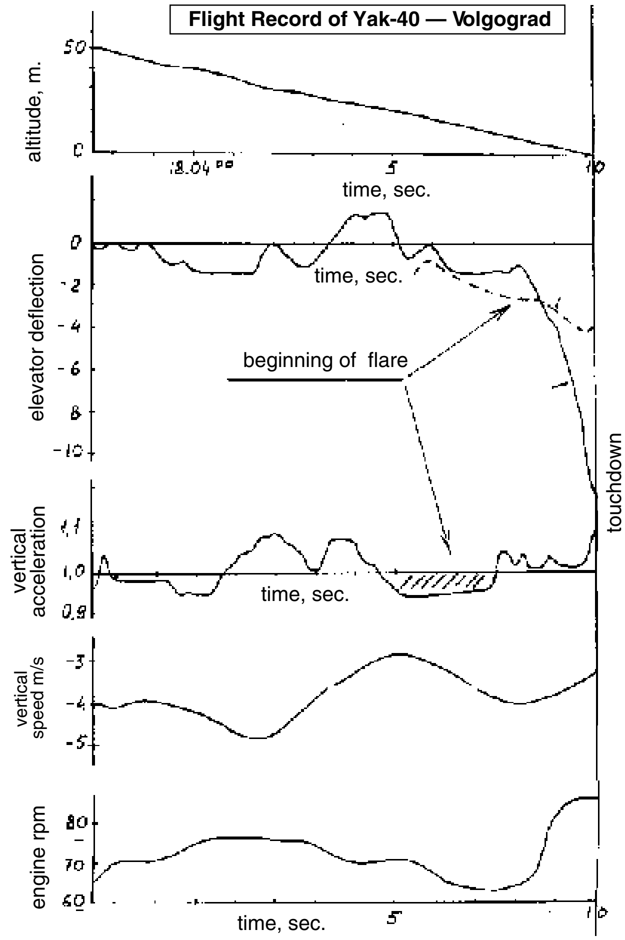
oped almost in the same way as in the Norilsk case. At an altitude of 35 meters (115 feet), the control wheel was also pulled to bring up a nose-down pitch with a simultaneous decrease of the engine thrust. The aircraft went into a steep descent, and a belated pulling of the control wheel all the way back (one second before touchdown) along with increasing the thrust was not sufficient to prevent a hard landing with a vertical rate of descent of 5.5 m/s (1,080 fpm) because of the lack of time and altitude.

Krasnovodsk, Tu-154 airplane. On final approach, the pilot ducked under at an altitude of 50 meters (165 feet), the vertical rate of descent increased to 10 m/s (1,970 fpm), and a belated (2.5 sec. before touchdown) attempt to reduce the vertical rate of descent to an acceptable level by pulling the control wheel all the way back produced no effect.

These are classic examples of duck-under at a low altitude.

Another example involved a Yak-40 landing at the Volgograd airport. At an altitude of 65 meters (215 feet), the vertical rate of descent was increased, and at 35 meters (115 feet) the aircraft descended below the glidepath. In this case, the vertical rate of descent fluctuation was obvious.





The vertical rate of descent reached its maximum value of 4.8 m/s (945 fpm) at an altitude of 35 meters, with a subsequent decrease to 2.8 m/s, and at the moment of starting to flare, it again increased, to 4.1 m/s. The flare was initiated with a vertical acceleration of 0.95 g. In such conditions, a vertical acceleration increment of 0.15 g., resulting from routine movement of the control yoke, somewhat diminishes due to the airplane being out of trim before starting to flare. The proper vertical acceleration exceeded 1 g later, after the control yoke was pulled to flare, and even a slight exceedance of the vertical rate of descent automatically affects the value of vertical acceleration at touchdown. In this case, a hard landing resulted with relatively low vertical acceleration (2.2 g).

The analysis of flight dynamics of different types of aircraft in the landing phase of flight, resulting in hard landings, enabled us to identify a common piloting element in these aircraft in the final approach phase: the duck-under. It is necessary to differentiate between such pitch adjustment maneuvers at low levels of flight (below 60 meters, 197 feet) and at higher altitudes, since they are characterized by significant differences in pilot actions and in aircraft behavior.

In the first case, premature descent of the aircraft at low altitudes generally is not adequately recognized by the pilot, and to flare the aircraft he must apply full elevator. In such cases, the hazard is identified no sooner than three seconds before touchdown. In the second case where the aircraft is higher than 60 meters, the flight parameters may remain within prescribed limits, for example, vertical rate of descent, but changing the descent path leads to a cycling change of the parameters and an untrimming of the airplane at the moment of touchdown. In such a case, the hazard is not recognized until touchdown occurs.

What makes pilots perform such dangerous maneuvers so close to the ground? The reasons, we believe, may be as follows. Statistical analysis of the distribution of approach speeds in line operations shows that, on average, they are 15 km/h (9 mph) higher than prescribed. Higher approach speeds shorten the available stopping distance on the runway, which induces pilots to attempt a touchdown closer to the runway threshold in order to have adequate stopping distance. This makes the duck-under a strong temptation.

In order to prove that the duck-under maneuver is the main factor involved in hard landings, aircraft landing dynamics characteristics were included in simulations using various pilot and engine control techniques, as well as various center of gravity positions. The results showed that engine thrust decrease is a less significant factor than out-of-trim pitch.

If the airplane is out of trim in pitch at the initiation of the flare, it is difficult to control pitch through the flare, and a high probability of a hard landing exists.

It should be noted that, in the U.S.S.R., the existing regulatory documents contain all of the necessary information and recommendations that prescribe performance of the approach in steady flight conditions on a trimmed airplane on an extended glidepath. But if the pilot does not adhere to these criteria, the result will be a hard landing. One of the reasons for ignoring these recommendations is the absence of procedures for monitoring such actions by flight crews with the help of flight data quick analysis programs.

To ensure effective monitoring of the quality of piloting techniques in the approach phase of the flight, special programs in automatic processing and analysis of flight data recorders are being developed, with the purpose of identifying unstabilized approaches and crew training needs.

With accident prevention in mind, we in the Soviet Union hold regular briefings with the flight crews, explaining that a duck-under in the approach phase of the flight at low altitude is the main cause of hard landings, regardless of the aircraft type. This maneuver is extremely dangerous, because it is practically impossible to accurately monitor the changing flight path parameters and to take timely corrective actions with respect to the limitations in time and altitude. These explanations to the crews are accompanied by mandatory simulator demonstrations of the consequences of duck-under maneuvers. New training techniques are being developed to enable flight crews to acquire proper skills to ensure a stabilized approach.♦

About the Author

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Previously, Kutskov was a division head in the Scientific Research Institute of Civil Aviation. Prior to that, he worked with the ground aviation facilities at Sheremetyevo International Airport, Moscow, in various capacities as an engineer, senior engineer and deputy chief manager.

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