



# AEROSPACE INFORMATION REPORT

**AIR4894™****REV. A**

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Superseding AIR4894

## (R) Landing Gear Stability

### RATIONALE

This document has been revised to modify the text regarding tire imbalance, add sections on static stability, remove the lessons learned section, and make other minor updates.

### FOREWORD

The landing gear is a complex multiple-degree-of-freedom dynamic system that may encounter vibrations induced by several diverse sources and influences aircraft ground stability and control. Insufficiently damped, forced, or self-excited vibrations of any of the degrees of freedom can have consequences ranging from pilot and passenger discomfort through reduced service life to structural damage and loss of control. Aircraft static stability is also a function of the landing gear design.

The possible dynamic and static stability problems include:

- a. Shimmy
- b. Gear torsional windup
- c. Gear walk
- d. Aircraft pitching, porpoising, and vertical oscillations
- e. Brake squeal, chatter, and whirl
- f. Bogie (truck) pitching
- i. Directional control
- j. Tire and wheel assembly imbalance
- k. Static tipping
- l. Static ground gust stability

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## 1. SCOPE

This SAE Aerospace Information Report (AIR) discusses the nature of landing gear stability, describes many common landing gear stability problems, and suggests approaches and methods for solving or avoiding them.

## 2. REFERENCES

### 2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

#### 2.1.1 SAE Publications

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AIR1064      Braking System Dynamics

AIR6280      Overview of Aircraft Landing Gear Shimmy Analysis Methods

#### Code of Federal Regulations (CFR) Publications

Available from United States Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, [www.gpo.gov](http://www.gpo.gov).

14 CFR Part 25    Airworthiness Standards: Transport Category Airplanes

#### 2.1.2 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, [www.faa.gov](http://www.faa.gov).

TSO-C62      Aircraft Tires

#### 2.1.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, [www.easa.europa.eu](http://www.easa.europa.eu).

CS25      Certification Specification for Large Aeroplanes

## 2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

### 2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

AIR1489      Aerospace Landing Gear Systems Terminology

Black, R., "Realistic Evaluation of Landing Gear Shimmy Stabilization by Test and Analysis," SAE Technical Paper 760496, 1976, <https://doi.org/10.4271/760496>.

Grossman, D., "F-15 Nose Landing Gear Shimmy, Taxi Test and Correlative Analyses," SAE Technical Paper 801239, 1980, <https://doi.org/10.4271/801239>.

### 2.2.2 Other Publications

Gamon, M. and Malone, T. (1975). Active shimmy control system (Report no. AFFDL-TR-75-136). Air Force Flight Dynamics Laboratory.

Li, G.X. (1991). *Preliminary shimmy analysis for landing gear systems* (Report no. RD002). Heroux.

Li, G.X. (1992). *Advanced shimmy analysis for landing gear systems* (Report no. RD003). Heroux.

Moreland, W.J. (1954). The story of shimmy. *Journal of the Aeronautical Sciences*, 21, 793.

Pritchard, J.I. (2013). *An Overview of Landing Gear Dynamics* (NASA Technical Reports Server Document ID 19990047095). <https://ntrs.nasa.gov/citations/19990047095>.

Southerland, K.F. (1971). *Shimmy analysis for the F-15 nose landing gear report* (Report no. MDS A0932). McDonnell Aircraft Company.

## 3. STABILITY CRITERIA

In the case of self-excited vibrations like shimmy and brake squeal, landing gear stability requires the presence of positive system damping under all required operating conditions. This requires more than the availability of damping. The masses, stiffnesses, and damping are arranged so that at any required load and speed the damping is sufficiently effective.

In the case of forced vibrations, like that resulting from an unbalanced tire/wheel assembly, the criteria are both objective and subjective. First, objectively, the criteria are that the response not be damaging enough to produce a loss of control, a structural failure, or a reduction in life below specified levels. Secondly, subjectively, the level of response is low enough to be acceptable to the owner, flight crew, and passengers.

In general, a dynamic system can be considered adequately damped if the oscillation, following a perturbation, is reduced after three cycles to one-third or less of the original amplitude. This is evaluated under the least favorable combination of expected operating conditions, including speed, strut loading, type of airfield surface, structural wear, and tire type and wear condition.

In the case of static stability, the aircraft's gross weight, center of gravity, and landing gear arrangement are designed to avoid aircraft tipping and sliding in all directions due to loading/unloading and ground gusts during towing or parking. It is not only the aircraft and landing gear design that are relevant in this case but also the aircraft maintenance procedures and the use of appropriate ground equipment (e.g., chocks and tethers).

## 4. STABILITY PROBLEMS

### 4.1 Characteristics of Stability Problems

Dynamic instabilities can result from ordinary forced vibrations (unbalanced tire/wheel assembly, adjacent rotating machinery, aerodynamic phenomena) or self-excitation (brake chatter, shimmy, gear walk). The resulting vibratory response can be divergent or a limit cycle. Avoiding or solving an instability problem may require consideration of several factors. Forced vibrations may require reducing the forcing function, such as by reducing tire, tire/wheel assembly or machinery imbalance, or separating the forcing frequency and response natural frequency by changing stiffness or mass. Vibration absorbers or added dampers may be appropriate. In the case of self-excited vibrations, changes in mass, stiffness, brake friction characteristics, damping, or geometry may be necessary to produce a system that exhibits positive damping.