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SUMMARY

The tension preload obtained by torquing a 7/8 in. diam UNC high strength bolt was determined for lubricated and dry conditions. Consistent preload with a variation of ±3% was obtained when the bolt head area was lubricated prior to each torque application. Preload tensions nearly 70% greater than the value predicted with the commonly used formula occurred with the lubricated bolt. A reduction to 39% of the initial preload was observed during 50 torque applications without relubrication. Little evidence of wear was noted after 203 cycles of tightening.

INTRODUCTION

Bolted flanges in high-pressure fluid systems require sufficient tension or preload in the fasteners to prevent separation and leakage when pressurized. One common method of obtaining this fastener tension is by tightening to a predetermined torque. Unfortunately, the variations in friction at the bolt head and nut or threaded flange introduce uncertainties in the fastener tension obtained by this means (ref. 1). Lubrication, thread fit, fastener material, and hardness are all important variables in relating the applied torque to the achieved fastener tension. Additional considerations in the use of flanges with tapped holes that undergo frequent disassembly are the combined effects of thread wear and relaxation or creep which cause a gradual loosening of the fit. A recent failure of a flanged joint using tapped holes emphasized the need for specific information in these areas of tightening torque and thread wear. An experiment was conducted therefore, duplicating as nearly as possible the service conditions of the bolted joint to determine the relation between tightening torque and bolt tension. The effects of wear and thread degradation were also appraised for 203 cycles of tightening.

EXPERIMENT

Apparatus

Photographs and a dimensioned sketch of the bolt and simulated flanges are shown in figures 1(a), 1(b) and 1(c). The bolts which are used in the service flange are 7/8 in. in diam, have unified national coarse threads with a pitch of 9/in. and are 5 in. long. They are made of a high-strength material, AMS6487, intended for aircraft applications, and have a minimum tensile yield strength of 137,880 N/cm^2 (200,000 psi). A short plug of steel was press fitted into an existing cavity in the head to facilitate accurate measurement of the bolt length. The simulated, clamped flange was made of the same material as the service flange--mild steel--and was the same thickness, 8.26 cm (3.25 in.). The nut which simulates the mating service flange with tapped holes was made of type 410 stainless steel, heat treated to a minimum tensile yield stress of 79,280 N/cm^2 (115,000 psi), and an elongation of 19%. The hardness of the nut was 22 on the Rockwell C scale and the threads which were tapped after heat treatment were a class 3B fit. A cast of the nut thread was made with a silicone rubber material and examined visually. The threads appeared to be normal in form. The bolt length was measured with a dial gage which was 9 cm (3-1/2 in.) in diam having a least count of 0.00025 cm (0.0001 in.). A photograph of the dial gage and holding fixture is shown in figure 1(b).

Test Procedure

The holding fixture was fastened to a building support beam in a position convenient for torquing. The torque wrench used for this experiment was a bending beam type that had a maximum capacity of 813 N-m (600 lb-ft). The torque was applied by pushing down on the torque wrench handle, and since the bending beam is at the handle end, a gravity tare of 63.0 N-m (46.5 lb-ft) was added to the indicated torque. In tightening the bolts on the service flange during an actual assembly, it is believed that some of the bolts would normally be torqued by lifting the wrench and others by pushing down on the wrench as a matter of convenience of access. In this process the gravity tare is expected to cause a ±12% variation in the desired assembly torque. In order to simulate the bolted flange as nearly as possible, the bolt was lubricated profusely on the threads and under the head with the same antiseize and lubricating compound used in the service assembly. The schedule of lubrication will be noted in the discussion of the results.

The bolt tension force, F_T, is computed from the relation, $F_T = S_T \times A$; where A is the cross-sectional area of the shank and S_T is the shank tensile stress. The value for S_T was obtained from the product of the unit elongation (strain) and the modulus of elasticity. The total elongation was found by measuring the bolt length immediately before and after each application of torque. The unit elongation was then obtained by dividing the total elongation by the grip length of 8.26 cm (3.25 in.). A small error in the shank unit elongation is introduced by using the total grip length because of the threads in the grip area. This error was estimated to be about +2.5%. The entire apparatus remained essentially at a room temperature of approximately 27° C (80° F) during the tests. No attempt was made to determine the effect of temperature on lubricant effectiveness. The time that the bolt was stressed was approximately 15 sec for each torque application, thus relaxation or long term creep effects were not simulated.

RESULTS AND DISCUSSION

The unit elongation of the bolt achieved by applying the service assembly torque of 606 N-m (447 lb-ft) is shown in figure 2 for 50 applications. The data for this figure were obtained with lubricant applied to the bolt head before each torquing and to the threads every fifth time. A rather consistent and high unit elongation of approximately 0.0057 was obtained. This represents a shank tensile stress in the range of 118,000 N/cm^2 (170,000 psi) which is 85% of the tensile yield strength with most of the data within ±3% of the mean value.

Values of tensile force to be expected from the assembly torque were computed with the commonly used torque formula, $T = K \times D \times F_T$; where T is the applied torque, K is a constant, D is the bolt diam, and F_T is the bolt tensile force. Using recommended values of 0.1 and 0.2 for K (ref. 2), corresponding to lubricated and dry fasteners, the values of 0.0017 and 0.0034 were computed for the unit elongations. The corresponding shank tensile stresses were 35,160 and 70,320 N/cm^2 (51,000 and 102,000 psi). These values are approximately 30% and 60% of the present results and it is apparent that a much lower coefficient of friction was achieved with the carefully lubricated test bolt than was assumed in the simple formula. Using the geometry of the bolt threads, and assuming equal friction coefficient for the head bearing area and the threads, the coefficient of friction for these data was calculated and found to be 0.049 giving a value of 0.059 for K.

In order to investigate the effect of lubricant extrusion during tightening, a series of torque applications was made at the service assembly torque of 606 N-m (447 lb-ft). These data are shown in figure 3. The bolt was lubricated under the head and on the threads prior to the first torque application but no additional lubricant was added. The torquing was continued for approximately 50 applications until a relatively stable tension was obtained. During this test the bolt was unscrewed approximately one turn past the unstressed position but was not completely removed between torque applications. The reduction of elongation at this constant applied torque was quite rapid during the first 20 applications falling to a value of approximately 55% of the initial value. The relatively stable elongation achieved after 50 applications was approximately 38% of the initial loading but was within approximately 20% of the prediction ($K = 0.2$) for an unlubricated bolt. The bolt was removed and relubricated on both the head and thread areas during torque applications number 54 and 55. The elongation after lubrication, however, was approximately 10% below the initial value (filled symbols). To see if galling or other damage had occurred, the bolt and threads were carefully cleaned and inspected. Only slight wear and burnishing were noted on the bolt and nut threads; however, some galling had occurred on the simulated flange under the bolt head indicating the need of a hardened washer. The nut threads were size checked with a plug gage and were still a class 3B fit. The bolt was then torqued three times in this dry, clean, unlubricated condition producing elongations similar to that found after the first 50 torque applications without relubrication. It may be seen from a comparison of the data of figures 2 and 3 (head lubed each time, threads every fifth time in fig. 2) that lubricant extrusion from the bolt head area is much more important than at the threads due to the higher bearing stress under the bolt head. If consistent bolt tension is to be achieved with lubrication, the bolt head area must be carefully lubricated prior to each torquing.

In order to investigate the effect of bolt elongation (tensile force) on lubricant extrusion, and linearity of the torque-tension relationship, the data of figure 4 were obtained. For these tests the bolt was lubricated under the head each time it was torqued and the threads were lubricated each fifth time. The influence of the torque wrench weight tare is seen in the bolt elongation achieved at zero indicated torque. The torque-tension relationship is linear up to an indicated torque of 271 N-m (200 lb-ft). The results are relatively consistent with a scatter of approximately 5%. At 407 and 542 N-m (300 and 400 lb-ft) indicated torque the achieved bolt elongation is less than the extrapolated value from the lower torque. It is believed that these higher bolt tensile forces may have caused more complete lubricant extrusion from the bolt head area resulting in a higher frictional torque. This would indicate that caution should be exercised in extrapolating test results to predict fastener elongation at other torque values.

CONCLUDING REMARKS

A high-strength bolt and nut specimen, 7/8-in. in diam, simulating a service flange assembly, was torqued 203 times to investigate the relation of tightening torque to achieved tension for lubricated and dry conditions. Although lubrication is desirable to minimize wear and galling in many applications requiring high preloads, it is seen that uncertainties in friction are increased unless care is taken in lubrication at assembly.

Several conclusions were noted:

1. Although slight wear, burnishing, and galling were observed on the clamped flange in the region contacted by the bolt head, the nut threads showed little evidence of wear and remained a class 3B fit throughout the test.

2. Tensions considerably in excess of the values predicted with the commonly used formula, $T = K \times D \times F_T$ with $K = 0.1$, were obtained with a bolt which was carefully lubricated on the threads and the head. In the tests at the service assembly torque of 606 N-m (447 lb-ft) the ratio of achieved bolt tension to predicted tension was 1.67.

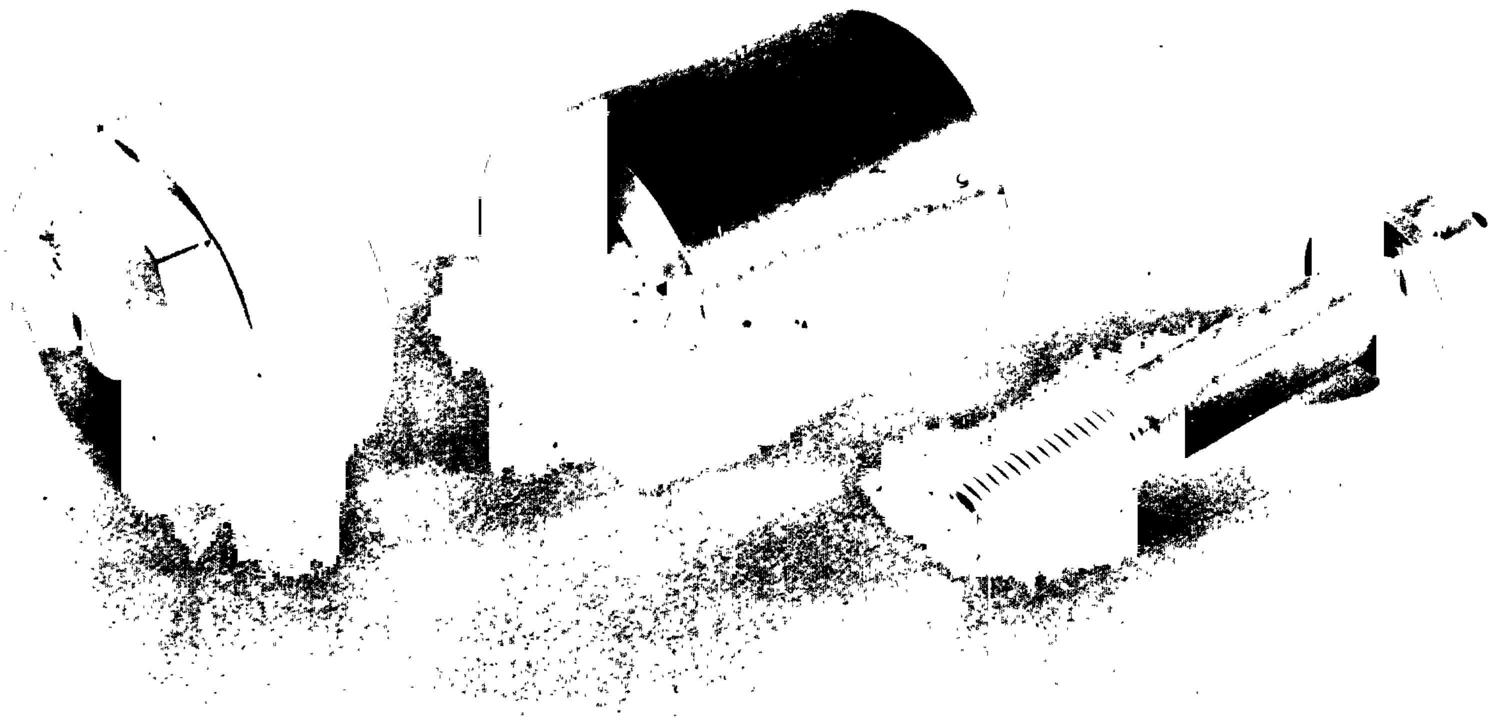
3. A marked decrease in bolt tension to 39% of the initial value was observed during 50 torque applications without relubrication. A tension approximately 20% greater than the predicted value for dry assembly, $K = 0.2$, was obtained for a degreased, dry bolt.

4. Consistent tension having a variation of only ±1% was obtained when lubrication was applied to the bolt head prior to each torquing.

REFERENCES

1. Roehrich, Roland L.: Torquing Stresses in Lubricated Bolts. Machine Design, June 8, 1967.

2. Bolt Torque Factors. Design News, Nov. 8, 1976, pp. 119-120.



(a) 7/8 x 9UNC bolt and simulated flanges.

Figure 1.- Experimental Apparatus.

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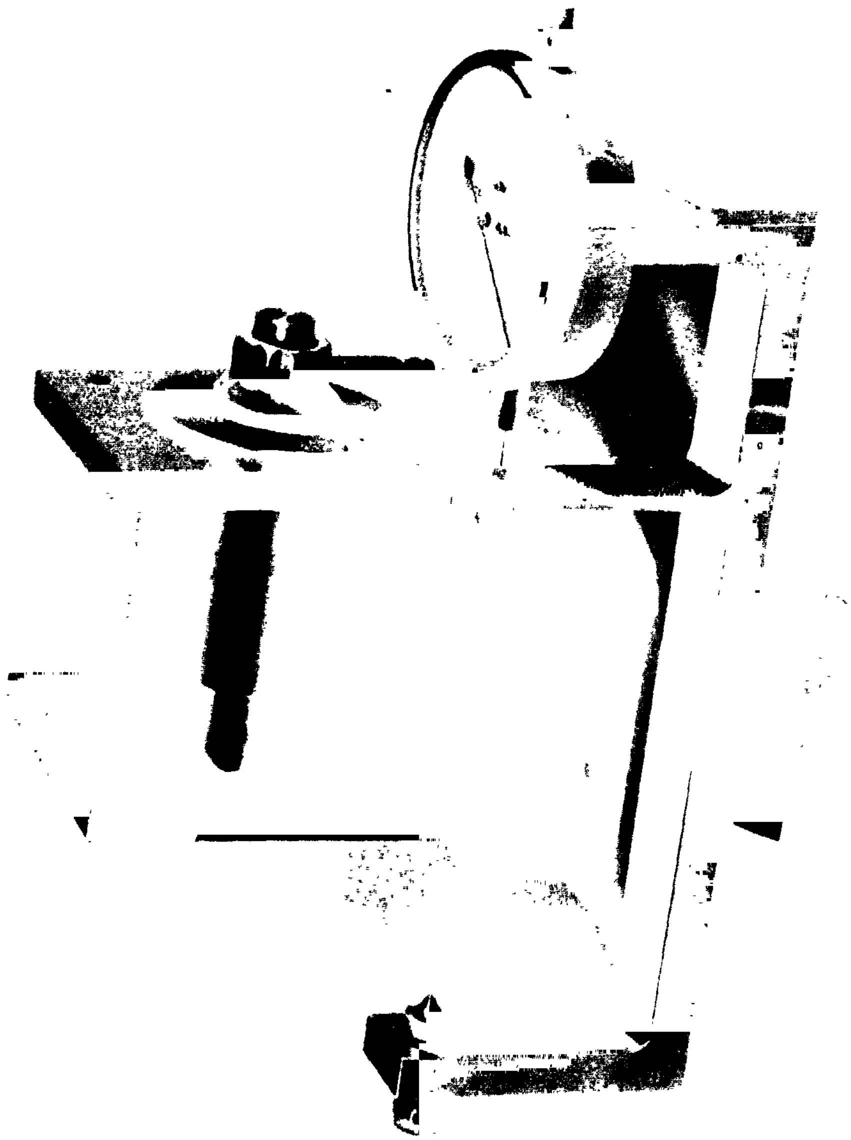
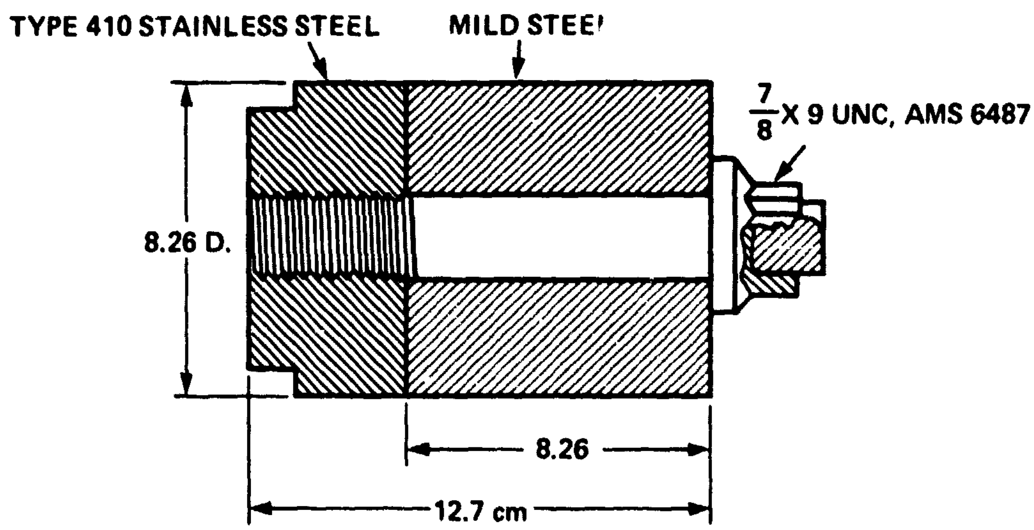


(b) Dial gage and holding fixture.

Figure 1.- Continued.



(c) Sketch of bolt and simulated flanges.

Figure 1.- Concluded.

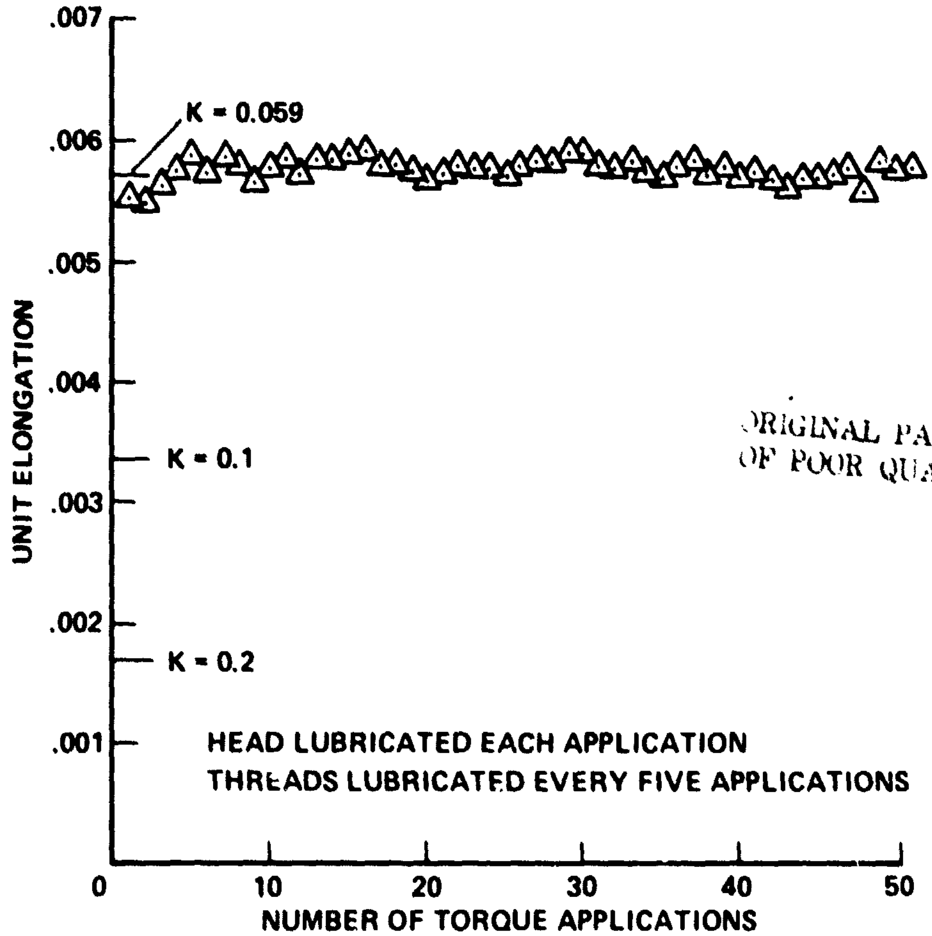


Figure 2.- Bolt tension achieved with 606 N-m torque and lubrication.

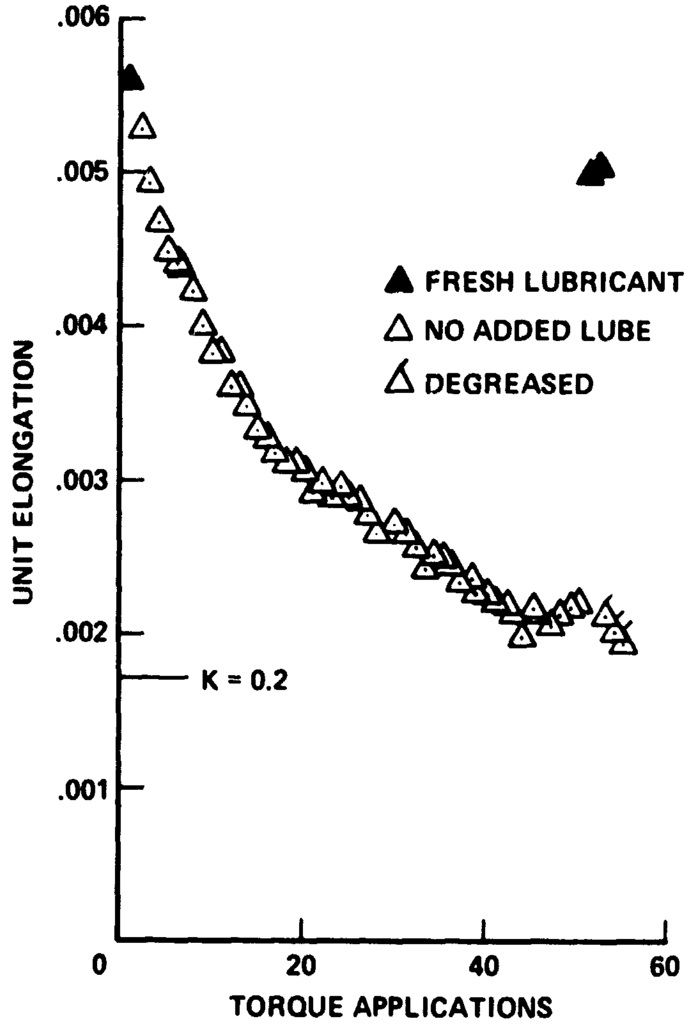


Figure 3.- Effect of lubricant extrusion on bolt tension for 606 N-m torque.

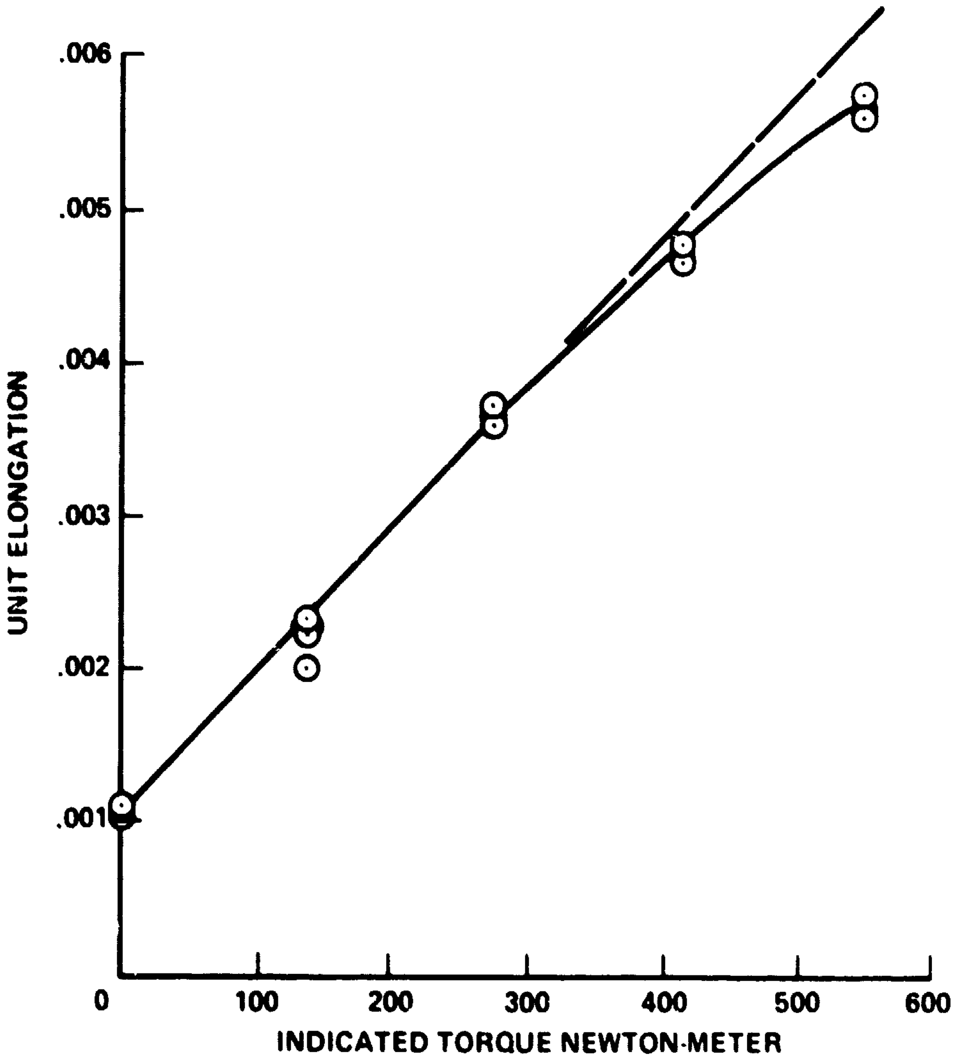


Figure 4.- Torque-tension result for lubricated bolt.

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