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K-Nut Factor of High Strength Bolts
Part-I

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Abstract
The thread lubricant condition of high strength bolts is important in determining the bolt-tensile characteristics. This paper presents .result of tests performed upon 20 mm (3/4-in.) diameter, 76.2-mm (3 in.) long, A325 (M164) bolts, as it varies under different thread and weathering conditions. Factors that affect the pretension-torque relation are K-nut factor, bolt diameter, bolt-material strength, thread conditions, and the surface conditions at the nut-washer-joint interface. Tests were performed upon 101 nut and bolt, to determine the effect of a lubricant and weather on the value of K-nut factor. Lubrication was found to influence the value of K-nut factor.

Keywords
High strength bolts, A325 bolts, Nut, Lubrication

Introduction

The clamping force generated within the bolt by tightening determines the behavior of the bolted connections. This clamping force must be known in order to properly design friction type connections where the slip load is directly proportional to the bolt tension. The present Specifications of the Research Council on Riveted and bolted Structural Joints approved three tightening methods (RCSC June 23, 2000).

Specifications for the design of steel structures generally permit the use one or more of the following techniques for achieving the required preload in a bolt: a-turn-of-nut installation, b- calibrated wrench installation, and c- direct tension indicator . The three tightening methods each designed to produce a minimum fastener tension equal to 70 percent of the specified minimum tensile strength of the bolt.

Factors that affect the K-nut factor of high strength bolt are thread conditions (such as thread damage, lubrication, and rust or dirt), inadequate storage of on-site bolts, improper snugging, improper tightening of the bolt or the connection, and the friction conditions at the nut-washer interface.

Many researcher have found a value of K = 0.20 to be reasonable for bolts and nuts in the as-delivered condition with a washer under the nut (Munse 1974). If a washer is used, the value of K = 0.30. Thread lubrication has been shown to reduce K to value of 0.15. The recommended value is K = 0.20.

A variety of lubricants on high strength bolts have been investigated (Abdalla and Chen 2004). The as-received bolts with light oil had about the same calibration curve as those with lubricants. Bolts with no lubricant performed poorly compared to the lubricated condition.

1. Research Objectives

The main purpose of this paper is to investigate the K-nut factor in 3/4 inch diameter and 3 inch long A325 bolts as it may vary under different conditions of lubricating and weathering. The K-nut factor is often used to establish torque requirements for installation and sizing wrenches to install bolts. The results of the tests are used to evaluate the effect of stick wax lubricant on bolt-nut-washer surfaces upon the tightening characteristics of high-strength bolts. In addition, three variables were studied to determine their effect upon the fastener-tightening behavior. These variables were the performance of the:
1. Nut type
a- 2H NUT
b- DH NUT
c- C NUT
2- Bolt lengths 76.2-mm (3 in.)).
3- Bolt -nut -washer condition

Rotational capacity tests are performed in order to obtain tension-torque relationship for a particular bolt with loading produced by rotation of the nut. The variables within this series of tests were: type of nut, and surface condition of the fastening system (bolts, nuts, washers). All bolts, ASTM 20 mm (3/4-in.) diameter, 76.2-mm (3 in.) long, A325 (M164)

2. Test Setup:

2.1 Specimen Description:

Bolts, nuts, and washers were received from one supplier from the United State. In total, 101 bolts, 3 in. long) bolts were tested. The target fasteners were 20 mm diameter by 76.2 mm long (3/4 in. diameter by 3 in. long)).

2.2 Test Regime:

An examination of bolts with various bolt threads, nut, and washer friction conditions was made. This included the following:
1. Bolt threads, nut, and washer in the as-delivered condition.
2. Bolts weathered for one week
3. Bolts weathered for two weeks
4. Bolt threads, nut, and washer completely cleaned of all the as-delivered surface condition.
5. Bolt threads, nut, and washer cleaned as in item 4 above and then only the nut threads are retreated with a stick wax Johnson # 140.
6. Nut face is retreated with stick wax Johnson # 140.
7. Washer face is retreated with stick wax Johnson # 140.
8. Bolt threads are retreated with stick wax Johnson # 140.
9. Nut threads and nut face surfaces are retreated with stick wax Johnson # 140. V".
10. Nut threads and washer face surfaces are retreated with stick wax Johnson # 140.
11. Bolt threads and nut threads surfaces are retreated with stick wax Johnson # 140.
12. Bolt threads and nut threads, face surfaces are retreated with stick wax Johnson # 140
13. Nut threads, face and washer face surfaces are retreated with stick wax Johnson # 140.

14. Bolt threads, nut threads and face, and washer face surfaces are retreated with stick wax Johnson # 140

In Bolt condition number 2 the bolts were exposed to the weather during the month of November, and condition number 3 the bolts were exposed to weather during the month of December, these two cases were given direct exposure to all of the atmospheric weathering elements such as rain-water, wind, and temperature to determine whether there was tendency for thread lubricant to deteriorate with time. All the other conditions were exposed to the environmental conditions of the laboratory.
The stick wax lubricant code, surface treatment condition, type and specimens number of each test are shown in Tables 1.

Table 1: Summary of tested A325 bolts.

Test Code	Number Tested	Length inches	Remarks		
I - 2H	4	3	As-delivered – nut type 2H		
I – C	4	3	As-delivered – nut type C		
I – DH	4	3	As-delivered – nut type DH		
II - 2H	4	3	One week weathered condition – nut type 2H		
III – 2H	4	3	Two weeks weathered condition – nut type 2H		
IV – 2H	4	3	nut threads – nut type 2H		
IV – C	4	3	Nut threads – nut type C		
V – 2H	5	3	Nut face – nut type 2H		
VI – 2H	4	3	Washer face – nut type 2H		
VII – 2H	4	3	Bolt threads – nut type 2H		
VII – C	4	3	Bolt threads – nut type C		
VIII – 2H	4	3	Nut threads, face – nut type 2H		
VIII – C	4	3	Nut threads, face - nut type C		
VIII - DH	4	3	Nut threads, face – nut type DH		
IX – 2H	4	3	Nut threads, Washer face - nut type 2H		
IX – C	4	3	Nut threads, Washer face - nut type C		
X – 2H	4	3	Bolt threads, Nut threads - nut type 2H		
X – C	4	3	Bolt threads, Nut threads - nut type C		
XI – 2H	4	3	Bolt threads, Nut threads, face – nut type 2H		
XI – C	4	3	Bolt threads, Nut threads, face – nut type C		
XII – 2H	4	3	Nut threads, face, Washer face – nut type 2H		
XII – C	4	3	Nut threads, face, Washer face – nut type C		
XII - DH	4	3	Bolt threads, Nut threads, face, Washer face – nut type DH		
XIII – 2H	4	3	Bolt threads, Nut threads, face, Washer face – nut type 2H		
XIII – C	4	3	Bolt threads, Nut threads, face, Washer face – nut type C		
Total	101		Nut Type	2H	53
				C	36
				DH	12

2.3. Required Devices and Material to Conduct the Test Program are:
Calibrated bolt tension measuring device: (Skidmore- Whilhelm)
a. Calibrated torque wrench
b. Hand wrench
c. Protractor

d. Bolts, nut, and washer

3. Testing Procedure for Performance Rotational Capacity Test:

1. Install nut on bolt and measure stick out of bolt when 3 to 5 full threads of the bolt are located between the bearing face of the nut and the bolt head. Measure the bolt length, the distance from the end of the threaded shank to the underside of the bolt head.
2. Instal1 the bolt into the tension measuring device.
3. Using the calibrated manual torque wrench, tighten the bolt to the rotation as specified in Table 8.2 (4). At this rotation, the minimum bolt tension 124.47 kN (28 kips) for 20 mm diameter (3/4 inch diameter) and record the torque required to reach the tension and the value of the bolt tension. Torque must be measured with the nut in motion.
4. Further tighten the bolt to the rotation 2/3 for 76.2mm . The rotation is measured from the initial marking in Step 4. Record the bolt tension. Assemblies which fail prior to this rotation either by stripping or fracture are considered to fail in the test.
5. Loosen and remove nut, and examine the threads on the nut and bolt. No signs of thread shear failure, stripping, or torsional failure of the bolt should be evident. Assemblies which have evidence of stripping have been considered to be failed in the test.
6. Calculate and record the value of

$$T = K * P * D \quad (1)$$

Where:
K = 0.25
T: Torque
P: the tension (pounds = kips x 1000) measured in Step 3
D: the bolt diameter in feet.

4. Test Results

Experimental K-nut factor (Ke) and recommended K-nut factor (Kr) are normalized in terms of (Ke/Kr). The average of four specimens result from each case studied is summarized in Table 2.

4.1 Results of M164 (A325) bolts 76.2 mm (3 in.) long.

The results of tests are summarized in Table 2. The results shown are average of four tests for each lubrication condition. Only the specimens with test code number II-2H,III-2H, V-2H and 6-2H failed, the torques required to produce a minimum required preload (tension) were higher than the allowable.

4.1.1 As-Delivered Bolts

Information regarding the effect of nut type conditions as shown in Table 2 the specimen with test code (I-2H, I-C and I-DH) show acceptable results with normalized values (0.935, 0.93, and 0.975), respectively, of their average K-nut factor .The K-nut factor was lower when C nut is used than those when DH nut type used.

4.1.2 Bolts with Full Exposure to Weather

Subjecting the bolts to full exposure to the weather had a measurable effect on the torques required to obtain the preloads required. The results as shown in Table 2, the specimens exposed for one week give a normalized K-nut factor value of 1.276 this value exceeds the acceptable value for the torque limit. For two weeks exposure give a normalized K-nut factor value of 1.489 , this value exceed the acceptable value for the torque limit. Due to high torque required to obtain the minimum preload these two tests (II-2H and III-

2H) were failed. The amount of lubricant degradation affects the K-nut factor attained, and the amount of degradation depends on the local climate.

4.1.3 Effect of Stick Wax Johnson # 140

a- Nut Surface Condition

After the lubricant was removed from the bolts using acetone and re-lubricating the nut threads with stick wax, as shown in Table 2, the specimens with test code number (IV-2H and IV-C) shown acceptable results with normalized K-nut factor values of (0.930 and 0.890), respectively.

When re-lubricating the nut surface or the washer of dry bolts (V-2H and VI-2H) produce a K-nut factor ratio 1.284 and 1.254. These tests results provide important information about the distribution of frictional torque between the threads and washer. In the case where only the nut face or the washer face was re-lubricated with stick wax, the torque is 8.2%, 4.2% higher than the required torque which is unacceptable.

Table 2: K – nut factor values from test results for 76.2 mm (3 in.) long A325 Bolts

Test Code	Degrees								
	30	60	90	120	150	180	210	240	Average
I - 2H	0.221	0.202	0.197	0.192	0.178	0.168	0.168	0.169	0.187
I – C	0.211	0.197	0.188	0.181	0.178	0.178	0.177	0.176	0.186
I – DH	0.217	0.208	0.201	0.195	0.187	0.185	0.178	0.187	0.195
II - 2H	0.242	0.254	0.252	0.266	0.262				
III – 2H	0.291	0.286	0.293	0.319					
IV – 2H	0.205	0.192	0.188	0.181	0.176	0.177	0.180	0.188	0.186
IV – C	0.197	0.190	0.185	0.175	0.171	0.171	0.169	0.171	0.178
V – 2H	0.254	0.250	0.252	0.271					
VI – 2H	0.240	0.250	0.252	0.261					
VII - 2H	0.185	0.171	0.160	0.156	0.156	0.155	0.156	0.158	0.162
VII - C	0.172	0.166	0.156	0.151	0.150	0.149	0.151	0.152	0.156
VIII - 2H	0.187	0.173	0.159	0.152	0.148	0.149	0.149	0.150	0.158
VIII - C	0.165	0.162	0.154	0.149	0.145	0.145	0.144	0.142	0.151
VIII - DH	0.184	0.177	0.163	0.158	0.154	0.155	0.157	0.154	0.163
IX – 2H	0.184	0.172	0.165	0.160	0.157	0.149	0.148	0.148	0.161
IX – C	0.166	0.158	0.152	0.143	0.139	0.138	0.137	0.137	0.146
X – 2H	0.173	0.164	0.160	0.156	0.152	0.151	0.151	0.153	0.158
X – C	0.173	0.161	0.152	0.145	0.142	0.140	0.139	0.139	0.149
XI – 2H	0.179	0.169	0.162	0.157	0.154	0.154	0.153	0.155	0.160
XI – C	0.165	0.160	0.156	0.150	0.146	0.143	0.142	0.140	0.150
XII - 2H	0.183	0.176	0.167	0.161	0.158	0.155	0.155	0.154	0.164
XII - C	0.154	0.156	0.152	0.149	0.143	0.140	0.141	0.142	0.147
XII - DH	0.178	0.174	0.166	0.159	0.154	0.153	0.151	0.150	0.160
XIII - 2H	0.177	0.166	0.151	0.148	0.144	0.145	0.143	0.144	0.152
XIII - C	0.154	0.144	0.142	0.135	0.130	0.129	0.129	0.130	0.137

The test result for the case in which the nut threads and face were re-lubricated of dry bolt, as shown in Table 2, the specimens test code number (VIII-2H, VIII-C and VIII-DH) show acceptable results with normalized values (0.790, 0.755 and 0.815), respectively for K-nut factor. These values indicate that using stick wax on nut threads and face was effective.

Test result for the case in which the nut threads and washer face were re-lubricated and bolt threads were dried, as shown in Table 2, the specimens with test code number (IX-2H and IX-C give acceptable results with normalized K-nut facto values are (0.805 and 0.730), respectively. These values are very close to the case when nut threads and face were re-lubricated.

Test result for the case in which the nut threads, face and washer face were re-lubricated and bolt threads were dried, as shown in Table 2, the specimens with test code number (XII-2H and XII-C give acceptable results with normalized K-nut facto values are (0.82 and 0.735), respectively. These values are very close to the case when nut threads and face were re-lubricated. For a given bolt tension (preload) is a good indicator of the efficiency of the lubricant.

4.2 Bolt Surface Condition

The test results for the case in which the bolt assembly was first cleaned with acetone and then the bolt threads only re-lubricated with stick wax surface, as shown in Table 2 the specimens test code number (VII-2H and VII-C), show acceptable results with normalized values of (0.81 and 0.780), respectively for K-nut factor. Using stick wax , on the bolt threads was effective.

The tests in which the bolt threads and nut threads were treated with stick wax lubricant, as shown in Table 2, the specimens with test code number (X-2H and X-C), show acceptable results with normalized preload values (0.790 and 0.745) respectively. In this case the torque required to turn the nut 1/3 turn was less than the case when the bolt threads were re-lubricated with stick wax lubricant.

The tests in which the assembly were cleaned with acetone and then were re-lubricated the bolt threads, and nut threads, face with stick wax lubricant, as shown in Table 2. The specimens with test code (XI-2H and XI-C), reach acceptable results with normalized K-nut factor values of (0.800 and 0.750), respectively. The tests in this case provides important information about the distribution of frictional torque between this case and the case when bolt threads and nut threads were re-lubricated, the preload increased by (2.6%, 5.6%) and the torque decreased by (3.5%,4.05%) this means that the nut face treated was effective.

Test result for the case in which the bolt threads, nut threads, face and washer face were re-lubricated, as shown in Table 2, the specimens with test code number (XIII-DH, XIII-2H and XIII-C give acceptable results with normalized K-nut facto values are (0.800, 0.760 and 0.685), respectively.

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The results in figure 1 to 5 illustrates the K-nut factor range when 2H nut used is between 0.152 to 0.187 and when C nut used 0.137 to 0.187 and when DH nut used 0.160 to 0.195. The clean and weathered condition show the largest value. The average value of K-nut factor for all conditions is approximately 0.162. This is lower than the average value often used of 0.20 for normally lubricated bolts.

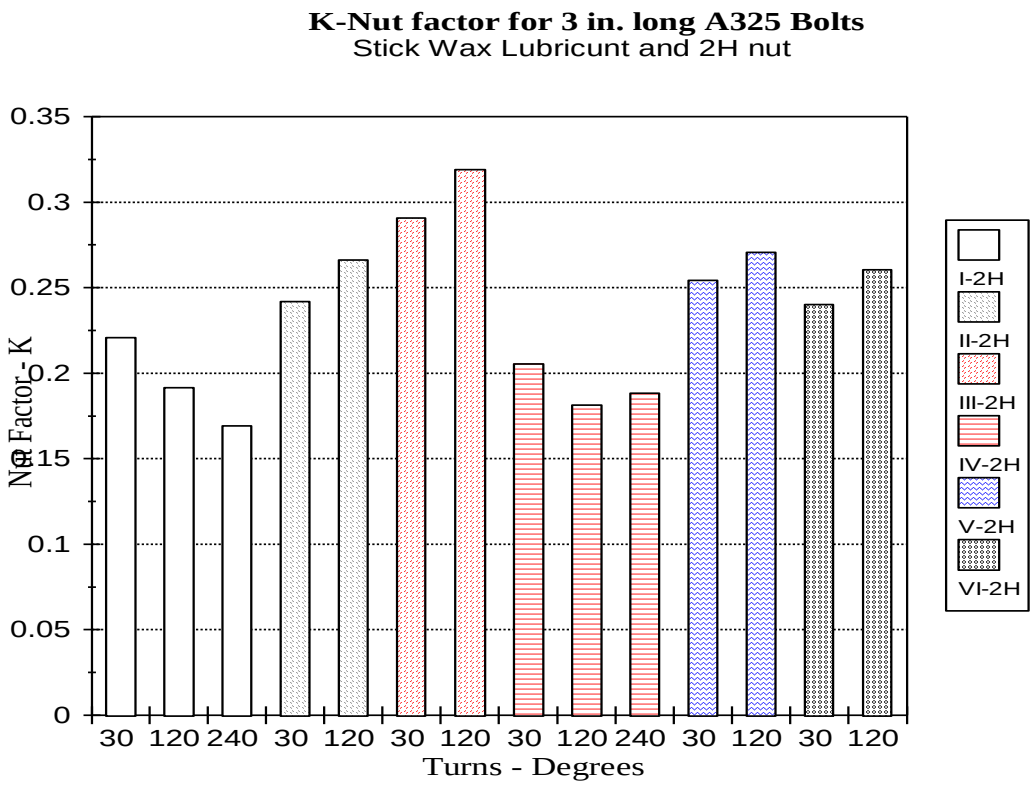

Figure 1. K-Nut factor for 3/4 inch diameter A325

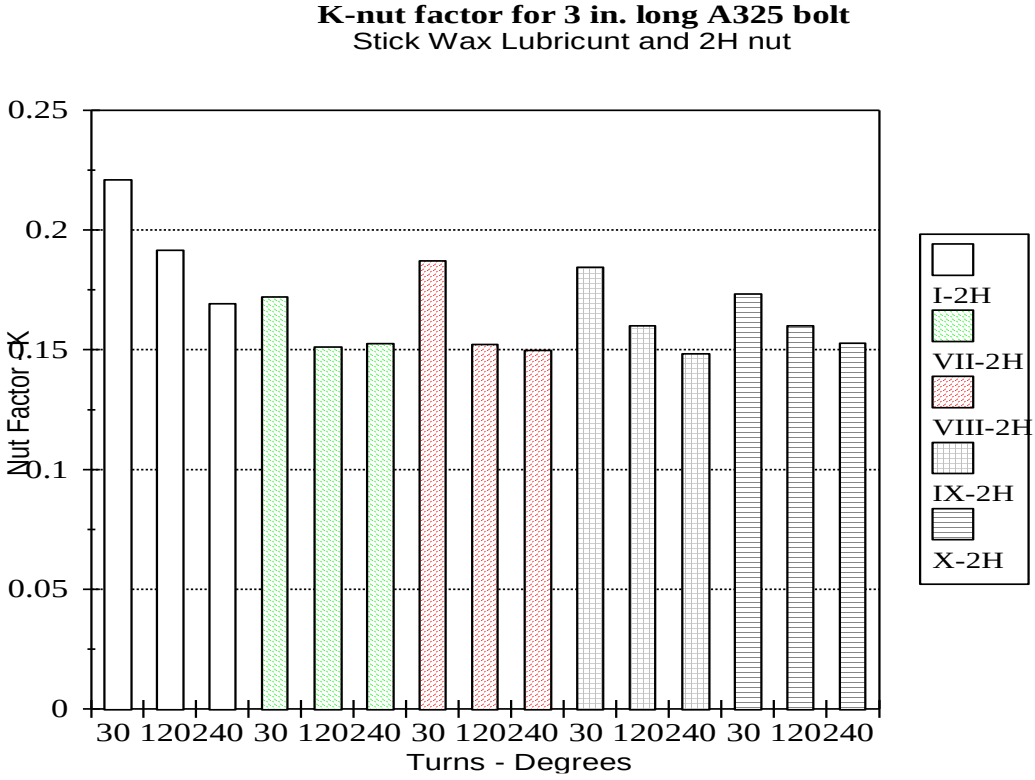

Figure 2. Comparison of K-nut factor value for different tests 3/4 inch A325

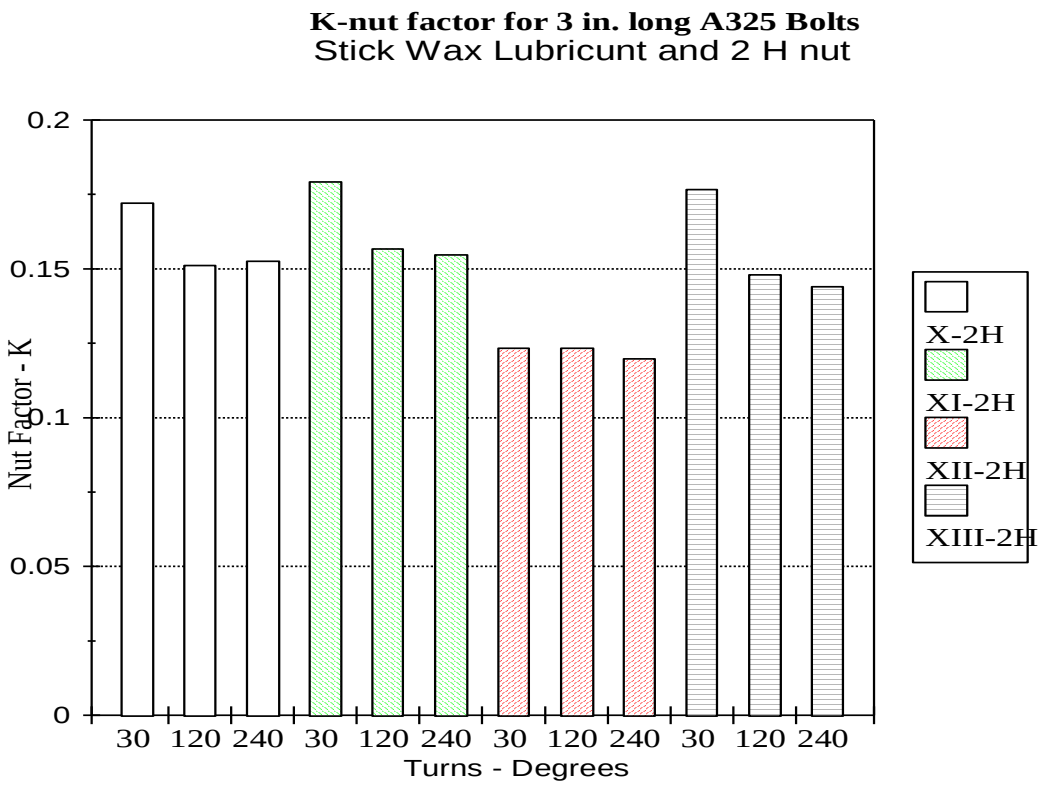

Figure 3. Comparison K-nut factor value for 3/4 in. A325 tests

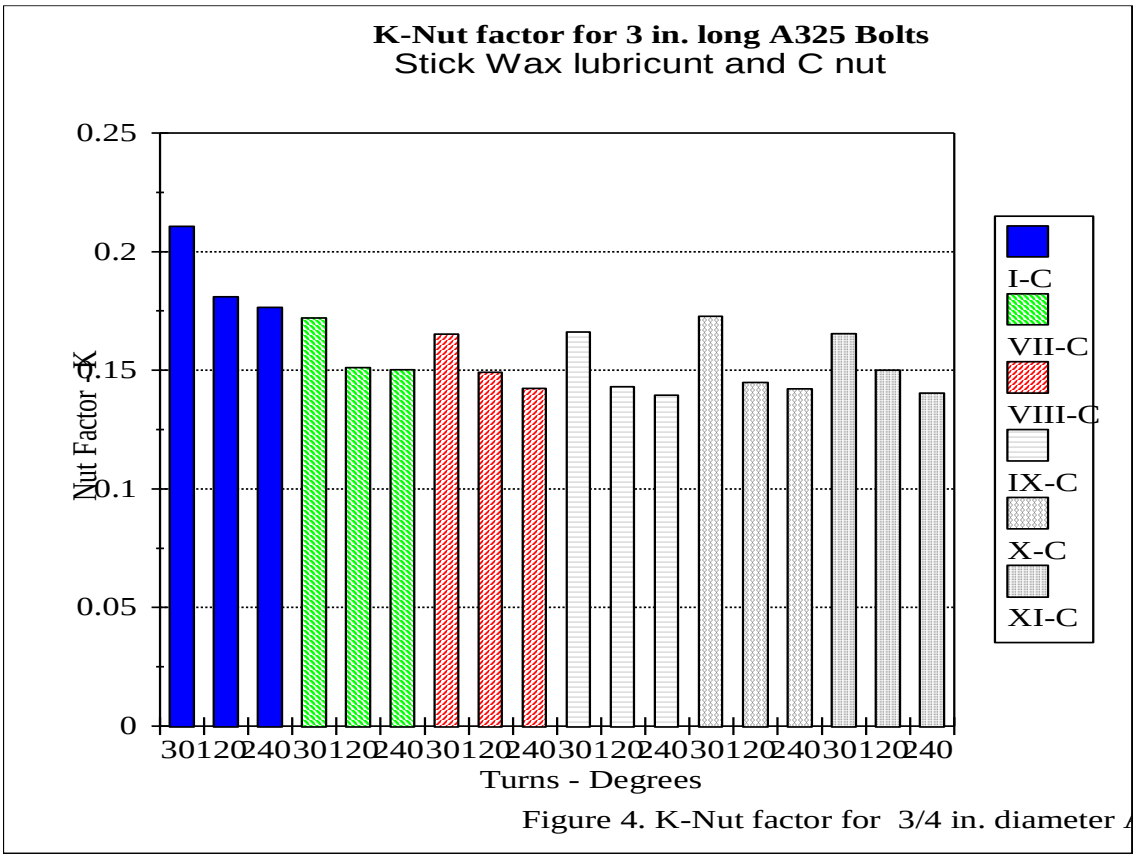

Figure 4. K-Nut factor for 3/4 in. diameter A

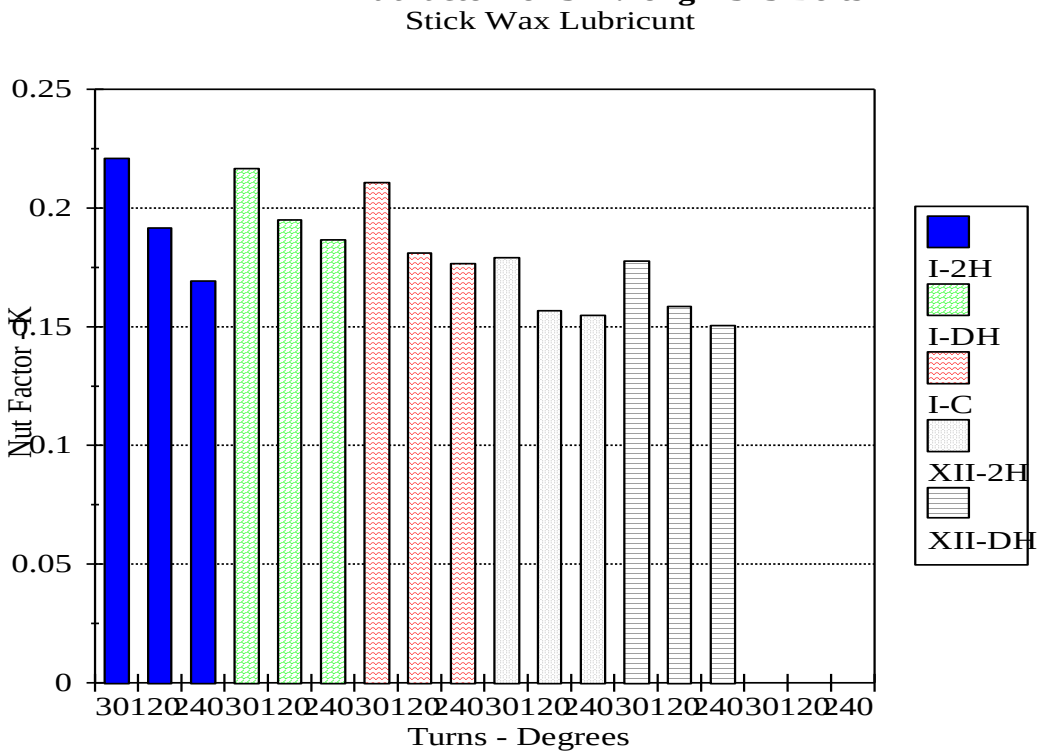

Figure 5. Comparison nut factor for 2H, DH, C nuts

Conclusion

The data indicates that properly lubricated bolts can provide lower K-nut factor and consistent torque-tension behavior

References

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