When a torsion link is completely severed as a result of a shimmy event, it can leave oscillating tire marks on the runway.

Preventing Main Landing Gear Shimmy Events

Main landing gear (MLG) shimmy is a rare event that starts at airplane touchdown and continues during rollout. Boeing has determined several causes of shimmy, particularly for the 737-200/-300/-400/-500 fleet and offers specific actions that can prevent this vibration from occurring.

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Based on operator reports, MLG shimmy is an infrequent event that is characterized by strong vibration, usually from one MLG, that begins at touchdown and continues until the airplane is fully stopped. Historically, there have been two or three shimmy events a year in the worldwide 737-200/-300/-400/-500 fleet. However, in the last few years, the rate of shimmy events has increased sharply on these models. In a few particularly severe shimmy events, the affected main landing gear collapsed during the landing.

This article discusses causes of shimmy and recommended actions operators can take to reduce the likelihood of it occurring.

UNDERSTANDING SHIMMY EVENTS

Boeing sometimes receives reports from operators of what is assumed to be a hard landing because of the violent nature of the landing and the observation of a torsion link fracture. However, Boeing's experience with these landings reveals that such damage actually suggests a shimmy event occurred.

Despite the presence of shimmy damper hardware, which is attached to the apex lugs on each MLG and is designed to reduce the torsional vibration energy generated during landing, airplanes occasionally experience MLG shimmy. Shimmy events almost always result in damaged torsion links and shimmy dampers (see fig. 1). When a torsion link is completely severed, it can leave oscillating tire marks on the runway. Following a shimmy event, the airplane typically needs to be temporarily removed from revenue-generating service for inspections and repairs.

Figure 1: Fractured torsion link

A main-landing-gear shimmy event fractured the lower torsion link and damaged the wheel, tire, and shimmy damper.

Boeing has studied shimmy events in an attempt to understand their root causes and to develop preventative actions or recommendations. Shimmy can occur on large or small commercial, commuter, and military airplanes with a single-axle MLG. In-service history indicates that shimmy events usually stem from maintenance errors in installation, excessive wear and freeplay in the landing gear joints, improper servicing of the damper or shock strut, or landings with extremely low sink rates.

The number of reported shimmy events has increased somewhat during the past several years. But the rate has significantly increased due to new operators with less familiarity in maintaining and operating 737-200/-300/-400/-500 airplanes along with the decreasing number of these airplanes in the worldwide fleet (see fig. 2). Because some operators mistakenly categorize the event as a hard landing instead of a shimmy, the amount of shimmy reports is considered to be lower than what actually occurs.

ABOUT SHIMMY

Shimmy is a torsional vibration excitation of the landing gear in which the inner cylinder, wheels, and tires rotate (or oscillate) relative to the outer cylinder that is fixed to the airplane structure (see fig. 3).

For shimmy to occur, the landing gear must have a force applied to it that excites this torsional vibration mode. The 737 has a vibration frequency of approximately 15 Hertz (Hz). Boeing engineers theorize that the force needed to initiate shimmy is probably an alternating drag force, such as if one tire touches down, causing a twisting motion of the inner cylinder in one direction and the second tire touches down a fraction of a second later, causing the inner cylinder to twist in the opposite direction. If the timing between the first tire and second tire contacting the runway is similar to the shimmy frequency, the gear can oscillate in the shimmy mode.

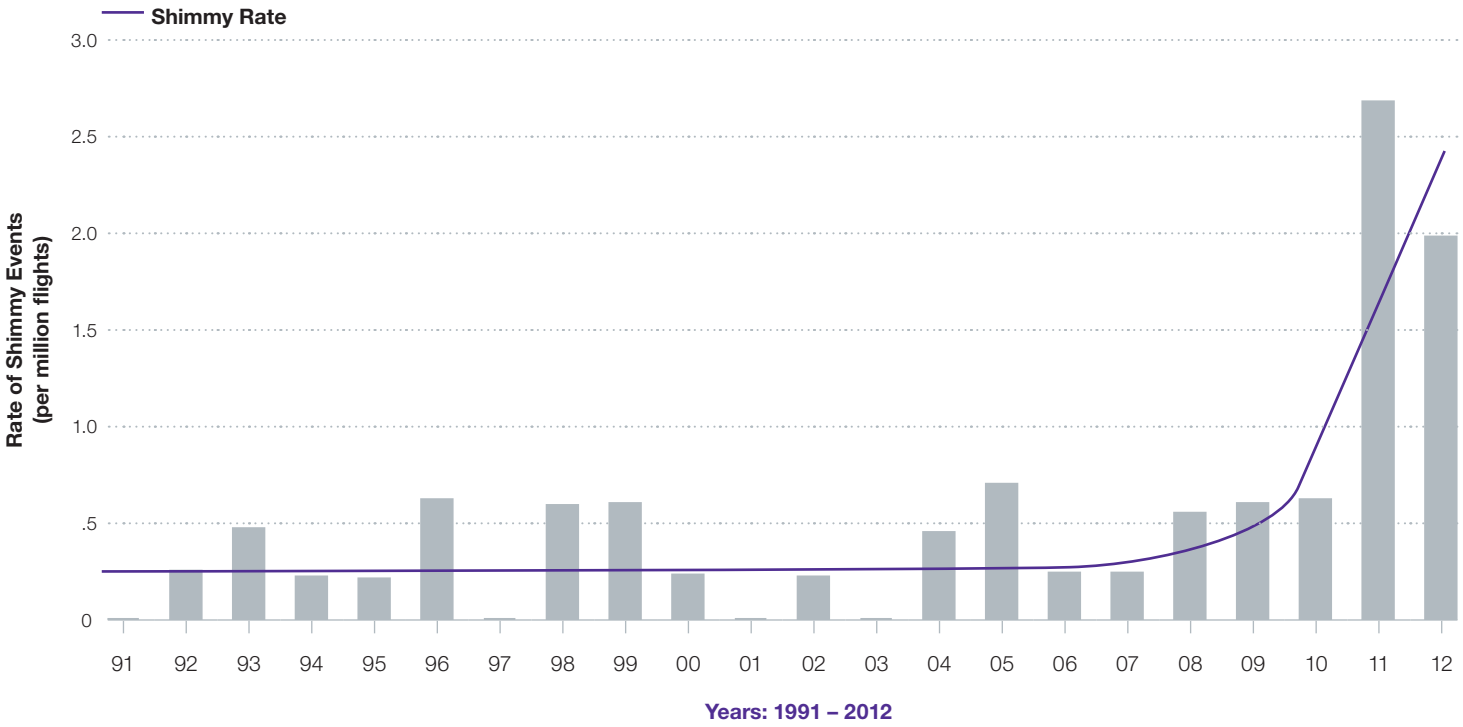
HOW BOEING HAS ADDRESSED SHIMMY

To prevent this vibration mode, all Boeing 737 airplanes use a hydraulic shimmy damper. The damper is connected between the upper and lower torsion links on the MLG and allows a small, but highly damped, motion to occur around the torsional axis of the gear.

Due to the geometry of the torsion links, the shimmy damper is most effective when the landing gear strut is compressed in the ground mode. With the shock strut fully or near fully extended, the torsion links hang in a near vertical position, which gives the damper less mechanical advantage to perform its function. MLG shimmy on a takeoff roll has never been reported, most likely because severe twisting forces are never applied to the gear during a takeoff and the gear is compressed into the ground mode.

Figure 2: Increase in shimmy occurrence

The shimmy rate is calculated by dividing the number of reported shimmy events by the average flight cycles accumulated by the fleet annually. The rate has significantly increased due to new operators with less familiarity in maintaining and operating 737-200/-300/-400/-500 airplanes along with the decreasing number of these airplanes in the worldwide fleet.



HOW DAMPERS CAN LOSE THEIR EFFECTIVENESS

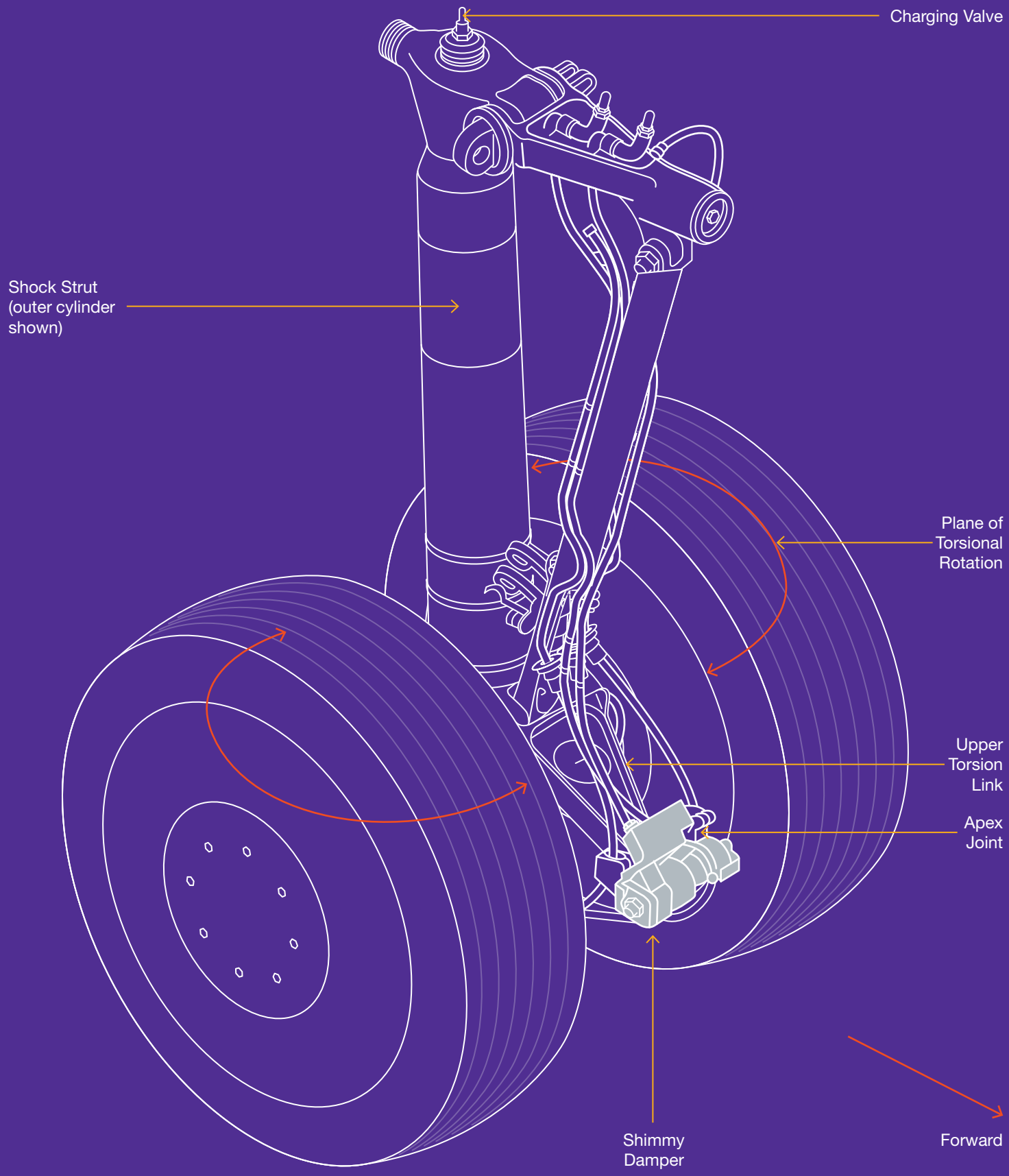
Although shimmy dampers have been very successful at preventing shimmy, problems can arise that render the dampers ineffective. Detailed studies of 737-200/-300/-400/-500 shimmy events have revealed several root causes. In approximate order of likelihood, they are:

- Excessive wear or freeplay in the joint where the shimmy damper connects to the lower torsion link (referred to as the apex joint). Wear at this location allows undamped torsional freeplay to exist in the landing gear at the apex joint, which greatly increases the likelihood of shimmy.
- Wear or freeplay in the torsion link bushings (e.g., where the torsion links connect to the outer and inner cylinder). Wear at these locations also allows undamped torsional freeplay.
- Landing with extremely low sink rates. This type of landing is more likely to experience shimmy than a firmer landing because the torsion links remain in an extended, vertical position where the damper has less mechanical advantage for longer periods to time.
- Air in the damper. Several shimmy events occurred within a few flights after a new or overhauled damper was installed. In these cases, it is suspected that a thorough bleeding of air from the damper was not performed, thus preventing proper damper operation.
- Damper piston fracture. In a small number of events, it is suspected that the damper piston fractured due to a preexisting fault (e.g., a fatigue crack).
- Overserviced shock strut. In several events, an overserviced shock strut has been suspected to have been a contributing factor. A shock strut overserviced with nitrogen allows the torsion links to have a reduced mechanical advantage to react to the torsional motion of the inner cylinder.
- Incorrect damper installation. In one event, a damper designed for a very early 737-200 had inadvertently been installed on a later airplane that required a more heavy-duty damper.
- Unconnected hydraulic tube. In one event, a hydraulic tube for the damper was inadvertently left unconnected after unrelated maintenance, so there was no hydraulic fluid available to the damper.

On the newer Next-Generation 737 airplanes, advances in technology enabled Boeing to redesign the details so that the joint is more robust and less prone to shimmy. Boeing accomplished this by using an improved shimmy damper, strengthening the torsion link apex joint, and by making the links from titanium without the lightening holes. Fleet experience is showing that this joint is now less susceptible to in-service wear than the earlier 737 models. However, appropriate maintenance is still necessary on the Next-Generation 737 models to prevent shimmy.

Figure 3: Torsional vibration is the cause of shimmy

Shimmy is a torsional vibration mode of the landing gear in which the inner cylinder, along with the wheels and tires, rotates (or oscillates) relative to the outer cylinder. To prevent this vibration mode, airplanes have a hydraulic damper installed between the upper and lower torsion links to allow a small, highly damped motion to occur around the torsional axis of the gear.



Boeing also recommends that pilots strive for a landing with normal sink rates with particular emphasis on ensuring that the auto speedbrakes are armed and deploy promptly at touchdown. An overly soft landing, or a landing in which the speedbrakes do not promptly deploy, allows the landing gears to remain in the air mode longer, which makes them more vulnerable to shimmy.

RECOMMENDED OPERATOR ACTIONS

Boeing has published several maintenance documents that advise operators of recommended maintenance to prevent shimmy events. These include:

- Service Letter 737-SL-32-057.
- Multi-Operator Message MOM-MOM-12-0127-01B.
- Fleet Team Digest Article 737-FTD-32-11001.
- 737 Aircraft Maintenance Manual 32-11-00/601, Torsional Free Play Inspection.
- 737 Aircraft Maintenance Manual 32-11-81/501, Main Gear Damper Adjustment.

Boeing has revised the relevant aircraft maintenance manuals (AMMs) and component maintenance manuals (CMMs) to improve the directions and procedures concerning shimmy damper and torsion link maintenance. For example, Boeing has added 737-300/-400/-500 AMM section 05-51-68, Main Landing Gear Shimmy/Vibration – Maintenance Practices (Conditional Inspection). Boeing recommends that operators review these maintenance publications, which are available on the MyBoeingFleet.com Web portal.

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SUMMARY

Dampers have eliminated most MLG shimmy events. However, these events can still occur in certain situations, particularly in the case of maintenance errors in installation, excessive wear and freeplay in the landing gear joints, improper servicing of the damper or shock strut, or during landings with extremely low sink rates. Landing gear collapse is even a possibility if the joints and dampers are not maintained according to Boeing recommendations. Boeing has published several maintenance documents that operators can use to maintain and operate airplanes in a manner that reduces the possibility of shimmy.

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