DRD TECHNOLOGY

WEBINAR

# Torque Evaluation on Threaded Fasteners

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Feb 27, 2025

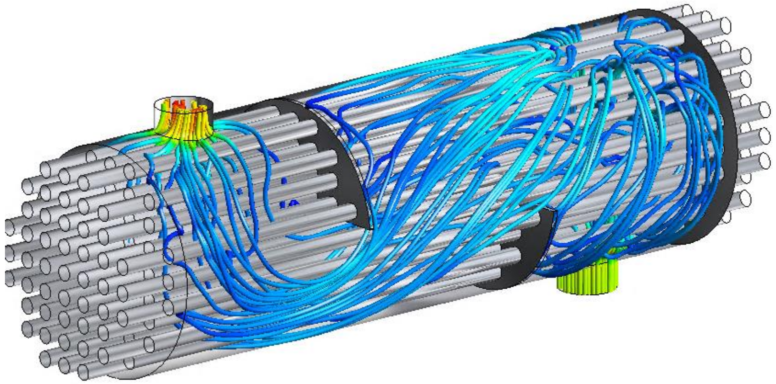
DRD

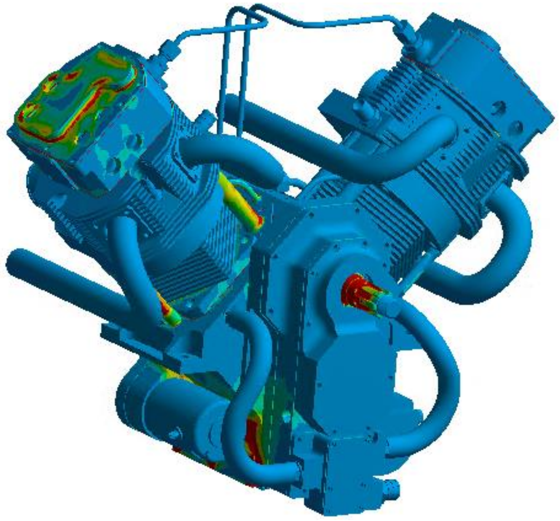
# Agenda

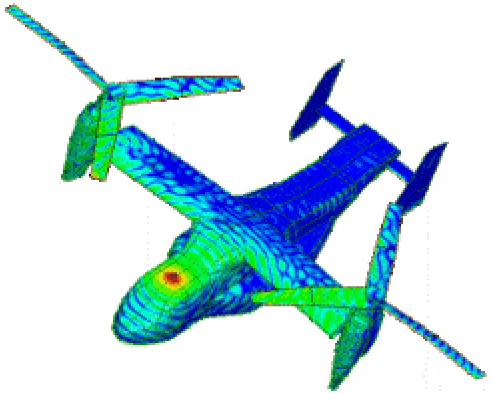
- DRD Mission Statement and Support Options
- Overview of Torque on Threaded Fasteners
- Creating Geometric Interference to Simulate Applied Torque on Threaded Fasteners
- Discussion of Techniques to Evaluate Torque on Threaded Fasteners
- Demo : Techniques to Evaluate Torque in ANSYS Workbench for Threaded Parts
- Summary

# Mission Statement

DRD Technology helps engineering teams accelerate product development. With in-house expertise spanning the entire range of physics, we ensure customers succeed when using Ansys simulation tools for virtual prototyping and design verification.







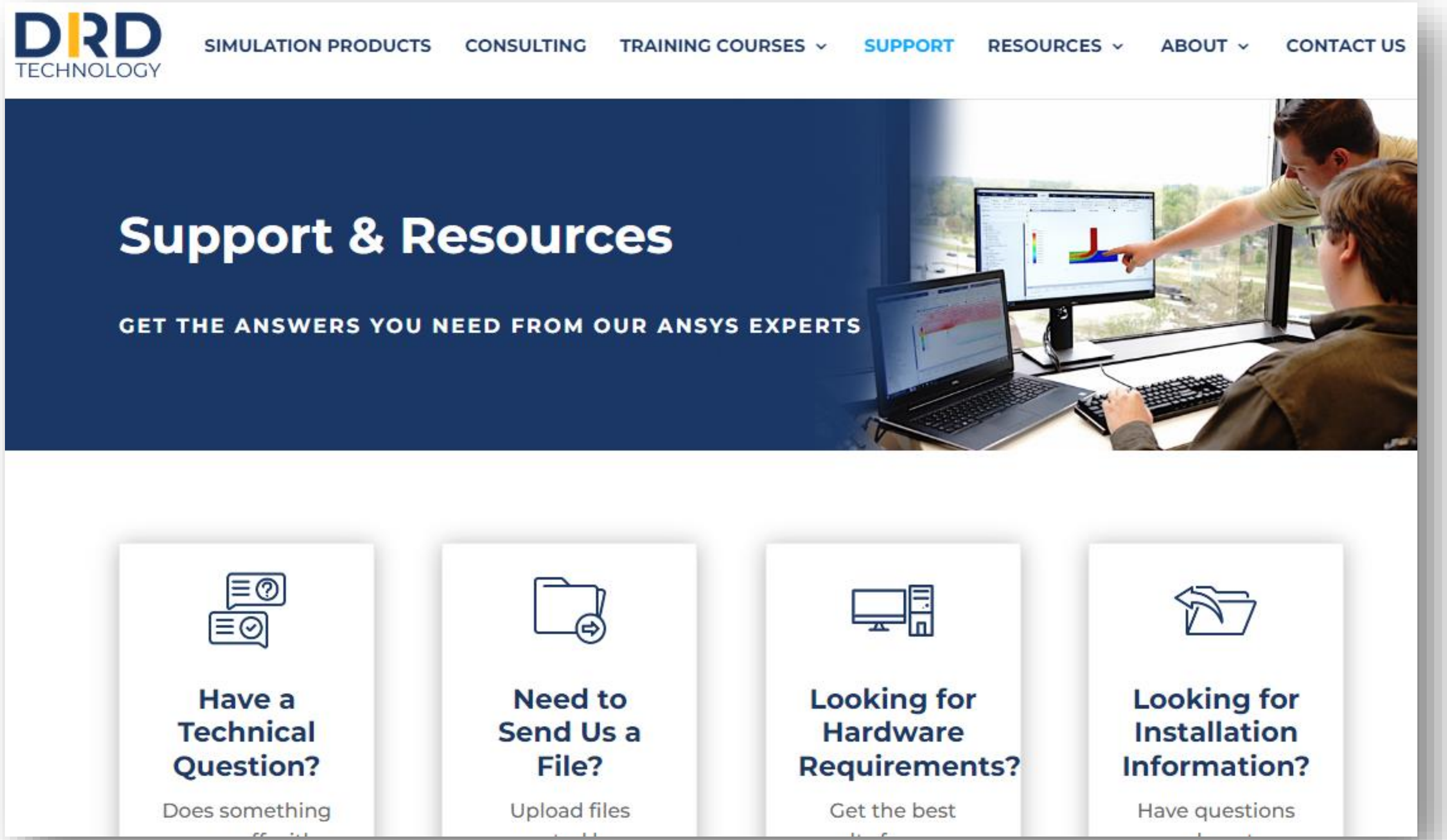
Ansys

CERTIFIED ELITE CHANNEL PARTNER

# Technical Support Contact Coordinates

**Support:**
**(918) 743-3013 x1**
**support@drd.com**

**Or through our website at**
**www.drd.com**



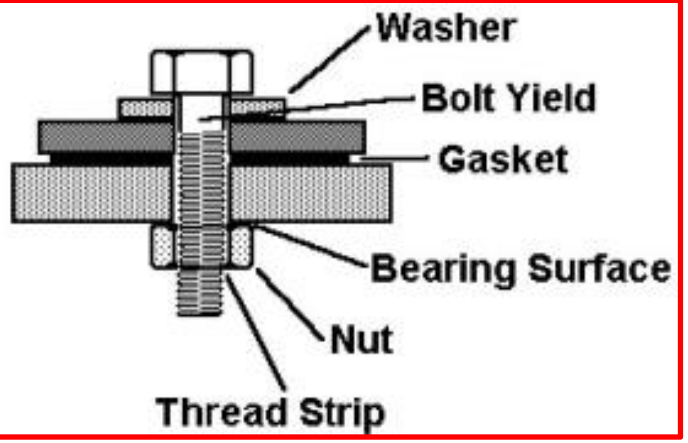

*I have had over 40 years of experience working with DRD Technology and have been very satisfied with them through the years.*

- *David Stribling, P.E.*

*Owner, Buffalo Hump Solutions*

# Overview of Torque on Threaded Fasteners

- **The process of tightening threaded fastener assemblies, especially for bolted joints, involves controlling both the input torque and angle of turn in order to achieve desired preload of the bolted assembly.**
- **Understanding the role of friction in both the underhead and threaded contact zones is an important factor in defining the relationship between torque, angle and tension.**




**Elastic Torque-Tension Relationship :**

$$T = K*D*F$$

T = Torque, lbf-inch
K = Nut Factor (0.03 ~ 0.35)
D = Nominal Diameter, inch
F = Clamping Force, lbf

Engineering Fundamentals of Threaded Fastener Design and Analysis
By Ralph S. Shoberg, P.E.,
Director of Technology, PCB Load & Torque, Inc.

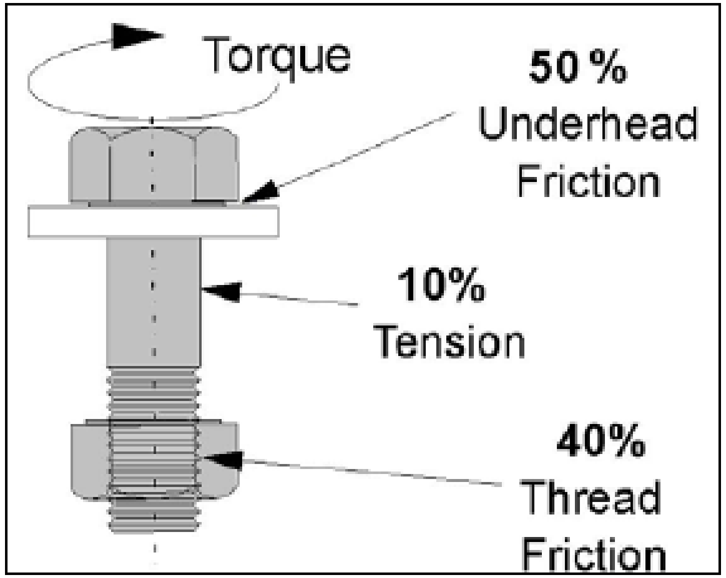
# Overview of Torque on Threaded Fasteners

- **The torque applied to a fastener is absorbed primarily in 3 main areas:**

1. **Underhead Friction**
2. **Thread Friction**
3. **Developing Clamping Force that holds components together.**

$$\text{Total Torque} = T_{\text{Underhead}} + T_{\text{Thread}} + T_{\text{Clamping}}$$

# Overview of Torque on Threaded Fasteners




PCB LOAD & TORQUE
A PCB GROUP COMPANY

Engineering Fundamentals of Threaded Fastener Design and Analysis

By Ralph S. Shoberg, P.E.,
Director of Technology, PCB Load & Torque, Inc.

$$\text{Total Torque} = T_{Underhead} + T_{Thread} + T_{Clamping}$$

# Overview of Torque on Threaded Fasteners

## Torque-Angle of Turn Relationship:

$T = K*D*F$

$\Delta T = K*D*\Delta F$

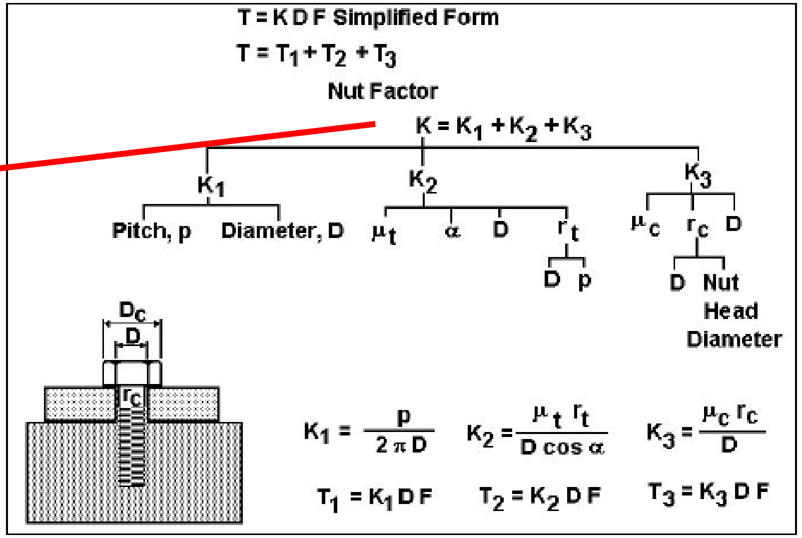
$\Delta F = k_{stiffness}*\Delta x$ ----- (Hooke's Law)

$k_{stiffness} = (k_b*k_m)/(k_b + k_m)$

$k_b$: bolt stiffness
$k_m$: Joint Member Stiffness

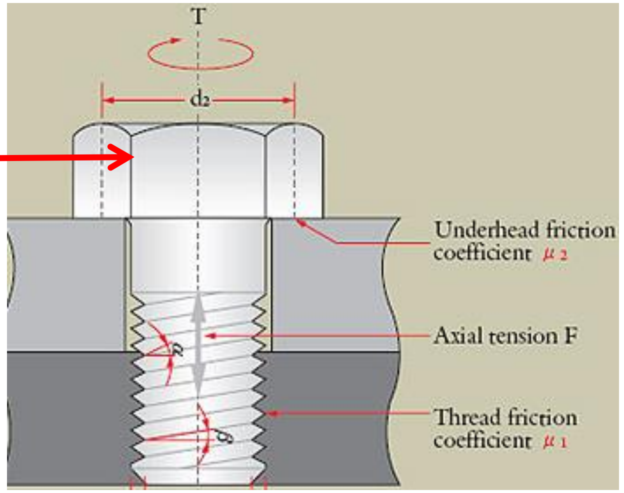
$\Delta T = K*D*k_{stiffness}* \Delta x$

$\Delta T = K*D*k_{stiffness}*(\Delta\theta/360)* P$




$k_b$

$k_m$





Engineering Fundamentals of Threaded Fastener Design and Analysis
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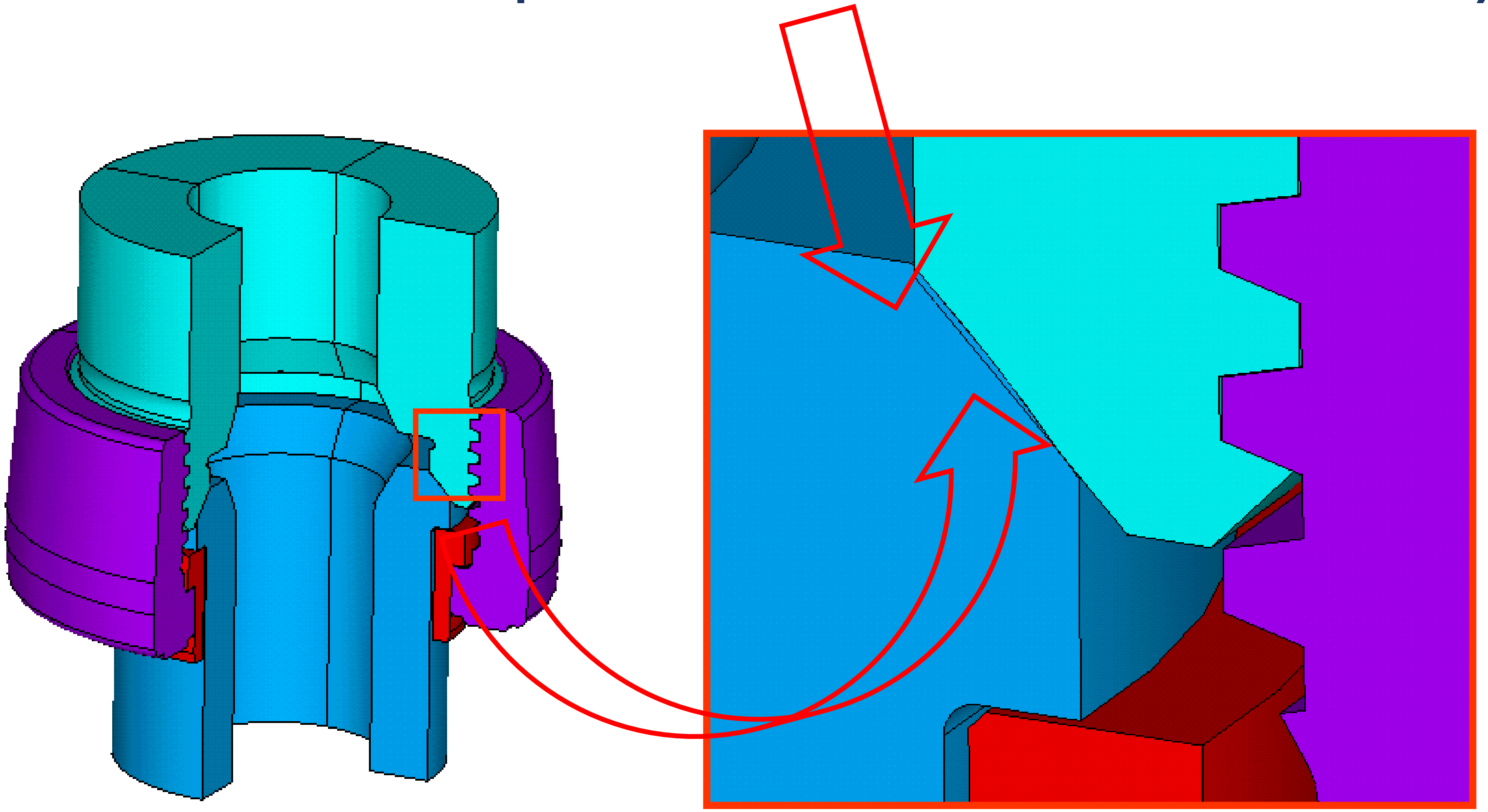
http://www.wtools.com.tw/Relation-Formula.shtml

# Creating Geometric Interference to Simulate Applied Torque on Threaded Fasteners

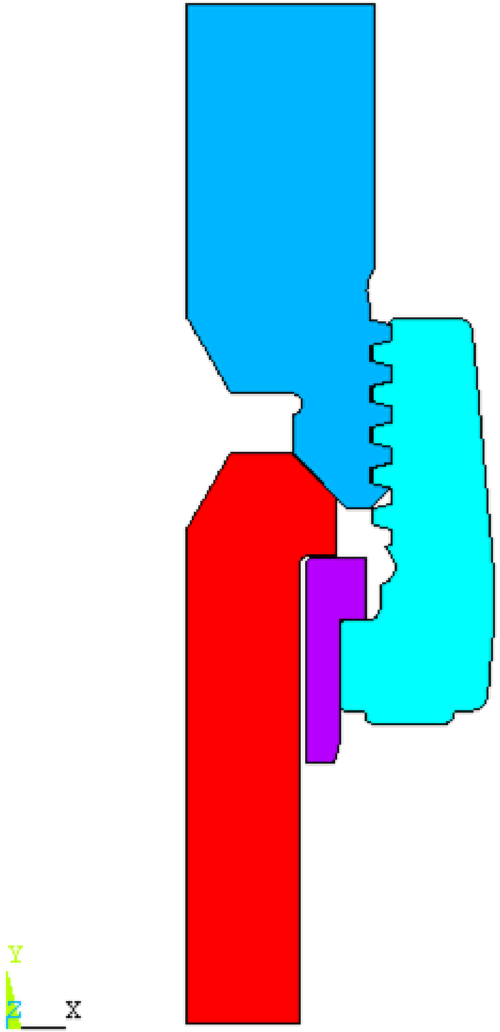
- **Torque applied on threaded parts introduce geometric overlap as shown below (due to axial movement coupled with rotational movement of threads).**



# Creating Geometric Interference to Simulate Applied Torque on Threaded Fasteners

- **Common assumption in FEA is to model the threaded flanks as axisymmetric (although in reality the threads are helical in nature).**

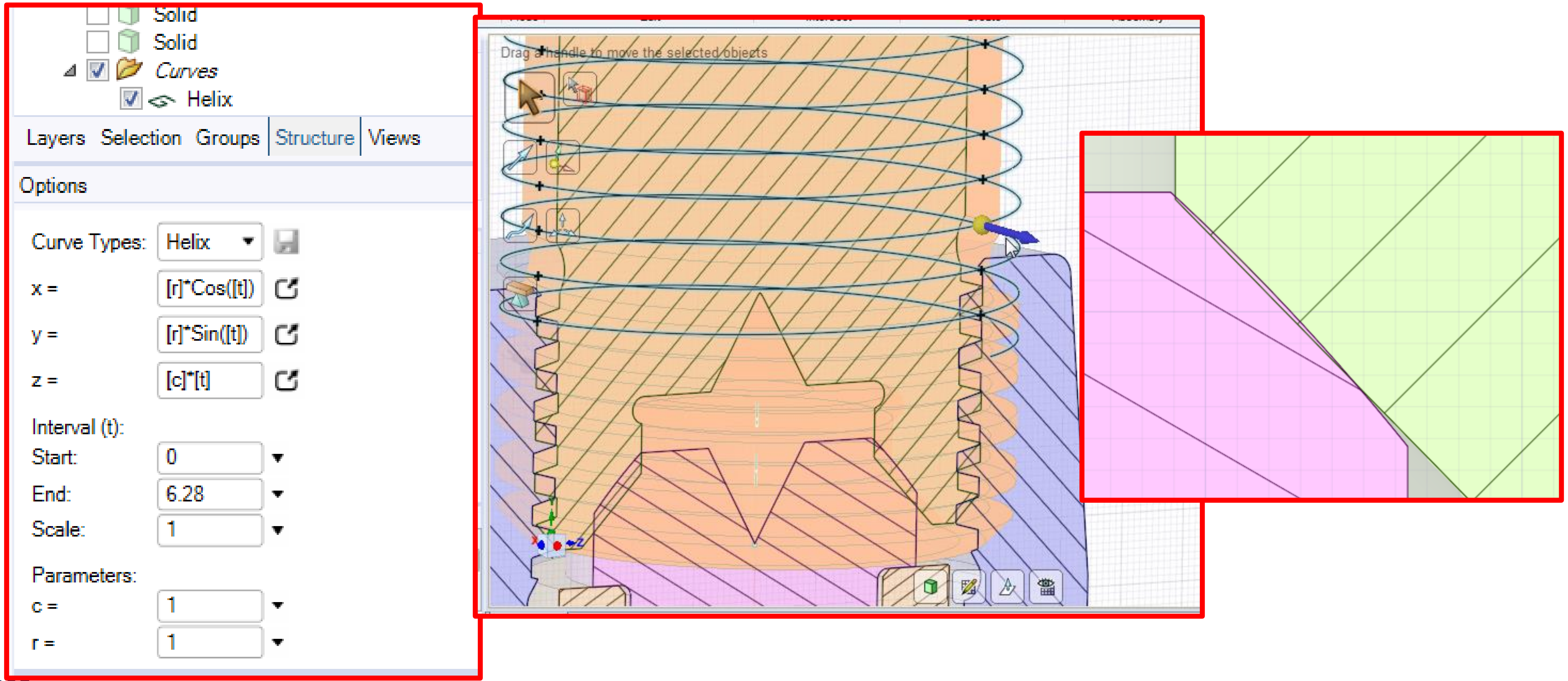
- **This allows us to perform a 2d axisymmetric analysis in ANSYS Workbench.**



# Creating Geometric Interference to Simulate Applied Torque on Threaded Fasteners

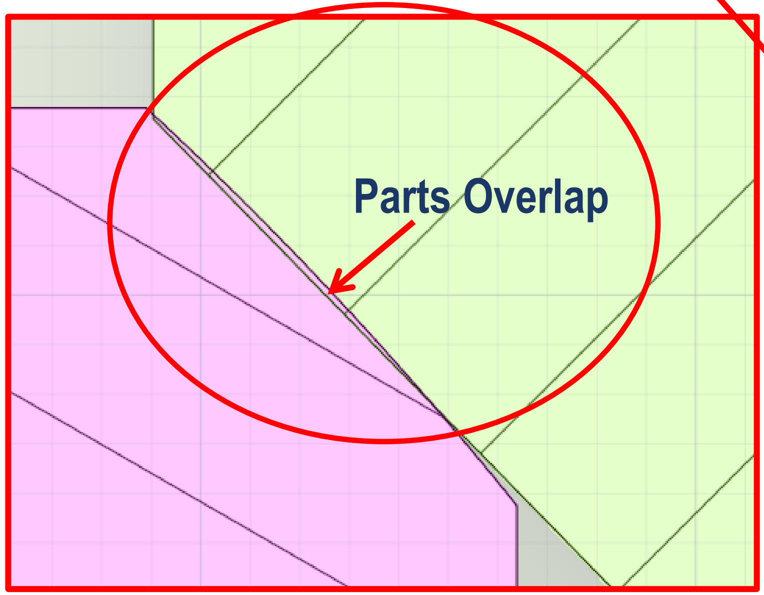
## Techniques to simulate geometric interference from applied torque :

**Method # 1 : Rotate the parts in ANSYS Discovery along a helical trajectory to simulate rotation and axial movement from torque as shown below. The geometry overlaps and then you take a section of this overlap to do 2d axisymmetric analysis.**



# Creating Geometric Interference to Simulate Applied Torque on Threaded Fasteners

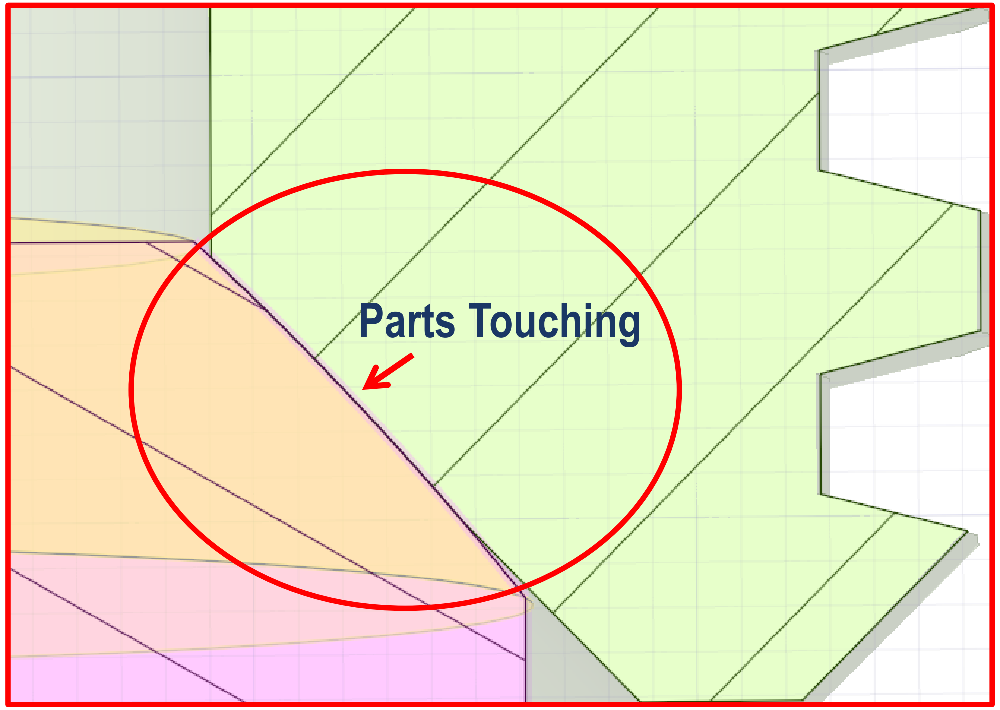
**The contact offset value is set to zero to allow for initial geometric overlap to account for the interference fit as shown.**




| | |
|---|---|
| Type | Frictionless |
| Scope Mode | Automatic |
| Behavior | Program Controlled |
| Trim Contact | Program Controlled |
| Trim Tolerance | 1.8647e-002 in |
| Suppressed | No |
| **Advanced** | |
| Formulation | Program Controlled |
| Detection Method | Program Controlled |
| Penetration Tolerance | Program Controlled |
| Normal Stiffness | Program Controlled |
| Update Stiffness | Program Controlled |
| Stabilization Damping Factor | 0. |
| Pinball Region | Program Controlled |
| Time Step Controls | None |
| **Geometric Modification** | |
| Interface Treatment | Add Offset, Ramped Effects |
| Offset | 0. in |

# Creating Geometric Interference to Simulate Applied Torque on Threaded Fasteners

**<u>Method # 2</u> : If unsure on the appropriate amount of rotation/axial movement from applied torque, another option is to bring the 2d axisymmetric geometry without any initial geometric overlap. You can induce overlap (axial movement of the threads) from applied torque through "<u>contact based interference</u>" as shown here.**




| | |
|---|---|
| **Definition** | |
| Type | Frictionless |
| Scope Mode | Automatic |
| Behavior | Program Controlled |
| Trim Contact | Program Controlled |
| Trim Tolerance | 1.8647e-002 in |
| Suppressed | No |
| **Advanced** | |
| Formulation | Program Controlled |
| Detection Method | Program Controlled |
| Penetration Tolerance | Program Controlled |
| Normal Stiffness | Program Controlled |
| Update Stiffness | Program Controlled |
| Stabilization Damping Factor | 0. |
| Pinball Region | Program Controlled |
| Time Step Controls | None |
| **Geometric Modification** | |
| Interface Treatment | Add Offset, Ramped Effects |
| Offset | 1.5e-003 in |
| Contact Geometry Correction | None |

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners

## ANSYS Methodology to Output Torque :

- **ANSYS can report maximum torque based on friction coefficient of unity. Results can be scaled with appropriate friction coefficient to get desired torque.**

### 3.19.4. Reviewing Contact Results in the `Jobname.cnd` File

You can issue NLDIAG,CONT to monitor contact pair-based results during the solution according to a specified writing frequency (each iteration, substep, or load step). The resulting output is stored in a text file named `Jobname.cnd`. The following is a subset of information contained in this file that may be of interest:

| | |
|---|---|
| CFNX | Total force due to contact pressure - X component |
| CFNY | Total force due to contact pressure - Y component |
| CFNZ [2] | Total force due to contact pressure - Z component |
| CFSX | Total force due to tangential stress - X component |
| CFSY | Total force due to tangential stress - Y component |
| CFSZ [2] | Total force due to tangential stress - Z component |
| CTRQ [1] | Maximum torque in an axisymmetric analysis with MU = 1.0 |

1. For the 2D axisymmetric case, the maximum torque M (CTRQ) is defined as:

   $$M=2\pi\int x^2 p ds$$

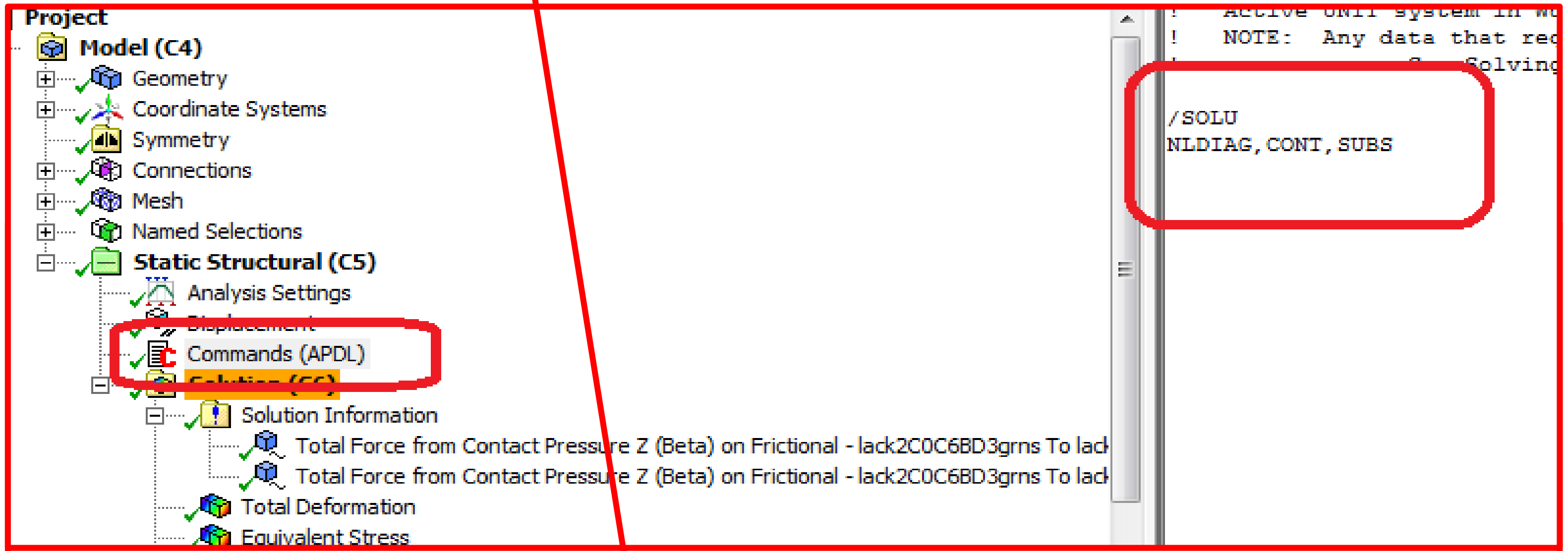
   where p is the contact pressure, x is the x coordinate of the contact point on the interface, and s is the length domain of the contact interface. This definition of torque is associated with a friction coefficient of unity. It can be evaluated by scaling the friction coefficient for a particular contact pair. The reported torque M is useful in modeling threaded connectors.

2. For the case of 2D axisymmetric with torsion (KEYOPT(3) = 4), CFNZ and CFSZ represent moments along the Y direction.

See the NLDIAG command for a complete list of contact results written to `Jobname.cnd`.

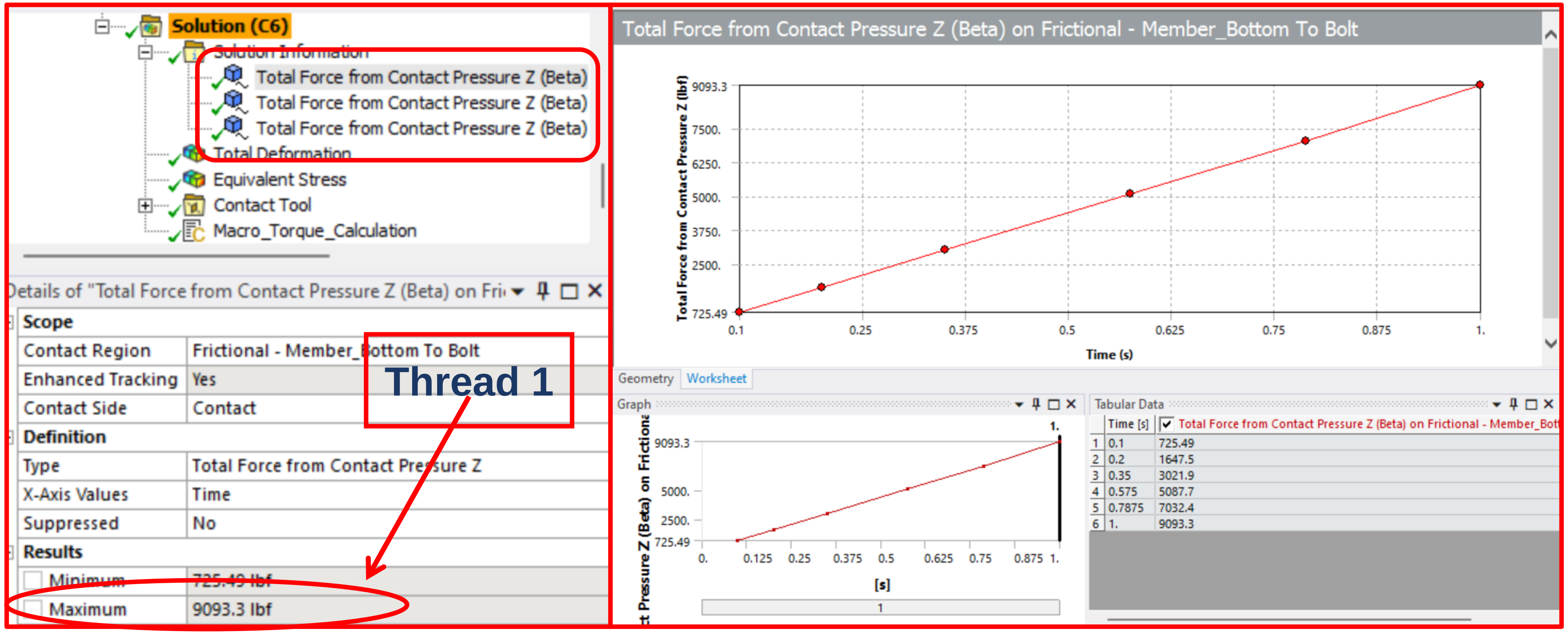
# Discussion of Techniques to Evaluate Torque on Threaded Fasteners

- **You can issue the command NLDIAG,CONT,SUBS to output results for Torque Distribution as shown. The multiple entries correspond to values for underhead friction and thread friction torques.**




| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 30 | -267.8227 | 93492.43 | 60789.85 | 0.000000 | 0.000000 | 0.000000 |
| 33 | -53931.76 | 82365.19 | 47591.20 | 18118.88 | 11127.24 | 0.000000 |
| 36 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 36 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 54 | 700.0146 | 93558.47 | 59860.32 | 6263.681 | -66.04270 | 0.000000 |

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners

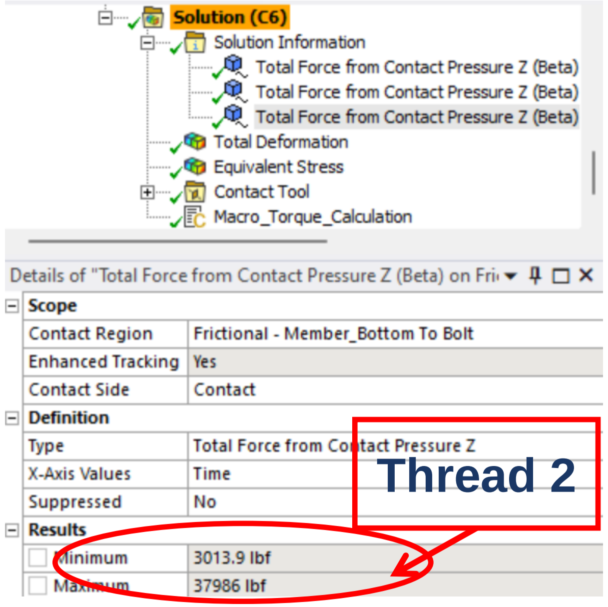


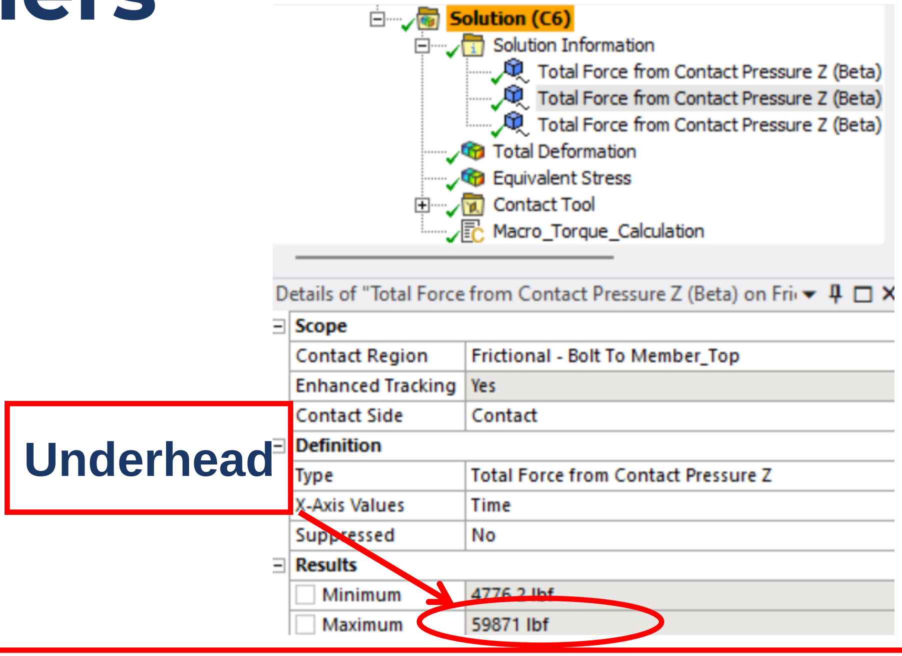

| | Time [s] | Total Force from Contact Pressure Z (Beta) on Frictional - Member_Bot |
|---|---|---|
| 1 | 0.1 | 725.49 |
| 2 | 0.2 | 1647.5 |
| 3 | 0.35 | 3021.9 |
| 4 | 0.575 | 5087.7 |
| 5 | 0.7875 | 7032.4 |
| 6 | 1. | 9093.3 |

- ANSYS Workbench contact pair ID[4]
- Total force due to contact pressure - X component
- Total force due to contact pressure - Y component
- Total force due to contact pressure - Z component[5]
- Total force due to tangential stress - X component

5. In a 3-D model, the reported item is total force along the Z-axis. In a 2-D axisymmetric model, the reported item is maximum torque that can potentially act on the Y-axis.

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners




**Total Torque = $(T_{Underhead} + T_{thread}) / 0.9$**

$T_{thread} = T_{thread1} + T_{thread2}$

$(\mu_{thread} = 0.3)$ $T_{thread1} = 9093.3*0.3 = 2727.99$, lbf-in

$T_{thread2} = 37986*0.3 = 11395.8$, lbf-in

$T_{thread} = 2727.99 + 11395.8 = 14123.79$, lbf-in

$(\mu_{underhead} = 0.5)$ $T_{underhead} = 59{,}871*0.5 = 29935.5$, lbf-in

**Total Torque = (2727.99 + 11395.8 + 29935.5)/0.9 = <u>48954.76</u>, lbf-in**

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners

**Methods of Validation of ANSYS Results for Total Torque :**

**Method # 1 : Hand Calculation (Traditional method using Spreadsheet)**

**One method for hand calculation is to simply use the same equation for Maximum Torque evaluation used by ANSYS as shown below which is a good basis for validation study.**

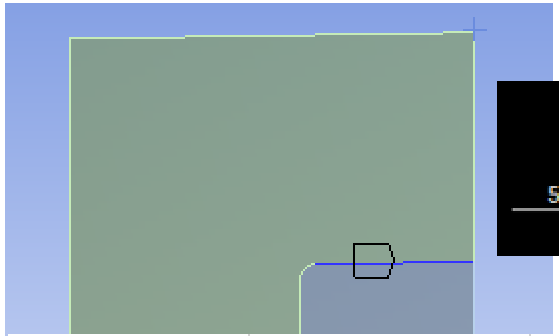
The maximum torque M (CTRQ) is defined as:

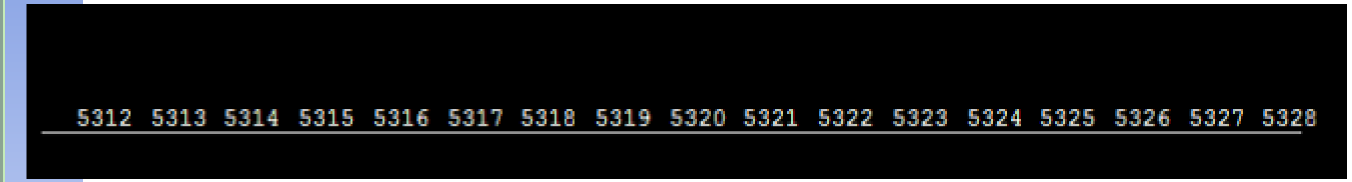
$$M = 2\pi \int x^2 p ds$$

where p is the contact pressure, x is the x coordinate of the contact point on the interface, and s is the length domain of the contact interface.

**Note : The contact pressure is multiplied with area of the contact elements to get normal force on each contact element. The normal force on each contact element is multiplied with friction coefficient to get the shear force on each contact element. The shear force from each contact element is multiplied with the distance of contact element (centroid) from axis to get torque on that contact element. The torques from all contact elements are summed to get overall torque. The torques are evaluated separately for underhead friction and thread friction and then summed up. Generally, the torques from underhead and thread friction accounts for about 90% of overall torque. Therefore, knowing the torque from underhead and thread friction allows us to evaluate the actual torque.**

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners



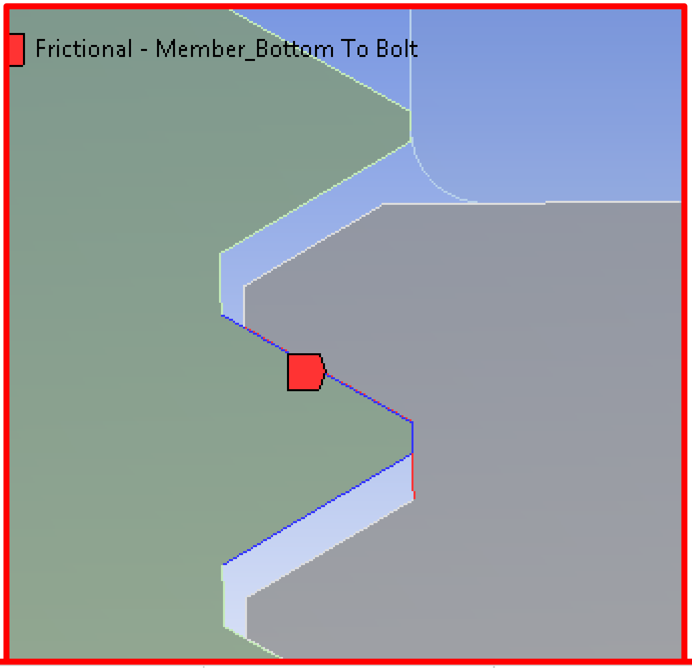


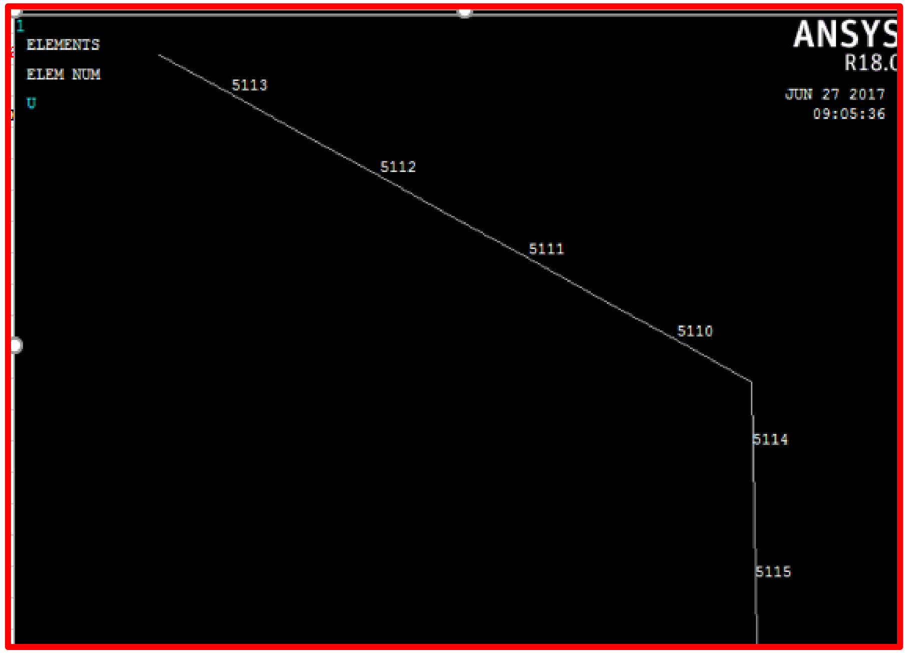

| Contact Pressure | Area of Contact Elements | Normal Force Contact Elemenets | Frictional Force on Contact Elements | Distance from Axis | Element Length | Torque |
|---|---|---|---|---|---|---|
| 3.04E+05 | 0.06885592 | 2.09E+04 | 1.05E+04 | 0.54 | 0.020294 | 5.65E+03 |
| 1.56E+05 | 0.071466373 | 1.11E+04 | 5.57E+03 | 0.5605 | 0.020293 | 3.12E+03 |
| 1.04E+05 | 0.074080219 | 7.73E+03 | 3.86E+03 | 0.581 | 0.020293 | 2.24E+03 |
| 85085 | 0.076630312 | 6.52E+03 | 3.26E+03 | 0.601 | 0.020293 | 1.96E+03 |
| 72750 | 0.079180406 | 5.76E+03 | 2.88E+03 | 0.621 | 0.020293 | 1.79E+03 |
| 64108 | 0.0817305 | 5.24E+03 | 2.62E+03 | 0.641 | 0.020293 | 1.68E+03 |
| 57240 | 0.084408098 | 4.83E+03 | 2.42E+03 | 0.662 | 0.020293 | 1.60E+03 |
| 51496 | 0.086958191 | 4.48E+03 | 2.24E+03 | 0.682 | 0.020293 | 1.53E+03 |
| 46480 | 0.089508285 | 4.16E+03 | 2.08E+03 | 0.702 | 0.020293 | 1.46E+03 |
| 41974 | 0.092185883 | 3.87E+03 | 1.93E+03 | 0.723 | 0.020293 | 1.40E+03 |
| 37834 | 0.094735977 | 3.58E+03 | 1.79E+03 | 0.743 | 0.020293 | 1.33E+03 |
| 33961 | 0.097413575 | 3.31E+03 | 1.65E+03 | 0.764 | 0.020293 | 1.26E+03 |
| 30278 | 0.099963669 | 3.03E+03 | 1.51E+03 | 0.784 | 0.020293 | 1.19E+03 |
| 26719 | 0.102513762 | 2.74E+03 | 1.37E+03 | 0.804 | 0.020293 | 1.10E+03 |
| 23219 | 0.105063856 | 2.44E+03 | 1.22E+03 | 0.824 | 0.020293 | 1.01E+03 |
| 19707 | 0.107741454 | 2.12E+03 | 1.06E+03 | 0.845 | 0.020293 | 8.97E+02 |
| 16104 | 0.110291548 | 1.78E+03 | 8.88E+02 | 0.865 | 0.020293 | 7.68E+02 |
| | | | | | Total Torque | 3.00E+04 |

**Underhead**

**Close match with ANSYS Results of underhead torque 29,936 lbf-in!**

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners




| Contact Pressure | Area of Contact Elements | Normal Force Contact Elemenets | Frictional Force on Contact Elements | Distance from Axis | Element Length | Torque |
|---|---|---|---|---|---|---|
| 1.03E+05 | 0.053982376 | 5.58E+03 | 1.67E+03 | 0.441 | 0.019482 | 7.38E+02 |
| 1.00E+05 | 0.05599925 | 5.61E+03 | 1.68E+03 | 0.4575 | 0.019481 | 7.70E+02 |
| 7.97E+04 | 0.058115873 | 4.63E+03 | 1.39E+03 | 0.4745 | 0.019493 | 6.60E+02 |
| 46789 | 0.060179472 | 2.82E+03 | 8.45E+02 | 0.4915 | 0.019487 | 4.15E+02 |
| | | | | | Total Torque | 2.58E+03 |

**Close match with ANSYS Results of Thread 1 torque 2728, lbf-in!**

**Thread 1**

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners

**Another method to calculate the <u>total torque</u> is to simply use the Torque-Angle of turn relationship to calculate it.**

**K : Nut factor (includes contribution from geometric factor, thread friction factor and underhead friction factor)**

**K = 0.7574**

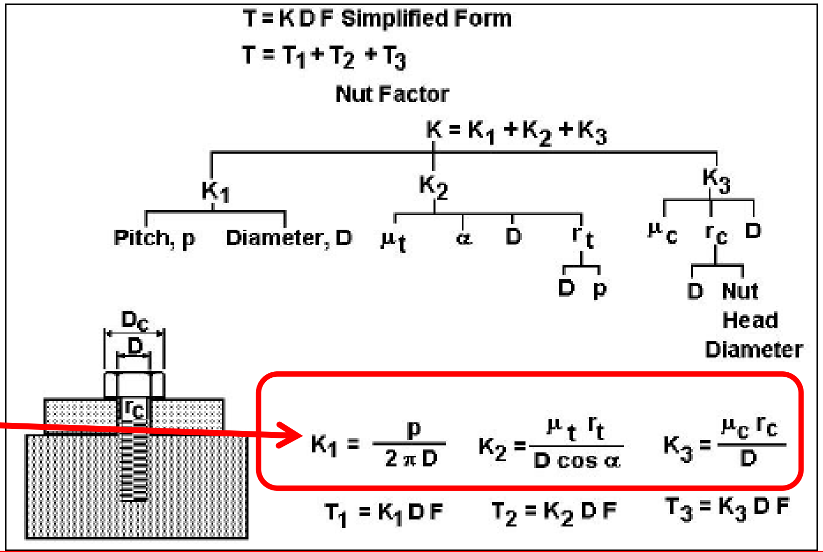
**$\Delta x$ = 0.0125 inches contact offset as shown.**

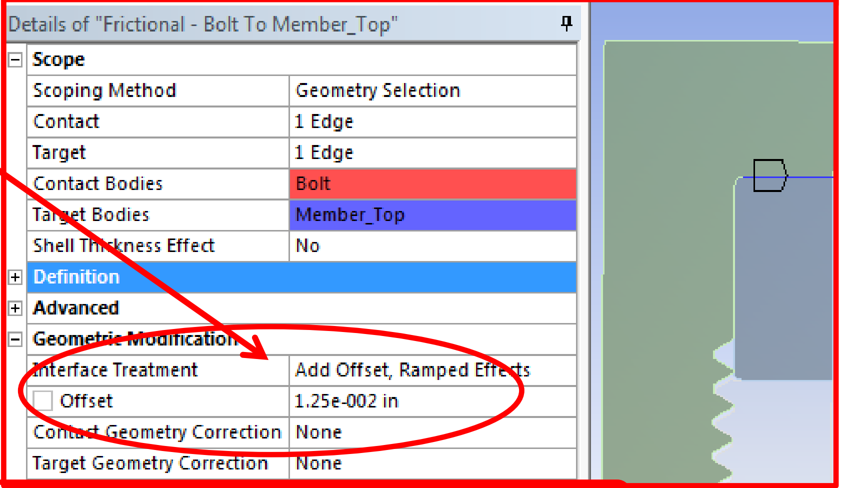
**$k_{stiffness} = (k_b * k_m)/(k_b + k_m)$ = 5.558E06, lbf/in**

**$k_b$: bolt stiffness**
**$k_m$: Joint Member Stiffness**

**D : Nominal diameter of bolt; D = 1 inch**

**$\Delta T = K * D * k_{stiffness} * \Delta x$ = 52628, lbf-in**




**Close match with ANSYS Results of total torque estimate of 48955, lbf-in!**

# Discussion of Techniques to Evaluate Torque on Threaded Fasteners

**Method # 2 : Programming with MAPDL Macro (Automated way!)**

Contact Tool
Macro_Torque_Calculation

**Close match with ANSYS Results of total torque 48954.76 lbf-in!**

| Results | |
|---|---|
| my_total_torque_underhead | 30021 |
| my_total_torque_thread | 11393 |
| my_Total_Torque_Thread_01 | 2715.7 |
| my_Total_Torque | 49033 |

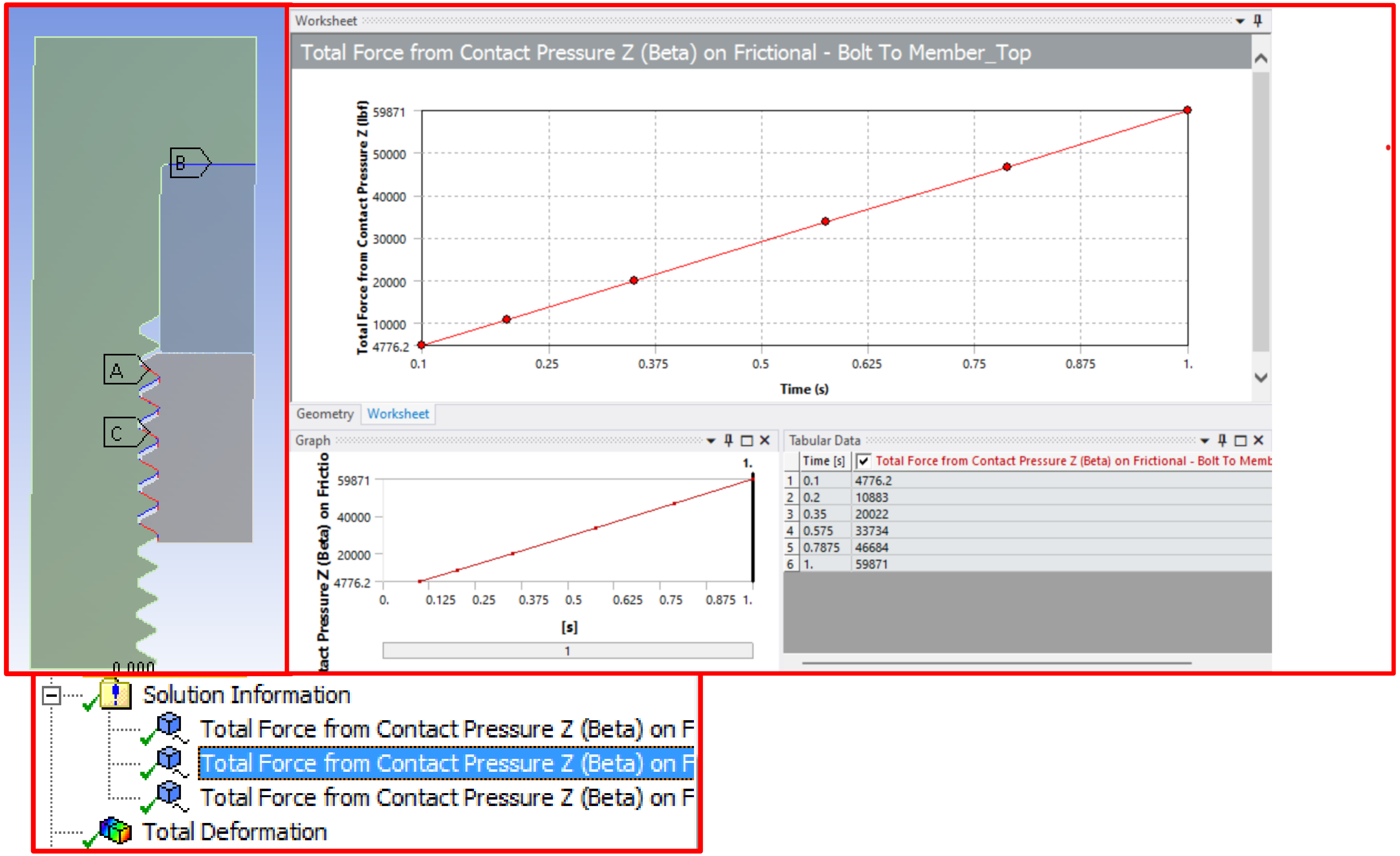
## Torque Calculation on Threads

```
/POST1

SET,LAST

! Torque calculation to overcome thread friction

Friction_Coeff_Thread = 0.3

ESEL,S,TYPE,,cont_id_thread_01
ETABLE,CN_P_T01,CONT,PRES
ETABLE,CN_A_T01,VOLU,
ETABLE,Rad_T01,CENT,X
SMULT,F_T01,CN_P_T01,CN_A_T01,1,1,
SMULT,Torque_T01,F_T01,Rad_T01,Friction_Coeff_Thread,1,
SSUM,
*get,my_Total_Torque_Thread_01,ssum,,item,Torque_T01

ALLSEL,ALL

Friction_Coeff_Thread = 0.3

ESEL,S,TYPE,,cont_id_thread
ETABLE,CN_P_Thread,CONT,PRES
ETABLE,CN_A_Thread,VOLU,
ETABLE,Rad_Thread,CENT,X
SMULT,F_Thread,CN_P_Thread,CN_A_Thread,1,1,
SMULT,Torque_Thread,F_Thread,Rad_Thread,Friction_Coeff_Thread,1,
SSUM,
*get,my_Total_Torque_Thread,ssum,,item,Torque_Thread

ALLSEL,ALL
```

## Torque Calculation on Underhead

```
! Torque calculation to overcome underhead friction

Friction_Coeff_Underhead = 0.5

ESEL,S,TYPE,,cont_id_underhead
ETABLE,CN_P_Underhead,CONT,PRES
ETABLE,CN_A_Underhead,VOLU,
ETABLE,Rad_Underhead,CENT,X
SMULT,F_Underhead,CN_P_Underhead,CN_A_Underhead,1,1,
SMULT,Torque_Underhead,F_Underhead,Rad_Underhead,Friction_Coeff_Underhead,1,
SSUM,
*get,my_Total_Torque_Underhead,ssum,,item,Torque_Underhead

ALLSEL,ALL

PRETAB,CN_P_T01,CN_P_Thread,CN_P_Underhead

my_Total_Torque = (my_Total_Torque_Underhead + my_Total_Torque_Thread + my_Total_Torque_Thread_01)/0.9
```

# Demo : Techniques to Evaluate Torque in ANSYS Workbench for Threaded Parts



# Summary

- Several techniques presented here including traditional methods such as hand calculations, as well as using Ansys gives us a way to validate torque on threaded fasteners.

- The FEA techniques using Ansys presented 2 options : One including the solution result tracker, as well as the second method using MAPDL macro; both yields accurate torque results over the traditional methods such as hand calcs which gives us a ballpark estimate.

- Provides a mode of calibrating torque if angle of turn is unknown to achieve desired/set amount of torque.

- Gives an opportunity to set up FEA for threaded fasteners including determining stresses and strains at threaded joints.

# Conclusion

**Thank you for your time!**

**Questions?**