

ENGINEERING PRACTICE STUDY (EPS)

MIL-DTL-38999

Composite Bending Moment Torque Requirements

PROJECT NUMBER: 5935-2020-011

13 MARCH 2020

Prepared by: Jacob Bender
Project officer (Circular Connector – DLA - Columbus)
DLA Land and Maritime-VAI

ENGINEERING PRACTICE STUDY

MIL-DTL-38999

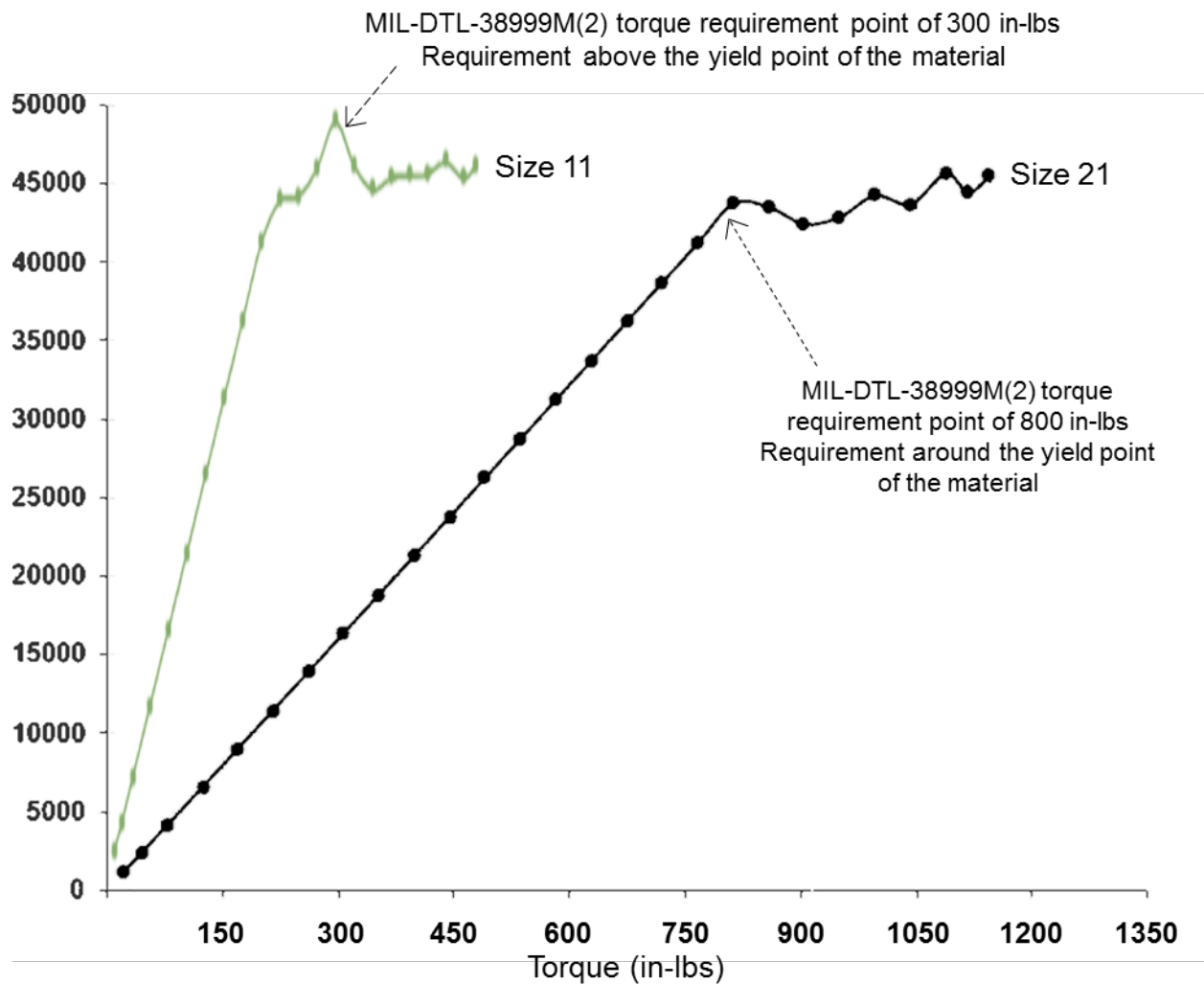
Objective: Assess if the MIL-DTL-38999 flange mounted design can withstand the bending moment torques when composite material is used in construction. If this cannot be reliably achieved, determine appropriate bending moment torque accounting for normal variation raw material and real world variation while keeping the bending moment requirement as high as possible to maintain the robustness of the connector design and manufacture.

Background: The base document [MIL-DTL-38999M(2)] requires bending moment testing in paragraph 3.20. Testing is described in paragraph 4.5.16. TABLE XVII provides torque values for the testing.

Composite shell material was added to the document (MIL-C-38999J, 6 Apr 1990) as the new class J (cadmium olive drab) and class M (nickel plated). No changes or consideration for differences in material properties were found for the change from aluminum to composites. Composites and aluminums used in connector constructions have similar yield strengths (usually around 40kpsi). Aluminum (typ. 17% strain at failure) elastically stretches more than composites (typically 2% strain at failure). In any construction, when loaded by a force, the maximum stress usually occur at a single point. When using aluminum, the higher elasticity (over a composite) spreads the max stress point over more area. Even with similar yield strengths, aluminum will generally provide a part capable of withstanding higher forces due to the greater elasticity compared to the more brittle composite.

Two manufactures attempted to qualify the composite jam nut receptacle (MIL-DTL-38999/24, classes J & M) but failed the bending moment testing. Bending moment torques were reduced for composite hex jam nut receptacles (MIL-DTL-38999/24, classes J & M) in revision E (07 Jun 1995) which allowed the passage of the test resulted qualification of parts. The origins of the reduced torque values is unknown.

Recently a manufacturer has had some composite wall mounted flanges (MIL-DTL-38999/20, classes J & M) fail bending moment testing. Failures were the minority of the testing result but frequent enough to justify additional investigation. Additional testing and finite element analysis (FEA) using composite material showed the torque requirements were operating at and around the part yield point on a stress-strain curve. FEA stress vs applied torques are shown for size 11 and 21 shell sizes.



Operating at this point with variations in the material strength and other real world variations (variation from nominal) causes some parts to withstand and some to fail.

Methodology: Calculations were completed using statistical distribution using the nomenclature:

σ = standard deviation

σ^2 = variance

μ = mean

$\mathcal{N}(\mu, \sigma^2) \sim$ normal distribution

The raw material used in the construction of connectors bodies were characterized by a normal distribution of the material's yield stress.

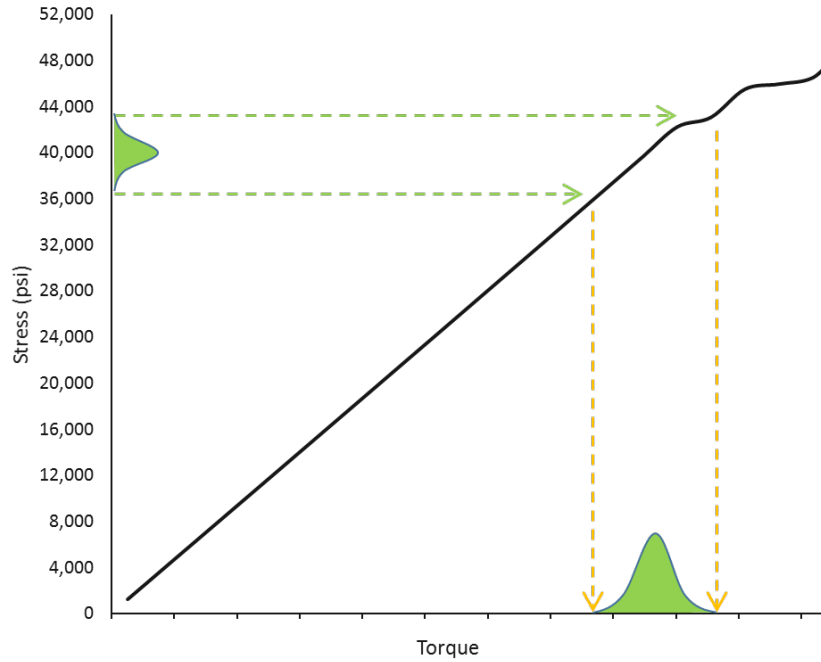
$\mu_{\text{material,yield}}$ = mean material yield stress

$\sigma_{\text{material,yield}}$ = material yield stress standard deviation

$$Stress_{material,yield} = \text{material stress at yield} \sim \mathcal{N}(\mu_{material,yield}, \sigma_{material,yield}^2)$$

The mean and standard deviation were determined by analyzing historical record of testing from lots of connector raw material. The mean was taken as 40,000 *psi* and the standard deviation was 2,000 *psi*.

These material properties relate to the bending moment torque by a stress-torque curve (similar to a stress-strain curve). The stress-torque curves were obtained from FEA analysis and validated by sample testing.



The general linearity in this range around the yield stress allows the definition of a conversion constant:

$$\alpha_{yield} = \frac{\text{yeild stress}}{\text{yield torque}}$$

With this constant, the distribution of torques at yield can be determined:

$$\begin{aligned} \tau_{material,yield} &= \text{material yield torque} = \frac{Stress_{material,yield}}{\alpha_{yield}} \\ &= \frac{1}{\alpha_{yield}} \mathcal{N}(\mu_{material,yield}, \sigma_{material,yield}^2) \\ &= \mathcal{N}\left(\frac{\mu_{material,yield}}{\alpha_{yield}}, \frac{\sigma_{material,yield}^2}{\alpha_{yield}^2}\right) \end{aligned}$$

At this point, the material variation (tensile strength) effect on the torque the connector can endure before reaching yield is complete. Additionally there are additional real world factors which create variation in the system. This variation was accounted for by a normal distribution with a mean of zero:

$$\begin{aligned}\tau_r &= \text{real world torque variation} \\ \tau_r &= \mathcal{N}(0, \sigma_r^2)\end{aligned}$$

σ_r was experimentally determined by testing connectors from from a single lot of raw material with identical tensile strengths.

The combined effect of the material and real world variations are capture by τ_{yield} :

$$\begin{aligned}\tau_{yield} &= \text{yield torque} = \tau_{material,yield} + \tau_r \\ &= \mathcal{N}\left(\frac{\mu_{material,yield}}{\alpha_{yield}}, \frac{\sigma_{material,yield}^2}{\alpha_{yield}^2}\right) + \mathcal{N}(0, \sigma_r^2) \\ &= \mathcal{N}\left(\frac{\mu_{material,yield}}{\alpha_{yield}}, \frac{\sigma_{material,yield}^2}{\alpha_{yield}^2} + \sigma_r^2\right)\end{aligned}$$

with a mean and standard deviation:

$$\begin{aligned}\mu_{yield} &= \frac{\mu_{material,yield}}{\alpha_{yield}} \\ \sigma_{yield} &= \sqrt{\frac{\sigma_{material,yield}^2}{\alpha_{yield}^2} + \sigma_r^2}\end{aligned}$$

This provided a normal distribution of yield torques. From this distribution, the testing requirement for the connectors can be set allowing for acceptable level variation. Simply using the mean would produce a 50% failure in the test (due to 50% of the distribution lying below the mean). As the requirement is reduced from the mean, more connectors will pass. The requirement was set as 3 standard deviations below the mean:

$$\tau_{requirement} = \mu_{yield} - 3 * \sigma_{yield}$$

$$\tau_{requirement} = \frac{\mu_{material,yield}}{\alpha_{yield}} - 3 * \sqrt{\frac{\sigma_{material,yield}^2}{\alpha_{yield}^2} + \sigma_r^2}$$

which corresponds to 998.7 part passing for every 1000 tested.

Shell Size	Material					Real World Variation τ_r (in * lbs)	Requirement (in * lbs)
	Tensile Strength (psi)		α_{yield} $\left(\frac{psi}{in * lbs}\right)$ $\left(\frac{1}{in^3}\right)$	Yield Torque $\tau_{material,yield}$ (in * lbs)			
	mean	SD		$\frac{\mu_{material,yield}}{\alpha_{yield}}$	$\frac{\sigma_{material,yield}}{\alpha_{yield}}$		
	$\mu_{material,yield}$	$\sigma_{material,yield}$					
9	40000	2000	415.61	96.2	4.81	3.46	78.5
11			123.56	323.7	16.19	13.22	261.0
13			108.31	369.3	18.47	10.74	305.2
15			75.70	528.4	26.42	49.88	359.0
17			71.87	556.6	27.83	22.37	449.4
19			68.25	586.0	29.30	32.23	455.4
21			44.01	908.8	45.44	45.28	716.4
23			43.74	914.4	45.72	87.64	617.9
25			37.20	1075.3	53.77	71.00	808.2

*Note: Shell size 9 was not in the original scope of the testing. Values were estimated off simulations and other shell size data.

Comparing to existing requirements shows decreases across the board with approximately 25% reduction on average.

Shell Size	Existing Requirement (in * lbs)	Proposed Requirement (in * lbs)	Percent Change
9	100	78.5	-21.5%
11	300	261.0	-13.0%
13	400	305.2	-23.7%
15	500	359.0	-28.2%
17	600	449.4	-25.1%
19	700	455.4	-34.9%
21	800	716.4	-10.5%
23	900	617.9	-31.3%
25	1000	808.2	-19.2%

Average: -23.0%

Comparing to the previous reduction in bending moment requirements of the composite jam nut receptacles shows the propose reduction is about half that of the jam nut receptacle reduction.

Shell Size	Existing Requirement (in * lbs)	Proposed		Composite Jam Nut Receptacle Reduction	
		Requirement (in * lbs)	Percent Change	Percent Change	Requirement (in * lbs)
9	100	78.5	-21.5%	-25.0%	75
11	300	261.0	-13.0%	-58.3%	125
13	400	305.2	-23.7%	-56.3%	175
15	500	359.0	-28.2%	-50.0%	250
17	600	449.4	-25.1%	-45.8%	325
19	700	455.4	-34.9%	-42.9%	400
21	800	716.4	-10.5%	-40.6%	475
23	900	617.9	-31.3%	-38.9%	550
25	1000	808.2	-19.2%	-35.0%	650

Average: -23.0% -43.6%

Proposal: New bending moment requirements were proposed (above) for MIL-DTL-38999/20 & /26 connectors. Solicited input from industry and users. Feedback on any of the parameters used was of particular value (such as raw material tensile strength mean and standard deviation).

Results:

Responses from the EP study is shown in the table below:

Responses (# of Entities)	Adjustment	Values
1	Lower	MIL-DTL-38999 Series I & IV
1	Lower	5 to 10% Reduction
2	Lower	Jam nut (/24) values
3	Lower	Proposed values in EP study

All respondents were in favor of lower the bending moments with a variations in the opinion of the values that should be used.

A mean of 40 kpsi with a SD of 2 kpsi was used for the proposed requirement calculations. 2 respondents provided tensile strength raw material data. The first respondent had a minutely lower mean and minutely tighter SD. The second respondent had a slightly lower mean and slightly tighter SD. Both validated the 40 kpsi and 2 kpsi SD used. Considering the somewhat limited number of samples in the distribution, a more precise determination of the these values is not possible at this time. For the requirement calculation, the lower mean lowers the calculated requirement but is offset by the tighter (smaller) SD increasing the calculated requirement.

Intrinsic variation with the manufacturer of composite, the importance of tight process control, and dimensional difference between manufacturers were commonly discussed and cited.

Two companies expressed potential interest in performing additional testing.

If there are any questions, please contact Mr. Jacob Bender, phone DSN 850-9185/commercial 614-692-9185, E-mail Jacob.Bender@dla.mil, DLA Land and Maritime-VAI, P.O. Box 3990, Columbus, OH 43218-3990.