Evaluation of preload scatter in torque strategy and torque-angle strategy for tightening of high strength fasteners

Deepa K S[1], Mohit Rajput[2], Christopher Solomon S[3], Dr.K.S.Suresh[4]

[1]Mtech student, Dept. of Mechanical Engineering, NSS college of Engineering, Kerala, India
[2]Scientist, MMD, Vikram Sarabhai Space Centre, ISRO, TVM, India
[3]Scientist, MMD, Vikram Sarabhai Space Centre, ISRO, TVM, India
[4]Associate Professor, Dept. of Mechanical Engineering, NSS college of Engineering, Kerala, India

---

Abstract - *Fasteners play an important role in the assembly of aerospace structures. Fasteners are commonly tightened by applying torque, as a result a preload is produced which holds the components together in a joint if the fastener is not adequately tightened, it will be subjected to cyclic loading and fail due to fatigue. Hence it is pertinent that the designers shall select proper tightening processes to minimize the preload variation in order to ensure required joint safety. Torque-Tension tests are conducted on M12 bolts with Cadmium plating and Aluminium IVD and MoS2 coating with hexagonal nut and Nylock nut combinations. Torque strategy and Torque-angle strategy are established to determine the preload scatter. Nut factor and snug torque values are also determined. Results show that torque-angle strategy have better control on preload scatter than torque strategy.*

Key Words: Fasteners, tightening processes, Torque-tension tests, Nut factor, Snug torque, Preload Scatter.

1. INTRODUCTION

Fasteners are components used to join two or more components in an assembly. The different types of fasteners used are screws, bolts, nuts, rivets, pins, blind rivets, blind bolts, anchor nuts, solid inserts, collars etc. Fasteners used in aerospace applications should be light, durable, shall withstand high loads, vibrations and hostile environments. High tensile fasteners are normally used in aerospace applications.

35NCD16 steel is the material widely used in fasteners in aerospace applications. It is used for making fasteners with axial tensile stress rating of 1250MPa.

In this paper, a comparison of torque strategy and torque-angle strategy is done. Torque –tension tests are done M12 cadmium plated and Aluminium IVD and MoS_2 coated bolts using hexagonal nut and Nylock hexagonal nut combinations. It was found that preload scatter in torque strategy is more than 20% and it is less in torque-angle strategy

1.1 Test Specimens

Test specimens used are bolts, nuts and washers. Bolts used are M12 bolts made of material 35NCD16 of 1250MPa property class and of surface treatment cadmium plating and aluminium IVD and MoS_2 coating. Nuts used are hexagonal nuts and Nylock hexagonal nuts. Washers used are made of 15CDV6.

2. EXPERIMENTAL DETAILS

Torque-tension tests are performed to determine the torque-preload relation, characterization of nut factor and snug torque. Fasteners are assembled with two to three free threads between grips i.e., between the nut or internal thread bearing face and the external thread to shank run-out. When nuts are used, a minimum of one complete thread shall extend beyond the top of the nut. The externally threaded member should be fixed with the torque applied through the nut. Torque is applied at a rate that will permit the torque readings to be read while the nut is in motion. The induced load is read simultaneously from the strain meter.

2.1 Bolt Force Sensor Calibration

The bolt force sensor is calibrated in a Universal Testing Machine (UTM).The sensor is kept over calibration support block and positioned using M12 Hexagonal socket head bolt to apply load in compression mode. The sensor is powered using power supply and is connected to strain meter (OMEGA). For each load increments (10kN) up to 130kN, corresponding strain meter reading is noted. A total of 3 tests are done on the fasteners. The averages of 3 tests are determined. The error in load values is also computed. These errors in load value are corrected when the torque – tension test is done on fasteners.

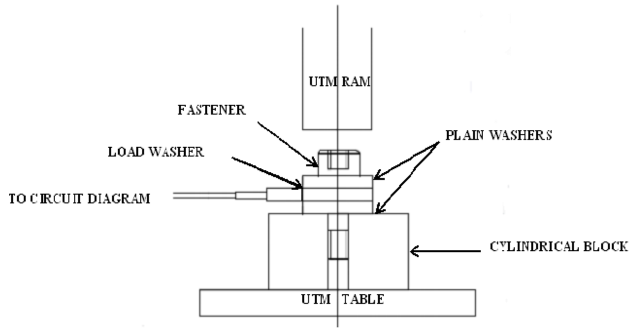

Fig -1: Schematic Diagram of Load Washer Calibration Setup

Table -1: Bolt Sensor Calibration for M12 Fastener

M12					
UTM	LOAD WASHER				
	1	2	3	AVG	Error
0	2	0	0.1	0.70000	-0.70000
10	15	11.9	14.7	13.86667	-3.86667
20	25.4	20.7	25	23.70000	-3.70000
30	35.8	30.1	34.6	33.50000	-3.50000
40	46.2	39.1	43.9	43.06667	-3.06667
50	56.2	47.8	52.8	52.26667	-2.26667
60	66	56.2	61.4	61.20000	-1.20000
70	75.7	64.8	69.8	70.10000	-0.10000
80	85.2	73.3	78.1	78.86667	1.133333
90	94.3	81.5	86.3	87.36667	2.633333
100	103.3	89.5	94.4	95.73333	4.266667
110	112.1	97.11	102.5	103.9033	6.096667
120	120.8	104.6	110.5	111.9667	8.033333
130	129.1	112	118.3	119.8000	10.20000

2.2 Experimental Setup for Torque-Tension Test

The experimental setup consists of the required bolt which is inserted between the test plates and load washers and the hardened steel washers are kept and required nut is placed. The load values are indicated by the strain meter which is connected to the load washer. The test plate is kept in a bench vise. The nut is tightened by applying torque using the torque wrench (Freedom^3 SPC). For each torque increments (10kN) up to 150 kN, corresponding angles and load values are noted. A total of 5 tests are done with fresh fasteners on fresh holes on the same flange.

Fig -2: Experimental Setup

Table -2: Torque and load values for M12 Cd plated fastener

T(Nm)	LOAD 1	LOAD 2	LOAD 3	LOAD 4	LOAD 5
0	0	0	0	0	0
50	19.3	23.3	16.7	18.2	24.8
60	25.8	29.4	26.3	20.8	32.9
70	32.2	35.4	28.9	28.4	37.9
80	37.7	40.1	33.6	36.1	43.0
90	43.6	50.3	38.9	39.1	51.6
100	50.5	56.8	43.8	44.8	60.8
110	56.4	62.9	49.3	52.1	67.1
120	62.6	67.0	54.4	57.0	77.5
130	68.9	75	60.7	64.2	90.2
140	61.9	67	53.8	56.1	89.3
150	65.8	71.1	57.3	62.3	96.5
160	69.2	74	61.3	66.3	100.5
170	71.6	77.1	65.5	69.9	104
180	74.3	79	68.5	75.2	108

Table -3: Torque and load values for M12 Al IVD & MoS_2 coated fastener

TORQUE (Nm)	FORCE(kN)				
	1	2	3	4	5
0	0	0	0	0	0
50	32.8	32.3	47.8	31.9	41.1
60	45.3	40.7	64.6	40.7	51.3
70	58.9	51.9	79.1	51.2	62.5
80	75.2	64.2	94.2	61.4	73.3
90	87.8	70.9	106.2	69.9	86.1
100	101.8	81.3	117.9	80.9	98.1

3. EVALUATION OF NUT FACTOR

The nut factor is evaluated using the formula,

$K=T/(F*D)$

For each torque values the force value is obtained from the strain meter and nut factor is calculated using the given formula and average of this nut factor is taken.

The nut factor value obtained for the given M12 Cadmium plated fastener is 0.174 and for the M12 Aluminium IVD and MoS_2 coated fastener is 0.096.

4. RESULTS AND DISCUSSIONS

4.1 Torque Strategy

In torque strategy the given fastener is tightened for the required assembly torque value, Ta which is calculated using the formula given below. The assembly torque value is computed for 60% of preload value.

$Ta=K*D*P_{0.6Y}$

K – Nut factor

D – Nominal diameter of the bolt

$P_{0.6Y}$ = Preload corresponds to 60% of the yield strength

Table -4: Torque and Preload values for M12 Cadmium plated fastener

Ta	F
118.84	61.49
118.84	67.17
118.84	53.63
118.84	56.42
118.84	74.71

Table -5: Torque and Preload values for M12 Al IVD & MoS_2 coated fastener

Ta	F
65.57	52.56
65.57	46.71
65.57	72.48
65.57	46.35
65.57	57.4

4.2 Torque-Angle Strategy

In torque-angle strategy, snug torque, Ts and angle of turn, α value is computed from the torque angle curves obtained from the torque-tension tests. In torque-angle strategy the assembly torque equals that torque value which corresponds to snug torque plus angle of turn.

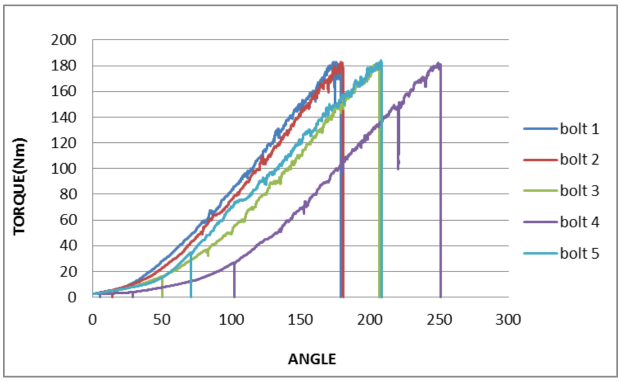

Chart -1: Torque vs. angle curve for M12 Cd plated fastener

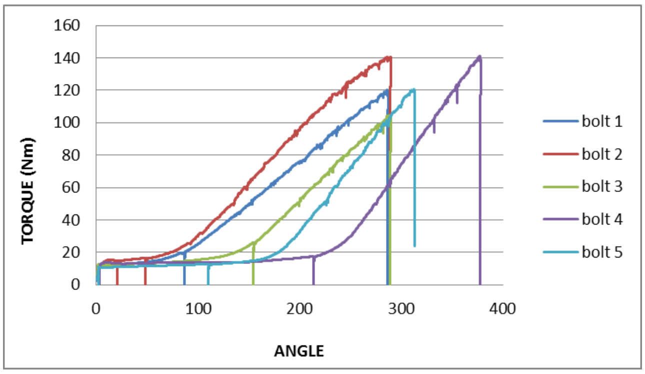

Chart -2: Torque vs. angle curve for M12 Al IVD & MoS_2 coated fastener

Table 6 and 7 shows the snug torque and angle of turn values for M12 Cadmium plated and Aluminium IVD and MoS_2 coated bolt with hexagonal nut and Nylock hexagonal nut combinations.

Table -6: Ts and α values for M12 Cd plated fastener

Ts	α
55	45
60	53
40	54
45	60
60	52
AVG 52	**52.8**

Table -7: Ts and α value for M12 Al IVD & MoS2 coated fastener

Ts	α
51	24
40	40
52	23
40	30
40	30
AVG 44.6	**29.4**

Table 8 and 9 shows the assembly torque and preload values in torque-angle strategy for M12 Cadmium plated and Aluminium IVD and MoS_2 coated bolt with hexagonal nut and Nylock hexagonal nut combinations.

Table -8: Assembly torque and preload values for Cd plated fastener in torque-angle strategy

Ts+α	F
120	62.6
115	65
120	52
119	56.5
105	63.93

Preload scatter is found to be only 13% in torque-angle strategy for the given M12 Cadmium plated bolt and hexagonal nut combination.

Table -9: Assembly torque and preload values for Al IVD & MoS2 coated fastener in torque-angle strategy

Ts+α	F
70	58.9
65	46.3
60	64.6
65	45.95
62	54.27

Preload scatter is found to be only 18.3 % in torque-angle strategy for the given M12 Aluminium IVD and MoS_2 coated bolt with hexagonal nut and Nylock hexagonal nut combinations.

Table -10: Comparison of Torque and Torque-angle strategy

Fastener combination	K	Ta	Ts	α	Preload Scatter	
					Torque strategy	Torque-angle strategy
M12 Cd+ Hex nut	0.174	118.84	52	53	21.08	13
M12 Al IVD & MoS_2 Nylock Hex nut	0.096	65.57	45	30	26.13	18.3

3. CONCLUSIONS

Torque- tension tests were conducted on M12 Cd plated and Al IVD and MoS_2 coated bolts with hexagonal nut and Nylock hexagonal nut combinations. The most important conclusions of the work are summarized below:

1) The torque-tension relationship which is represented by nut factor (K) is determined for the M12 fasteners with Cadmium plating, Aluminium IVD and MoS_2 coated fasteners with hexagonal nut and Nylock hexagonal nut combination.
2) Nut factor value is found to be higher for cadmium plated fasteners than, Aluminium IVD and MoS_2 coated fasteners .The snug torque values (T_s) and the angle of turn (α) has been characterized for M12 fasteners.
3) Preload scatter has been determined for both torque strategy and torque angle strategy.
   Preload scatter for torque-angle strategy is less compared to torque strategy.

ACKNOWLEDGEMENT

The authors are thankful to Vikram Sarabhai Space Centre, Indian Space Research Organization, Thiruvananthapuram and NSS College of Engineering, Palakkad for providing facilities for research and conducing experiments.

REFERENCES

[1] D. Croccolo, M. De Agostinis,N. Vincenzi," Experimental analysis on the tightening torque – preloading force relationship in threaded fasteners", Canada : s.n, 2010. IMECE2010-37153.

[2] M. Hagiwara, N. Ohashi," A New Tightening Technique for Threaded fasteners", 1994, ASME, pp. 64-69.

[3] Xiwen Zhang, Xiaodong Wang,Yi Luo," An Improved Torque Method for Preload Control in Precision Assembly of Miniature Bolt Joints", 2012.

[4] Sayed A. Nassar,Xianjie Yang," Novel Formulation of the Tightening and Breakaway Torque Components in Threaded Fasteners", 2007, Journal of Pressure Vessel Technology

[5] Ali Alkelani and Basil Housari," Development Of Tightening Torque For Self Tapping and Thread Rolling Fasteners", Proceedings of the ASME 2011 Pressure Vessels & Piping Division Conference PVP 2011.

[6] Bickford ,J.H and Nassar S.A,1998 " Handbook of Bolts and Bolted joints",Marcel Dekker,New York