Prevailing Torque Locking Feature in Threaded Fasteners using Anaerobic Adhesive

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Abstract

This paper presents results from tests to assess the use of anaerobic adhesive for providing a prevailing torque locking feature in threaded fasteners. Test procedures are developed and tests are performed on three fastener materials, four anaerobic adhesives, and both unseated assembly conditions. Five to ten samples are tested for each combination. Tests for initial use, reuse without additional adhesive, and reuse with additional adhesive are performed for all samples. A 48-hour cure time was used for all initial use and reuse tests. Test data are presented as removal torque versus removal angle with the specification required prevailing torque range added for performance assessment. Percent specification pass rates for the all combinations of fastener material, adhesive, and assembly condition are tabulated and reveal use of anaerobic adhesive as a prevailing torque locking feature is viable. Although not every possible fastener material and anaerobic adhesive combination provides prevailing torque values within specification, any combination can be assessed using the test procedures presented. Reuse without additional anaerobic adhesive generally provides some prevailing torque, and in some cases within specification. Reuse with additional adhesive often provides comparable removal torque data as in initial use.

Introduction and Background

Prevailing torque locking features and anaerobic adhesives are used to provide secondary locking in threaded fasteners. The aerospace industry has embraced prevailing torque locking in fasteners, in part, due to the ease in which the feature can be validated during installation. In addition, the industry has well-defined standards and specifications for this type of locking feature [1-6].

Anaerobic adhesives provide excellent locking and can maintain preload in fasteners provided sufficient curing occurs, but this is not always guaranteed. Although validation for this type of locking is possible [7], it is not yet in widespread use in practice.

Recent application of anaerobic adhesive for repair of worn prevailing torque locking in inserts on the Space Shuttle windshield [8, 9] has given rise to the premise of this work. Namely, use of adhesive for providing prevailing torque type locking feature, and quantifying its performance using the well-defined prevailing torque standards and specifications. No published research on this concept currently exists.

Use of anaerobic adhesive for providing prevailing torque locking actually relaxes the usual expectation of adhesive to maintain preload to the common expectation for prevailing torque locking features which is to prevent disassembly.

This paper presents results from tests performed to assess the use of anaerobic adhesive to provide a prevailing torque type locking feature. This work provides much needed test data supporting the use of adhesive in providing prevailing torque locking for repair as well as on fasteners without secondary locking.

Performance of prevailing torque locking fasteners in reuse is required in qualification specifications. However, these requirements are often stated in terms of reuse in unseated rather than seated conditions and this distinction is sometimes missed. This issue has been recently examined through a series of tests

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and presented elsewhere [10]. All prevailing torque features tested [10] exhibit a decrease in prevailing torque with reuse with the largest decrease during first reuse. The effect of seating to preload is a higher loss in prevailing torque (e.g., 10 to 25% loss during initial use) compared to unseated results.

In addition to tests performed to assess initial use of anaerobic adhesives to provide prevailing torque type locking, this paper presents results from tests to assess reuse. Reuse with and without adding additional anaerobic adhesive are tested. It is found in most cases that reuse with additional adhesive performs comparable to the initial use case. The significance of this result is that using anaerobic adhesive to provide prevailing torque locking may have the added benefit of negligible degradation with reuse due to self-repair with additional adhesive.

Test Specimens and Equipment

Tests were performed using ¼-28 (M6x1) threaded fasteners. Three fastener materials were tested including plain grade 8, yellow-zinc grade 8, and aerospace A286. Four low to medium strength anaerobic adhesives (Loctite 290, Loctite 222MS, Loctite 242, and Loctite 243) were tested with each of the three fastener materials. Unseated assembly conditions were tested for all fastener materials and adhesive combinations. Five to ten samples were tested for each combination of fastener material, adhesive and assembly condition for a total of 96 samples. Three tests were performed for each of these samples including 1) an initial use test, 2) a reuse with no additional adhesive, and 3) a reuse with additional adhesive. For each of these tests, torque measurements were obtained at multiple removal angles including 0 (i.e., breakaway), 2-5, 90, 180, 270 and 360 degrees.

The grade 8 test fasteners have ¼-28 UNF (M6x1) threads and the aerospace A286 test fasteners have ¼-28 UNJF (M6x1) threads. All test nuts are hex nuts and all test washers are flat. Specifications for the test fasteners are as follows:

1. Plain grade 8:
    a. Cap screw: ¼-28 UNF, 1.25-in length (M6x1, 31.75 mm)
    b. hex nut: ¼-28 UNF, 0.22-in thickness (M6x1, 5.6 mm)
    c. flat washer: 0.057-in thickness (1.45 mm)
2. Yellow-zinc plated grade 8:
    a. Cap screw: ¼-28 UNF, 1.25-in length (M6x1, 31.75 mm)
    b. hex nut: ¼-28 UNF, 0.22-in thickness (M6x1, 5.6 mm)
    c. flat washer: 0.081-in thickness (2.06 mm)
3. A286 passivated (aerospace):
    a. NAS1004-1A cap screw: ¼-28 UNJF, 0.6-in length (M6x1, 15 mm)
    b. hex nut: ¼-28 UNJF, 0.22-in thickness (M6x1, 5.6 mm)
    c. flat washer: 0.032-in thickness (0.81 mm)

Four types of anaerobic adhesive were used in the tests. These were Loctite 290, 222MS, 242 and 243. Loctite 290 is a medium strength wicking grade which was found to consistently exceed the specification required prevailing torque range of 3.5-30 in-lb (0.40-3.4 N-m) for ¼-28 (M6x1) fasteners, so limited testing was performed with this adhesive. The main characteristics for the other three anaerobic adhesives are as follows:

1. Loctite 222MS is low strength and purple in color.
2. Loctite 242 is medium strength and blue in color.
3. Loctite 243 is medium strength and blue in color. It has activator or primer added to provide better curing and performance with inactive materials such as A286 stainless steel.

Dial torque wrenches were used for measuring the removal and prevailing torque of the threaded fasteners. A torque wrench with a 75 in-lb (8.5 N-m) range and 1 in-lb (0.1 N-m) increments was used for prevailing torque measurements for both seated and unseated tests.

All test fasteners were inspected for smooth assembly and cleaned prior to tests. All test fasteners (i.e., cap screws, nuts and washers) and fixtures were cleaned using an ultrasonic cleaner with methyl ethyl ketone (MEK) solvent for 5 minutes and allowed to air dry before testing.

Test Procedures

Tests include an initial use test, reuse without additional adhesive test, and reuse with additional adhesive test. The preparation procedures for these three tests are different, but the test procedure is the same as listed below.

Preparation for unseated initial use tests:

1) Apply 2 drops of anaerobic adhesive to cap screw threads.
2) Apply 1 drop of anaerobic adhesive to hex nut threads.
3) Assemble cap screw and hex nut until three full threads extend beyond nut.
4) Allow adhesive to cure for 48 hours on a lint free paper towel.
5) After curing time, wipe any excess adhesive from cap screw threads with a lint free paper towel.

Test procedure for unseated initial use tests, unseated reuse without additional adhesive tests, and unseated reuse with additional adhesive tests:

1) Clamp head of cap screw in a vise.
2) Use 0-75 in-lb (0-8.5 N-mm) dial-type torque wrench to apply torque to nut in counter-clockwise direction gradually until motion is initiated. Record breakaway torque at the instant of motion.
3) Continue applying torque and record torque values at 2-5, 90,180, 270, and 360 degrees.

Preparation for unseated reuse without additional adhesive tests:

1) Remove hex nut completely from cap screw.
2) Reassemble hex nut to the same position as in initial use test.
3) Allow adhesive to cure for 48 hours on a lint free paper towel.

Preparation for unseated reuse with additional adhesive tests:

1) Remove hex nut completely from cap screw.
2) Add 2 drops of anaerobic adhesive to cap screw threads.
3) Add 1 drop of anaerobic adhesive to hex nut threads.
4) Reassemble hex nut to the same position as in initial use test.
5) Allow adhesive to cure for 48 hours on a lint free paper towel.

Test Data and Analysis

All the test data has been assembled in plots of measured removal torque in inch-pounds versus removal angle in degrees [11]. The allowable range of prevailing torque for ¼ -28 (M6x1) thread size is between 3.5 and 30 in-lb per specification [1-6]. This is indicated by horizontal dashed lines in the plots for quick assessment of results. Each plot includes data from 5 to 10 test fasteners. Overlap of data points in the plots occurs.

Figure 1 shows three plots for the unseated grade 8 fasteners with Loctite 222MS for the initial use, reuse without additional adhesive, and reuse with additional adhesive. This shows all removal torque measurements were within the specification of 3.5 to 30 in-lb (0.40-3.4 N-m) for initial use giving a 100% pass rate for this fastener and adhesive combination. For reuse without additional adhesive, many torque measurements fall below the specification, whereas for reuse with additional adhesive, only a couple fall below specification. This data shows the effect of reuse with versus without additional adhesive.

An unseated test specimen passes the prevailing torque specification only when the measured removal torque is within the 3.5 to 30 in-lb (0.40-3.4 N-m) range over the entire removal angle range from breakaway to 360 degrees. When all measured removal torque values from all test samples for a combination of fastener material and adhesive are with this range, the test combination has 100% pass rate.

Table 1 lists the pass rates with respect to the 3.5 to 30 in-lb (0.40-3.4 N-m) prevailing torque specification for unseated plain grade 8 threaded fasteners. The first entry in the table shows 100% pass rate for all initial use tests of plain grade 8 fasteners with Loctite 222MS in unseated assembly. Reuse without additional adhesive tests for this case have only a 10% pass rate. An unseated test specimen passes the prevailing torque specification only when the measured removal torque is within the 3.5 to 30 in-lb (0.40-3.4 N-m) range over the entire removal angle from breakaway to 360 degrees. Reuse with additional adhesive tests for this case have an 80% pass rate.

Table 1. Unseated plain grade 8 specification pass rate

Plain Grade 8	Loctite 222MS	Loctite 242	Loctite 243
Initial use	100%	90%	10%
Reuse w/o additional adhesive	10%	80%	0%
Reuse w/ additional adhesive	80%	80%	100%

The same analyses has been performed for unseated grade 8 fasteners with Loctite 242 and Loctite 243 [11]. The pass rates for these cases are included in Table 1. This data shows the effect of different adhesives for the same fastener material in the initial use and reuse conditions. Reuse with additional adhesive outperforms reuse without additional adhesive for this fastener material.

Similar results are found for the unseated tests with yellow-zinc grade 8 fasteners and A286 fasteners. The plots for the unseated A286 aerospace fasteners with Loctite 243 adhesive are shown in Figure 2. This combination of fastener and adhesive is shown because A286 is an inactive material and the Loctite 243 has activator or primer included to improve cure. This adhesive performs the best for the unseated A286 fasteners as shown in Table 2 which lists pass rates for all unseated A286 fastener tests. Note that the low pass rate for unseated initial use tests for A286 fasteners with adhesives lacking primer or activator (e.g., 222MS and 242) is due to the fact that A286 material is inactive which inhibits cure.

Table 2. Unseated A-286 specification pass rate

A-286	Loctite 222MS	Loctite 242	Loctite 243
Initial use	0%	0%	100%
Reuse w/o additional adhesive	60%	50%	10%
Reuse w/ additional adhesive	78%	78%	100%

The unseated test results reveal several combinations of fastener material and adhesive that provide prevailing torque within specification for initial use and reuse with additional adhesive. This proves using adhesive to provide prevailing torque locking within specification is a viable option.

Conclusions

This work assessed the use of anaerobic adhesive to provide a prevailing torque locking feature. Test procedures were developed for this assessment that can be used in practice to assess any fastener and adhesive combination and joint conditions. Tests were conducted with different threaded fastener materials and anaerobic adhesives in unseated assembly conditions. Initial use, reuse without additional adhesive, and reuse with additional adhesive cases were tested. A 48-hour cure time was used for all initial use and reuse tests.

Test data were presented as removal torque versus removal angle with required prevailing torque range per specification added for easy assessment. Percent pass rates for the various fastener material, anaerobic adhesive, and assembly condition combinations were tabulated.

The results of this work show:

1. Use of anaerobic adhesive as a prevailing torque locking feature is viable.
2. Not all possible fastener material and anaerobic adhesive combinations provide prevailing torque values within specification. However, any combination can be assessed using the test procedures developed.
3. Reuse without additional anaerobic adhesive generally provides some prevailing torque, and in some cases within specification. Note that a reuse test in this work follows complete disassembly, reassembly and 48-hour cure time regardless of whether additional adhesive is used.
4. Reuse with additional adhesive often provides comparable removal torque data as in initial use.

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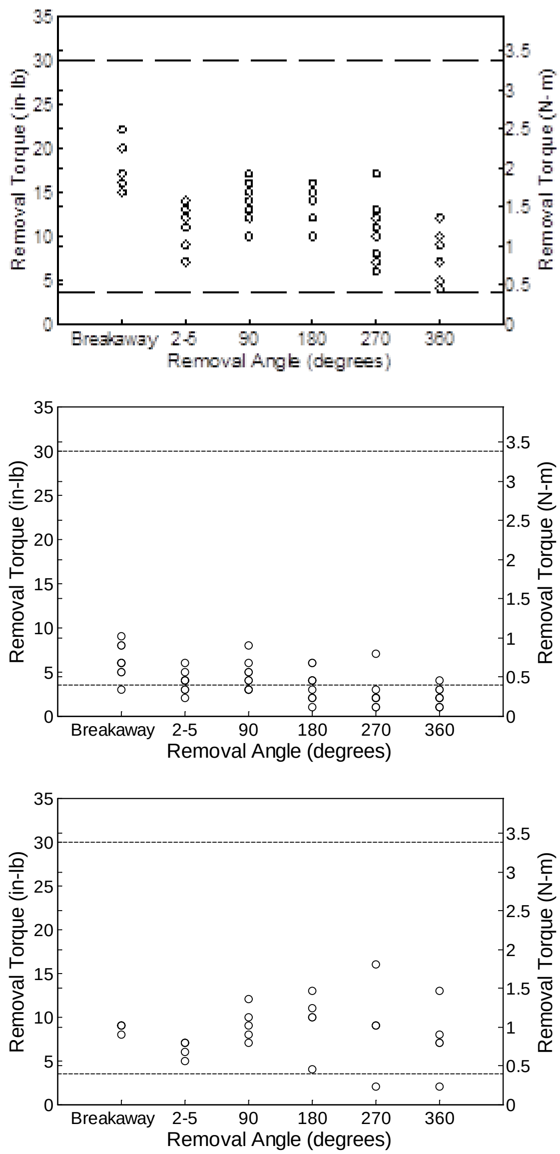

Figure 1. Unseated plain grade 8 with Loctite 222MS: initial use, reuse without additional adhesive, and reuse with additional adhesive.

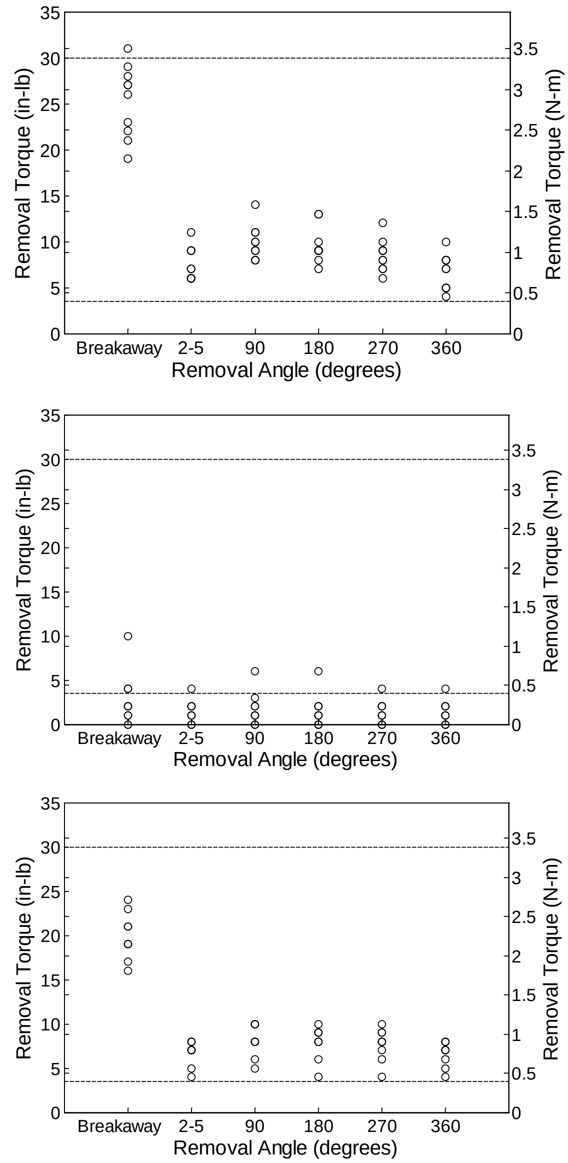

Figure 2. Unseated A-286 with Loctite 243: initial use, reuse without additional adhesive, and reuse with additional adhesive.