



AEROSPACE INFORMATION REPORT

AIR5914™

Issued 2014-06
Reaffirmed 2020-02

Landing Gear Fatigue Spectrum Development For Part 25 Aircraft

RATIONALE

This document provides a means for deriving a spectrum of loads for assessing the life of a main and nose landing gear for Part 25 tricycle landing gear structural components. Many of the recommendations herein are generalizations based on data obtained from a wide range of landing gears.

FOREWORD

This SAE Aerospace Information Report (AIR) provides recommendations for the derivation of analytical fatigue spectra for the design and qualification of landing gear structural components and the relevant actuation systems for Part 25 tricycle landing gear configuration.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides guidelines for the development of landing gear fatigue spectra for the purpose of designing and certification testing of Part 25 landing gear. Many of the recommendations herein are generalizations based on data obtained from a wide range of landing gears. The aircraft manufacturer or the landing gear supplier is encouraged to use data more specific to their particular undercarriage whenever possible.

1.1 Purpose

With the ever-increasing length of aircraft operating life, design for good fatigue resistance assumes greater prominence, particularly for civil aircraft with low reaction factors where landing loads are assumed to have little significance.

In recent years, the ability to gather field data on actual aircraft landing gear loading has allowed aircraft manufacturers to develop large data sets for use in developing fatigue spectra for new aircraft. This spectrum generally varies with the type of aircraft such as military versus commercial, as well as the various configurations of commercial aircraft from wide body transports to regional aircraft and business jets. In most cases, in the past the aircraft manufacturer has provided the fatigue spectrum in the design specification. This has ranged from block loads for similar maneuvers to the modern flight-by-flight spectrum. In cases where the fatigue spectrum is not provided, a standardized method of developing the fatigue spectrum is needed. This methodology can be used by landing gear supplier to develop the fatigue spectrum based on a set of parameters supplied by the aircraft manufacturer.

The purpose of this document is to establish guidelines for the landing gear supplier to develop Landing Gear Fatigue Spectra (LGFS) from loads data supplied by the aircraft manufacturer or with no data supplied by the manufacturer. It is the intent to base the recommendations for the various aircraft configurations upon historical data used in landing gear design as well as input from the aircraft manufacturers and in some cases, the aircraft users.

Individual landing gear units may be initially designed and qualified to fatigue requirements in excess of those stated in this report. This may be for a variety of reasons such as:

- a. Simplifying analysis and testing.
- b. Ensure adequate life availability for future increased weight versions of the airplane.

This report addresses the fatigue load spectrum requirements of the landing gear. Requirements in addition to those of this report may be imposed to verify functional and endurance aspects of the gears.

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 Military

- 2.1.1.1 MIL-A-8866, Airplane Strength and Rigidity Requirements, Repeated Loads, Fatigue and Damage Tolerance
- 2.1.1.2 MIL-S-8812D, Steering System: Aircraft General Requirements For
- 2.1.1.3 MIL-L-8552C, Landing Gear, Aircraft Shock Absorber

2.1.2 Regulatory Requirements

- 2.1.2.1 FAR 14 CFR Part 25, Federal Aviation Administration, Department of Transportation Part 25--Airworthiness Standards: Transport Category Airplanes
- 2.1.2.2 EASA CS 25, European Aviation Safety Agency Certification Specifications for Large Airplanes CS-25
- 2.1.2.3 NPA No. 2011-09, Notice of Proposed Amendment (NPA) No 2011-09, "Incorporation of generic SC and AMC CRIs in CS-25", May 2011.

2.1.3 Standards

- 2.1.3.1 ARP1383, Aerospace - Impulse Testing of Hydraulic Components
- 2.1.3.2 AIR1489, Aerospace Landing Gear Systems Terminology
- 2.1.3.3 ARP5429, Landing Gear Fatigue Tests with Equivalent Damage Spectra
- 2.1.3.4 AS8860, Landing Gear Structural Requirements as Listed in the MIL-886X Series of Specifications

2.1.4 Other Publications

- 2.1.4.1 Royal Aircraft Establishment Library Translation No. 1462, Cumulative Frequency Distribution of Aircraft Landing Gear Loads, O. Buxbaum and E. Gassner
- 2.1.4.2 Engineering Sciences Data Unit (ESDU) 75008, Frequencies of Vertical and Lateral Loads Factors Resulting from Ground Maneuvering of Aircraft
- 2.1.4.3 Advisory Group for Aeronautical Research and Development (AGARD), Report No. 118, A Review of Landing Gear and Ground Loads Problems, J.F. McBearty
- 2.1.4.4 DEF-STAN-00-970, Leaflet 41, Part 1 Section 4, Issue 2, Dec 1999, Fatigue Loads Spectra for Main Undercarriage Units, Design of Undercarriages-General Requirements, Fatigue Load Spectra for Main Undercarriage Units
- 2.1.4.5 NASA Technical Note TN D-4586, Trends in Repeated Loads on Transport Airplanes, Coleman, Thomas L.
- 2.1.4.6 Aeronautical Fatigue: Key to Safety and Structural Integrity, Loads at the Nose Landing Gears of Civil Transport Aircraft During Towbarless Towing Operations, G. Buxbaum, J.J. Cuny, H. Klatschle, H. Steinhilber
- 2.1.4.7 DOT/FAA/AR-97/106, Video Landing Parameter Survey Washington National Airport (DCA):June 1995
- 2.1.4.8 DOT/FAA/AR-00/72, Video Landing Parameter Survey - Honolulu International Airport, May 2001
- 2.1.4.9 18th Annual Airport Conference, March 1995, Landing Survey Discussions of Landing Parameter Data for Typical Transport Operations
- 2.1.4.10 UDR-TR-2002-00108, Statistical Loads Data for Bombardier CRJ200 Aircraft In Commercial Operations, University of Dayton Research Institute
- 2.1.4.11 DOT/FAA/AR-02/35, Statistical Loads Data for the Airbus A-320 Aircraft in Commercial Operations, April 2002
- 2.1.4.12 DOT/FAA/AR-00/10, Statistical Loads Data for B-767-200ER Aircraft in Commercial Operations, March 2000
- 2.1.4.13 DOT/FAA/AR-98-65, Statistical Loads Data for MD-82-83 in Commercial Operations, February 1999.
- 2.1.4.14 DOT/FAA/AR-00/11, Statistical Loads Data BE-1900D Aircraft in Commuter Operations, April 2000

- 2.1.4.15 DOT/FAA/AR-02/129, Side Load Factor Statistics from Commercial Aircraft Ground Operations, January 2003
- 2.1.4.16 AGARD Conference Proceedings 484, Landing Gear Design Loads; October 1990.
- 2.1.4.17 DOT/FAA/AR-98/28, Statistical Loads Data for Boeing 737-400 Aircraft in Commercial Operations, August 1998.

2.2 Terminology

CG	Center of Gravity
Dmax, Dmin	Maximum/Minimum Drag Load
EASA	European Aviation Safety Agency
FAR	Federal Aviation Regulations
Ftow	Towing Load applied in the Horizontal Direction
JAR	Joint Airworthiness Requirements
LGFS	Landing Gear Fatigue Spectra
MAC	Mean Aerodynamic Chord
MLG	Main Landing Gear
NLG	Nose Landing Gear
RR	Tire Rolling Radius (Dynamic)
TLR	Tire Loaded Radius
RTO	Rejected Takeoff
Smax, Smin	Maximum/Minimum Side Loads
SF	Scatter Factor
SSVP	Shock Strut Vertical Position
VAT	Vertical Axle Travel
V _{BR1}	NLG reaction load for the corresponding MLG Vertical and Drag Load during Medium Braking
V _{BR2}	NLG reaction load for the corresponding MLG Vertical and Drag Load during Maximum Braking
V	Vertical Load
V _D	MLG/NLG vertical load at the design maximum descent rate
V _{dr}	Aircraft Descent Rate
V _{ST}	MLG/NLG Static Vertical Load at the prescribed weight usage
WI	Landing Weight
Wr	Ramp Weight

3. GENERAL

The structural design of the landing gear is such that repeated loads do not cause failure or permanent deformation of any part of the landing gear, interfere with its mechanical operation, or affect its aerodynamic characteristics. Further, the design does not require repair, inspection, or replacement of components other than as specifically approved by the contracting activity. The above requirements apply to the planned service life of the airplane for the repeated loads environment resulting from ground and flight operations.

4. SERVICE LIFE

The service life of the airplane should not be less than that specified by the contracting activity in terms of the following (as applicable):

1. Flight hours
2. Ground-air-ground cycle (flights)
3. Taxi runs
4. Takeoff runs
5. Landings

5. GENERAL REQUIREMENTS

5.1 Typical Flight Profile

The fatigue life requirements are specified in terms of airplane flights. One airplane flight is defined, in sequence of ramp-to-ramp events, which includes pushback/towing, taxi out, takeoff run, liftoff, gear retraction, cruise, gear extension, touchdown, landing rollout, and taxi in.

5.2 Scatter Factor

The life requirements for the landing gear structure should be specified in number of airplane flight hours or flight cycles with a relationship between airplane flight hours and number of landings.

Appropriate life scatter factors (SF) should be used for analysis and test.

Fatigue design life implies the average life expected under average aircraft utilization and loads environment. To this design life, application of a scatter factor accounts for the typical variations from the average utilization, loading environments, and basic fatigue strength allowable. This leads to a safe-life period during which the probability of a detectable structural crack occurring is very low.

Scatter factors ranging from four to five have been used to account for statistical variation in component fatigue tests and unknowns in loads. Load unknowns involve both methods of calculation and type of service actually experienced.

CFR 14 Part 25 AC 25.571 and EASA AMC 25.571 present guidance in determining the scatter factor.