

BRAKE RELEASE RESPONSE TIME REQUIRED FOR
AUTOMATIC SKID CONTROL

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Revised

Introduction

This report deals with establishing a reasonable time that can be allowed for brake release in relation to accomplishing skid control that prevents severe tire damage. The recommended brake release time set forth in this report is based on limiting the skid distance to that short enough to prevent "flat spotting" of the tire. Yet, the time is long enough to have been commonly achieved.

(For clarification; the term "skid" in this report is used to mean a locked wheel that has linear velocity, and "slip" is used to mean that the wheel is rotating but has some relative velocity at the contact point on the runway.)

1. Purpose:

The purpose of this report is to set forth the maximum time that can be permitted in releasing brake pressure to achieve skid control without causing tire damage.

2. Summary:

- 2.1 The maximum distance that a tire may be permitted to skid on a dry concrete runway is about 40 feet.
- 2.2 To prevent exceeding this distance with a locked wheel, the locked time cannot be greater than .157 seconds at 150 knots and .118 seconds at 200 knots.
- 2.3 To allow a locked wheel to resume rotation before the skid exceeds 40 feet on a dry concrete runway, the brake pressure must be reduced to at least 13.5% of that pressure that caused the braked wheel to start decelerating into the locked condition.
- 2.4 The brake release time recommended will permit the brake pressure to be reduced to the value that will permit resumption of wheel rotation before the wheel has skidded 20 feet at 150 knots and 30 feet at 200 knots.
- 2.5 The recommended brake release curve without line losses can be expressed by the following equation:

$$p/P_1 = \frac{1}{(2.72) t/.043}$$

- 2.6 This requires that the brake pressure be reduced to 10% of the initial pressure in 0.10 seconds.

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- 2.7 The temperature at which data was taken that has been used in this report ranged from 20 to 100° F. The recommended release time can be taken to apply to approximately $\pm 40^\circ$ F.

Factors Influencing Brake Release

1. In order to establish the maximum allowable time for brake release, we must first establish how long and far the tire may be permitted to skid. Figure 1 shows a plot of actual data taken from fighter airplane landings on concrete runways. In all these tests the maximum skidding distance on a dry runway was approximately 27 feet and on a wet runway was approximately 40 feet. The airplane was such that its wing lift was very low after touch-down so there was at least 75% of the airplane's weight on the wheels during any skid. No flat spots or other appreciable damage resulted from these skids. Further study of Figure 1 reveals that the locked wheel may be released by reducing the brake pressure to some percentage of the pressure that caused the wheel to start into the deceleration that terminated as a skid. As the length of skid increases, the brake pressure must be further and further decreased to release the locked wheel. By the time the wheel has skidded 40 feet on dry concrete, the brake pressure must be reduced to about 13.5% of that pressure that caused the skid to start.
2. The time duration for skids of 20, 30, and 40 feet in length, is shown in Figure 2. Since most jet powered airplanes have maximum ground handling speed between 150 to 200 knots, these two speeds have been used in this study. To gain some conception of the time to release the brakes to resume rotation; study of Figure 2 shows that when the skid is limited to 20 feet the brake release must be achieved within .059 seconds if the plane has a speed of 200 knots, or if the skid is to be limited to as much as 40 feet and the airplane has a speed of 150 knots, the brake release time may be as long as .157 seconds.
3. The effect of slip on braking is shown in Figure 3. This shows that in order to avoid drastic reduction in braking, the percentage of slip must be held to less than 50%. In order to prevent the braked wheel from increasing the amount of slip, the brakes must be released faster than the wheel decelerates. The release must be initiated before slip has progressed beyond requiring more than about 20% reduction in brake pressure.
4. The required reduction of braking to stop undesirable slip or a skid in relation to time is shown in Figure 4. Two curves for airplane speeds of 150 and 200 knots were established by use of Figures 1 and 2. Figure 2 established the time of skid for various skid lengths at these two speeds and Figure 1 established the percent of braking that the brakes must be reduced to in order to stop the skid. These curves can be used for establishing maximum allowable brake release time. These curves show that in order to limit the skid to not more than 40 feet; at 200 knots the brakes must be released to 14% in .118 seconds and at 150 knots they must be released to the same percentage in .157 seconds.

5. In order to establish a realistic brake release curve, the brake release time of many airplane brakes were plotted on a percentage basis in Figure 5. Study of this data showed that the brakes release along a curve similar to the discharge of a capacitor through a resistance. This curve can be closely approximated by the equation;

$$p/P_1 = \frac{1}{E^{t/K}}$$

Where: p = Pressure at any time (t) and

P_1 = Pressure at the time brake release is initiated.

E = Base of natural log. (2.72)

K = Constant

By plotting a straight line curve through most of the points of actual release data and 100% braking a curve was established that conforms to the equation;

$$(1) \quad p/P_1 = \frac{1}{(E)^{t/.043}}$$

Another curve drawn parallel to the one discussed above that covers the maximum brake release time can be expressed by the equation;

$$(2) \quad p/P_1 = \frac{1}{(E)^{\frac{t-.015}{.043}}}$$

These release data were established on the airplane in actual landing rolls so hydraulic line losses affected the release time.

By study of these two equations plotted on Figure 5 it can be readily seen that this brake release can insure the skidding to be limited within 20 feet at 150 knots and 30 feet at 200 knots.

Conclusion

1. The brake release as expressed by equations (1) and (2) will allow the control to prevent severe tire damage.

Recommendation

1. It is recommended that equation (1) be used to establish maximum brake release time for brakes where line losses are not being considered.
2. Where line losses are considered, equation (2) is recommended as the maximum allowable time for brake release.

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