

# Prevailing Torque Locking in Threaded Fasteners

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Submitted: 1 October 2018 / Published online: 30 October 2018  
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**Abstract** This paper presents analyses of prevailing torque locking features common in locknuts, inserts and bolts. Existing manufacturing specifications for these components quantify required minimum and maximum locking torque values for a wide range of thread sizes. The self-loosening moment inherent to threaded fasteners and dependent on joint preload and thread pitch is computed and compared to the specification locking torque values. The self-loosening moment alone, i.e., not including loosening from external loads, is found to exceed the minimum locking torque manufacturing specification values for all fastener sizes at typical preload and for some large thread sizes is found to exceed the maximum locking torque specification. Calculations are provided for SAE and AN fasteners. Sample prevailing torque measurements from locknuts are presented which are well above the minimum specification. Analysis for the loosening moment from an external axial load is developed and presented with example calculations. Fastener locking requirements are defined.

**Keywords** Fastener · Bolt · Locknut · Insert · Locking · Prevailing torque · Running torque · Loosening

## Introduction and Background

Threaded fasteners continue to find widespread use in mechanisms and structures for assembly and attachment. The integrity of structures and reliability of mechanisms depend on proper function of fasteners.

Despite the use of locking features, loosening of threaded fasteners remains an all too common source of failure in mechanisms and structures. A simple engineering analogy highlights the underlying issue.

A structural engineer generally assesses and quantifies the stress within a component or structure from loads and compares this with the quantified strength of the material used. To mitigate failure, proper engineering design requires that the strength must equal or exceed the stress by a margin.

This basic engineering approach is not currently used in specifying fastener locking. Engineers generally specify a locking feature ad hoc, i.e., without quantifying the loosening moment in the joint and comparing it to a quantified locking moment provided by the locking feature. This is analogous to designing a structure without quantifying stress and comparing it with the material strength.

A proper approach to specifying a threaded fastener locking feature is to quantify the loosening moment (both inherent and from loads) on a fastener and compare this to the locking moment of the locking feature used. To mitigate failure, proper engineering requires that the locking moment must equal or exceed the loosening moment by a margin.

Recent efforts [1, 2] have provided the basis for quantifying the inherent self-loosening moments and loosening moments from external loads in threaded fasteners as well as quantifying (through analysis and testing) the locking moment provided by several locking features.

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This paper focuses on prevailing torque locking features common in locknuts, inserts and bolts. Prevailing torque locking is independent of preload. Fasteners with prevailing torque are frequently used and accepted because of: (1) widespread availability in a broad range of sizes and formats, (2) existence of defined standards and specifications for fasteners with prevailing torque locking [3–8], and (3) relative ease in verifying the presence and amount of locking at use.

If no preload or load acts on a fastener with prevailing torque locking feature, loosening or relative angular motion cannot occur. This is useful for applications where loss of hardware due to complete loosening and separation of parts must be avoided.

The specifications [3–8] for prevailing torque locking fasteners list minimum and maximum locking torque, however, no basis for these values is provided.

Despite the existence of specifications for locking torque values, there are many examples of loosening failures even when using prevailing torque locking. A recent costly and high profile example includes fasteners securing the sun shield on the James Webb Space Telescope (JWST).

What is the underlying cause for loosening of prevailing torque locking fasteners? The possible causes for loosening of prevailing torque locking fasteners include: (1) misuse (e.g., locking feature not fully engaged in assembly), (2) existing specification locking torque values are not sufficient, and (3) general lack of quantification and comparison of loosening moments and required locking moment.

This paper compares prevailing torque locking fastener specification torque values with loosening moments. A somewhat alarming result is that the self-loosening moment alone (i.e., not including loosening from external loads) notably exceeds the minimum locking torque manufacturing specification values for all fastener sizes at a typical preload and in some cases exceeds the maximum locking torque specification. Fortunately, in the author’s experience, the actual measured prevailing torque is often much higher than the minimum manufacturing specification. Regardless, efforts are needed to revisit and revise these specifications and to provide a clear basis for their listed locking torque values.

### Prevailing Torque

Threaded fastener prevailing torque (also known as running torque) is generally defined as the torque required to continue turning unseated mated fasteners.

Prevailing torque for a threaded fastener locking feature such as a locknut or lock insert is defined and measured when the locking feature is completely engaged and the

fastener is unseated. This torque can be measured in either a loosening or a tightening direction while the mating threads are in relative motion.

Once fasteners seat against joint materials, further turning results from a torque that includes components for bolt stretch as well as thread and nut face (or bolt face when using inserts) friction. The tightening torque for a threaded fastener in a bolted joint is generally defined [9–11] as

$$T_t = F_p \left( \frac{p}{2\pi} + \frac{\mu_t r_t}{\cos \beta} + \mu_n r_n \right) + T_{pv} \tag{Eq 1}$$

This tightening torque is the torque required to stretch the bolt and overcome thread friction, nut friction and locking feature prevailing torque. Here  $T_t$  is the tightening torque,  $F_p$  is the preload,  $p$  is the thread pitch,  $\mu_t$  is the thread interface friction coefficient,  $r_t$  is the nominal thread interface radius,  $\mu_n$  is the nut interface friction coefficient, and  $r_n$  is the nominal nut interface radius. The first term in this equation is the torque required to stretch the bolt. The second and third terms are the torque required to overcome thread and nut friction. These first three terms are dependent on preload  $F_p$ . The last term,  $T_{pv}$  is the prevailing torque. This usually results from a secondary locking feature such as a locknut or locking insert. It is independent of preload  $F_p$ .

Prevailing torque is introduced into nuts, bolts and inserts by altering or distorting the thread or introducing nonmetallic rings or patches. Fasteners with a prevailing torque locking feature must meet manufacturing specifications [3–8]. These specifications include a range of allowable locking torque that vary with thread size and series (i.e., fine and coarse threads).

Table 1 lists the allowable locking torque ranges from NASM25027 [3] for fine thread series locknuts. The minimum values in Table 1 are defined in terms of minimum breakaway torque. Here, breakaway torque is the torque required to initiate turn in unseated mated threaded fasteners. Recall, prevailing torque is the torque required to continue turning unseated mated threaded fasteners. Since static friction is generally higher than kinetic friction, breakaway torque is generally higher than prevailing or running torque.

The maximum values in Table 1 are defined in terms of installation or removal locking torque. This torque can be either the breakaway or prevailing torque in either direction (i.e., clockwise or counterclockwise) for unseated fasteners.

As an example, the allowable range for a 0.250–28 UNF thread locknut is between 3.5 and 30 in-lb. A 0.250–28 UNF locknut manufactured to this specification [3] must have a locking torque between 3.5 and 30 in-lb when its locking feature is fully engaged.

**Table 1** Allowable locking torque range for fine thread series locknuts [3]

Thread size	Minimum breakaway torque (in-lb)	Maximum locking torque, installation or removal (in-lb)
0.190–32 (10–32)	2.0	18
0.250–28	3.5	30
0.312–24	6.5	60
0.375–24	9.5	80
0.437–20	14.0	100
0.500–20	18.0	150
0.562–18	24.0	200
0.625–18	32.0	300
0.750–16	50.0	400
0.875–14	70.0	600
1.000–12	90.0	800
1.125–12	117.0	900
1.250–12	143.0	1000
1.375–12	180.0	1200
1.500–12	210.0	1400

Table 2 lists the allowable locking torque ranges from NASM25027 [3] for coarse thread series locknuts. As an example, the allowable range for a 0.250–20 UNC thread locknut is between 4.5 and 30 in-lb. Compared with a 0.250–28 UNF locknut, this locknut has the same nominal diameter but a larger pitch of 1/20, instead of 1/28. Since the self-loosening moment [1, 2] of a threaded fastener is proportional to pitch, it makes sense to have a larger locking torque requirement for a fastener with a larger pitch.

Similar locking torque values and ranges are provided in other specifications [4–8] for locknuts and inserts.

The specifications [3–8] provide no basis for the values listed for required minimum and maximum locking torque. These values may be based on some combination of, or relation to, the self-loosening moment, experience, or manufacturing capability.

### Self-Loosening Moment

The tightening torque for a threaded fastener in a bolted joint was presented in Eq 1. The corresponding removal torque for a threaded fastener in a bolted joint is defined as

$$T_r = F_p \left( -\frac{p}{2\pi} + \frac{\mu_t r_t}{\cos \beta} + \mu_n r_n \right) + T_{pv} \quad (\text{Eq 2})$$

This removal torque is the torque required to overcome thread friction, nut friction and locking feature prevailing torque minus the torque from bolt stretch. This negative

**Table 2** Allowable locking torque range for coarse thread series locknuts [3]

Thread size	Minimum breakaway torque (in-lb)	Maximum locking torque, installation or removal (in-lb)
0.086–56 (2–56)	0.2	2.5
0.112–40 (4–40)	0.5	5
0.138–32 (6–32)	1.0	10
0.164–32 (8–32)	1.5	15
0.190–24 (10–24)	2.0	18
0.250–20	4.5	30
0.312–18	7.5	60
0.375–16	12.0	80
0.437–14	16.5	100
0.500–13	24.0	150
0.562–12	30.0	200
0.625–11	40.0	300
0.750–10	60.0	400
0.875–9	82.0	600
1.000–8	110.0	800
1.125–7	137.0	900
1.250–7	165.0	1000
1.375–6	200.0	1200
1.500–6	230.0	1400
1.750–5	300.0	1800
2.000–4.5	360.0	2200
2.250–4.5	430.0	2600
2.500–4	500.0	3000

term from bolt stretch is a self-loosening moment inherent to threaded fasteners and is defined by

$$M_{\text{self-1}} = \frac{F_p p}{2\pi} \quad (\text{Eq 3})$$

This moment results from the bolt stretch torque and associated potential energy in the bolt. It is inherent to the threaded fastener and is proportional to preload and thread pitch.

In the limiting case where thread and nut friction are ineffective due to cyclic slip in the joint, the prevailing torque must counter the self-loosening moment to prevent loosening such that

$$T_{pv} \geq M_{\text{self-1}} \quad (\text{Eq 4})$$

As an example, consider a 0.25–28 UNF thread fastener in a joint with a 2270 lb preload. The thread pitch is 1/28 inch. The self-loosening moment is

$$M_{\text{self-1}} = \frac{F_p p}{2\pi} = \frac{2270}{2\pi(28)} = 12.9 \text{ in-lb} \tag{Eq 5}$$

If a prevailing torque locking feature is used with a prevailing torque of 15 in-lb, then the locking moment is 15 in-lb and there is a margin against loosening.

This example assumes no thread or nut friction which would add to the locking moment and increase the margin against loosening. The example also assumes no external loads which would add to the loosening moment and decrease the margin against loosening. In general, the total locking moment needs to be greater than or equal to the total loosening moment

$$M_{\text{locking}} \geq M_{\text{loosening}} \tag{Eq 6}$$

This paper focuses on prevailing torque locking features, but locking can also be introduced with adhesives [1] or mechanical methods [2] (e.g., safety lock wire and cotter pins).

### Comparing Self-Loosening Moment with Prevailing Torque

It is informative to compare manufacturer specification prevailing torque values with calculated self-loosening moments for fasteners with typical preload. For this purpose, calculation of self-loosening moments for SAE bolts and AN bolts are provided and compared to prevailing torque specifications. A conservative preload value of 65% yield strength of the fastener is used.

For SAE bolts, the minimum yield strength requirements are provided by SAE J429 [12]. Specifically, SAE grade 2 bolt minimum yield strength is 57,000 psi for 0.25 thru 0.75 inch diameter and 36,000 psi for greater than 0.75 up to 1.5 inch diameter. SAE grade 5 bolt minimum yield strength is 92,000 psi for 0.25 thru 1.0 inch diameter and 81,000 psi for greater than 1.0 up to 1.5 inch diameter. SAE grade 8 bolt minimum yield strength is 130,000 psi for 0.25 thru 1.5 inch diameter.

For a preload of 65% of yield strength  $Y$ , the preload is defined by

$$F_p = 0.65Y A_s \tag{Eq 7}$$

Here  $A_s$  is the tensile stress area

$$A_s = 0.7854(D - 0.9743p)^2 \tag{Eq 8}$$

$D$  is the nominal fastener diameter and  $p$  is the thread pitch.

Using this yield strength data and equations for preload and stress area, the self-loosening moment defined by Eq 3 is computed for SAE bolts. Table 3 presents the computed tensile stress area, preload at 65% yield, and corresponding self-loosening moment for 0.25–1.5 inch diameter SAE

**Table 3** Self-loosening moment for SAE grade 2, 5 and 8 fine thread series fasteners with preload at 65% yield

Thread size	Area (in <sup>2</sup> )	Preload (lb)			Self-loosening moment (in-lb)		
		Grade 2	Grade 5	Grade 8	Grade 2	Grade 5	Grade 8
0.250–28	0.0364	1348	2175	3074	7.66	12.4	17.5
0.312–24	0.0579	2143	3460	4889	14.2	23.0	32.4
0.375–24	0.0878	3254	5252	7421	21.6	34.9	49.2
0.437–20	0.118	4387	7081	10,006	34.9	56.4	79.7
0.500–20	0.160	5926	9565	13,516	47.2	76.2	107.6
0.562–18	0.203	7506	12,114	17,118	66.4	107.2	151.4
0.625–18	0.256	9483	15,306	21,628	83.9	135.4	191.3
0.750–16	0.373	13,818	22,303	31,515	137.5	222.0	313.7
0.875–14	0.510	11,922	30,467	43,051	135.6	346.5	489.7
1.000–12	0.663	15,515	39,650	56,027	205.9	526.1	743.5
1.125–12	0.856	20,024	45,054	72,308	265.7	597.9	959.5
1.250–12	1.073	25,107	56,491	90,664	333.2	749.6	1203
1.375–12	1.315	30,764	69,220	111,093	408.2	918.5	1474
1.500–12	1.581	36,996	83,241	133,596	490.9	1105	1773

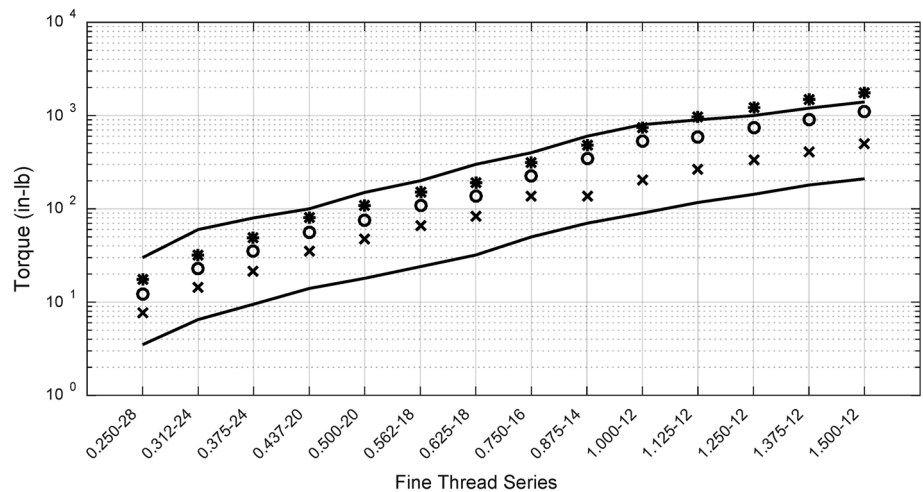
grade 2, 5 and 8 fine thread series fasteners. As an example, a 0.25–28 UNF grade 8 SAE bolt has a preload of 3074 lb at 65% yield and a corresponding self-loosening moment of 17.5 in-lb.

Figure 1 plots the self-loosening moment for each thread size and grade from Table 3 together with the minimum and maximum prevailing locking torque values from Table 1. This shows the minimum locking torque requirement for prevailing torque hardware is below the self-loosening moment for all thread sizes and grades. Furthermore, even the maximum locking torque requirement is below the self-loosening moment for the four largest fine thread size, grade 8 bolts.

For the example of a 0.25–28 UNF grade 8 bolt with a self-loosening moment of 17.5 in-lb, the minimum and maximum locking torque requirements are 3.5 and 30 in-lb. This means a manufacturer must produce locknuts with a prevailing torque value in the range of 3.5–30 in-lb to meet the specification. Given two locknuts, one with 20 in-lb prevailing torque and one with 10 in-lb prevailing torque. Both locknuts are within manufacturing specification. The locknut produced with a 20 in-lb locking torque exceeds the self-loosening moment of 17.5 in-lb with margin. A locknut produced with a 10 in-lb locking torque does not provide enough locking to counter the 17.5 in-lb loosening moment.

Consider an example with a 1.25–12 UNF grade 8 bolt with preload at 65% yield and a corresponding self-

**Fig. 1** Minimum and maximum locking torque requirements (solid lines) with self-loosening moment for SAE grade 2 (x), 5 (o) and 8 (\*) fine thread series bolts at preload of 65% yield



loosening moment of 1203 in-lb. The minimum and maximum locking requirements for a locknut of this size from Table 1 are 143 and 1000 in-lb, respectively. Any 1.25–12 UNF locknut manufactured within this specification does not provide enough locking to counter the 1203 in-lb self-loosening moment. In this case, the locknut may give a false sense of security.

Changing the preload in a given bolt will change the self-loosening moment values in Table 3 and Fig. 1. Increasing or decreasing the preload from 65% yield for a given bolt size and grade shifts the self-loosening moment values up or down, respectively.

Table 4 presents the computed preload at 65% yield and corresponding self-loosening moment for SAE coarse thread series fasteners. Figure 2 plots the self-loosening moment together with the minimum and maximum prevailing locking torque for coarse thread series from Table 2. This shows the minimum locking torque requirement for prevailing torque hardware is below the self-loosening moment for all thread sizes and grades, and the maximum locking torque requirement is below the self-loosening moment for 0.75–10 UNC and larger grade 8 bolts and 1.25–7 UNC and larger grade 5 bolts.

The standards for AN bolts are as follows. AN3 THRU AN20 [13] covers fine thread series from 10–32 to 1.25–12 UNF. NASM20073 [14] supersedes MS20073 [15] and covers AN73–AN81 or 10–32 to 0.75–16 UNF fine thread series. NASM20074 [16] supersedes MS20074 [17] and covers AN73A–AN81A or 10–24 to 0.75–10 UNC coarse thread series.

The minimum yield strength for these AN bolts are provided by these standards [14–17] and MIL-B-6812 E [18]. The standards [14–17] list the minimum yield strength as 76.7% of the rated tensile strength and MIL-B-6812 E [18] lists the minimum tensile strength as 125,000

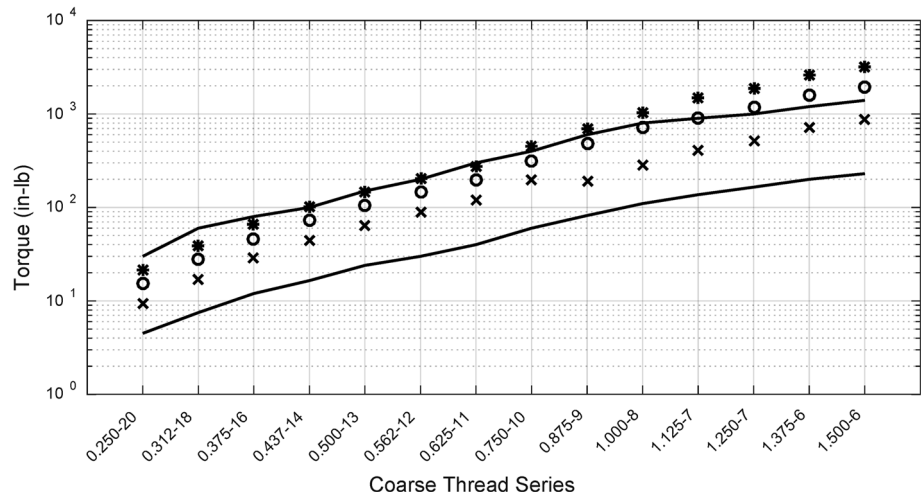
**Table 4** Self-loosening moment for SAE grade 2, 5 and 8 coarse thread series fasteners with preload at 65% yield

Thread size	Area (in <sup>2</sup> )	Preload (lb)			Self-loosening moment (in-lb)		
		Grade 2	Grade 5	Grade 8	Grade 2	Grade 5	Grade 8
0.250–20	0.0318	1179	1903	2689	9.39	15.2	21.4
0.312–18	0.0525	1935	3123	4413	17.1	27.6	39.0
0.375–16	0.0775	2871	4634	6548	28.6	46.1	65.2
0.437–14	0.106	3928	6340	8959	44.7	72.1	101.9
0.500–13	0.142	5257	8486	11,990	64.4	103.9	146.9
0.562–12	0.182	6727	10,858	15,342	89.3	144.1	203.6
0.625–11	0.226	8373	13,515	19,097	121.2	195.6	276.5
0.750–10	0.335	12,392	20,001	28,262	197.3	318.5	450.0
0.875–9	0.462	10,805	27,612	39,017	191.2	488.5	690.3
1.000–8	0.606	14,174	36,224	51,185	282.1	721.0	1019
1.125–7	0.763	17,861	40,186	64,497	406.3	914.2	1467
1.250–7	0.969	22,677	51,024	81,890	515.9	1161	1863
1.375–6	1.155	27,024	60,805	97,588	717.2	1614	2590
1.500–6	1.406	32,883	73,987	118,744	872.7	1964	3151

psi. Therefore, the minimum yield strength is  $0.767(125,000) = 96,000$  psi.

Using this yield strength data and Eqs 7 and 8 for preload and stress area, respectively, the self-loosening moment defined by Eq 3 is computed for all AN bolts [13–17]. Tables 5 and 6 present the computed tensile stress area, preload at 65% yield, and corresponding self-loosening moment for AN fine and coarse thread series bolts, respectively. As an example, an AN4 bolt (i.e., 0.25–28 UNF) has a preload of 2270 lb at 65% yield and a corresponding self-loosening moment of 12.9 in-lb.

**Fig. 2** Minimum and maximum locking torque requirements (solid lines) with self-loosening moment for SAE grade 2 (x), 5 (o) and 8 (\*) coarse thread series bolts at preload of 65% yield



**Table 5** Self-loosening moment for AN3 thru AN20 fine thread series fasteners with preload at 65% yield

Thread size	Area (in <sup>2</sup> )	Preload (lb)	Self-loosening moment (in-lb)
0.190–32 (10–32)	0.0200	1248	6.21
0.250–28	0.0364	2270	12.9
0.312–24	0.0579	3610	24.0
0.375–24	0.0878	5480	36.4
0.437–20	0.118	7389	58.8
0.500–20	0.160	9981	79.5
0.562–18	0.203	12,641	111.8
0.625–18	0.256	15,972	141.3
0.750–16	0.373	23,273	231.6
0.875–14	0.510	31,791	361.6
1.000–12	0.663	41,374	549.0
1.125–12	0.856	53,397	708.6
1.250–12	1.073	66,952	888.4

Figure 3 plots the self-loosening moment for AN fine thread series bolts from Table 5 together with the minimum and maximum prevailing locking torque from Table 1. Figure 4 plots the self-loosening moment for AN coarse thread series bolts from Table 6 together with the minimum and maximum prevailing locking torque from Table 2. These figures show the minimum locking torque requirement for prevailing torque hardware is below the self-loosening moment and the maximum locking torque requirement for prevailing torque is above the self-loosening moment for all fine and coarse thread sizes. Changing the preload in a given bolt will change the self-loosening moment values in these tables and figures. Increasing or decreasing the preload from 65% yield for a given bolt size shifts the self-loosening moment values shift up or down, respectively.

**Table 6** Self-loosening moment for AN73A thru AN81A coarse thread series fasteners with preload at 65% yield

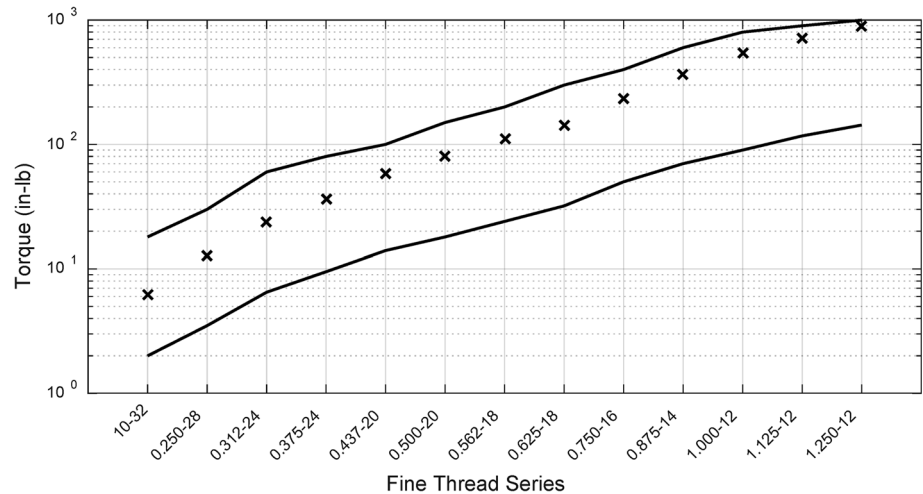
Thread size	Area (in <sup>2</sup> )	Preload (lb)	Self-loosening moment (in-lb)
0.190–24 (10–24)	0.0175	1094	7.26
0.250–20	0.0318	1986	15.8
0.312–18	0.0525	3259	28.8
0.375–16	0.0775	4835	48.1
0.437–14	0.106	6616	75.3
0.500–13	0.142	8854	108.5
0.562–12	0.182	11,330	150.3
0.625–11	0.226	14,103	204.2
0.750–10	0.335	20,870	332.3

For completeness, in addition to the results for SAE bolts and AN bolts, calculations are performed for all fastener sizes specified in NASM25027 [3] and listed in Tables 1 and 2. These include smaller fastener sizes, such as 2–56, 4–40, 6–32 and 8–32, often used in mechanisms. The smallest SAE and AN bolt sizes are 10–32 and 10–24.

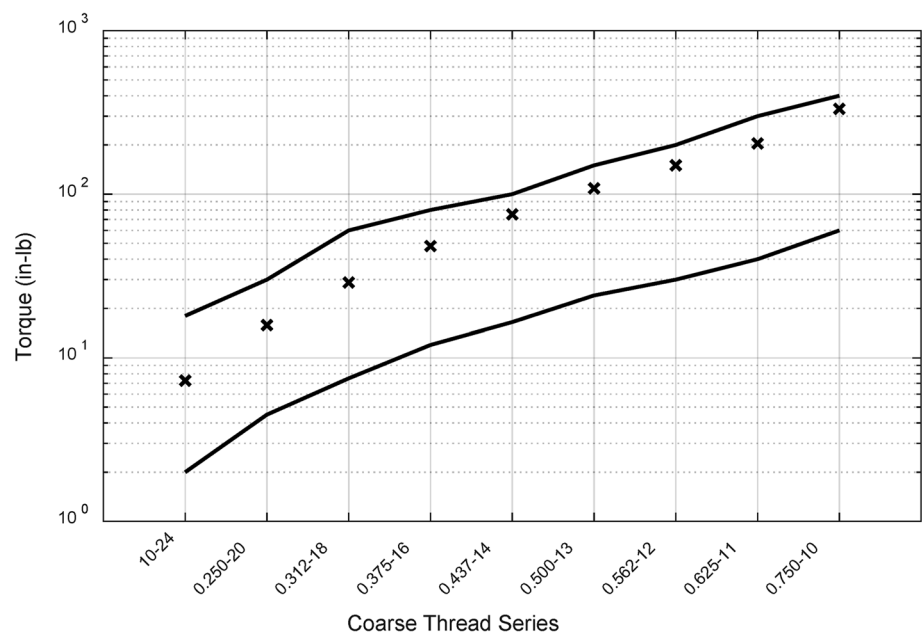
For these calculations, a preload of 65% of yield strength of the locknut is used. NASM25027 [3] specifies the axial tensile load requirement for each thread size. The minimum yield load is 75% of this tensile load. The preload for the following calculations is 65% of this minimum yield load. This tensile load, yield load and preload are listed in Tables 7 and 8 for all thread sizes listed in NASM25027. In addition, the resulting self-loosening moment defined by Eq 3 is computed and included in both tables. As an example, a 4–40 fastener (i.e., 0.112–40 UNC) has a preload of 366 lb at 65% yield and a corresponding self-loosening moment of 1.46 in-lb.

Figure 5 plots the self-loosening moment for fine thread series fasteners from Table 7 together with the minimum and

**Fig. 3** Minimum and maximum locking torque requirements (solid lines) with self-loosening moment for AN3 thru AN20 bolts at preload of 65% yield



**Fig. 4** Minimum and maximum locking torque requirements (solid lines) with self-loosening moment for AN73A thru AN81A bolts at preload of 65% yield



maximum prevailing locking torque from Table 1. This shows the minimum locking torque requirement for prevailing torque hardware is below the self-loosening moment and the maximum locking torque requirement is above the self-loosening moment for all fine thread series sizes.

Figure 6 plots the self-loosening moment for coarse thread series fasteners from Table 8 together with the minimum and maximum prevailing locking torque from Table 2. This shows the minimum locking torque requirement is below the self-loosening moment for all coarse thread series sizes. However, the maximum locking torque requirement is above the self-loosening moment only for coarse thread series sizes up to 1.00–8 UNC. For coarse thread series sizes from 1.125–7 UNC through 2.50–

4 UNC, even the maximum locking torque requirement is below the self-loosening moment.

As an example of a relatively small fastener commonly used in mechanisms, consider a 4–40 screw with a prevailing torque locknut. The locking moment specification [3] for a 4–40 locknut from Table 2 is 0.5 in-lb minimum and 5.0 in-lb maximum for fully engaged locking feature. With a preload of 366 lb (i.e., 65% yield of the locknut), the self-loosening moment is 1.46 in-lb as computed in Table 8. If the actual measured locking moment of the locknut is 3.0 in-lb, then the locking moment exceeds the self-loosening moment with margin. If the actual measured locking moment of the locknut is 1.0 in-lb, then the locking moment is below the self-loosening moment. In this case,

**Table 7** Self-loosening moment for fine thread series NASM25027 locknuts with preload at 65% yield

Thread size	Tensile load (lb)	Yield load (lb)	Preload (lb)	Self-loosening moment (in-lb)
0.190–32 (10–32)	2460	1845	1199	5.97
0.250–28	4580	3435	2233	12.7
0.312–24	7390	5543	3603	23.9
0.375–24	11,450	8588	5582	37.0
0.437–20	15,450	11,588	7532	60.0
0.500–20	21,110	15,833	10,291	81.9
0.562–18	26,810	20,108	13,070	115.6
0.625–18	34,130	25,598	16,638	147.2
0.750–16	50,020	37,515	24,385	242.7
0.875–14	68,440	51,330	33,365	379.5
1.000–12	90,000	67,500	43,875	582.2
1.125–12	116,700	87,525	56,891	754.9
1.250–12	147,940	110,955	72,121	957.0
1.375–12	171,000	128,250	83,363	1106
1.500–12	205,000	153,750	99,938	1326

the presence of a dynamic environment sufficient to cause cyclic slip within the joint will result in loosening.

If the locking feature is not fully engaged, then the locking moment will be less than its full potential. Good practice includes two threads extending beyond the nut or insert locking feature to ensure full engagement with the locking feature.

As an example of a relatively large fastener, consider a 1.5–6 UNC SAE grade 5 bolt with a prevailing torque locknut. The locking moment specification [3] for a 1.5–6 UNC locknut from Table 2 is 230 in-lb minimum and 1400 in-lb maximum for fully engaged locking feature. With a preload of 73,987 lb (i.e., 65% yield of the bolt), the self-loosening moment is 1964 in-lb as computed in Table 4. All locknuts within specification provide insufficient locking to counter the self-loosening moment.

**Sample Prevailing Torque Data**

Measured prevailing torque values are presented from a small sample of locknuts. Test fasteners include cadmium-plated steel AN4-6A bolts with AN365-428A elastic stop locknuts and AN363-428 all metal locknuts shown in Fig. 7 as well as stainless steel AN4C-6A bolts with COM365-428SS elastic stop locknuts and AN363C428 all metal locknuts shown in Fig. 8. Components are assembled as-received without preload as shown.

Tests are performed by securing the bolt head with a wrench or vise and applying a dial type torque wrench to the locknut to measure prevailing torque in the clockwise

**Table 8** Self-loosening moment for coarse thread series NASM25027 locknuts with preload at 65% yield

Thread size	Tensile load (lb)	Yield load (lb)	Preload (lb)	Self-loosening moment (in-lb)
0.086–56 (2–56)	440	330	215	0.61
0.112–40 (4–40)	750	563	366	1.46
0.138–32 (6–32)	1130	848	551	2.74
0.164–32 (8–32)	1720	1290	839	4.17
0.190–24 (10–24)	2010	1508	980	6.50
0.250–20	3760	2820	1833	14.6
0.312–18	6360	4770	3101	27.4
0.375–16	9540	7155	4651	46.3
0.437–14	13,140	9855	6406	72.9
0.500–13	17,730	13,298	8643	105.9
0.562–12	22,890	17,168	11,159	148.1
0.625–11	28,530	21,398	13,908	201.3
0.750–10	42,770	32,078	20,850	332.0
0.875–9	60,330	45,248	29,411	520.4
1.000–8	79,280	59,460	38,649	769.3
1.125–7	99,500	74,625	48,506	1103
1.250–7	125,000	93,750	60,938	1386
1.375–6	150,000	112,500	73,125	1941
1.500–6	181,000	135,750	88,238	2342
1.750–5	245,000	183,750	119,438	3804
2.000–4.5	322,000	241,500	156,975	5555
2.25–4.5	414,000	310,500	201,825	7142
2.50–4	510,000	382,500	248,625	9897

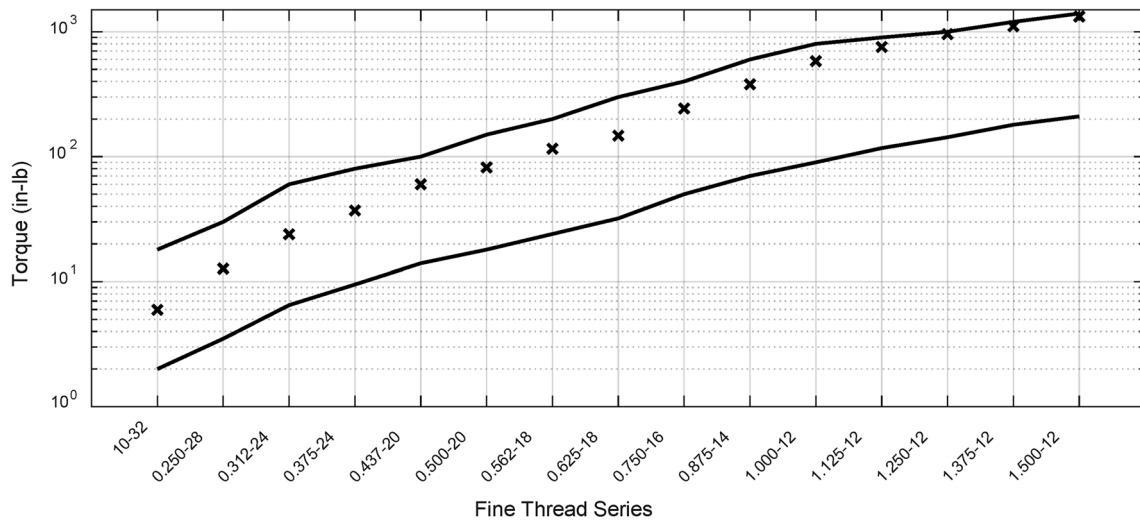
(cw) or tightening direction and then in the counterclockwise (ccw) or loosening direction.

Test results are shown in Table 9. This includes data for initial use and four reuses with complete removal before each reuse. Locknut specifications for 0.25–28 UNF threads require 3.5–30 in-lb prevailing torque. The torque measurements in Table 9 show all test fasteners within this range even with four reuses. As expected, reuse results in lower prevailing torque.

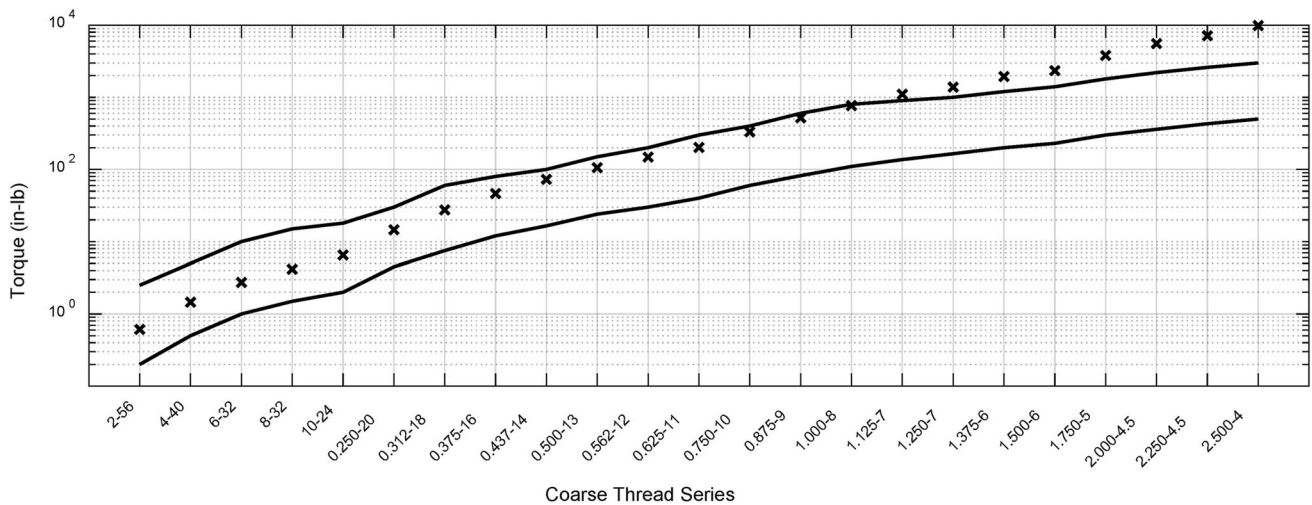
The initial clockwise prevailing torque measurements for the tests ranged from 11 to 24 in-lb. As expected, these values fall within the 3.5–30 in-lb specification range, and notably exceed the minimum specification value by a factor of about 3 to almost 7.

If these locknuts are used with an AN4 (0.25–28 UNF) bolt with a preload of 65% yield, the self-loosening moment is 12.9 in-lb. Three of the four locknuts tested provide sufficient initial prevailing torque to counter this self-loosening moment with margin.





**Fig. 5** Minimum and maximum locking torque requirements (solid lines) with self-loosening moment for fine thread series NASM25027 locknuts at preload of 65% yield



**Fig. 6** Minimum and maximum locking torque requirements (solid lines) with self-loosening moment for coarse thread series NASM25027 locknuts at preload of 65% yield

**Fig. 7** Cadmium-plated steel AN test bolts and locknuts

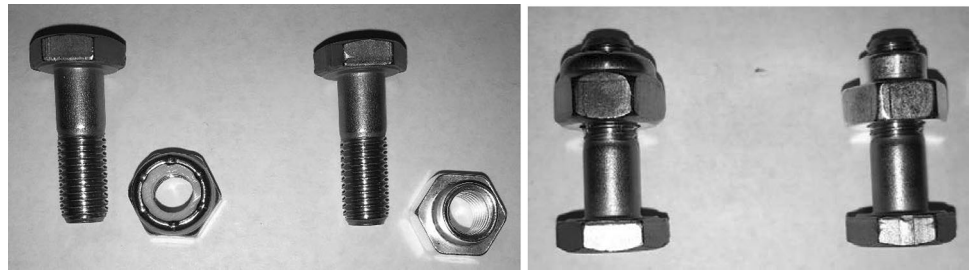


Even though this is a very limited set of test data, it is representative in the author’s experience that actual measured prevailing torque is often much higher than the minimum manufacturing specification.

**Loosening Moment from External Axial Load**

External axial loads on a bolted joint with preload are shared by the bolt and clamped joint components [10, 19]. A smaller amount of the total axial load on a bolted joint is carried by the bolt when (a) a relatively elastic bolt is used

**Fig. 8** Stainless steel AN test bolts and locknuts



**Table 9** Locknut prevailing torque (in-lb) measurements

Fastener material	Locknut type	$T_{prev}$	$T_{prev}$	$T_{prev}$	$T_{prev}$	$T_{prev}$
		cw/ initial	1st reuse cw/ccw	2nd reuse cw/ccw	3rd reuse cw/ccw	4th reuse cw/ccw
Cad steel	Elastic stop	11/9	8/7	7/7	7/6	7/6
Cad steel	All metal	24/18	12/10	8/7	9/8	10/10
Stainless steel	Elastic stop	19/17	13/10	10/9	10/7	10/7
Stainless steel	All metal	21/16	18/14	15/13	16/12	14/12

with stiff clamped components, (b) the external load is introduced from within the clamped components rather than under the bolt head (i.e., the load plane introduction factor is less than one), and (c) the preload is larger than the external axial load to prevent gapping. Once gapping occurs, the bolt carries all of the external axial load. Analysis procedures exist [10, 19] to estimate the relative amount of axial load the bolt carries.

Goodier and Sweeney [20] studied the cyclic axial loading of threaded fasteners. When loaded in tension, the bolt diameter contracts and the nut expands. An increase in axial load causes the bolt thread to move radially inward and the nut thread to move radially outwards. The resulting slip deviates from the radial direction due to the circumferential loosening component once slip occurs. Net loosening occurred in each axial loading cycle in all tests [20].

The loosening moment from an external axial load is defined as

$$M_{ext-l-ax} = \frac{nF_{ax}p}{2\pi} \tag{Eq 9}$$

Here  $p$  is the thread pitch,  $F_{ax}$  is the total axial load, and  $n$  is a load factor that adjusts for the amount of the total axial load carried by the bolt. The load factor  $n$  depends on bolt stiffness, clamped component stiffness, load plane introduction factor, and preload. The mechanics and resulting equation for this moment are of the same form as for the self-loosening moment from preload.

As an example, consider a 0.25–28 UNF AN bolt in a joint with a 2270 lb preload, 2000 lb external axial load, and 0.2 load factor. This load factor results from the product of a load plane introduction factor of 0.5 and a stiffness ratio  $k_b/(k_b + k_c)$  of 0.4 where  $k_b$  is bolt stiffness and  $k_c$  is clamped component stiffness. The loosening moment from the external axial load is

$$M_{ext-l-ax} = \frac{nF_{ax}p}{2\pi} = \frac{0.2(2000)}{2\pi(28)} = 2.3 \text{ in-lb} \tag{Eq 10}$$

This loosening moment is relatively small compared to the loosening moment from an external transverse load [1]. Proper joint design with respect to joint component stiffness and load plane introduction factor make this generally true. However, higher values of stiffness ratio and load plane introduction factor could push the load factor and loosening moment up 500%.

**Primary Locking**

The friction terms in the tightening and removal torque equations define the primary locking moment in a bolted joint [1]. This primary locking moment is dependent on preload and friction. This primary locking is absent in fasteners without preload. Even with preload, if cyclic slip occurs in a bolted joint due to an external load, this primary locking moment can be ineffective and locking must be provided by a secondary locking feature such as prevailing torque locking.

**Secondary Locking Requirement**

The total loosening moment in a threaded fastener is the self-loosening moment plus any external load loosening moment. In the absence of thread and nut friction, this total loosening moment defines the locking moment required from a secondary locking feature. The locking feature locking moment requirement becomes

$$M_{locking} \geq M_{self-l} + M_{ext-l} \tag{Eq 11}$$

As an example, consider a 0.25–28 UNF thread fastener in a joint with a 2270 lb preload and an external cyclic axial load creating a loosening moment of 2.3 in-lb. The self-loosening moment from Eq 5 is 12.9 in-lb.

The external load loosening moment of 2.3 in-lb combines with this self-loosening moment for a total loosening moment of 15.2 in-lb. If a locking feature is used with a locking torque of 14 in-lb, then insufficient locking is provided by the locking feature. However, in the absence of the external load loosening moment, the total loosening moment is 12.9 in-lb. In this case, the locking feature is sufficient and provides a small margin against loosening.

Good practice includes verification that the measured or calculated locking torque is greater than the loosening moment for a given application. Here, the loosening moment may be the result of both self-loosening and external loads as indicated in Eq 11. If this condition is not met, loosening is possible in dynamic environments.

In addition, the manufacturing specifications for prevailing torque locking are for a fully engaged locking feature. Good practice includes verification of full engagement with two threads extending beyond the nut or insert locking feature.

Although not common, achieving sufficient locking may involve combining or introducing additional locking with adhesives or mechanical methods.

## Conclusions

Manufacturing specifications for minimum and maximum values of prevailing locking torque for locking threaded fasteners were presented. The self-loosening moment inherent in threaded fasteners was computed and compared to the specification locking values for SAE and AN fasteners. The self-loosening moment was found to exceed the minimum locking torque manufacturing specification values for all fastener sizes at typical preload. The self-loosening moment was found to exceed even the maximum locking torque specification for large thread sizes.

Prevailing torque data from sample locknuts showed measured values of locking torque well above the minimum manufacturing specification. Analysis for the loosening moment from an external axial load was developed and presented with example calculations.

A goal of this paper was to raise awareness and caution. Specifically, awareness and caution that the self-loosening moment at typical preload is greater than minimum locking moment specification. Recommendations for fastener locking requirements and good practice were presented.

**Acknowledgment** The author gratefully acknowledges the support of Dr. Michael Dube and the NASA NESC.

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