Test Procedures for Evaluating Bolt-Load Retention of Magnesium Alloys

SAE/USCAR-35-1
Stabilized 2020-11

ISBN: 978-0-7680-1975-9

SAE/USCAR-35-1

Issued 2007-10
Stabilized 2020-11

TEST PROCEDURES FOR EVALUATING BOLT-LOAD RETENTION OF MAGNESIUM ALLOYS

STABILIZED NOTICE

This document has been declared “Stabilized” by USCAR and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

QUESTIONS REGARDING THIS DOCUMENT: (248) 273-2470 FAX (248) 273-2494
TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX (724) 776-0790

SUMMARY OF CONTENTS

1. SCOPE

1.1 A bolt-load retention (BLR) test is a practical test to determine the bolt load of a fastener joint with time and at given temperatures. There are three types of BLR tests described in this standard, namely general-purpose test, design-purpose test, and screening material test. A general-purpose BLR test may be used for screening materials, while a design-purpose BLR test is usually used to verify the BLR behavior of a specific joint. The screening material test is an example of the general-purpose test for typical automotive applications.

1.2 The test procedures provides guidance in the following areas: (a) BLR sample and test fixture, (b) test fastener, washer and nut, (c) bolt-load measurement and data acquisition, (d) heating device, (e) initial loading, (f) baseline test, and (g) instrumentation of strain gages and calibration (see Appendix B). A design-purpose test procedure differs from a general-purpose test procedure mainly in the areas dealing with sample and fixture, test washer and nut, and initial loading.

1.3 This standard is intended to evaluate and/or validate BLR of magnesium alloys, especially cast magnesium alloys, for automotive applications. It is implied that the test samples mentioned in this standard are to be produced from casting processes but are not restricted to castings and magnesium alloys.

This standard is intended to evaluate BLR behavior during long-duration BLR tests. The effect of thermal cycling without holding the samples at high temperatures for a long period of time is discussed in Appendix C.

2. REFERENCES

ASME B18.2.3.1M Metric Hex Cap Screws
ASME B18.2.4.1M Metric Hex Nuts, Style 1
ASTM A563M-04 - Specification for Carbon and Alloy Steel Nuts (Metric)
ASTM F568 Carbon and Alloy Steel Externally Threaded Metric Fasteners
ISO 4014 Hexagon Head Bolts - Product Grades A and B
ISO 4032 Hexagon Nuts, Style 1 - Product Grades A and B
ISO 898-1:1999(E) - Mechanical Properties of Fasteners Made of Carbon Steel and Alloy Steel, Part 1: Bolts, Screws and Nuts Studs
ISO 898-2:1992 - Mechanical Properties of Fasteners Made of Carbon Steel and Alloy Steel, Part 2: Nuts with Specified Proof Load Values - Coarse Thread
SAE J174M - Torque-tension Test Procedure for Steel Threaded Fasteners-Metric Series

3. GENERAL REQUIREMENTS

3.1 Test Sample

3.1.1 General-purpose Test Sample

The BLR sample for a general test procedure shall be a hollow cylindrical sample. The external (i.e. outside) diameter may be 1 to 1.5 times the diameter of washers (see 3.3), and a 1.5 times washer-size sample is recommended.

The mating surfaces shall be machined to give a 1.6-μm finish (Ra). The sample external surface and the internal surface of a through-bolt joint (see 3.2) are not critical and may be used in the as-received state, as is also the case for the external surface of a self-threaded bolt joint.

3.1.2 Design-purpose Test Sample

The BLR sample for a design-test procedure shall use the actual joint from the component. For test convenience, the joint may be removed from the component with the maximum external diameter or the external diameter no less than 1.5 times the diameter of washers (see 3.3). The mating surface condition (i.e. coating and fitting) shall be kept as original production.

In cases where production components are unavailable (such as in the initial design stage), the BLR samples for an intended application shall be produced using the intent manufacture process and have the same dimensions (i.e. external diameter, thickness and height). The sample shall be treated with production-intent coating and other processes.

3.1.3 Screening Material Test Sample

The BLR sample for screening material test procedure shall be the same as General-purpose Test Samples with the following exceptions: sample outside diameter 33.8 +/-0.2 mm, sample inside diameter 11.0 +/-0.2 mm, sample height 30.0 +/-0.2 mm.

3.2 Test Fixture

3.2.1 General-purpose Test Fixture

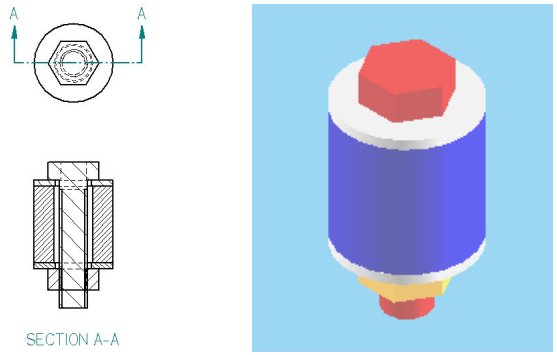
General-purpose test fixtures for the two common joint types are shown in Figure 1 using a hollow cylindrical sample (see 3.1.1) with washers (see 3.3).

3.2.2 Design-purpose Test Fixture

The BLR test fixture for a design-purpose test shall be the same as the actual bolt joint; the parts attached to the sample (i.e. the cross-member, see 3.1.2) to form a joint are critical and shall be included in the test fixture. The dimensions (or heights) of parts along the fastener loading direction are critical, but the sizes of part transverse to the fastener loading direction are less critical. The parts to be included in the fixture may be removed from the original parts with their maximum external dimension or the external diameter dimension no less than 1.5 times the diameter of washers (see 3.3).

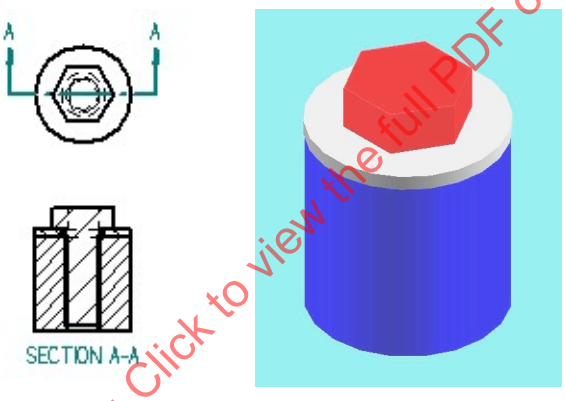
3.2.3 Screening Material Test Fixture

The Screening Material Test Fixture shall conform to Figure 1 (a) through-bolt type bolt type.



(Cross-section) (Three-dimension)

(a) The through-bolt type bolt joint



(Cross-section) (Three-dimension)

(b) The self-threaded type bolt joint

Figure 1 - Schematic of the BLR test fixtures

3.3 Test Fastener, Washer and Nut

3.3.1 General-purpose Test Fastener, Washer and Nut

Test fasteners (bolts) may be chosen based on the sample size and/or intended application. The steel fasteners shall meet the specifications set out in ISO 898 Part 1.

A round hardened steel washer shall be used on each mating surface of the sample (see 3.1.1). The washers (the dimensional, metallurgical and finish requirements) shall be selected according to the fastener used per SAE J174M. The use of excessive washers (i.e. more than one washer at each mating surface) shall be avoided because this increases the grip length.

The nut shall have the same grade as the fastener and the nut shall meet the specifications set out in ISO 898 Part 2 or ASTM A 563M.

3.3.2 Design-purpose Test Fastener, Washer and Nut

Test fasteners, washers and nuts for design-purpose tests should be chosen exactly as required for the intended applications, i.e. the type, geometry, material and surface processes.

3.3.3 Screening Material Test Fastener, Washer and Nut

Test washer geometry shall conform to the following: outside diameter 23.0/22.4 mm, inside diameter 11.4/11.2 mm, thickness 2.0/1.8 mm. See SAE J174M for metallurgical and finish requirements. M10 X 1.5 x 50 6g screws conforming to the general requirements of ASME B18.2.3.1M (ISO 4014), and heat treated in accordance with ASTM F568 (ISO 898-1), Property Class 10.9, shall be used. Decarburization of the screw threads shall be within the limits defined in SAE J121M (ISO 898-1), Class 3/4 H. A minimum of two full form threads shall protrude through the test nut when the screw is fully seated. Test nuts shall be M10 x 1.5 6H conforming to the general requirements of ASME B18.2.4.1M (ISO 4032) and heat treated in accordance with ASTM A563M (ISO 898-2), Property Class 10.

3.4 Bolt-Load Measurements and Data Acquisition

Bolt loads shall be monitored at room temperature, during heating-up, at test temperatures, and during cooling-down to room temperature. Three thermal cycles between test and room temperatures shall be performed at the end of test, and the bolt loads shall be recorded.

Data should be acquired using a technique that has provision for enough speed to catch the initial load increase of Mg alloys due to thermal expansion mismatch. A rate of 10 readings/s has proven useful. The acquisition speed should ideally be able to change during tests because BLR tests are usually long-term tests.

A recommended technique for load measurement and associated data acquisition is described in Appendix B.

3.5 Heating Device

3.5.1 General-purpose Test Heating Device

Oil baths shall be used for the general-purpose BLR tests. Temperature control shall be +/- 1.0°C.

3.5.2 Design-purpose Test Heating Device

Either oil baths or electric furnaces can be used for the design-purpose BLR tests and shall be documented. Since BLR tests for automotive applications are usually conducted at temperatures below 250°C, the use of electronic furnaces may be less efficient to reach the test temperature.

3.5.3 Screening Material Heating Device

Oil baths shall be used for the screening material BLR test. Temperature control shall be +/- 1.0°C.

3.6 Initial Loading

3.6.1 General-purpose Test

For general-purpose tests, an initial load shall be applied based on the fastener geometry and grade and/or the intended application. The initial load shall be no more than 90% of the proof load of the fastener.

Load shall be applied to the test fixture by torque at room temperature. To achieve the required initial load for BLR tests, the applied load shall be about 3-5% higher than the target load and shall allow a 2 hour waiting period at room temperature before testing.

When attempting to compare BLR test results from different fasteners, washer sizes, and sample geometries, the effective stresses in test samples should be same and may be estimated using the following effective stress area equations. For the hollow cylindrical BLR sample and the through-bolt fixture (as shown schematically in Figure 1a) when the sample diameter (D_{sample}) is greater than the washer diameter (D_{washer}) but less than the $3D_{washer}$, the effective stress area (A_c) can be estimated as:

$$A_c = \frac{\pi}{4}\left(D_{washer}^2 - D_c^2\right) + \frac{\pi}{8}\left(\frac{D_{sample}}{D_{washer}} - 1\right)\cdot\left(\frac{D_{washer}H_{sample}}{5} + \frac{H_{sample}^2}{100}\right) \quad (1)$$

where D_c is the core diameter of the sample, and H_{sample} is the height of the sample. When the joint diameter is greater than $3D_{washer}$ in design-purpose test fixtures, the effective stress area is

$$A_c = \frac{\pi}{4}\left[(D_{washer} + 0.1H_{sample})^2 - D_c^{\,2}\right] \quad (2)$$

These equations may also be used as a first approximation for the self-threaded type of bolt joint as shown schematically in Figure 1b. Whenever more accurate finite-element analysis results are available, they should be used to estimate the effective stress area for BLR test samples.

3.6.2 Design-purpose Test

For design-purpose tests, the initial load and fastener loading practice shall be consistent with the intended application. Initial loading is critical to BLR behavior.

3.6.3 Screening Material Test

For screening material tests, the initial load shall be 30 kN at room temperature. Allow a 2 hour waiting period at room temperature and initial loading. After the 2 hours, adjust load if necessary back to 30 kN.

3.7 Testing

3.7.1 General-purpose Test

A baseline test for a fixture shall be performed on a hardened steel sample similar to the test sample for general-purpose tests. The tests shall be performed at the test temperatures and loads. This shall be followed by testing the actual test samples at the test temperatures and loads.

3.7.2 Design-purpose Test

There is no need to perform baseline tests for design-purpose tests unless some modifications are made to the test fixture, fastener, nut and loading to facilitate the tests, and these modifications shall be documented. Testing shall be performed to simulate the actual design.

3.7.3 Screening Material Test

As part of the Screening material test, a baseline test shall be performed with a hardened steel test sample meeting the dimensions in 3.1.3. Baseline testing shall utilize the initial loading for screening material test and test time and temperature as for screening material. This shall be followed with testing the screening material test samples. Testing will be done for two temperature conditions, 125 ºC and 175 ºC. The initial loading shall be followed by testing samples for 100 hours at test temperature, followed by cooling down to room temperature.

4. REPORT

Bolt-load retention test details shall be reported.

Test results are usually reported as remaining fractions of initial loads vs time. In reviewing the test data, the load drops in the baseline test should be excluded to compensate for the load drops for tests on test samples.

Variability of cast samples is usually larger than that of wrought (and annealed) samples, and therefore multiple samples (at least three) are recommended.

BLR tests uniformly heated in an oil bath yield conservative results if the test temperature selected is the highest temperature in the joint that may have a non-uniform temperature distribution.