



Airplane takeoff speeds are designed to ensure the liftoff speed does not exceed the tire speed rating.

Exceeding Tire Speed Rating During Takeoff

Airplane tires are designed to withstand a wide range of operating conditions, including carrying very high loads and operating at very high speeds. It is common for a jet airplane tire to carry loads as heavy as 60,000 pounds while operating at ground speeds up to 235 miles per hour. To accommodate these operational conditions, each tire has specific load and speed ratings. Tires are carefully designed and tested to withstand operation up to, but not necessarily beyond, these ratings.

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It is uncommon to exceed the load rating of tires during normal airline operation because the weight and center-of-gravity position of the airplane are well controlled and well understood. However, on occasion the speed rating of tires can be inadvertently exceeded during takeoff.

This article discusses factors that can lead to a tire speed exceedance during takeoff, provides guidance to help prevent such tire overspeed events, and points out that there are no standardized industry maintenance guidelines if an overspeed event occurs.

INTRODUCTION

Boeing is receiving an increasing number of operator inquiries about tire speed limits being exceeded during takeoff. This does not appear to be a new issue. Rather, advanced data acquisition tools on modern airplanes have made operators more aware of tire speed exceedance events.

In most cases, the speed exceedance is small, only a few knots. Boeing is not aware of any of these overspeed events resulting in thrown treads, which suggests that airplane tires in good condition can withstand these small speed exceedances without damage. However, it is important to remember that at high speeds, heat is generated within the tire structure. This

heat, combined with extreme centrifugal forces from high rotational speeds, creates the potential for tread loss. Ensuring that tires are operated within their speed ratings will help prevent possible tread losses and the potential for airplane damage.

CONDITIONS THAT CAN LEAD TO EXCEEDING THE TIRE SPEED RATING DURING TAKEOFF

When dispatching an airplane in compliance with the certified Airplane Flight Manual, the airplane takeoff speeds are designed to ensure that the liftoff speed does not exceed the tire speed rating. While rotation and liftoff speeds are generally expressed in knots indicated airspeed, the tire speed

limit is the ground speed, which is usually expressed in statute miles per hour. This means that a tire rated at 235 miles per hour is designed for a maximum ground speed at liftoff of 204 knots.

A number of factors can lead to a tire-speed-limit exceedance during takeoff. Typically, this occurs when an airplane is dispatched at or near the tire-speed-limit weight and:

- The airplane rotation rate is slower than the Boeing-recommended rotation rate, and/or
- There is a late rotation, and/or
- The tailwind is higher than anticipated.

Dispatch at or near the airplane's tire speed limit is most likely to occur during takeoffs from airports at high altitudes on warm days, because these conditions tend to drive the ground speed at liftoff of the airplane closer to the tire speed limit. However, tire speed limits can be encountered during takeoff in less severe environmental conditions, such as when scheduling an improved climb takeoff.

Crosswinds can aggravate the situation by unexpectedly shifting into a tailwind, which may further increase the ground speed at liftoff. An unexpected (and therefore unaccounted for) tailwind component will directly add to the ground speed at liftoff.

RECOMMENDED TAKEOFF PROCEDURES FOR ALL BOEING AIRPLANE MODELS

Boeing publishes a recommended all-engine normal takeoff procedure in the Flight Crew Training Manual (FCTM) for 727, 737 Classic, and Next-Generation 737, 747, 757, 767 and 777 models and in the Flight Crew Operations Manual for 717, MD, and DC models. In order to avoid tire-speed-limit exceedance during takeoff, Boeing stresses adhering to the recommended average all-engine takeoff rotation rate of 2 to 3 degrees per second, which provides adequate tail clearance margins with a target liftoff attitude reached after approximately 3 to 4 seconds (see fig. 1).

Tail clearance margins for all 7-series models except the 717 are also outlined in the FCTM. Tail clearance and tail strike concerns are often the reason flight crews give for opting to use a slower rotation rate than recommended by Boeing. (More information about tail strike prevention can be found in *AERO* first-quarter 2007.)

When dispatching at or near the tire-speed-limit weight, which is most likely to occur at hot temperatures and high elevations, a slower rotation than the Boeing-recommended 2- to 3-degrees-per-second average may increase the actual groundspeed at liftoff beyond the certified tire speed limit. In addition, a slow rotation or under-rotation could significantly increase the runway distance required to reach the 35-foot point, which is another important reason for adhering to the Boeing-recommended rotation procedure.

WIND ACCOUNTABILITY

The certified tire-speed-limit weight does not contain any margin for wind accountability. For instance, the FAA-certified takeoff field-length-limit weight typically contains a conservative factor for wind accountability of 1.5 times the tailwind and 0.5 times the headwind. In comparison, the tire-speed-limit weight lacks any such conservative wind factor. Because of this, an unexpected tailwind component not accounted for in the takeoff analysis, occurring during a takeoff at or near the tire-speed-limit weight, may increase the true ground speed at liftoff beyond the tire speed rating.

To avoid a tire-speed-limit exceedance, Boeing recommends to conservatively account for the tailwind component when dispatching at or near the tire-speed-limit weight in a crosswind situation. General guidelines for crosswind takeoffs are outlined in the FCTM. These guidelines include the recommendation to use a higher thrust setting than the minimum required in order to minimize airplane exposure to gusty conditions during rotation, liftoff, and initial climb.

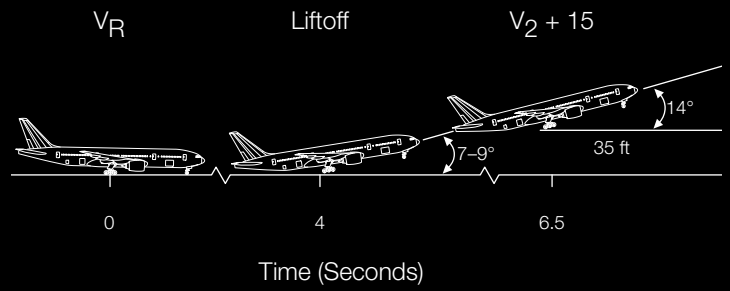
747-400 CASE STUDY

A case study of the 747-400 helps illustrate this point. The operator sporadically exceeded the tire speed limit even though the takeoff analyses showed a notable buffer between the tire-speed-limit weight

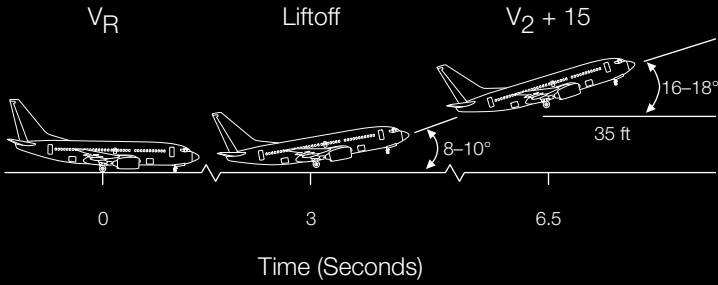
Figure 1: Typical rotation, all engines

The recommended rotation rate of 2 to 3 degrees per second provides adequate tail clearance margins with a target liftoff attitude reached after approximately 3 to 4 seconds.

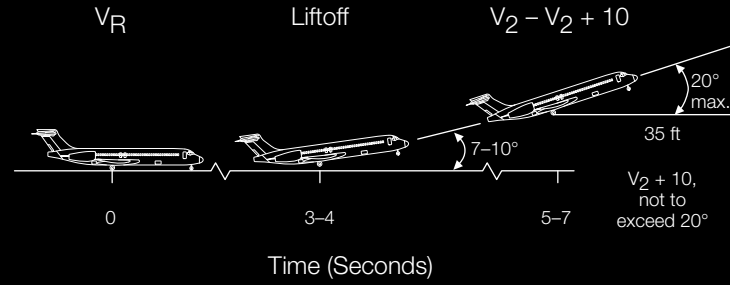
777-200 – 777-300ER



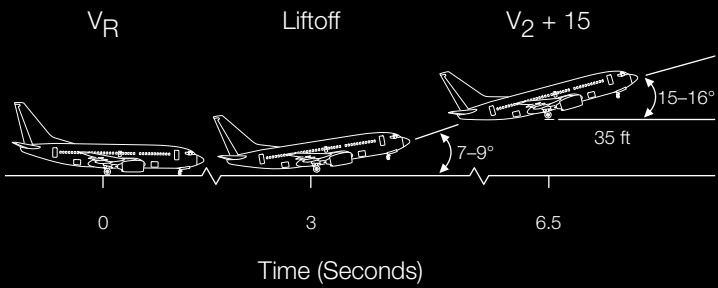
737-300/-400/-500



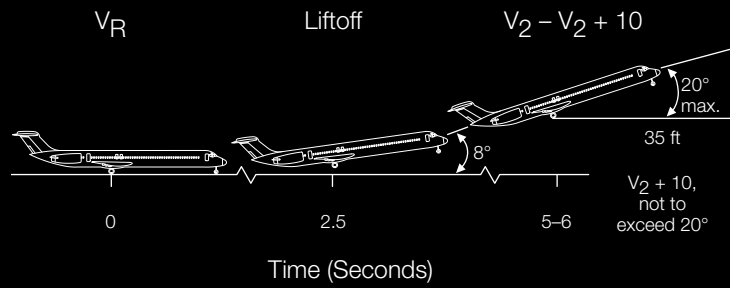
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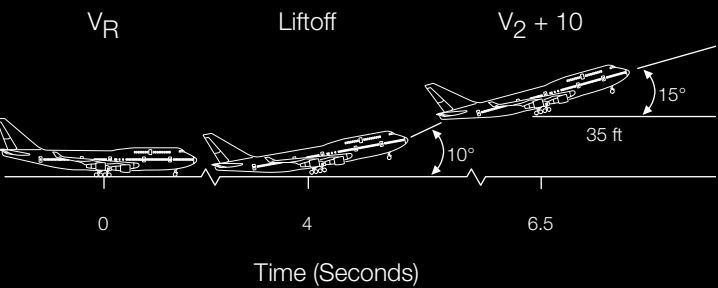
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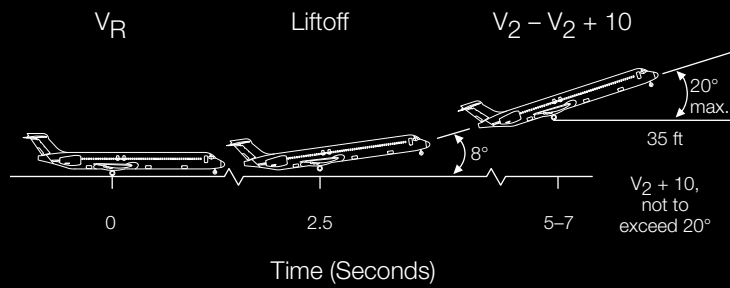
MD-80



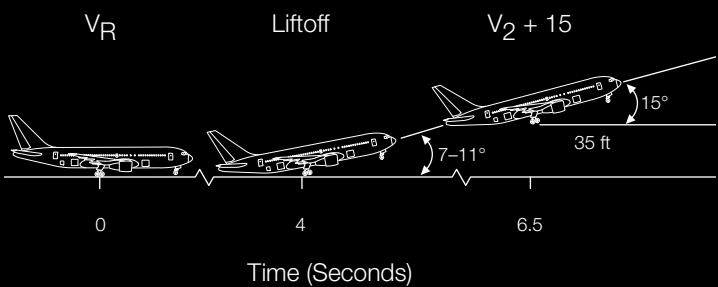
747-400



MD-90



757-200 – 767-400



MD-11

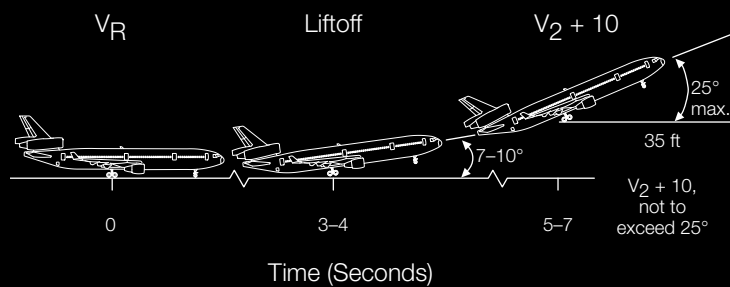


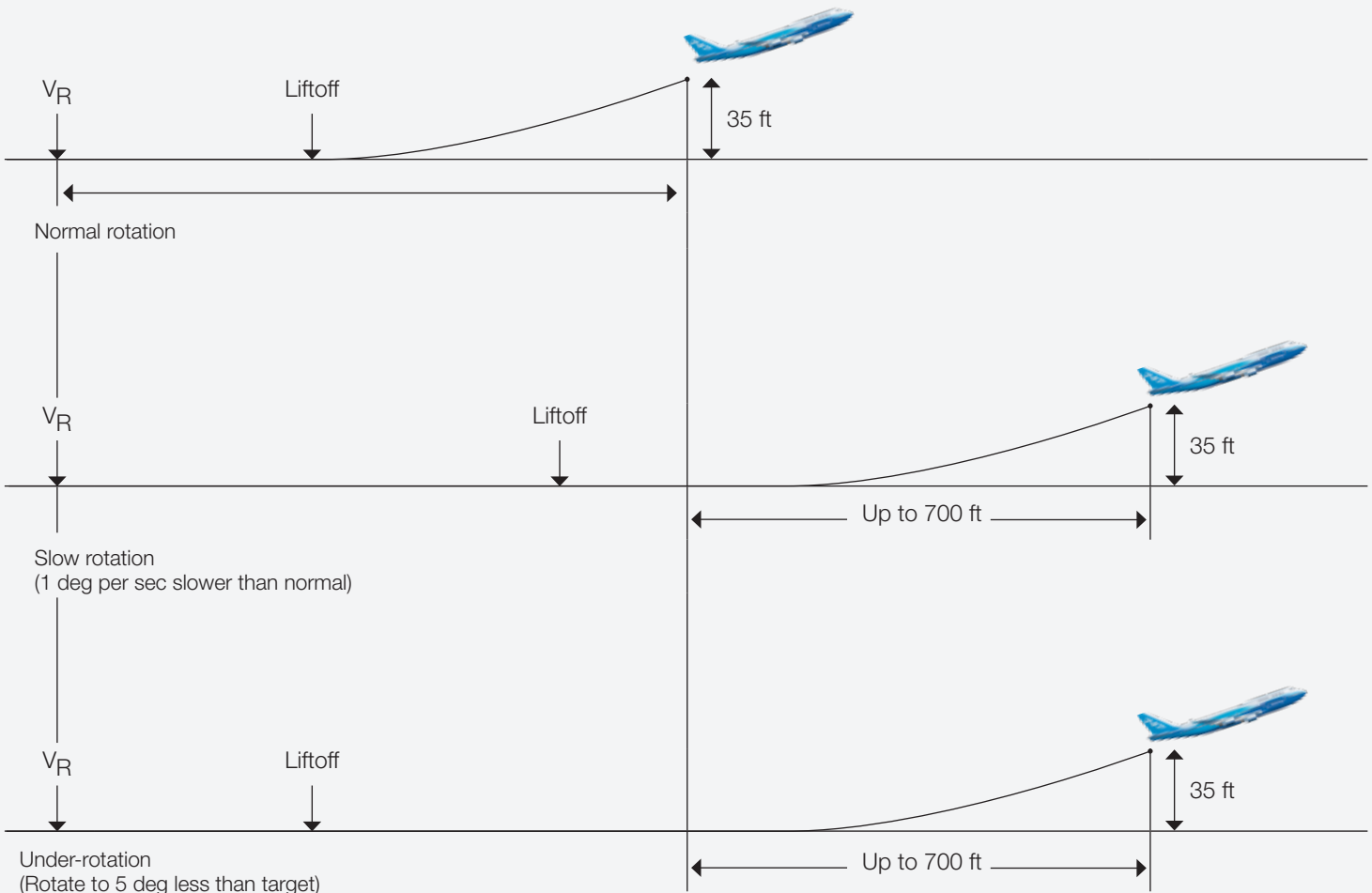
Figure 2: 747 Case study summary

Relatively large weight margins did not result in corresponding speed margins.

Takeoff I	Takeoff II
Dispatch Weight: 805,000 pounds	Dispatch Weight: 825,000 pounds
Tire-Speed-Limit Weight: 845,000 pounds	Tire-Speed-Limit Weight: 855,000 pounds
Weight Margin: 40,000 pounds	Weight Margin: 30,000 pounds
Scheduled Ground Speed at Liftoff: 196 knots	Scheduled Ground Speed at Liftoff: 199 knots
Rated Tire Speed: 204 knots (235 miles per hour)	Rated Tire Speed: 204 knots (235 miles per hour)
Speed Margin: 8 knots	Speed Margin: 5 knots

Figure 3: Effect of slow or under-rotation on all-engine takeoff distance

A 747-400 taking off with a rotation rate that is 1 degree per second slower than normal can result in a 4- to 5-knot liftoff speed increase.



and the actual dispatch weight. The airline approached Boeing for assistance.

The study was performed at two different dispatch weights: 805,000 pounds and 825,000 pounds. There was a 40,000-pound and a 30,000-pound margin between scheduled dispatch weight and the tire-speed-limit weight. These weight margins, which appear relatively large, only resulted in speed margins of 8 knots and 5 knots between the associated ground speeds at liftoff and the tire speed rating (see fig. 2).

This case study shows the relationship of a tire-speed-weight margin to the associated speed margin for a four-engine airplane. Under similar dispatch conditions on a two-engine airplane, a similarly large weight margin can be expected to result in an even lower speed margin, due to the higher all-engine acceleration.

The same case study showed that a rotation rate that is 1 degree per second slower than normal can result in a 4- to 5-knot liftoff speed increase. This is in addition to the increase in all-engine takeoff distance associated with the slow takeoff rotation (see fig. 3).

This illustrates how a slower-than-normal rotation rate can easily use up what may seem like a large tire-speed-limit margin, especially if paired with a higher tailwind component than accounted for in the takeoff analysis used for dispatch.

MAINTENANCE ACTIONS AFTER EXCEEDING THE TIRE SPEED LIMIT DURING TAKEOFF

Although tire-speed-limit exceedance events during takeoff are not a new phenomenon, widespread recognition of these overspeed events is relatively new because of advances in flight data recorder technology that enables easier data acquisition. Airplane manufacturers, tire suppliers, and regulators have not yet developed an industry-accepted set of maintenance

instructions following a tire-speed-limit exceedance event during takeoff.

One maintenance suggestion would be that all wheel/tire assemblies be removed from the airplane before further flight after such an event occurs. In practice, however, replacing all of the wheel/tire assemblies on an airplane represents a major logistical problem and likely results in flight cancellations and/or dispatch delays. It would be difficult to locate and ship 18 wheel/tire assemblies to a 747 at a remote location following one of these events! Additionally, if the overspeed was very small (say, 2 to 3 knots over the tires' speed limit), it is unlikely that the tires would have suffered any damage.

Some operators have elected to simply examine the tires after an overspeed takeoff event using the normal tire inspection criteria in Chapter 32 of the Airplane Maintenance Manual. If no damage is found, the airplanes are dispatched normally and no further maintenance actions are performed. Based on many years of service experience, this approach seems to have worked well because very few, if any, tire tread losses have been attributed to an overspeed event. Based on this service experience, Boeing has typically not objected to this practice even though there is no overspeed takeoff capability specifically designed into the tire.

If an operator has any questions about the integrity of the tires, the wheel/tire assemblies should be replaced before further flight.

Additional information on tire maintenance procedures can be found in the airplane maintenance manuals and in the following documents:

- FAA Advisory Circular 20-97B, "Aircraft Tire Maintenance and Operational Practices," April 18, 2005, U.S. Department of Transportation.
- "Aircraft Tire Care And Maintenance," Goodyear Aviation, 10/04, www.goodyearaviation.com/img/pdf/aircraftmanual.pdf.

- Bridgestone Aircraft Tires, Tire Care, and Maintenance, http://ap.bridgestone.co.jp/pdf/Care_and_Maintenance.pdf.
- Bridgestone Aircraft Tires, Examination, and Recommended Action, <http://ap.bridgestone.co.jp/candm/recommendedaction.html>.
- Aircraft Tire Care & Service Manual, Michelin, www.airmichelin.com/pdfs/Care_and_Service_manual.pdf.
- General practices manual for aircraft tyres and tubes, Dunlop Aircraft Tyres Limited, 01/08, www.dunlopaircrafttyres.com/tech_support/dm1172/DM1172.pdf.

SUMMARY

Although it is uncommon to exceed the load rating of tires during normal airline operation, Boeing is receiving an increasing number of operator inquiries about tire speed limits being exceeded during takeoff.

There is no industry consensus on the maintenance actions that should be taken following tire-speed-limit exceedance during takeoff. At this time, operators, in conjunction with their regulatory agency, must determine the most appropriate maintenance action based on the tire-speed-limit exceedance event.

The best approach is to try to avoid overspeed takeoffs altogether. By taking the following steps, flight operations personnel can reduce the possibility of tire-speed-limit exceedance during takeoff:

- Follow the Boeing-recommended rotation procedure.
- When dispatching at or near the tire-speed-limit weight in a crosswind situation, consider conservatively, accounting for the tailwind component.
- When dispatching at or near the tire speed limit in gusty wind and strong crosswind conditions, use a higher thrust setting than the minimum required.

For more information, contact Boeing Flight Operations Engineering at flightops_engineering@boeing.com. 