FLIGHT SAFETY FOUNDATION

ALAR
APPROACH-AND-LANDING ACCIDENT REDUCTION
TOOL KIT

FSF RSI BRIEFING NOTE

Pilot Braking Action Reports

Pilot braking action reports that are based on reliable assessment procedures and that use the proper terminology are potentially valuable supplements to other runway condition information. The limitations of pilot braking action reports should be understood.

Statistical Data

The Flight Safety Foundation Runway Safety Initiative (RSI) team found that overruns were involved in 50 percent of the runway excursion accidents[1] that occurred in 1995 through March 2008.[2]

Braking Action

When stopping an aircraft, the pilot expects a deceleration level that is proportional to the amount of wheel braking applied and to runway surface friction. When the actual deceleration is less than expected, braking action is degraded. The degree to which deceleration by the wheel brakes is degraded is indicated by the use of the terms "good," "medium" and "poor." The term "nil" is used in the United States for braking action that is less than poor (Table 1).

Braking action is directly affected by friction between the tire and the runway/taxiway surface. The available tire-to-surface friction is not only affected by the surface macro-/micro-texture but also by contaminants such as standing water, snow, slush and ice. In addition, the level of longitudinal braking force is inversely affected by the level of lateral force acting on the tires, sometimes referred to as "cornering force." Cornering forces are caused by pilot input, such as in nosewheel steering, or by crosswinds acting on the aircraft.

Braking Action Advisories

When braking action is less than good or weather conditions are conducive to deteriorating or rapidly changing braking action, air traffic control (ATC) should advise pilots that braking action advisories are in effect. This means that reports on braking action are expected from the pilots of landing aircraft.

During the time that braking action advisories are in effect, ATC will issue the latest braking action reports for the runway in use to each arriving and departing aircraft. The report issued should include the type of aircraft that made the report and the time the observation was made. Both of these items are very important to assess the validity of the report.

Pilot Braking Action Assessment

When the pilot applies wheel brakes, the wheels begin to slow down relative to the velocity of the aircraft. Wheel speed is expressed as a "slip ratio." A slip ratio of zero percent means that the wheel is rolling freely, and a slip ratio of 100 percent means that the wheels are locked and not rotating at all; values between these extremes indicate the extent to which the wheels are skidding (Figure 1).

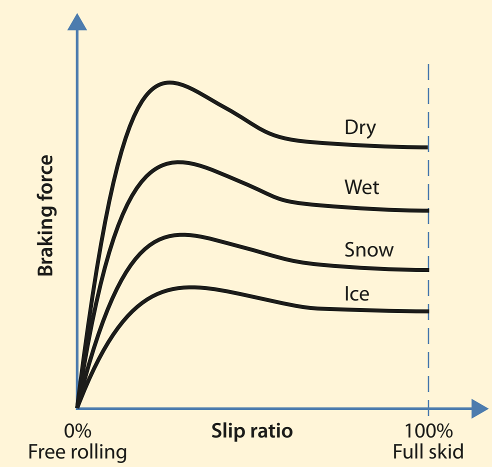
Braking Action Terms

Good	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.
Medium	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be slightly reduced.
Poor	Braking deceleration is significantly reduced for the wheel braking effort applied. Directional control may be significantly reduced.
Nil	Braking deceleration is minimal to nonexistent for the wheel braking effort applied. Directional control may be uncertain.

Source: Flight Safety Foundation Runway Safety Initiative

Table 1

Slip Ratio



Source: Flight Safety Foundation Runway Safety Initiative

Figure 1

As the slip ratio increases, braking force increases — to a point. Figure 1 shows that there is an optimum slip ratio for maximum braking force. The effect of reduced surface friction is to lower the possible braking force for a given slip ratio.

Anti-skid braking systems are designed to maintain the optimum slip ratio regardless of the surface conditions. The optimum slip ratio can be thought of as the anti-skid limit. The pilot has control of the level of wheel slip through the application of pedal braking as long as the anti-skid limit is not reached. Once the anti-skid limit is reached, pressing the brake pedals any harder will not increase the wheel braking force because the runway friction capability has been reached.

Consider an aircraft with anti-skid only, no thrust reverse or autobrakes. As the wheel brakes are applied upon landing, the pilot begins to feel the deceleration of the aircraft. The deceleration builds as brake pedal pressure increases. On a dry runway, it is unlikely that the pilot will ever reach the anti-skid limit because the resultant braking forces are more than enough to stop the aircraft. In fact, most pilots of large transport aircraft have never reached maximum manual braking on dry runways. It would be a very uncomfortable experience due to the very high deceleration rates.

The pilot's perception of increasing deceleration with application of pedal brakes is the key to pilot braking action reports, even when thrust reverse also is being used.

For example, when thrust reverse is selected after landing, the pilot feels a certain level of deceleration. As wheel brakes are applied, an increase in deceleration should be felt if the surface friction can support it.

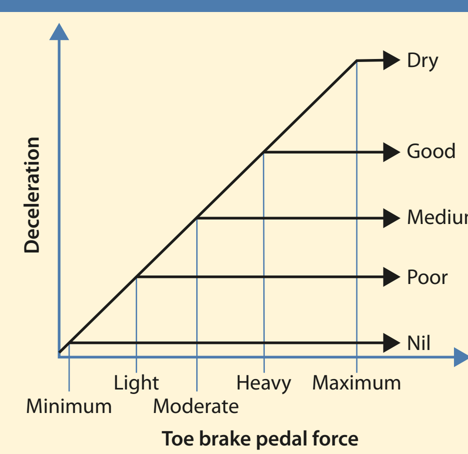
Autobrakes are designed to generate a specified level of deceleration. If thrust reverse alone meets the required deceleration for the autobrake setting used, the system will not apply any wheel brake pressure. The pilot may not know this has occurred. Consequently, in this case, pilot braking action cannot be assessed until autobrakes are overridden. By overriding the autobrakes with application of pedal braking, the pilot can assess braking action because he or she directly controls the wheel slip up to the anti-skid limit.

This is not to imply that autobrakes should not be used. On the contrary, autobrakes should be used in accordance with the manufacturer's recommendations. An advantage of using autobrakes is that the system will promptly apply wheel brakes after touchdown, thus avoiding pilot-induced delays.

Pilots can assess braking action by noting whether the deceleration force felt is increasing with increasing brake pedal force (Figure 2). The point at which the deceleration force remains constant with increasing brake pedal force is the anti-skid limit. If this occurs when only light pedal pressure is applied, braking action is poor. If this occurs with moderate brake pedal pressure, braking action is medium. If the anti-skid limit is reached with heavy braking, braking action is good.

It is important to understand that for proper operation of anti-skid braking systems, a steady increase in brake pedal force is needed. The pilot's goal in assessing braking action is to note at what brake pedal force the airplane's deceleration ceases to increase. However, the pilot should continue to increase the brake pedal pressure to maximum if necessary to ensure that the airplane remains at the anti-skid limit, providing the optimum wheel slip ratio.

Perceived Deceleration Rate



Source: Flight Safety Foundation Runway Safety Initiative

Figure 2

Benefits of Pilot Braking Action Reports

Although pilot braking action reports are subjective, they do provide valuable information about rapidly deteriorating runway surface conditions.

In addition, some aircraft manufacturers provide advisory landing distance performance information as a function of pilot braking action reports. They do this by choosing a conservative aircraft braking coefficient for the braking action terms of good, medium and poor. The appropriate value of aircraft braking coefficient is used in the manufacturer's advisory landing distance calculations.

Limitations of Pilot Braking Action Reports

Because the pilot is basing a braking action assessment on the amount of deceleration that he perceives, it may be challenging to discern the true "braking action" because it may be masked by the use of reverse thrust and any displacement/impingement drag from loose surface contamination.

The technique to get around this limitation is to note whether deceleration increases with the application of manual wheel braking. An increase in deceleration above that from thrust reverse may be felt, the magnitude of which will depend on the runway surface conditions.

If no increase in deceleration is felt with the application of manual wheel braking, the pilot should continue using thrust reverse, all the way to a stop if necessary.

Variability in pilot braking action reports can occur for reasons other than pilot subjectivity. The portion of the runway used by the landing airplane, as well as the type of airplane, may cause differences between what is reported and what is experienced by the pilot.

Reliable Braking Action Reports

A reliable braking action report is one that is submitted by the pilot of an airplane with landing performance capabilities similar to those of other airplanes being operated.

Consider the following aircraft characteristics when assessing the reliability of a braking action report:

- Type of power plant (turboprop or turbojet);
- Weight class (super, heavy, large, small);
- Main landing gear configuration (twin, dual twin-tandem, etc.); and,
- Thrust reverse configuration (turboprop, tail-mounted or wing-mounted turbine engines).

When the reporting airplane does not have similar characteristics to the airplane being operated, the pilot will have to decide the extent to which the report should be considered in the decision-making process. Such reports should not be summarily disregarded, especially if the report is conservative.

Making a Pilot Braking Action Report

When braking action advisories are in effect, the pilot might be asked to provide a braking action report to ATC. The report should include the following:

- The appropriate braking action term (i.e., good, medium, poor or nil);
- The portion of the runway for which the braking action report applies;
- The type of aircraft; and,
- Where the runway was exited.

When relaying a pilot braking action report, ATC should include the time since the report was made. For example: "Braking action reported 10 minutes ago as medium by a Boeing 737 that exited at Taxiway A7." The time of the last braking action report is very important; if it is not provided, the pilot should ask for it.

The report also should include braking action that varies along the runway. For example, "First half of landing roll medium, last half poor." However, the use of terms such as "good to medium" and "medium to poor" apply to intermediate levels of braking action, not to braking action that varies along the runway length.

Additionally, when providing a braking action report for taxiways or ramps, include the surface for which the report applies. For example, "Runway good, turn-off Taxiway A6 poor."

The U.S. National Transportation Safety Board recommends that if mixed braking action reports are received, such as medium to poor, the most conservative term should be used to increase landing safety margins.

NIL Braking Action

The term nil is not currently part of International Civil Aviation Organization (ICAO) braking action terminology; however it is used in the United States, where it would indicate to the airport authorities that runway treatment is required before further aircraft operations are allowed on that runway.

Historically, there has been some hesitation by pilots to report nil runway conditions. Perhaps this is due in part to the realization that reporting nil runway conditions will close the runway to subsequent aircraft.

Because of this, it may be helpful to pilots to have specific target criteria for determining when runway conditions are likely to be nil. A nil report should be made when any of the following conditions are encountered during a maximum-effort landing on a contaminated runway (following an on-speed and on-path crossing of the threshold):

- As brake pedal pressure is applied, the pilot perceives little or no increase in deceleration;

- Stowing the thrust reversers produces a sensation of acceleration despite having wheel brakes applied;
- Actual landing distance exceeds the distance calculated for poor braking action or for runway conditions equivalent to poor braking action, for those operators that have operational landing distances as a function of runway condition; or,
- Discontinuing the use of reverse thrust was required to restore directional control when the crosswind was within limits for the reported runway conditions.

If any of these results are experienced on at least some part of the runway, there has been a significant loss of friction and a report of nil is justified. If a nil report is not made, the following crew will not consider it a favor if they go off the end of the runway on which the previous aircraft only just got stopped.

Summary

Whenever braking action is less than good or runway surface conditions are conducive to braking action that is less than good, ATC advisories should state that braking action advisories are in effect. This alerts pilots that pilot braking action reports are expected.

The pilot should report the braking action experienced, the type of aircraft and the exit taxiway whenever possible.

ATC should report to arriving and departing aircraft the latest braking action report, including the type of aircraft and where that aircraft exited the runway.

Although pilot braking action reports are subjective assessments of runway conditions, they provide valuable information to supplement other runway condition information. Pilots are encouraged to use the descriptions of the braking action terms in Table 1 to provide standardized and reliable braking action reports.

It is important that pilots not base their runway surface assessment solely on pilot braking action reports. Pilots must consider all available information such as contaminant type and depth, Mu values, pilot braking action reports, snow-related notices to airmen (SNOWTAMs), aviation routine weather reports (METARS) and personal observations.

The FSF RSI Briefing Note *Runway Condition Reporting* provides information to supplement this discussion.

Notes

1. The Flight Safety Foundation Runway Safety Initiative (RSI) team analyzed 548 runway-excursion accidents that occurred in 1995 through March 2008 involving civil airplanes weighing more than 12,500 lb/5,700 kg.
2. The FSF RSI team defines a *runway excursion accident* as "a mishap characterized by an aircraft departing the usable surface of a runway during takeoff or landing." The team said, "An excursion can occur either by overrunning the end of the runway or by veering off its side. A runway excursion during takeoff assumes that the aircraft started its takeoff roll on the runway surface and later departed that surface with its wheels still on the ground. Runway excursions during landing are generally predicated on an aircraft having initially touched down on the runway surface, followed by a departure from that surface with its wheels still on the ground. Events where aircraft depart the runway while airborne are not considered runway excursions."

Related Reading From FSF Publications

Mook, Reinhard. "Treacherous Thawing —Slush may induce poor/nil aircraft braking action, contrary to runway friction readings." *AeroSafety World* Volume 3 (October 2008): 14-19.

Lacagnina, Mark. "Missed Assessment — Tired pilots neglected to perform a required review before landing." *AeroSafety World* Volume 3 (October 2008): 20-24.

Werfelman, Linda. "Safety on the Straight and Narrow — Aviation safety experts aim for the Runway Safety Initiative to provide the tools to help prevent runway incursions." *AeroSafety World* Volume 3 (August 2008): 12-17.

Lacagnina, Mark. "Overrun at Midway — The crew applied reverse thrust too late." *AeroSafety World* Volume 3 (February 2008): 28-33.

Werfelman, Linda. "Blindsided — The pilots of an Airbus A340 did not anticipate the 'severe deterioration' of weather as they approached the runway threshold at Toronto." *AeroSafety World* Volume 3 (February 2008): 40-45.

Mook, Reinhard. "Insidious Ice — Basic physics makes slippery-runway issues crystal clear." *AeroSafety World* Volume 2 (October 2007): 24-28.

Johnsen, Oddvard. "Improving Braking Action Reports — Using performance data from landing aircraft would eliminate current inaccuracies." *AeroSafety World* Volume 2 (August 2007): 36-40.

Rosenkrans, Wayne. "Knowing the Distance — The FAA plans to require commercial and fractional turbojet flight crews to confirm landing distance capability on arrival in specific situations." *AeroSafety World* Volume 2 (February 2007): 22-25.

Regulatory Resources

International Civil Aviation Organization. *International Standards and Recommended Practices, Annex 14 to the Convention on International Civil Aviation: Aerodromes*.

U.S. Federal Aviation Administration (FAA). *Aeronautical Information Manual*. Paragraph 4-3-8, "Braking Action Reports and Advisories." Paragraph 4-3-9, "Runway Friction Reports and Advisories."

FAA. Advisory Circular 91-79, *Runway Overrun Prevention*.

FAA Safety Alert for Operators 06012, *Landing Performance Assessments at Time of Arrival (Turbojets)*. Aug. 31, 2006.

Notice

The Flight Safety Foundation (FSF) Runway Safety Initiative (RSI) team produced this briefing note to help prevent runway excursion accidents. This is one of two RSI briefing notes included in the FSF *Approach-and-Landing Accident Reduction (ALAR) Tool Kit*, which comprises a variety of other safety products that have been developed to help prevent approach-and-landing accidents.

The briefing notes have been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines, but they can be adapted for those who operate airplanes with fuselage-mounted turbine engines, turboprop power plants or piston engines.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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