Test Report

# Torque-Tension Testing 3/8-16x3” G5 HHCS with matching hex nut

Conducted by: Peak innovations Engineering

David Archer
1/15/2015

## Test Introductions and Objectives

The primary purpose of this test is to determine the relationship between torque and bolt tension for the five bolt finishes listed in the matrix below. The test was conducted on a common surrogate bolt and nut described in the report. The test method used was ISO 16047. The hardened test washer against which the bolt was turned was degreased with a plain finish.

Test Matrix

| Test # | Bolt/Nut Finish |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

## Hardware, Equipment and Test Summary
## All Tests

| Hardware | | |
|---|---|---|
| **Fastener** | **Description** | **Part Number** |
| Driven Fastener | 3/8–16 x 3" Gr 5 hex head cap screw | unknown |
| Clamped Member(s) | Load cell and plates | N/A |
| Stationary Fastener or Nut Member | 3/8–16 x 3" Gr 5 Hex Nut | unknown |
| Washer / Other | Square Test Washer - Wilson-Garner | SFM010HS<br>Lot # PO58431A |

| Equipment | | | |
|---|---|---|---|
| **Description** | **Manufacturer and Model** | **Capacity** | **Equip. ID** |
| Transient Recorder and Ultrasonic System | Micro Controls MC 900 portable 4 channel | N/A | CO-03 |
| DC Controller | Stanley 21A114303 | N/A | CD-06 |
| Torque-Angle Transducer | Crane CheckStar | 180 N-m | ST-19 |
| DC Nut-Runner | Stanley E55LB5-2005 | 2001 N-m | TA-26 |
| Clamp Load Cell | RS 059810-01104 | 100 kN | SL-01 |

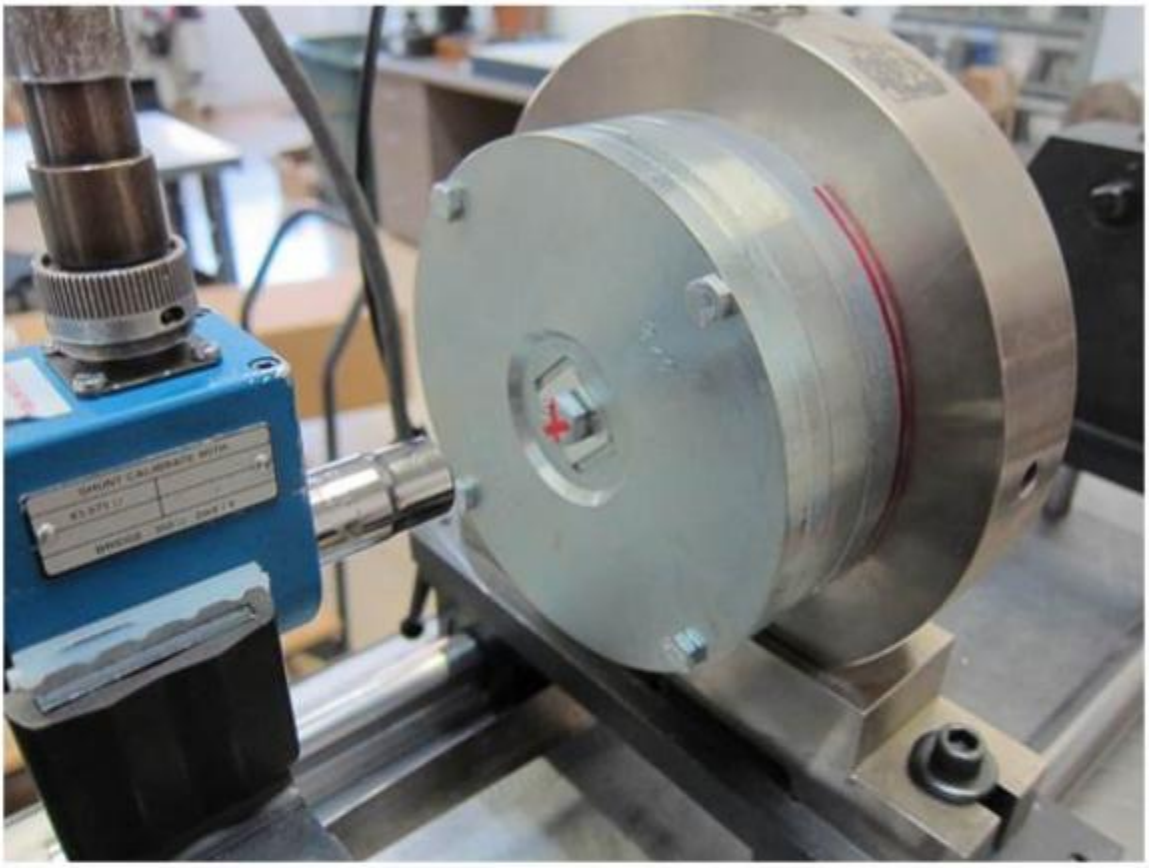
| Test Parameter | |
|---|---|
| **Parameter** | **Description** |
| Test Specification | ISO 16047 |
| Requestor | [redacted] |
| Test Date | 1/8/2015 |
| Temperature/Humidly | 22.6°C, 17% |
| Tightening Strategy | 30 RPM to greater than 75% proof load. |
| Test Technicians | Dave Archer, Eric Hannula |

## Test Hardware

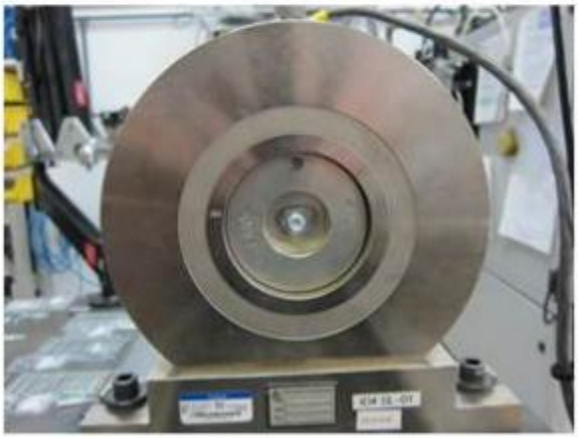
**Fasteners**

| | | |
|---|---|---|
| **Bolt** | Description: | 3/8–16 x 3" Gr 5 hex head cap screw |
| | Part Number/Lot # | Not Available |
| | Calculated Value of $D_b$: | 0.555 in, |
| | Surface Coating: | see test matrix |
| | Manufacturing Method of Thread: | Rolled |
| **Nut** | Description: | 3/8–16 x 3" Gr 5 Hex Nut |
| | Part Number/Lot # | Not Available |
| | Calculated Value of $D_b$: | N/A (bolt turned) |
| | Surface Coating: | see test matrix |
| | Manufacturing Method of Thread: | Rolled |
| **Washer** | Description: | Square Test Washer - Hardened |
| | Part Number/Lot # | Wilson Garner SFM010HS Lot # PO58431A |
| | Surface Coating: | Plain |
| | Washer I.D: | 0.407 in. |

## Test Setup



Test Setup



# ISO 16047 Variables and Calculations

**Dimensions highlighted in red were measured**

| Symbol | Designation |
|---|---|
| $d$ | Nominal thread diameter |
| $d_2$ | Basic pitch diameter of thread |
| $d_4$ | Diameter of hole of test fixture |
| $d_h$ | Clearance hole diameter of washer or bearing part (nominal value) |
| $D_b$ | Diameter of bearing surface under nut or bolt head for friction (theoretical or measured) |
| $D_o$ | Outer diameter of bearing surface, $d_{w\,min}$ or $d_{k\,min}$ (see product standards) |
| $D_p$ | Diameter of plain area of bearing plate |
| $F$ | Clamp force |
| $F_p$ | Proof load according to ISO 898-1, ISO 898-2 or ISO 898-6, whichever is relevant |
| $F_u$ | Ultimate clamp force |
| $F_y$ | Yield clamp force |
| $h$ | Thickness of test-bearing plate or test washer |
| $K$ | Torque coefficient, $K=\frac{T}{Fd}$ |
| $L_c$ | Clamp length |
| $L_t$ | Length of complete thread between bearing surfaces |
| $P$ | Pitch of the thread |
| $T$ | Tightening torque |
| $T_b$ | Bearing surface friction torque |
| $T_{th}$ | Thread torque |
| $T_u$ | Ultimate tightening torque |
| $T_y$ | Yield tightening torque |
| $\Theta$ | Rotation angle |
| $\mu_b$ | Coefficient of friction between bearing surfaces under nut or bolt head |
| $\mu_{th}$ | Coefficient of friction between threads |
| $\mu_{tot}$ | Coefficient of total friction |

The coefficient of total friction $\mu_{tot}$ is determined from the tightening torque/clamp force ratio by the approximate formula

$$\mu_{tot}=\frac{\frac{T}{F}-\frac{P}{2\pi}}{0{,}577d_2+0{,}5D_b}$$

where

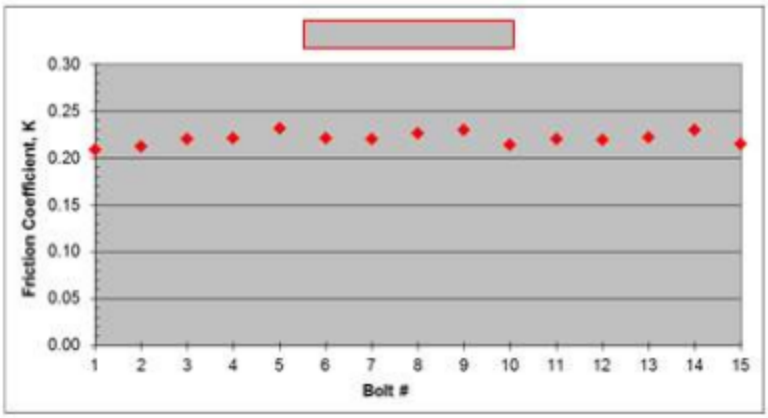
$$D_b=\frac{D_o+d_h}{2}$$

## Test Results

The torque required to achieve 4,941 lb bolt tension (75% of the 6,580 lb proof load), and resulting calculation of $\mu_{tot}$ are summarized below. The calculation of torque coefficient K (from T=KDF where T=torque, D= bolt diameter and F=bolt tension ) is also included for reference.

| Bolt # | Torque @ 4,941 lb (ft-lb) | Coeff of Friction, $\mu_{tot}$ | Torque Coefficient, K |
|---|---|---|---|
| 1 | 32.2 | 0.158 | 0.209 |
| 2 | 32.8 | 0.161 | 0.212 |
| 3 | 33.9 | 0.168 | 0.220 |
| 4 | 34.1 | 0.169 | 0.221 |
| 5 | 35.7 | 0.178 | 0.231 |
| 6 | 34.1 | 0.169 | 0.221 |
| 7 | 34.0 | 0.168 | 0.220 |
| 8 | 34.9 | 0.173 | 0.226 |
| 9 | 35.5 | 0.176 | 0.230 |
| 10 | 33.0 | 0.163 | 0.214 |
| 11 | 34.0 | 0.168 | 0.220 |
| 12 | 33.9 | 0.167 | 0.219 |
| 13 | 34.3 | 0.170 | 0.222 |
| 14 | 35.5 | 0.177 | 0.230 |
| 15 | 33.2 | 0.164 | 0.215 |
| N | 15 | 15 | 15 |
| MEAN | 34.1 | 0.169 | 0.221 |
| STD DEV | 1.0 | 0.006 | 0.007 |
| X - 3STD | 31.0 | 0.151 | 0.201 |
| X + 3STD | 37.1 | 0.186 | 0.240 |
| MIN | 32.2 | 0.158 | 0.209 |
| MAX | 35.7 | 0.178 | 0.231 |

d, in 0.375
d2, in: 0.331
dh, in: 0.409
Do, in: 0.555
P, in: 0.063
Db, in: 0.482
F, lb 4,941



## Test Results

The torque required to achieve 4,941 lb bolt tension (75% of the 6,580 lb proof load), and resulting calculation of $\mu_{tot}$ are summarized below. The calculation of torque coefficient K (from T=KDF where T=torque, D= bolt diameter and F=bolt tension ) is also included for reference.

| Bolt # | Torque @ 4,941 lb (ft-lb) | Coeff of Friction, $\mu_{tot}$ | Torque Coefficient, K |
|---|---|---|---|
| 1 | 33.3 | 0.164 | 0.216 |
| 2 | 36.0 | 0.179 | 0.233 |
| 3 | 34.4 | 0.170 | 0.223 |
| 4 | 41.7 | 0.212 | 0.270 |
| 5 | 37.9 | 0.190 | 0.245 |
| 6 | 38.8 | 0.195 | 0.251 |
| 7 | 38.3 | 0.192 | 0.248 |
| 8 | 38.3 | 0.192 | 0.248 |
| 9 | 39.5 | 0.199 | 0.256 |
| 10 | 37.8 | 0.189 | 0.245 |
| 11 | 38.5 | 0.193 | 0.249 |
| 12 | 35.9 | 0.179 | 0.233 |
| 13 | 35.5 | 0.177 | 0.230 |
| 14 | 36.8 | 0.184 | 0.238 |
| 15 | 38.8 | 0.195 | 0.251 |
| N | 15 | 15 | 15 |
| MEAN | 37.4 | 0.187 | 0.242 |
| STD DEV | 2.1 | 0.012 | 0.014 |
| X - 3STD | 31.0 | 0.151 | 0.201 |
| X + 3STD | 43.9 | 0.224 | 0.284 |
| MIN | 33.3 | 0.164 | 0.216 |
| MAX | 41.7 | 0.212 | 0.270 |

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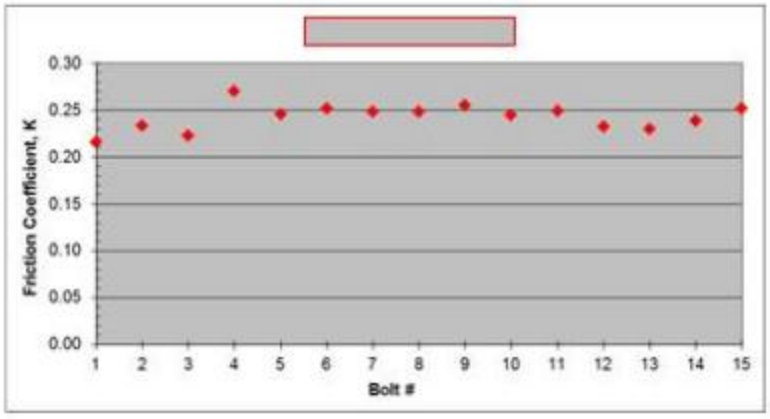

## Test Results

The torque required to achieve 4,941 lb bolt tension (75% of the 6,580 lb proof load), and resulting calculation of $\mu_{tot}$ are summarized below. The calculation of torque coefficient K (from T=KDF where T=torque, D= bolt diameter and F=bolt tension ) is also included for reference.

| Bolt # | Torque @ 4,941 lb (ft-lb) | Coeff of Friction, $\mu_{tot}$ | Torque Coefficient, K |
|---|---|---|---|
| 1 | 33.0 | 0.162 | 0.214 |
| 2 | 36.6 | 0.183 | 0.237 |
| 3 | 39.7 | 0.200 | 0.257 |
| 4 | 36.8 | 0.184 | 0.238 |
| 5 | 35.8 | 0.178 | 0.232 |
| 6 | 35.0 | 0.174 | 0.226 |
| 7 | 38.0 | 0.191 | 0.246 |
| 8 | 35.5 | 0.177 | 0.230 |
| 9 | 36.4 | 0.182 | 0.236 |
| 10 | 39.6 | 0.200 | 0.256 |
| 11 | 36.5 | 0.182 | 0.237 |
| 12 | 36.9 | 0.185 | 0.239 |
| 13 | 37.1 | 0.186 | 0.240 |
| 14 | 39.2 | 0.197 | 0.254 |
| 15 | 38.3 | 0.192 | 0.248 |
| N | 15 | 15 | 15 |
| MEAN | 37.0 | 0.185 | 0.239 |
| STD DEV | 1.8 | 0.010 | 0.012 |
| X - 3STD | 31.5 | 0.154 | 0.204 |
| X + 3STD | 42.4 | 0.215 | 0.275 |
| MIN | 33.0 | 0.162 | 0.214 |
| MAX | 39.7 | 0.200 | 0.257 |

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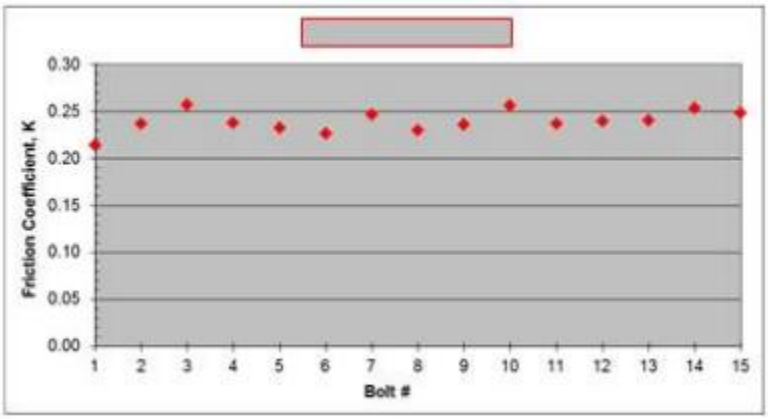

## Test Results

The torque required to achieve 4,941 lb bolt tension (75% of the 6,580 lb proof load), and resulting calculation of $\mu_{tot}$ are summarized below. The calculation of torque coefficient K (from T=KDF where T=torque, D= bolt diameter and F=bolt tension ) is also included for reference.

| Bolt # | Torque @ 4,941 lb (ft-lb) | Coeff of Friction, $\mu_{tot}$ | Torque Coefficient, K |
|---|---|---|---|
| 1 | 33.5 | 0.165 | 0.217 |
| 2 | 35.3 | 0.176 | 0.229 |
| 3 | 33.1 | 0.163 | 0.214 |
| 4 | 33.3 | 0.164 | 0.215 |
| 5 | 32.2 | 0.158 | 0.208 |
| 6 | 34.8 | 0.173 | 0.226 |
| 7 | 32.6 | 0.160 | 0.211 |
| 8 | 31.2 | 0.152 | 0.202 |
| 9 | 30.2 | 0.147 | 0.196 |
| 10 | 33.5 | 0.165 | 0.217 |
| 11 | 33.5 | 0.165 | 0.217 |
| 12 | 35.5 | 0.177 | 0.230 |
| 13 | 33.6 | 0.166 | 0.218 |
| 14 | 32.0 | 0.157 | 0.207 |
| 15 | 33.2 | 0.163 | 0.215 |
| N | 15 | 15 | 15 |
| MEAN | 33.2 | 0.163 | 0.215 |
| STD DEV | 1.4 | 0.008 | 0.009 |
| X - 3STD | 28.8 | 0.139 | 0.187 |
| X + 3STD | 37.5 | 0.188 | 0.243 |
| MIN | 30.2 | 0.147 | 0.196 |
| MAX | 35.5 | 0.177 | 0.230 |

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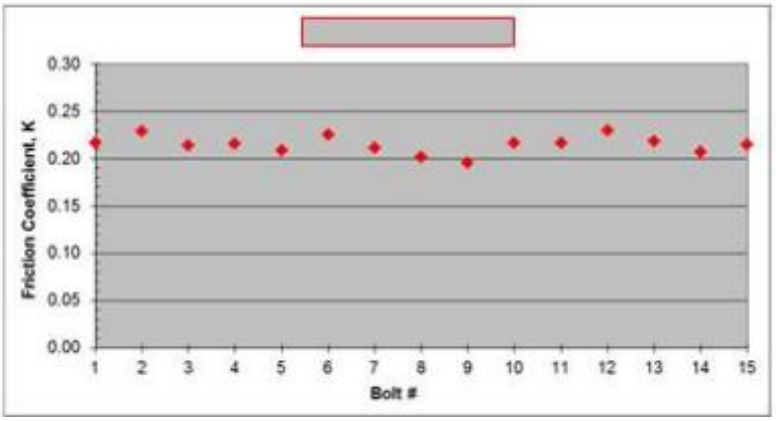

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The torque required to achieve 4,941 lb bolt tension (75% of the 6,580 lb proof load), and resulting calculation of $\mu_{tot}$ are summarized below. The calculation of torque coefficient K (from T=KDF where T=torque, D= bolt diameter and F=bolt tension ) is also included for reference.

| Bolt # | Torque @ 4,941 lb (ft-lb) | Coeff of Friction, $\mu_{tot}$ | Torque Coefficient, K |
|---|---|---|---|
| 1 | 39.7 | 0.200 | 0.257 |
| 2 | 44.5 | 0.227 | 0.288 |
| 3 | 39.7 | 0.200 | 0.257 |
| 4 | 44.5 | 0.227 | 0.288 |
| 5 | 45.0 | 0.230 | 0.291 |
| 6 | 45.0 | 0.230 | 0.291 |
| 7 | 49.1 | 0.253 | 0.318 |
| 8 | 36.6 | 0.183 | 0.237 |
| 9 | 43.7 | 0.223 | 0.283 |
| 10 | 44.5 | 0.227 | 0.288 |
| 11 | 44.7 | 0.228 | 0.289 |
| 12 | 49.9 | 0.257 | 0.323 |
| 13 | 46.6 | 0.239 | 0.302 |
| 14 | 48.8 | 0.251 | 0.316 |
| 15 | 48.8 | 0.251 | 0.316 |
| N | 15 | 15 | 15 |
| MEAN | 44.7 | 0.228 | 0.290 |
| STD DEV | 3.8 | 0.021 | 0.024 |
| X - 3STD | 33.4 | 0.165 | 0.216 |
| X + 3STD | 56.1 | 0.292 | 0.363 |
| MIN | 36.6 | 0.183 | 0.237 |
| MAX | 49.9 | 0.257 | 0.323 |

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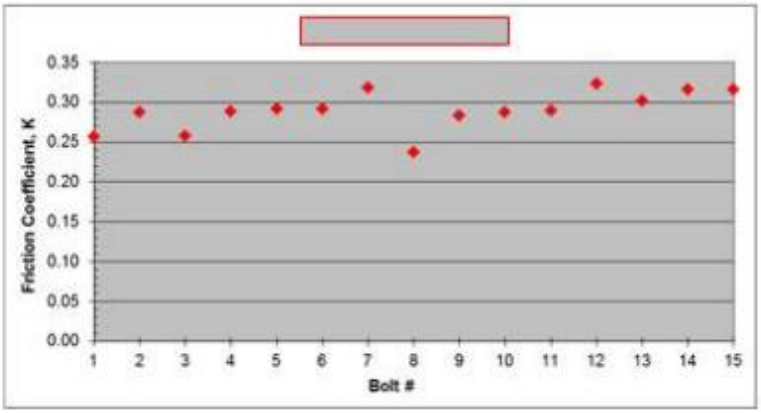
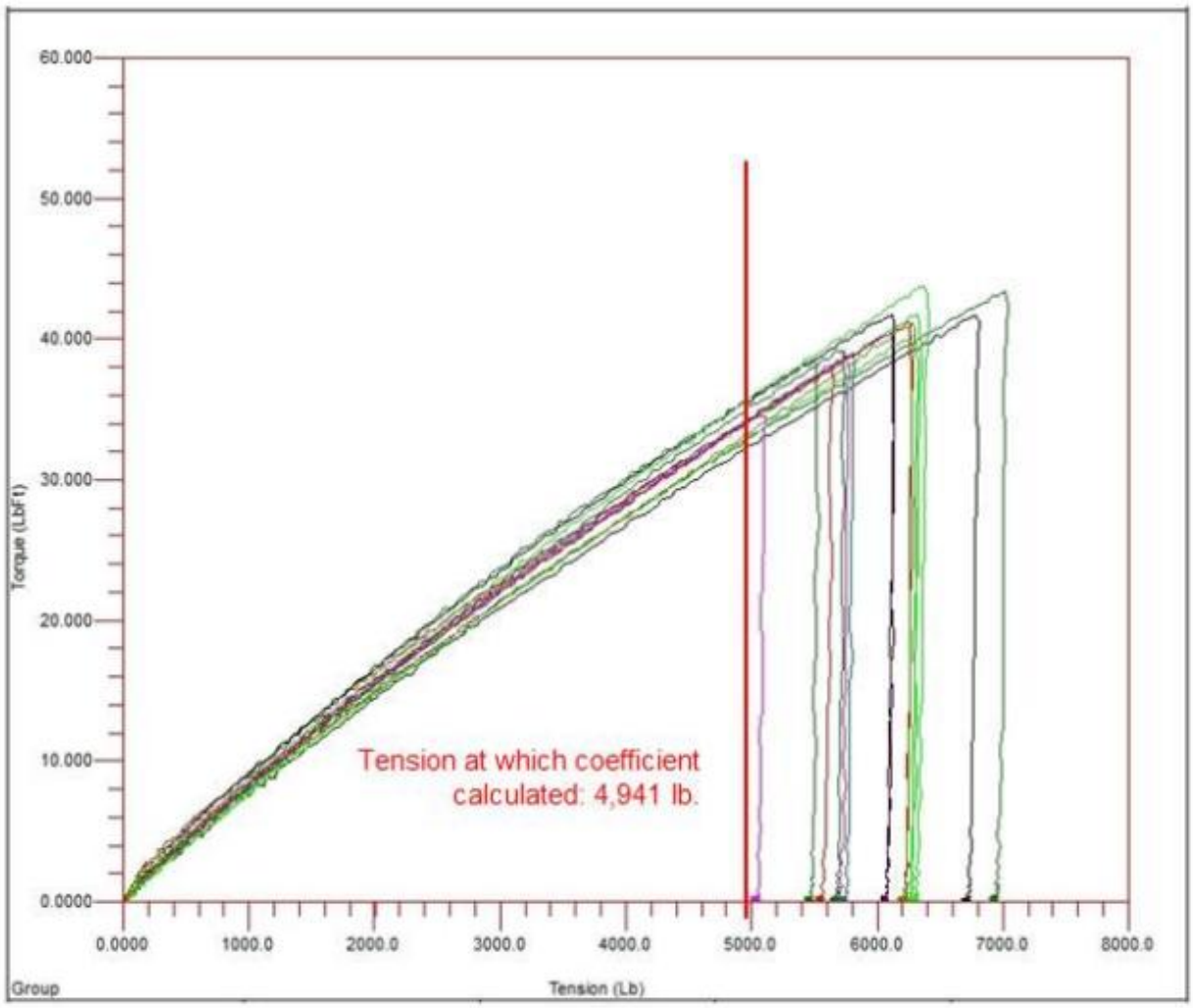


## Test Traces

Following is the group of torque-tension traces from which the test data was obtained.



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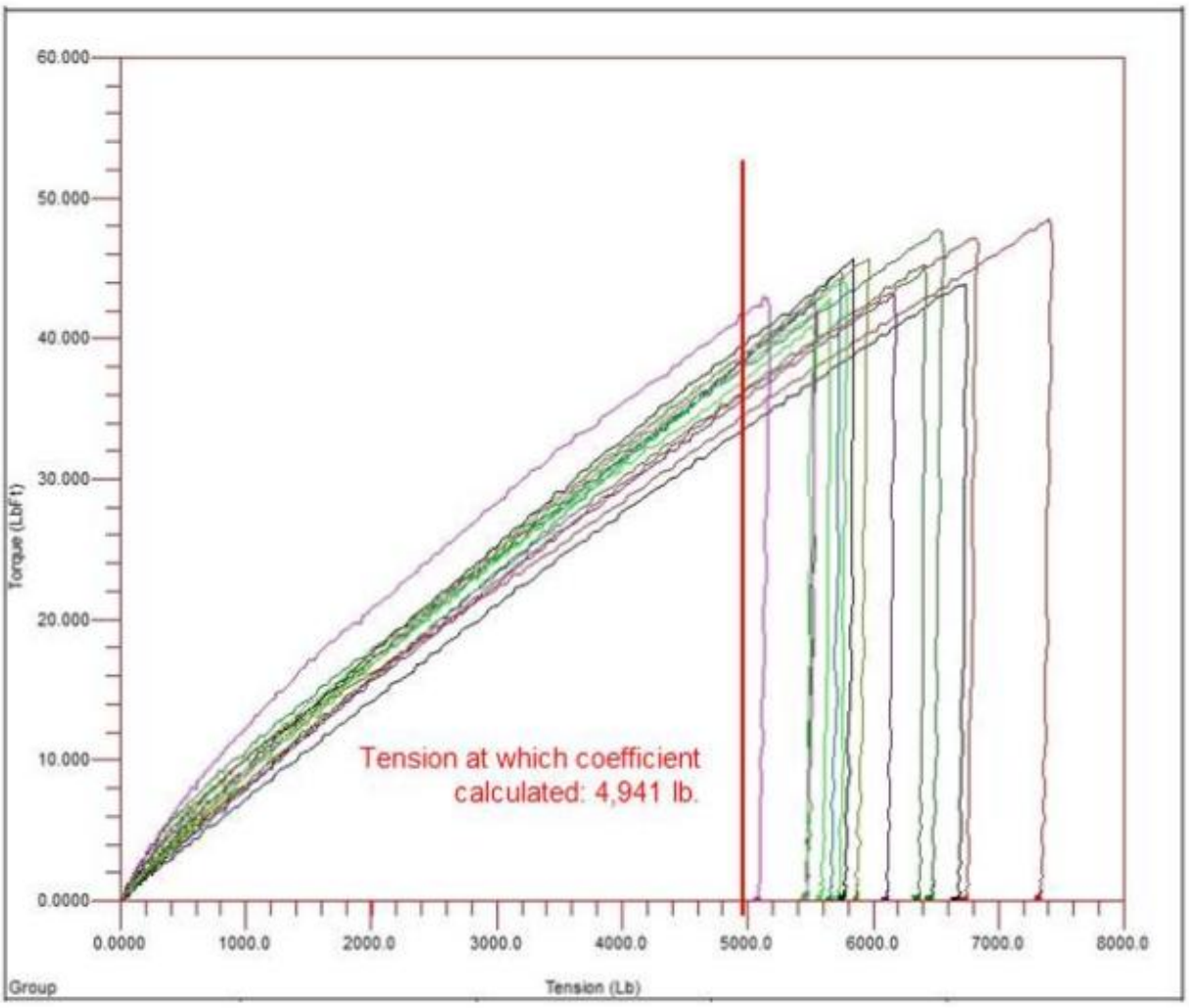

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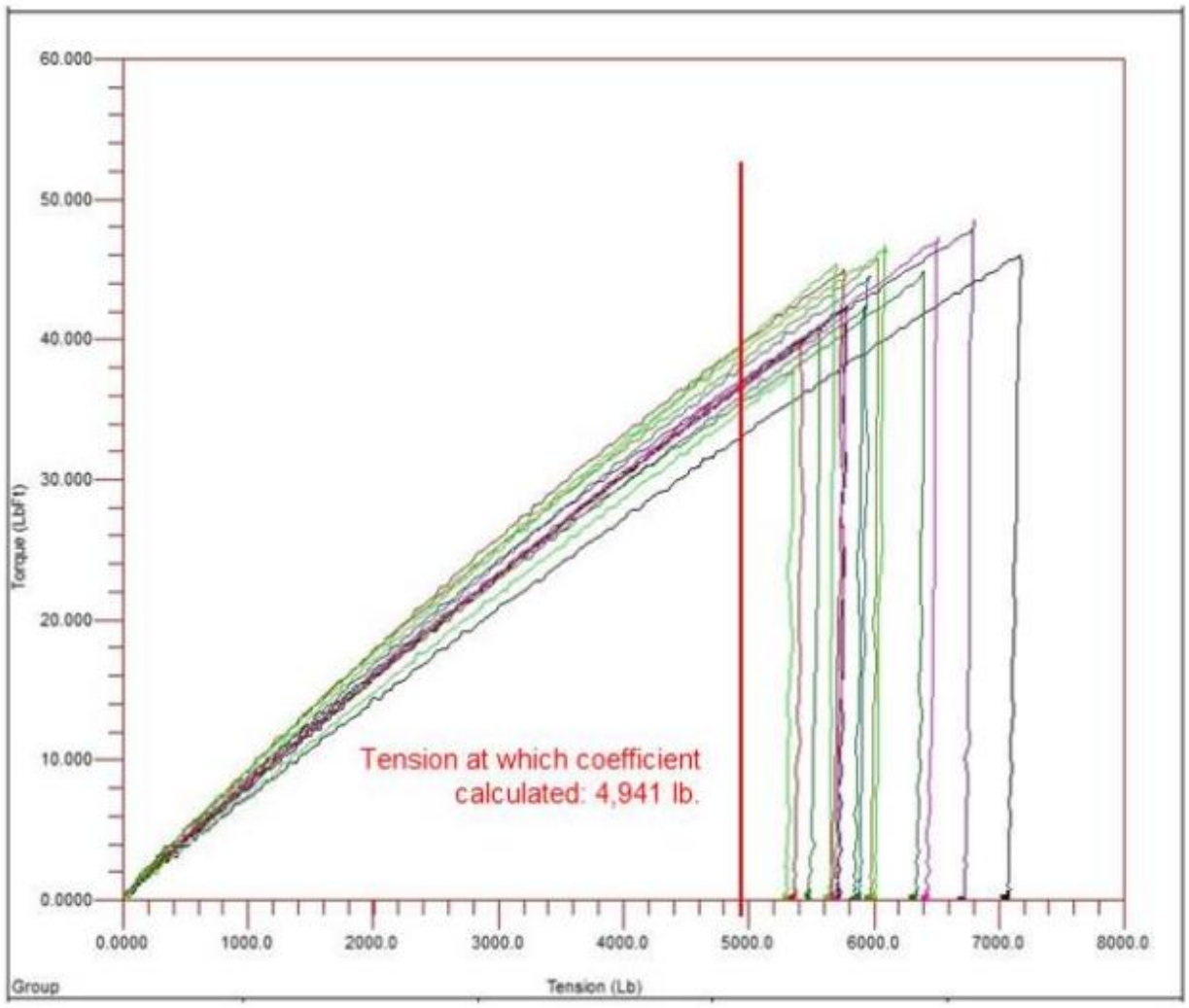

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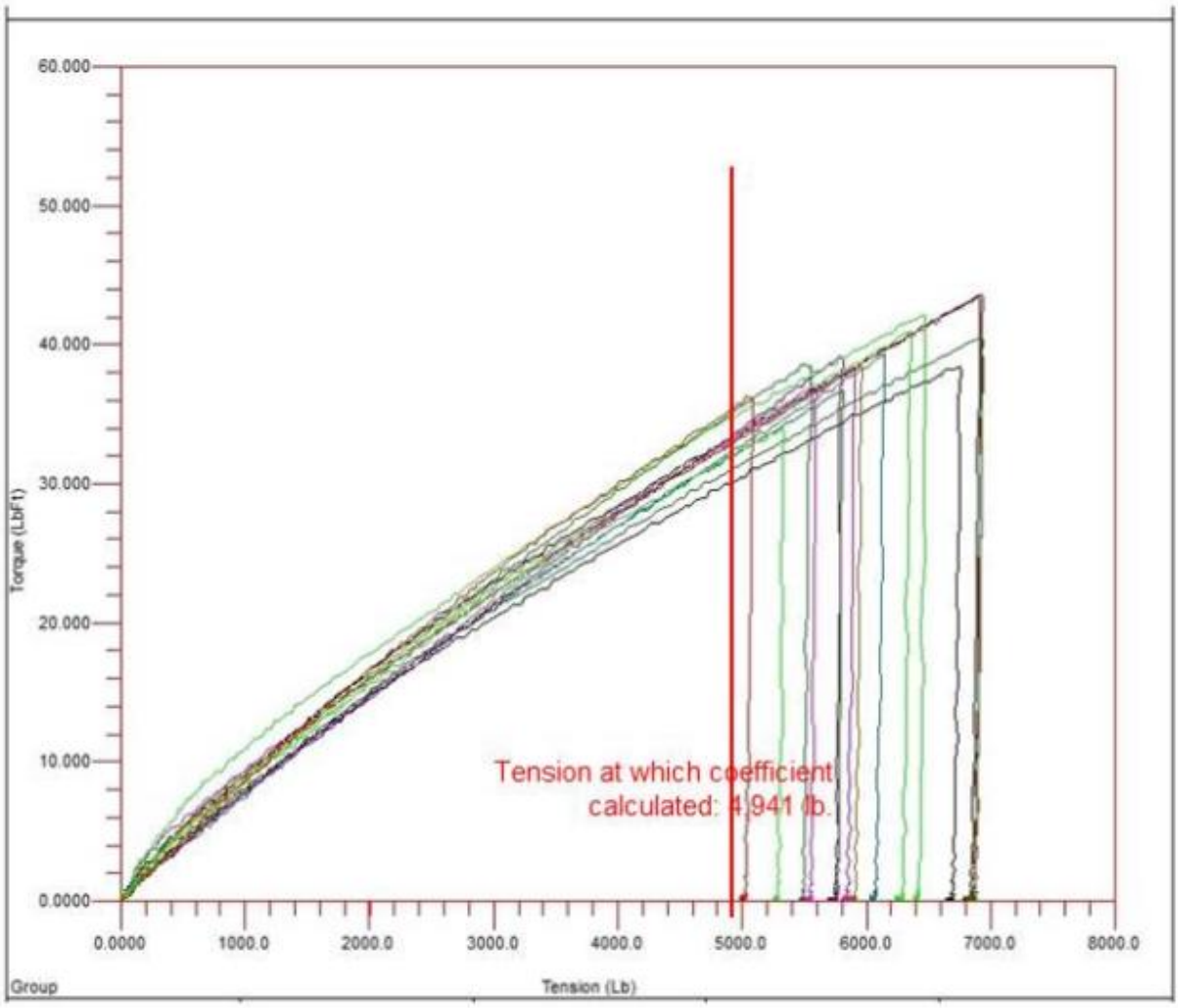

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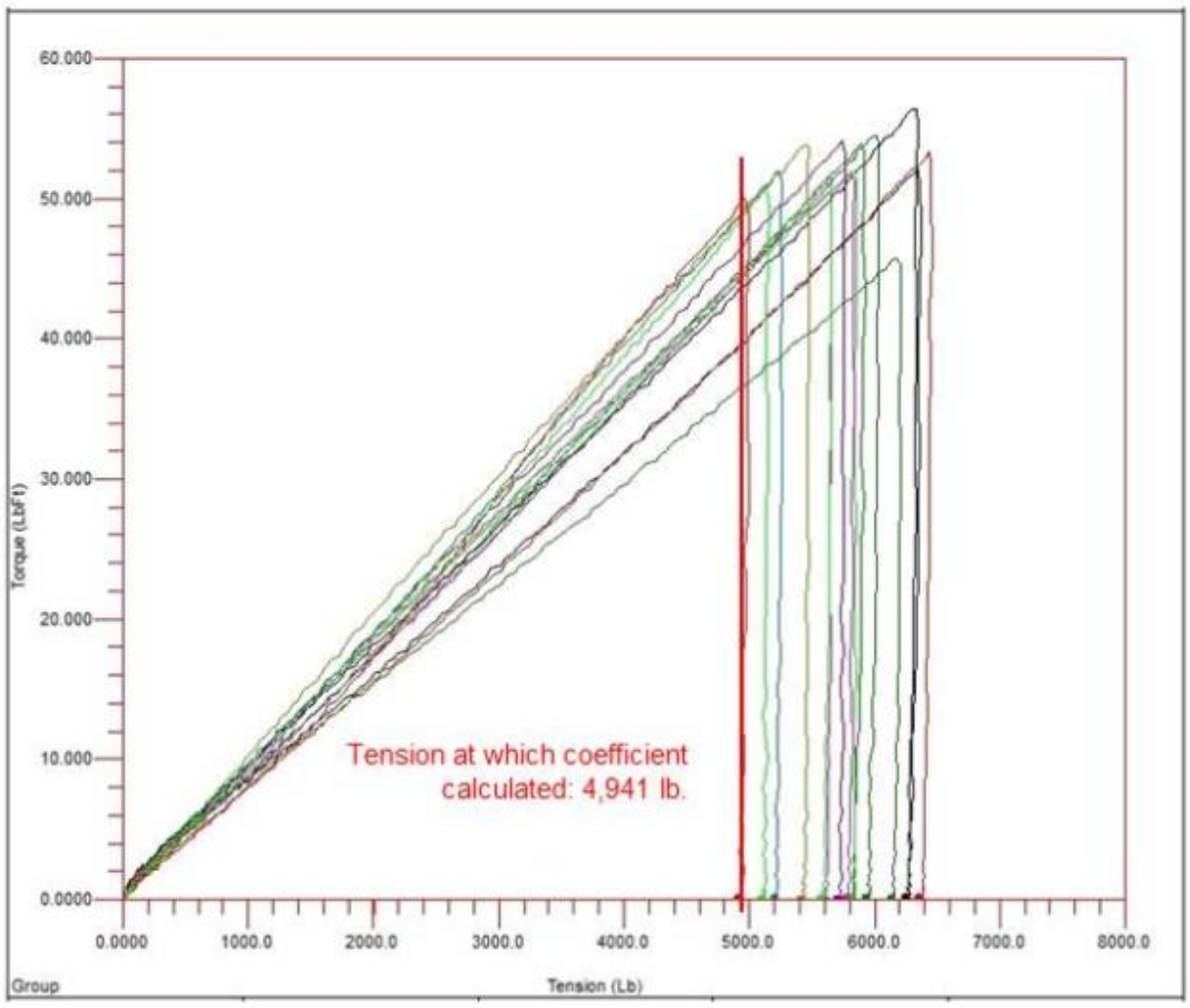
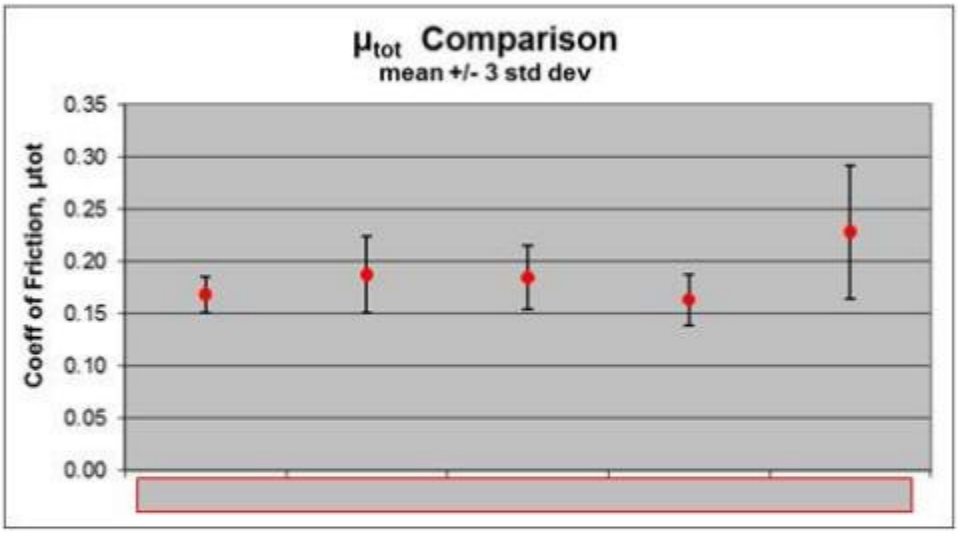
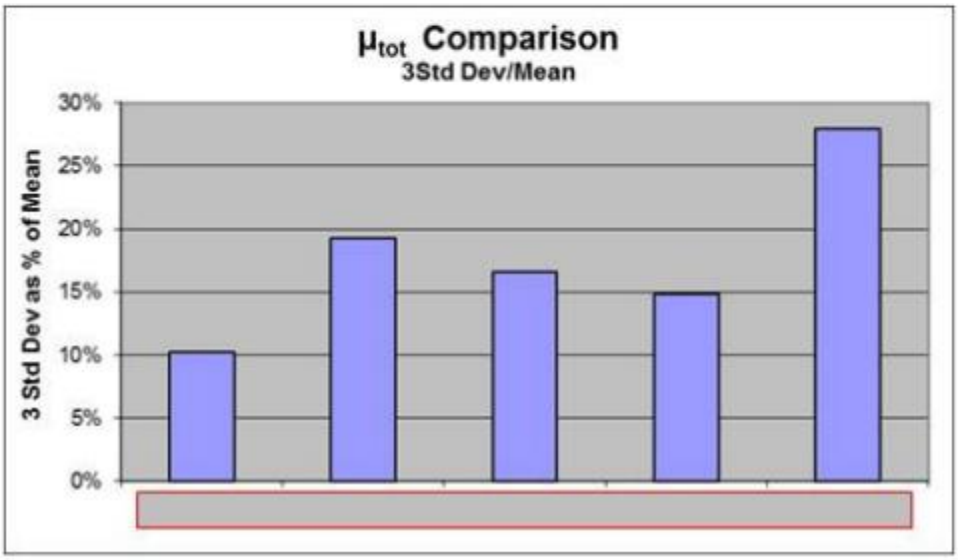


## Test Results Summary

Following is a summary comparison of the mean and scatter of the torque-tension relationship, as expressed by the Coefficient of Friction.

| Test # | Description | Coeff of Friction, $\mu_{tot}$ | | |
|---|---|---|---|---|
| | | Mean | Std Dev | 3SD |
| 1 | | 0.169 | 0.006 | 0.017 |
| 2 | | 0.187 | 0.012 | 0.036 |
| 3 | | 0.185 | 0.010 | 0.031 |
| 4 | | 0.163 | 0.008 | 0.024 |
| 5 | | 0.228 | 0.021 | 0.064 |



The results and comments contained in the report should be considered valid only for the specific components tested.