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Torque Tests on Threaded 6061-T651 Aluminum

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Abstract

This note summarizes bolt torque tests conducted on a 6061-T651 aluminum plate, 3/4 inches thick. The plate had 50 tapped holes. It was subjected to 3 stress relieving cycles, after which thread stripping tests were performed.

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LIGO PROJECT

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Scope

The purpose of this test was to determine whether tapped holes in a block of 6061-T651 aluminum, after 3 successive stress relieving treatments (190C (375F) for 6 hours each) would still be capable of adequate holding power. Aluminum looses its strength after many hours of stress relieving (on order 100 hours). The tests were also to assess the difference in load carrying associated with two different thread lengths (1/2”, and 5/8”) and two different thread pitches (20, and 28).

1. Discussion

A 3/4” block of aluminum was prepared for this test by drilling and tapping the following holes:

15 holes	1/4-20 x ½” deep
10 holes	1/4-20 x 5/8” deep
15 holes	1/4-28 x ½” deep
10 holes	1/4-28 x 5/8” deep

The block was then stress relieved 3 times at 375F for 6 hours, and cleaned with acetone. All of the screws’ bearing surfaces were covered with 30 weight oil to assure that there was no adhesion or galling between the components. Hex head bolts, 1/2” long were used to test the holes that were tapped 1/2” deep. Bolts that were 3/4” long were used to test the 5/8” deep tapped holes. Two washers were used on the 3/4” long bolts to prevent the bolts from bottoming out in their holes. The overall thickness of the washer pairs ranged from .132” to .144”. The bolts lengths varied from .722” to .732”. The thread engagement, therefore, varied from .578” to .6”.

2. Results

The data presented is approximate. The torque values listed represent the number at which the bolt continued to turn without an increase in applied torque. The feel and judgment of the experimenter are very much a factor in arriving at the results.

The results, in lb-in, are shown below.

Table 1: Plate Torque Limit Load (in-lb) 1/4-28 x 1/2” deep

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	σ
tighten	150	150	125	125	127	120	150	152	117	126	129	140	120	143	137	134	12.1
loosen	75	87	82	93	77	78	93	91	76	85	79	87	83	94	89	85	6.4

Table 2: Plate Torque Limit Load (in-lb) 1/4-28 x 5/8” deep

No.	16	17	18	19	20	21	22	23	24	25						mean	σ
tighten	155	232	180	142	142	135	128	215	150	117						160	35.9
loosen	96	135	110	105	103	101	88	138	110	87						107	16.4

Table 3: Plate Torque Limit Load (in-lb) 1/4-20 x 1/2” deep

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	σ
tighten	146	135	160	165	155	153	160	150	152	156	153	146	175	165	156	155	9.1
loosen	75	73	80	92	72	77	77	81	75	82	80	80	81	87	81	80	5.0

Table 4: Plate Torque Limit Load (in-lb) 1/4-20 x 5/8” deep

No.	16	17	18	19	20	21	22	23	24	25						mean	σ
tighten	130	132	112	113	135	130	126	123	125	(1)						125	7.6
loosen	69	76	60	60	78	80	76	72	72							71	6.9

(1) The tapped threads were too damaged to test.

3. Conclusions

The results obtained from the plate testing did leave some ambiguity. The anticipated results were expected to show that the fine threads would have a higher pull-out load since the finer pitch of the bolt results in more cross-sectional area. Standard practice at LANL was to use the finer threads since they are cheaper to cut and have better strength characteristics.

The above data leaves two unanswered questions.

1. Why is the standard deviation associated with the 5/8” deep UNF threads so much larger than the other three?
2. Why is the mean torque of the 5/8” deep UNC threads 20% lower than that of the 1/2” deep coarse threads?

In an academic sense, it would be interesting (but uneconomical) to pursue these questions. Descending to the practical side, these tests have answered the question of whether stress relieving this aluminum will result in weakened threaded holes. In short, the threads are still adequate.

The lowest torque measured in any of the tests was 112 lb.-in.. The axial load developed by this torque on a lubricated bolt is

$$W = CT \quad ^{(1)}$$

where C is a factor determined by the bolt size and lubrication

$$W = 32 \times 112 = 3{,}584 \text{ lbs.}$$

The stress area of a 1/4-28 bolt equals .0362 inches^2. (2)

Bolt stress equals

$$S = 3{,}584 / .0362 = 99{,}000 \text{ psi}$$

The yield stress of cold worked 303 stainless is 75-95,000 psi. (3)

Therefore, the calculated stresses resulting from these tests are about the same as the yield strength of the stainless bolts used in the test. ***The aluminum threads are more than adequate after stress relieving.***

Since both coarse and fine threads have proven acceptable, the optics table will use the fine threads, since they are the more economical to implement.

4. References

(1.) Machine Design, Feb. 11, 1982, "Predicting Initial Bolt Load".
(2.) Machinery's Handbook 14th edition, 1950.
(3.) ASME Metals' Properties, 1954

Note 1, Linda Turner, 09/03/99 02:12:38 PM
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