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EXPERIMENTAL DETERMINATION OF PRELOAD OF BOLTS
USING S-122 FLUOROCARBON RELEASE AGENT

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INTRODUCTION

One of the most frequent errors in the design of bolted joints occurs in the calculation of preload created by the bolts. Usually, the error is caused by assuming the wrong friction coefficient for the thread lubricant. Other contributing factors to the design error could be:

- (1) Inadequate engagement of threads,
- (2) Surface roughness under the bolt head or nut,
- (3) Misaligned surfaces or holes causing eccentric loading of the threads,
- (4) Axis of internal threads not perpendicular to the seating surface of the nut or bolt head,
- (5) Manufacturing method, i.e., rolled or cut thread,
- (6) Manner of torque application,
- (7) Class of fit,
- (8) Material properties.

This paper will deal only with the effect of thread lubricant and its variables. The other error-contributing factors above can be minimized by close design review, good workmanship, and careful inspection.

TECHNICAL DISCUSSION

A rule of thumb method of specifying torque for a bolted joint is described by the equation

T = CDF i in.-lb

where T in.-lb is the torque

C is the constant for thread condition

D is the nominal bolt diameter in inches

F_i is the initial load or tension in the bolt.

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It has been experimentally determined in industry that C varies between 0.17 and 0.18 for average bolts using an ordinary lubricant. Without lubricant, C averages about 0.20.

Because of uncertainties, several bolts used on the Phoebus 2 test assembly, PN1115858, were tested in a tensile machine where the torque and resultant tension load were recorded.

The test pieces were cleaned with acetone, lubricated, and dried prior to testing. The lubricant used was S-122 Fluorocarbon Release Agent manufactured by Miller-Stephenson Chemical Company. It is packaged in an aerosol can and applied by mist spraying. The active ingredient, tetrafluoroethylene polymer solids, is inert and compatible with liquid oxygen.

The first series of torque/load tests were conducted on the coaxial injector dome studs, KNS 624S-20. Figure 1 shows a stud prior to testing, a stud that has been tested to failure, and a stud that has been torqued to a load just below failure. Figure 2 shows the torque/load relationship. Superimposed on the torque/load curve is equation

$$T = (CDFi) + T_n$$

where $C = .08$, and

$$T_n \text{ (torque required to } = 50 \text{ in.-lb}$$

$$\text{overcome the locknut)}$$

The curve shown in Figure 3 is a composite of four tests where studs were exposed to a tension load alone and is included for general interest.

The second series of tests were conducted on the .750-in. bolts which fasten the adapter to the leg. The test set-up is shown in Figure 4 and the test results in Figure 5. The superimposed curve was calculated from $T = CDFi$ where $C = .15$

Since the .750-in. bolts are to be re-used, they were subjected to repeated testing. Two were torqued to 450 ft/lb and unscrewed four times each with no significant change in results or thread conditions.

Two other tests were conducted on the .750-in bolts using Neolube, a graphite-base lubricant. Both bolts galled before full torque could be applied.

The third series of tests were conducted using the .3125-in propellant fire bolts. Results of the tests are summarized in Figure 6. A calculated curve using $C = .15$ closely follows the experimental curve of the prototype bolts, AS 4099.

Self-locking nuts were used on the .3125-in bolts. Approximately 50 in.-lb torque was required to overcome the locking feature of the nuts.

One each of the two types of .3125-in. bolts were torqued with no lubricant. Due to the small sample, no conclusion could be reached; however, there was certainly a trend toward higher torque per unit of load.

CONCLUSIONS

The rule of thumb torque equation fails at high loads and should not be used on critically designed hardware. Realistic values of torque/load can be found at this time by simulating the bolted joint and actually reading the results on the torque wrench and tensile tester. Until more experimental data is available which considers the pertinent variables, we must continue to verify our best-guesses by experimental tests. Even after extensive experimental data has been compiled, generalizations must be limited because of the subtleties of design.

Torque/Load Test Samples

Figure 1

Torque/Load Relationship

Figure 2

Figure 3

Test Setup for .750-in. Bolts

Figure 4

Test Results for .750-in. Bolts

Figure 5

Test Results for .3125-in. Propellant Line Bolts

Figure 6