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Rotationally Molding Inserts
Analytical and Actual Performance

ASSOCIATION OF ROTATIONAL MOLDERS

2016 Annual Meeting of the Association of Rotational Molders &

40th Anniversary Celebration
New Orleans, LA
September 24-27, 2016

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in cooperation with Steve Harris of Rotaloc® Int'l, LLC

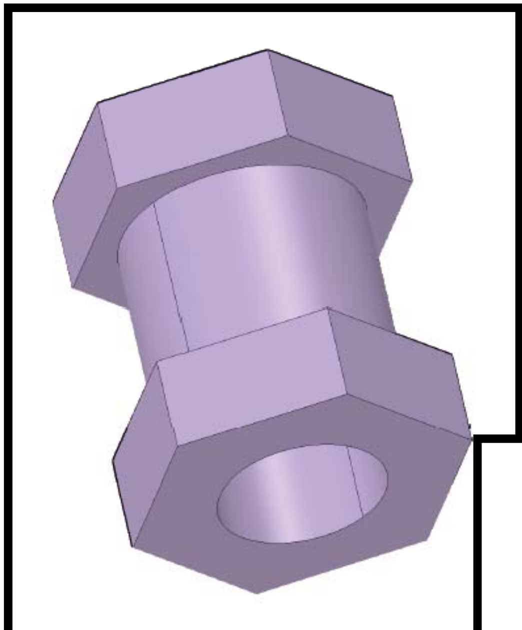
Rotaloc

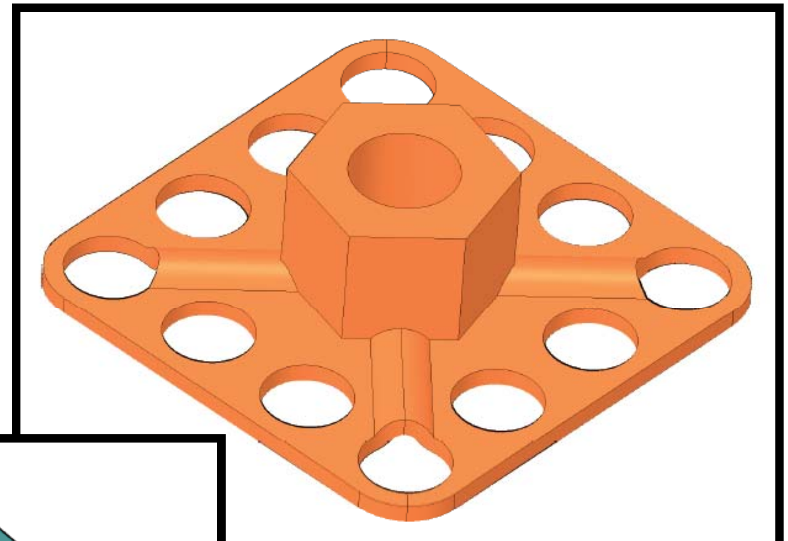
Project Objectives

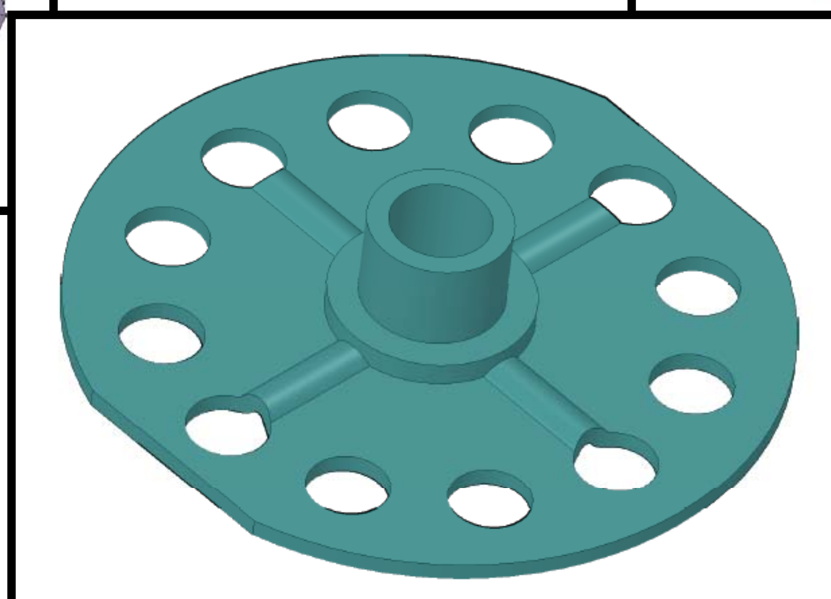
- Using Finite Element Analysis (FEA) simulations, show the load bearing performance of various inserts with different design features.
- Compare actual molded fitting performance in both pull-out and torque responses.
- Compare how material flow and tensile properties effect fitting performance in both pull-out and torque responses.

Molded-in Insert Simulation
Pull-Out Tensile

Marlex® HMN TR-938 Polyethylene
Rotational Molding

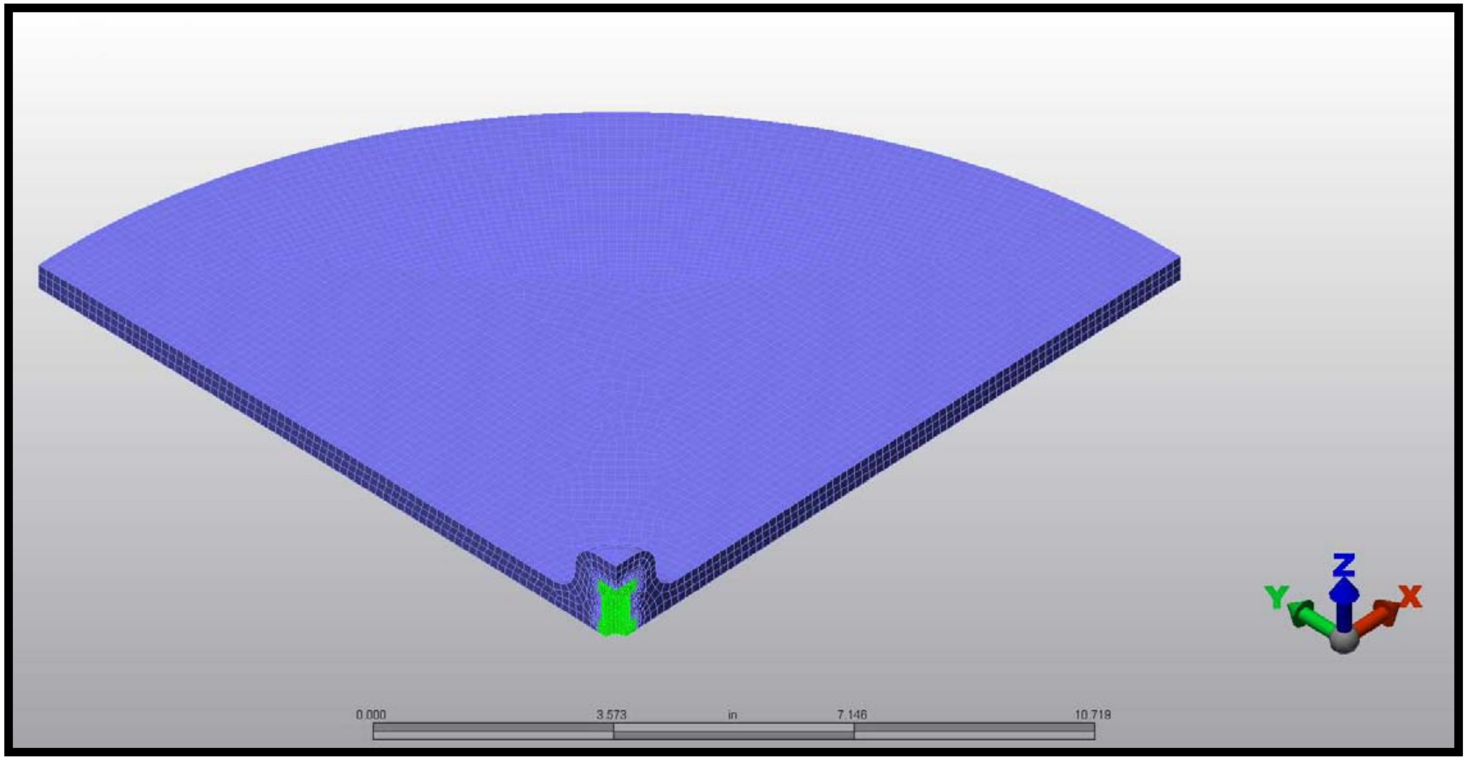






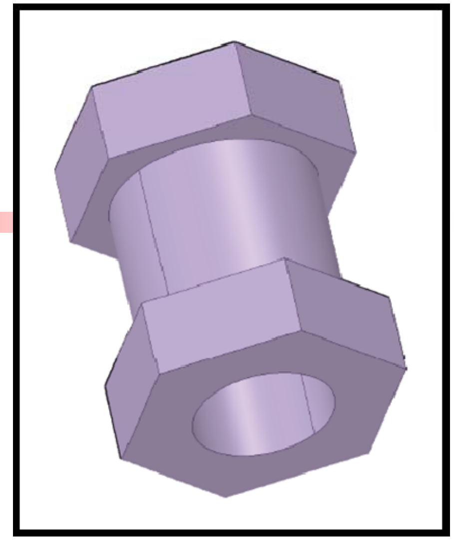
Rotaloc® Bonding Fasteners

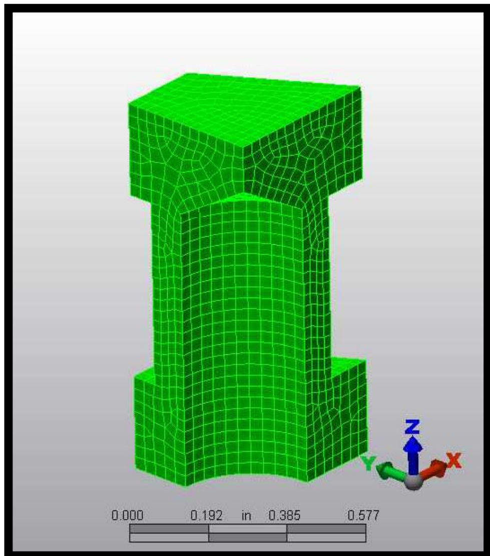
Analysis Description

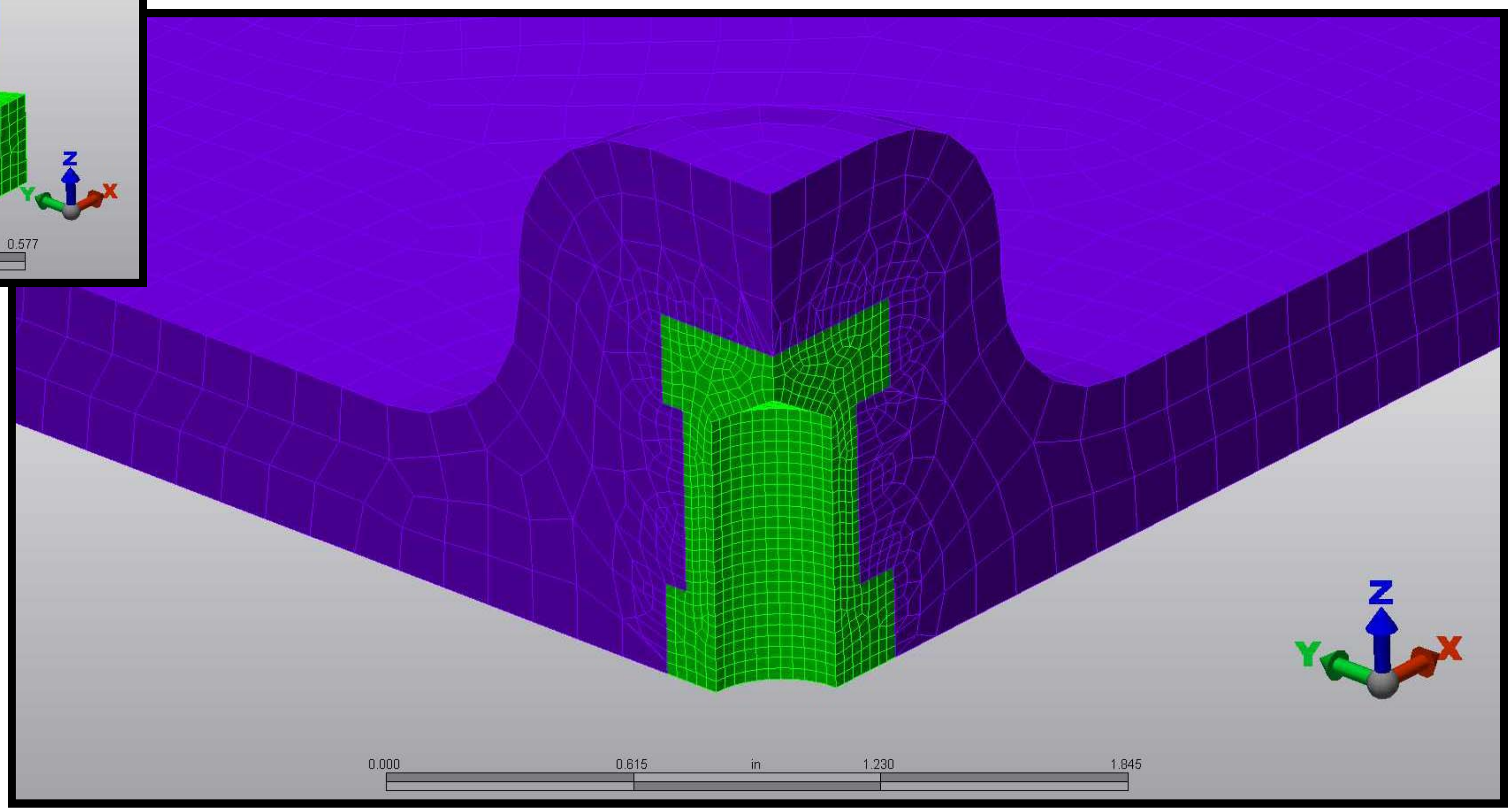


- **Plastic Part:** Round disk, 24 in. diameter, 0.45 in. thickness, molded-in insert at center
- **Material:** Marlex® HMN TR-938 medium density polyethylene
- **Assumed Symmetry:** Quarter symmetry on y-z plane and x-z plane
- **Constraints:** Part fixed in the vertical (z) direction on the bottom outer edge of the disk and the inner edge of the opening of the insert
- **Pressure Applied:** 2 psi on the entire bottom of the disk

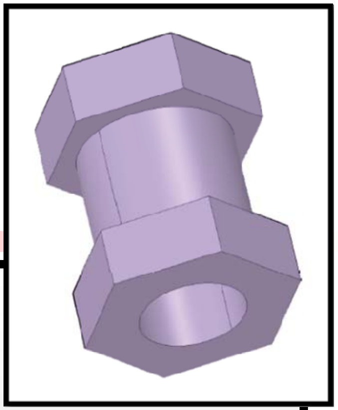
1 Inch X ¾ Inch Hex Insert

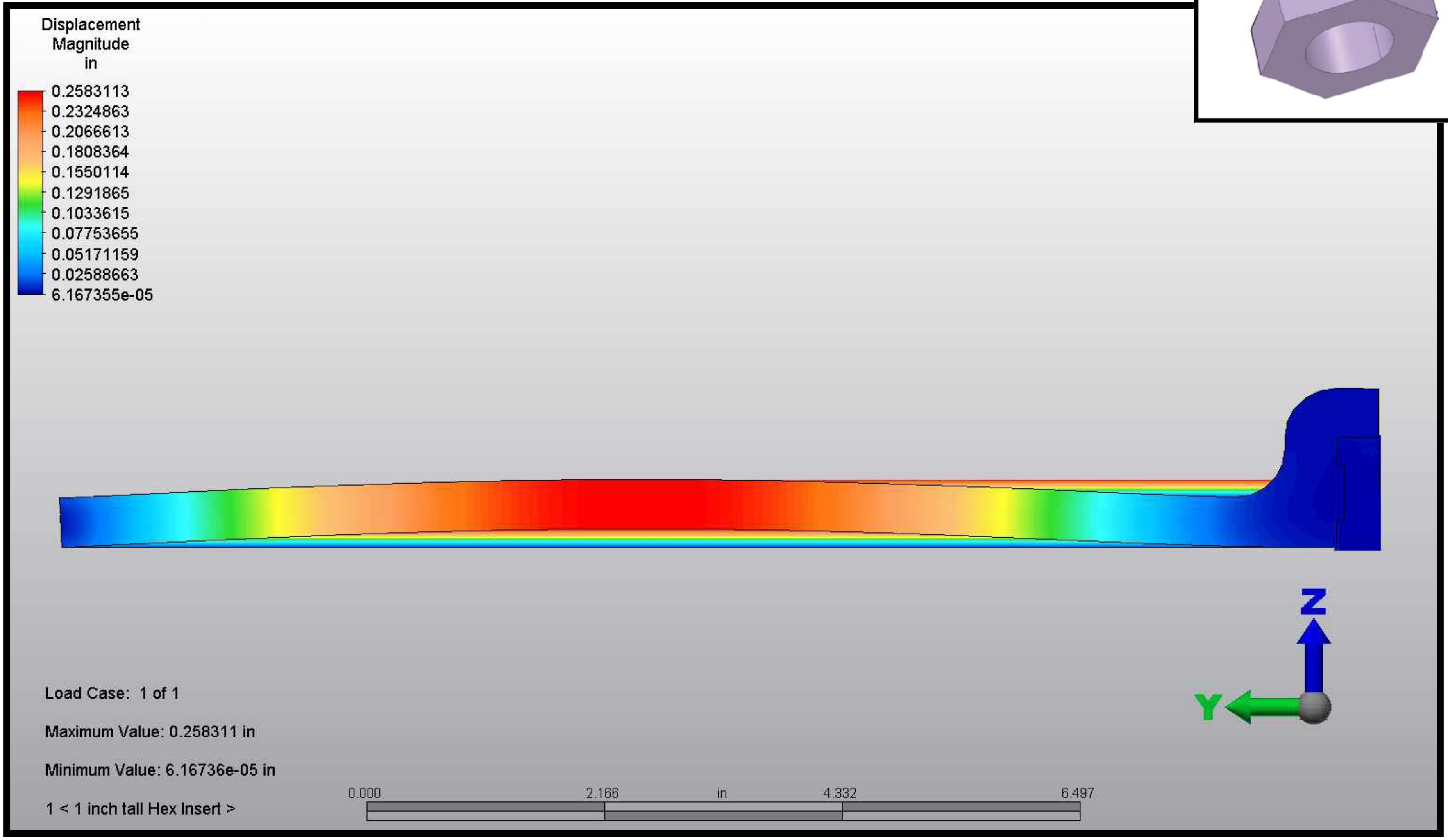






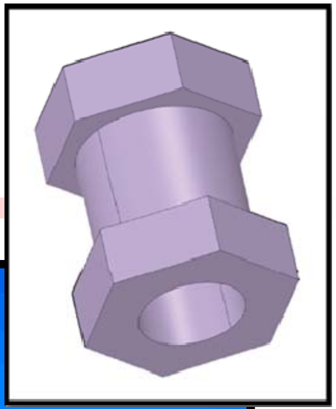
1 Inch X ¾ Inch Hex Insert
Magnitude of Displacement

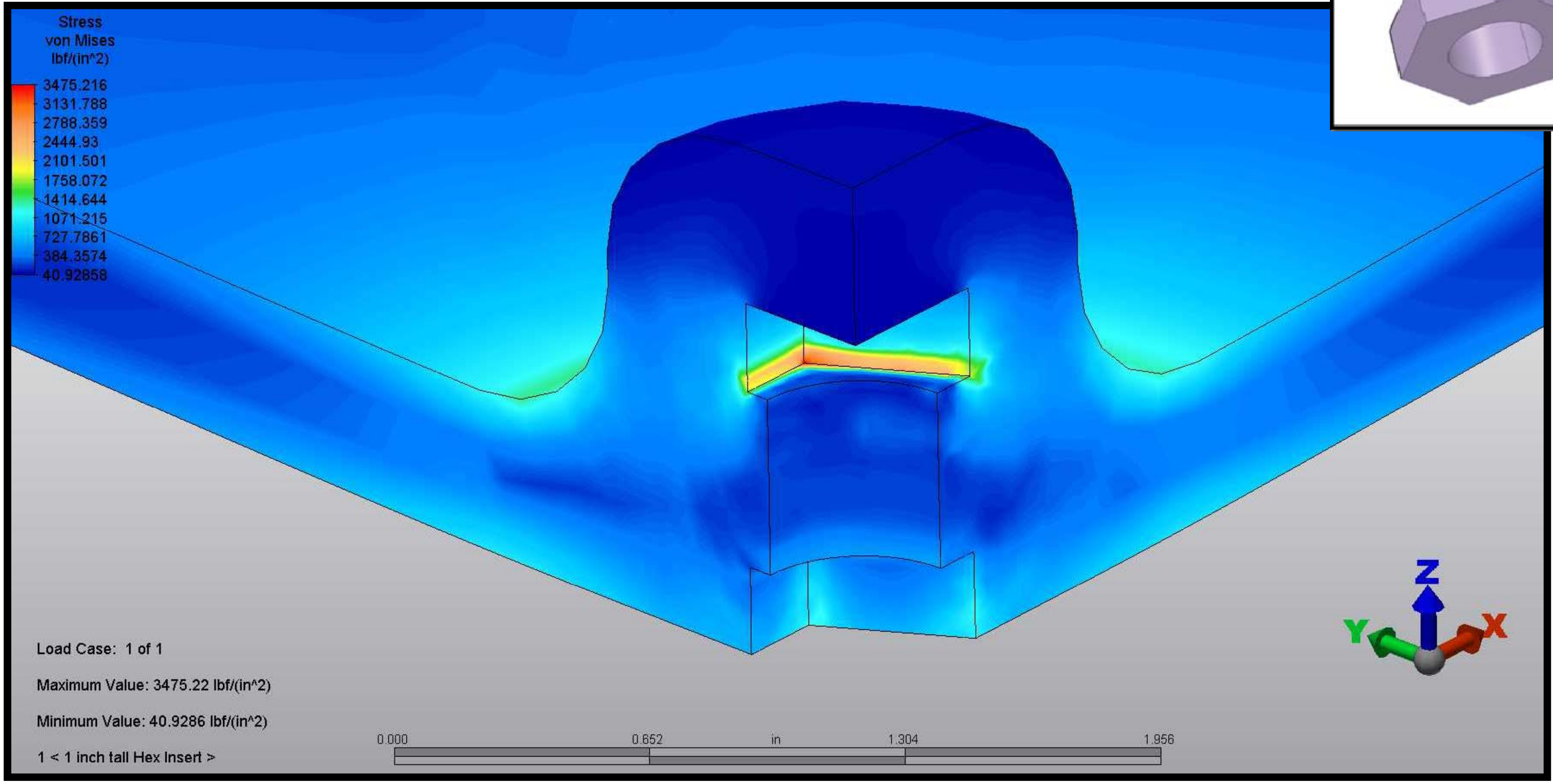




Disk deflects up to 0.25 inch circumferentially between the outer edge and center of the part.

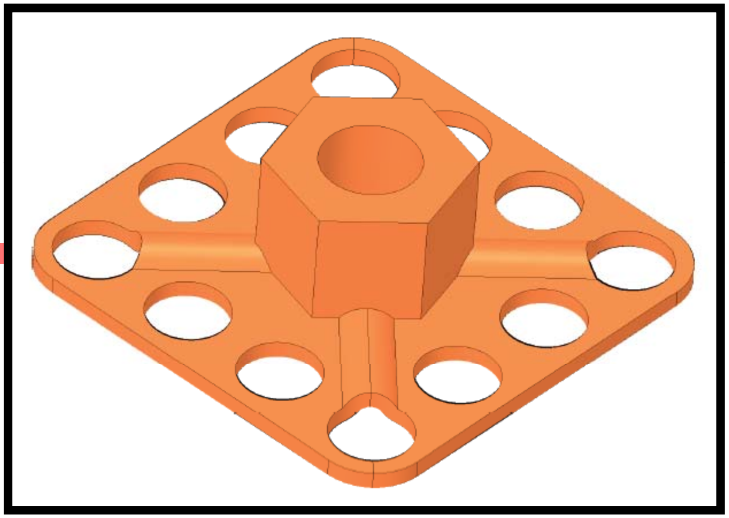
1 Inch X ¾ Inch Hex Insert Stress Analysis Results

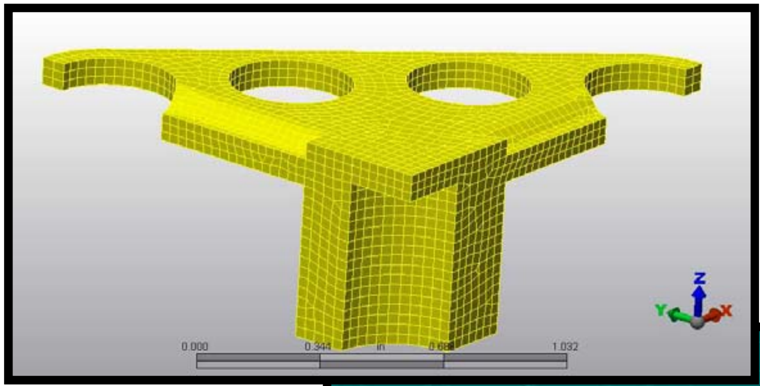


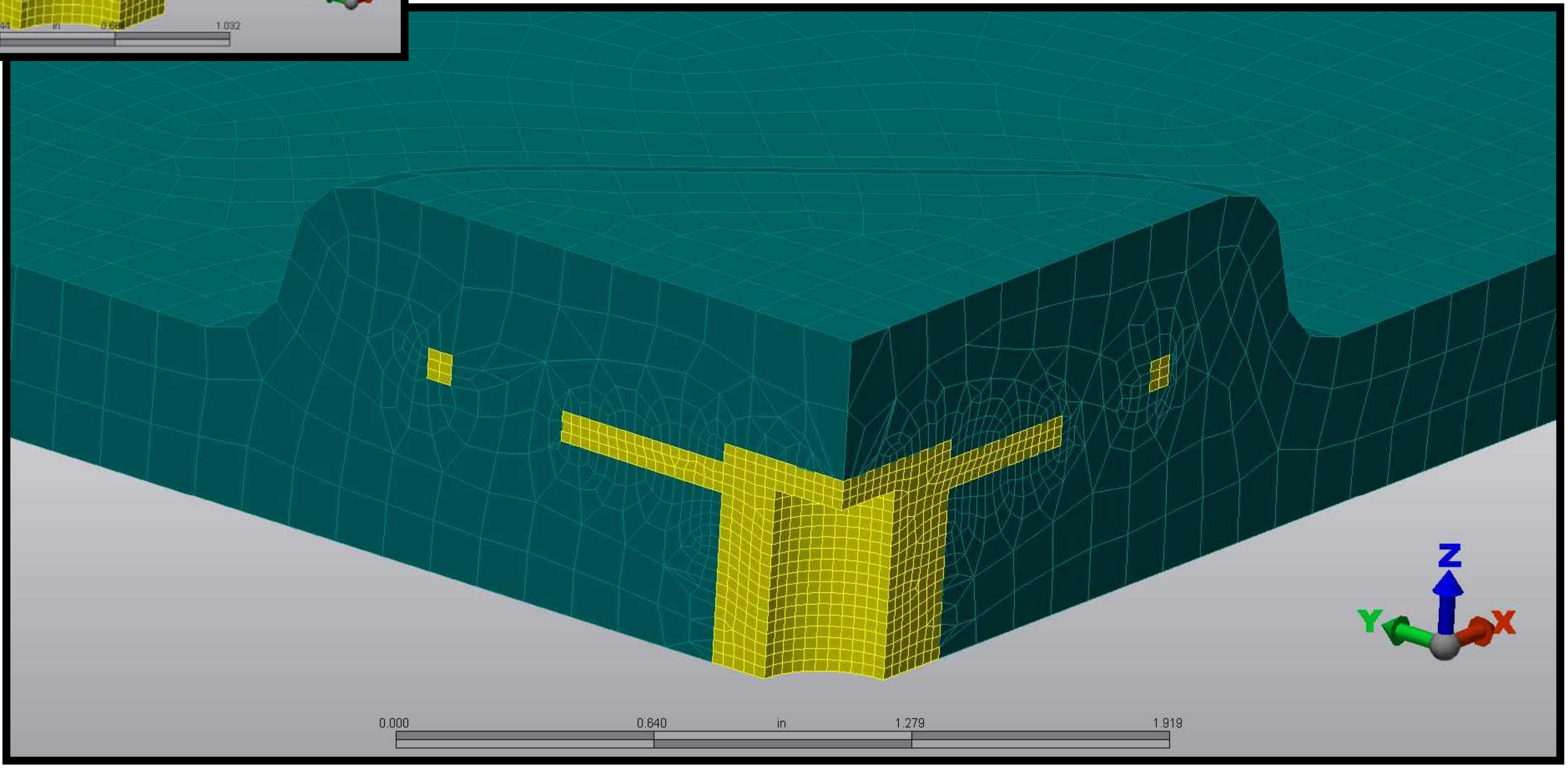


- The highest stresses are concentrated at the edge of the hex feature
- The stress level (3475 psi) is higher than the strength of the resin (2500 psi) (The metal insert is not shown.)

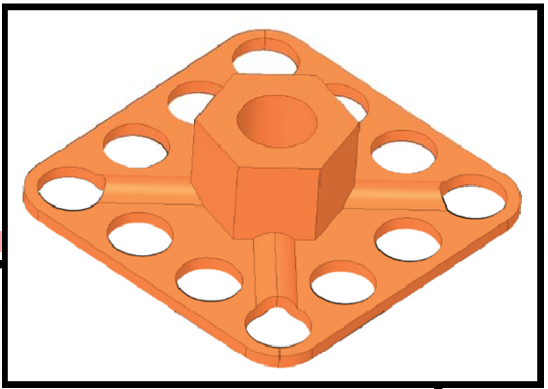
2 Inch Square Insert

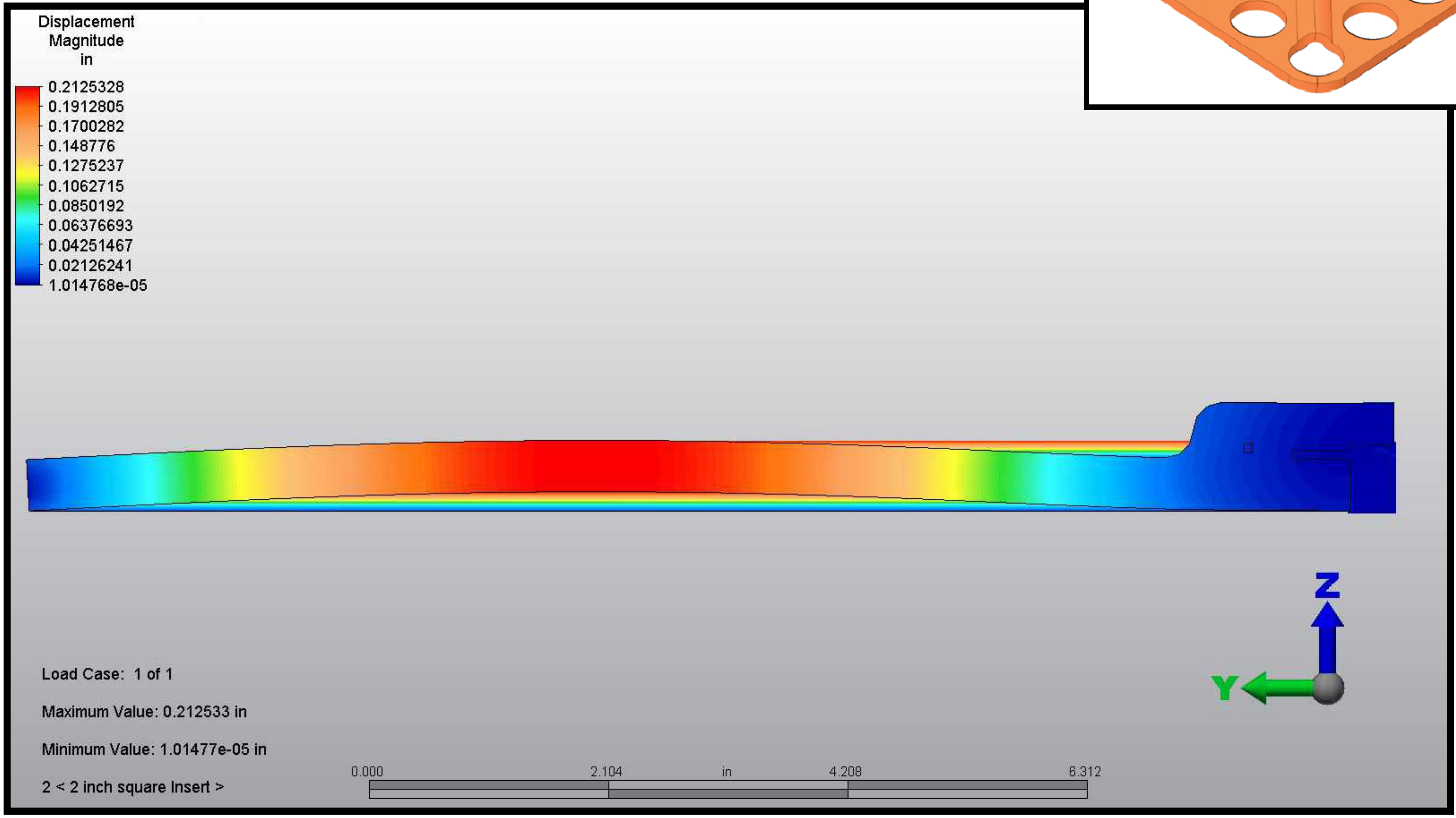






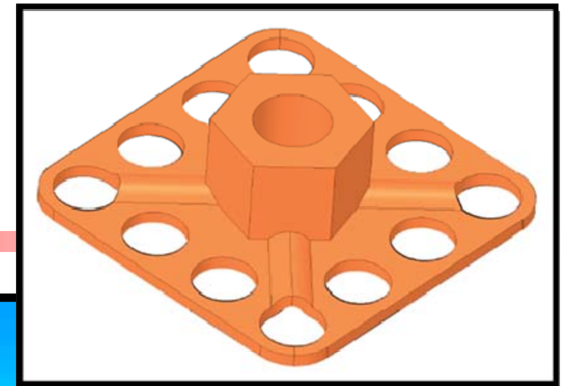
2 Inch Square Insert
Magnitude of Displacement

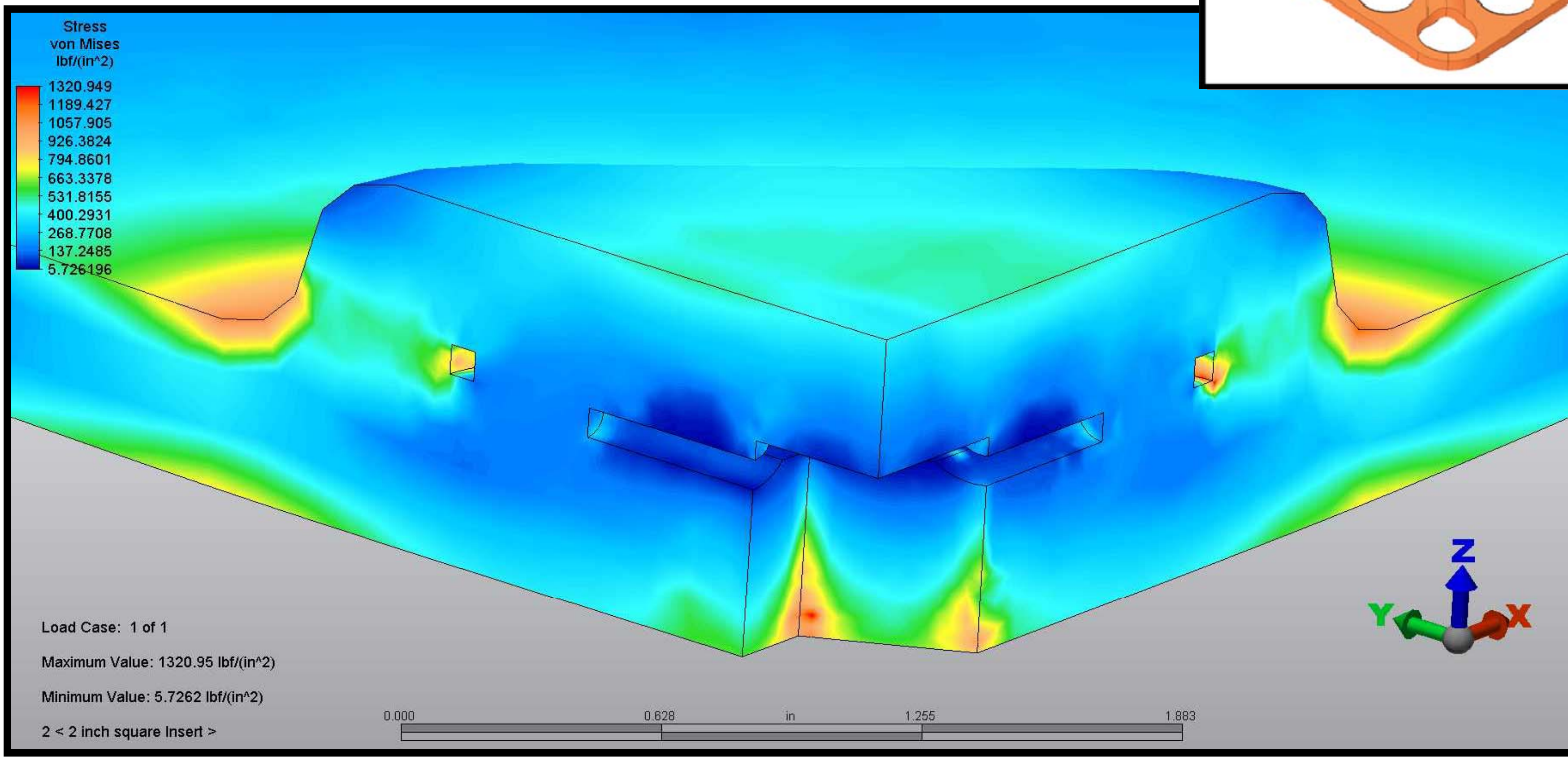




- **Disk deflects up to 0.21 inches circumferentially**
- **Displacement is slightly less than previous designs due to wider profile**

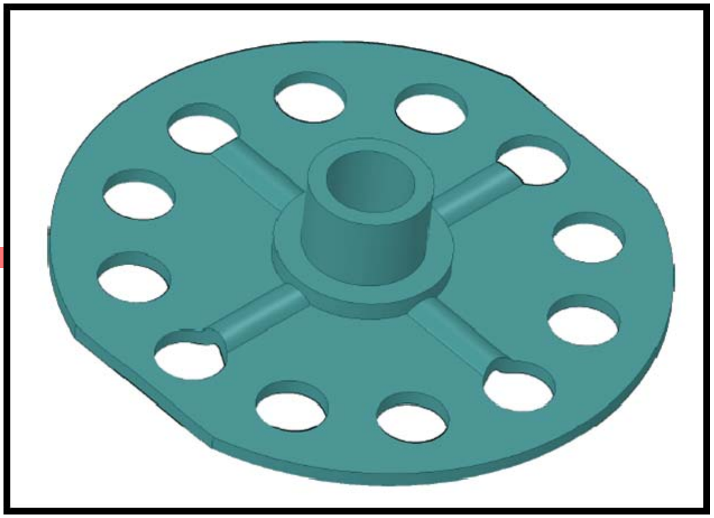
2 Inch Square Insert Stress Analysis Results

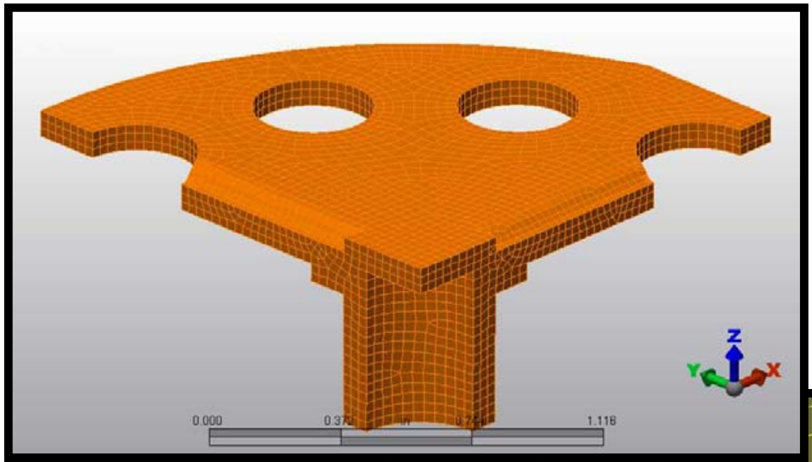


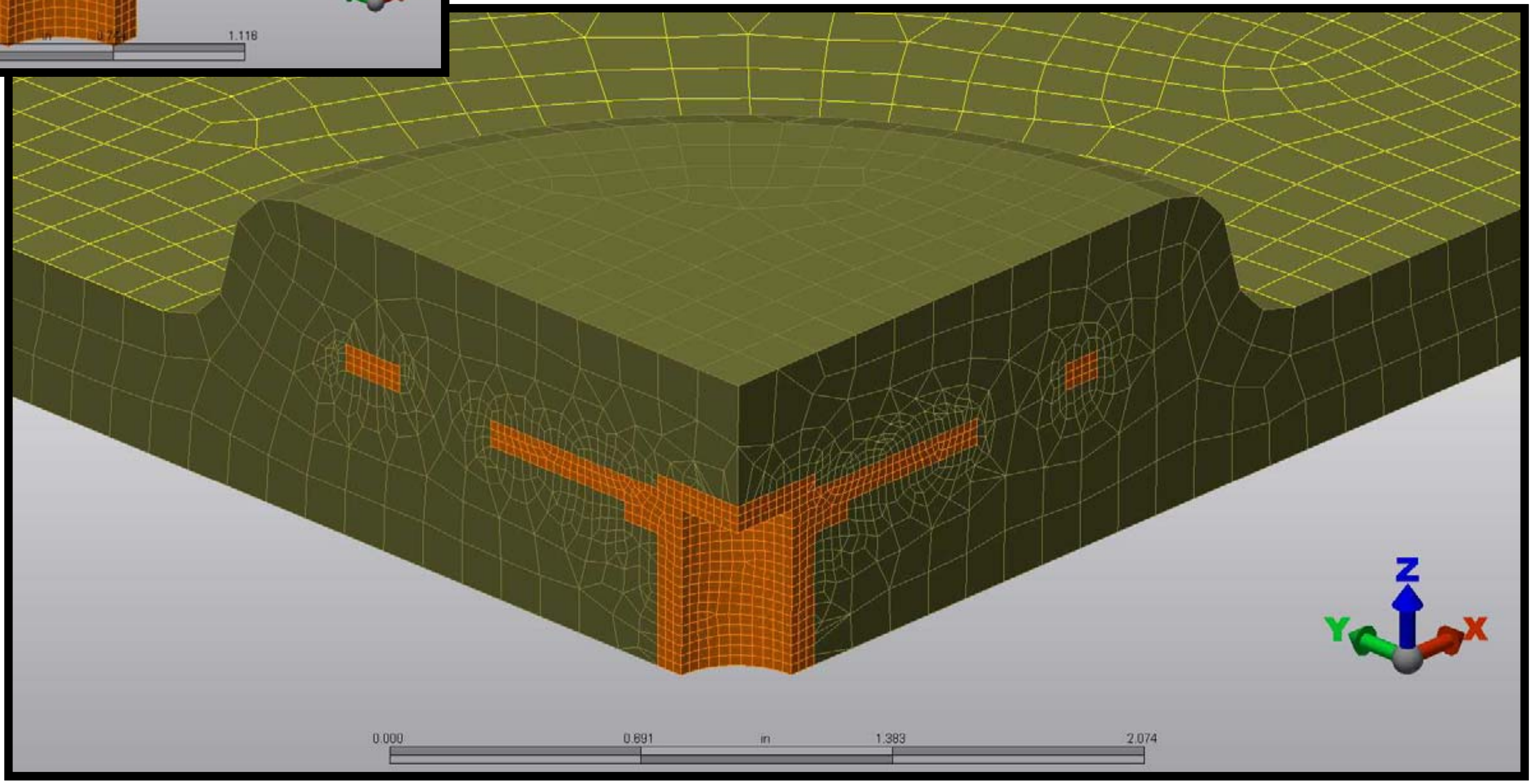


- **The stress in the plastic part is distributed over a large area rather than being concentrated in a small area**
- **The stress (1320 psi) is 62% lower than with the 1 in. tall Hex insert**
- **This is well below the strength of the material (2500 psi). (The insert is not shown.)**

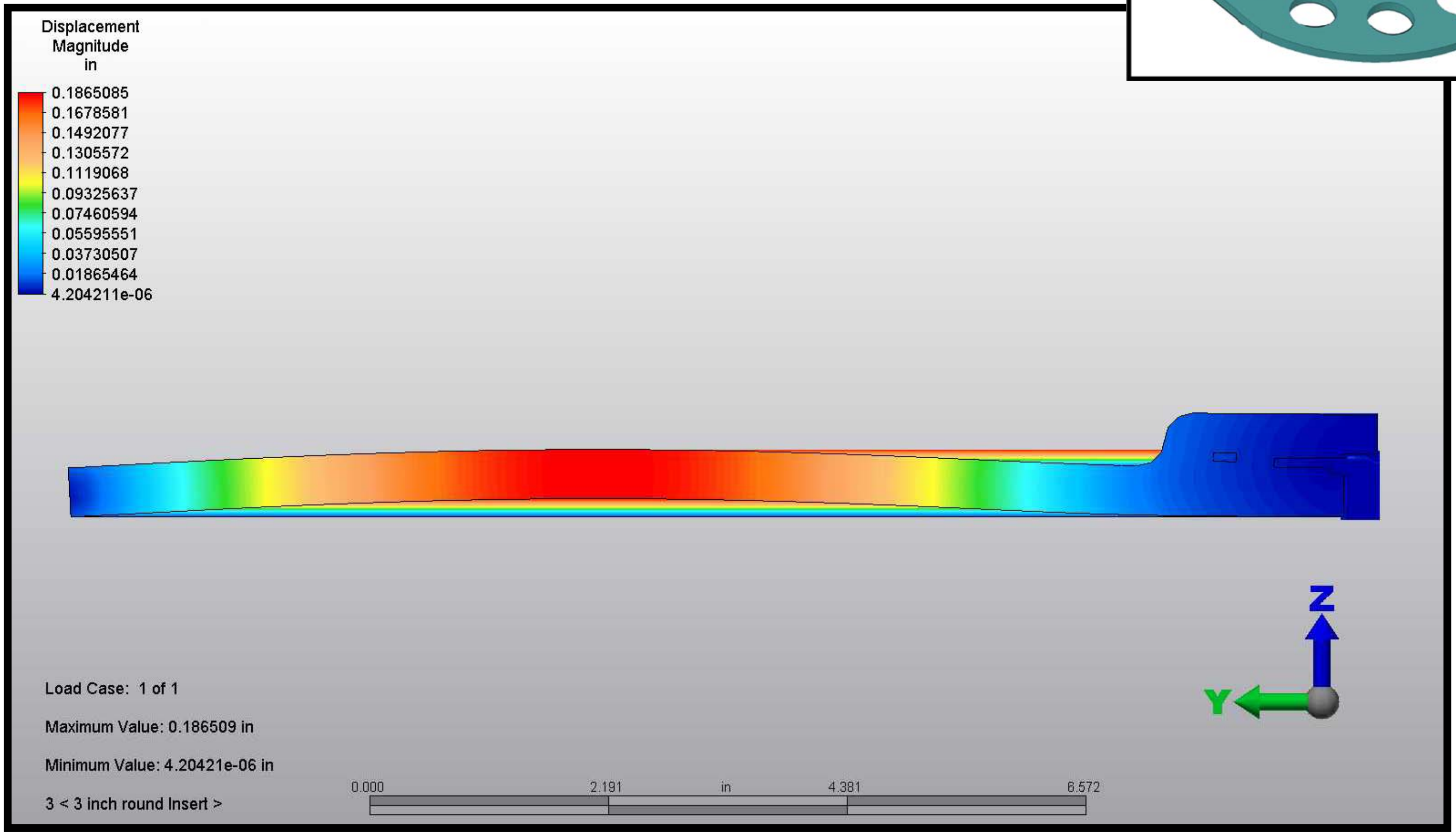
3 Inch Round Insert

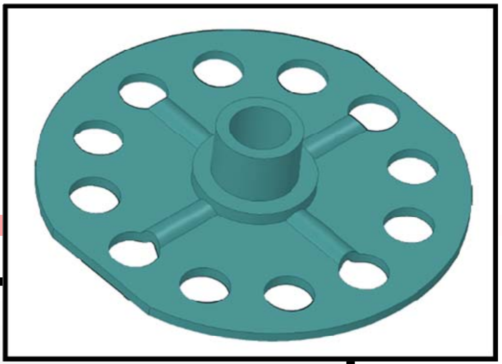






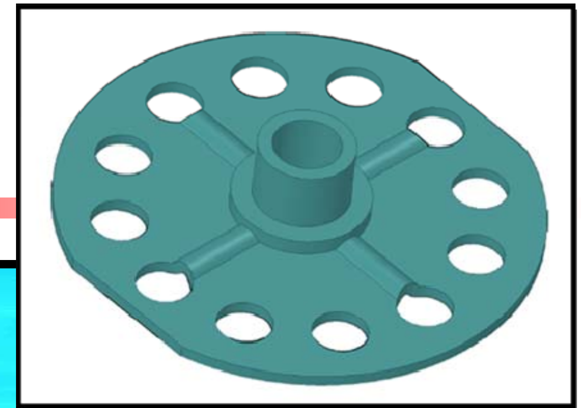
3 Inch Round Insert
Magnitude of Displacement

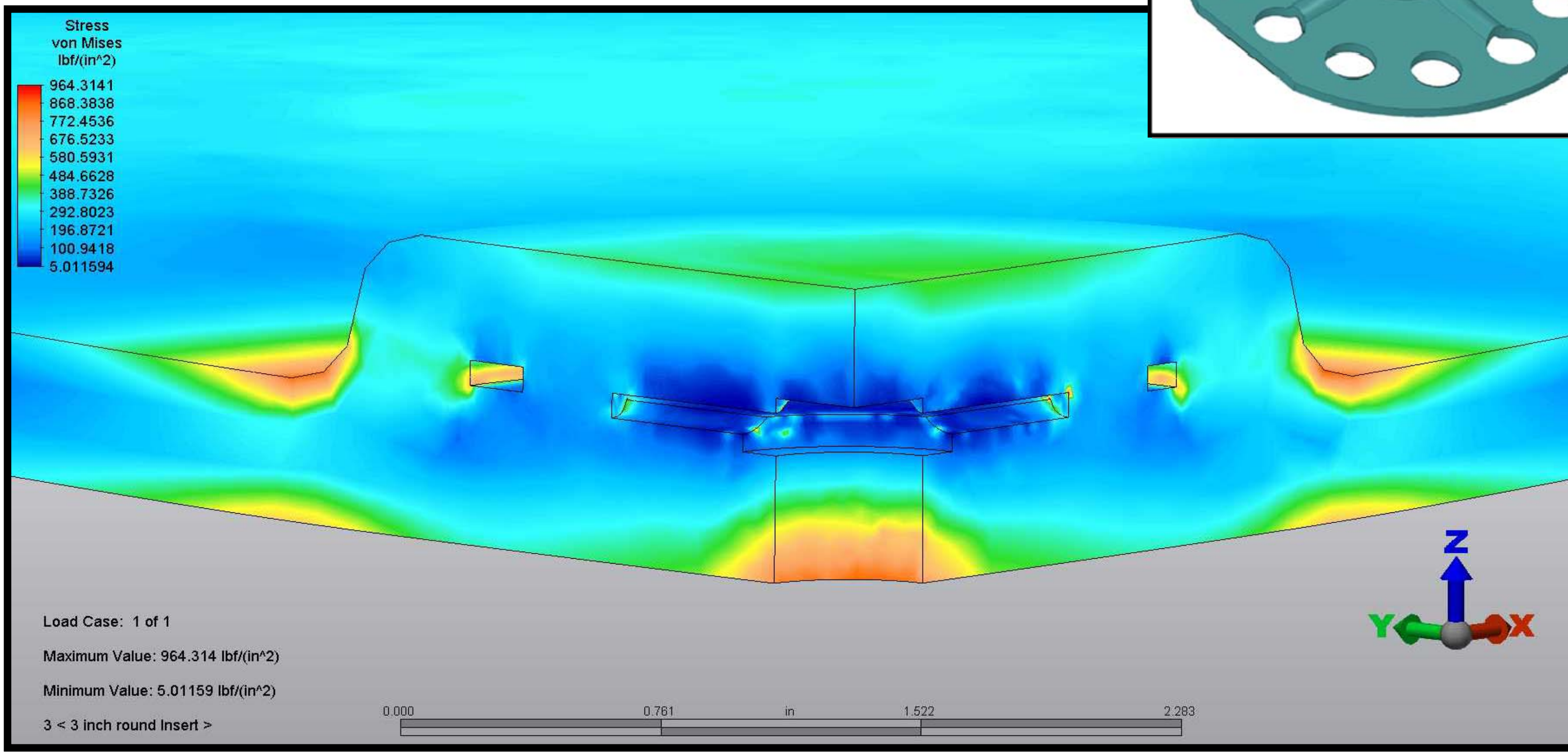




- **Disk deflects up to 0.18 inch circumferentially**
- **This is a further reduction due to wider profile**

3 Inch Round Insert Stress Analysis Results





- **The stress in the plastic part is distributed over a large area rather than being concentrated in a small area.**
- **The max stress (964 psi) is 73% lower than with the 1 in. tall Hex insert**
- **This is well below the strength of the material (2500 psi). (The insert is not shown.)**

Summary

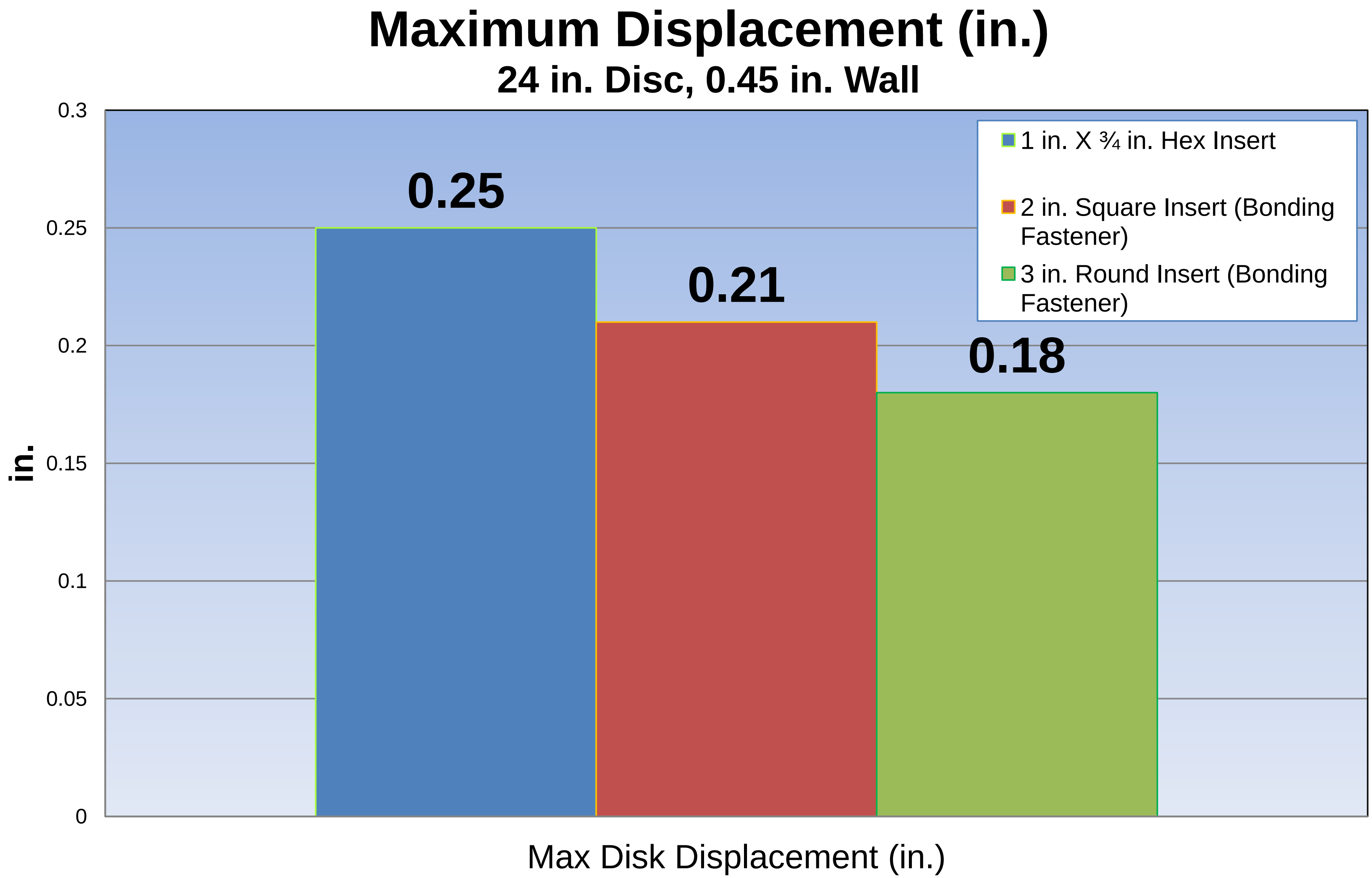
Insert Design	Max Disk Displacement	Maximum Stress in 24 in. Disk
1 in. X ¾ in. Hex insert	0.25 in.	3475 psi
2 in. Square insert (Bonding Fastener)	0.21 in.	1320 psi
3 in. Round insert (Bonding Fastener)	0.18 in.	964 psi

Model: 2-ft round disk, 0.45 in. thick, with the insert at the center.

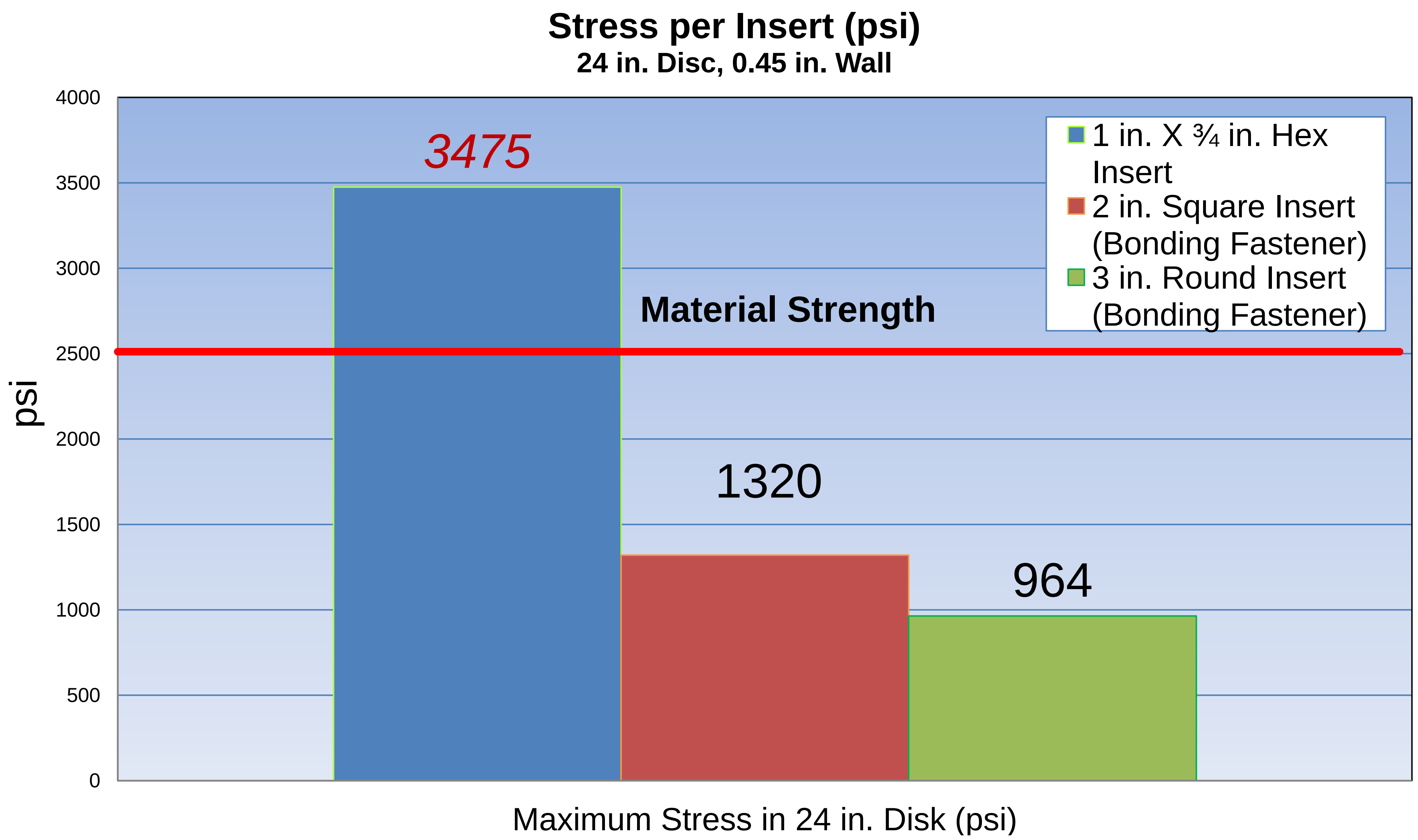
The assembly is constrained at outer edge of the disk and at the edge of opening to the insert. A pressure of 2 psi is applied to the bottom of the disk.

Material: Marlex® HMN TR-938 Polyethylene

Displacement



Stress


Stress per Insert (psi)
24 in. Disc, 0.45 in. Wall
4000
3500
3000
2500
2000
1500
1000
500
0
psi
3475
1320
964
Material Strength
1 in. X ¾ in. Hex Insert
2 in. Square Insert (Bonding Fastener)
3 in. Round Insert (Bonding Fastener)
Maximum Stress in 24 in. Disk (psi)

Conclusions
Simulation Pull-Out Tensile

- **Widening the top of the insert creates more surface area over which the load and stress are distributed**
- **Holes in the top of the insert creates internal columns of plastic or mechanical bonding points from bottom to top which also helps to distribute the load from the plastic underneath the insert to the plastic above the insert**

Chevron Phillips Chemical Company LP

Insert Testing

Real World

in cooperation with

Steve Harris of

Rotaloc®

Tensile Test on Molded inserts

- Chose two roto grades
  - 0.938 g/cc / 3 MI
  - 0.945 g/cc / 6 MI
- Inserts molded into parts at two different thickness
  - Thin = 0.187 in.
  - Thick = 0.330 in.
- Perform tensile test on inserts
- Record maximum tensile to pull insert from part or insert fails

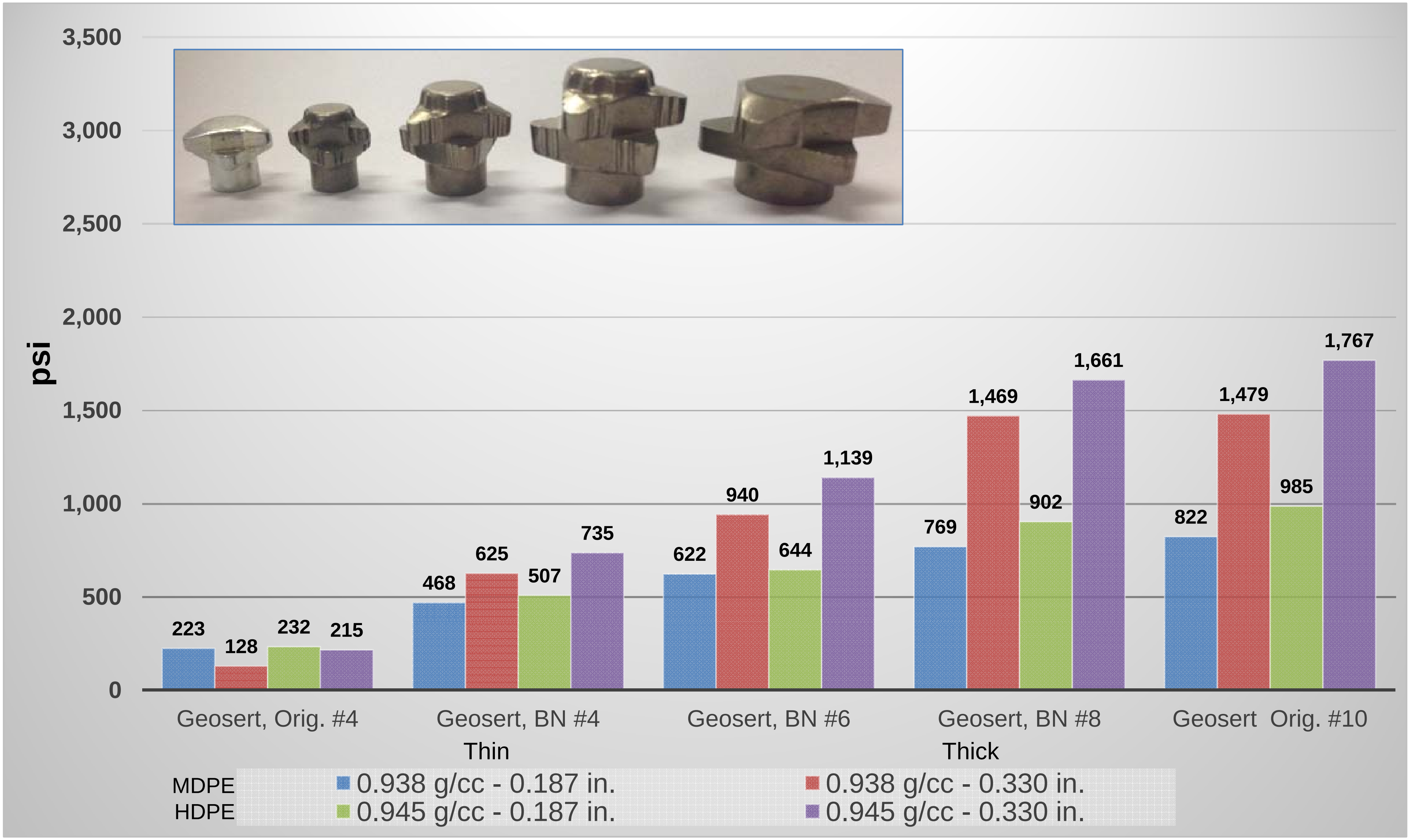
Rotaloc® Geoserts – New Design

- Bull nose for added thread depth
- Rounded top
  - Better flow
  - Eliminate sharp corners
- Vertical ribs to enhance torque resistance
- 10 degree chamfer under bottom triangle points
  - Better flow
  - Eliminate bridging
- Refined stainless steel for increase strength

Rotaloc® Geoserts

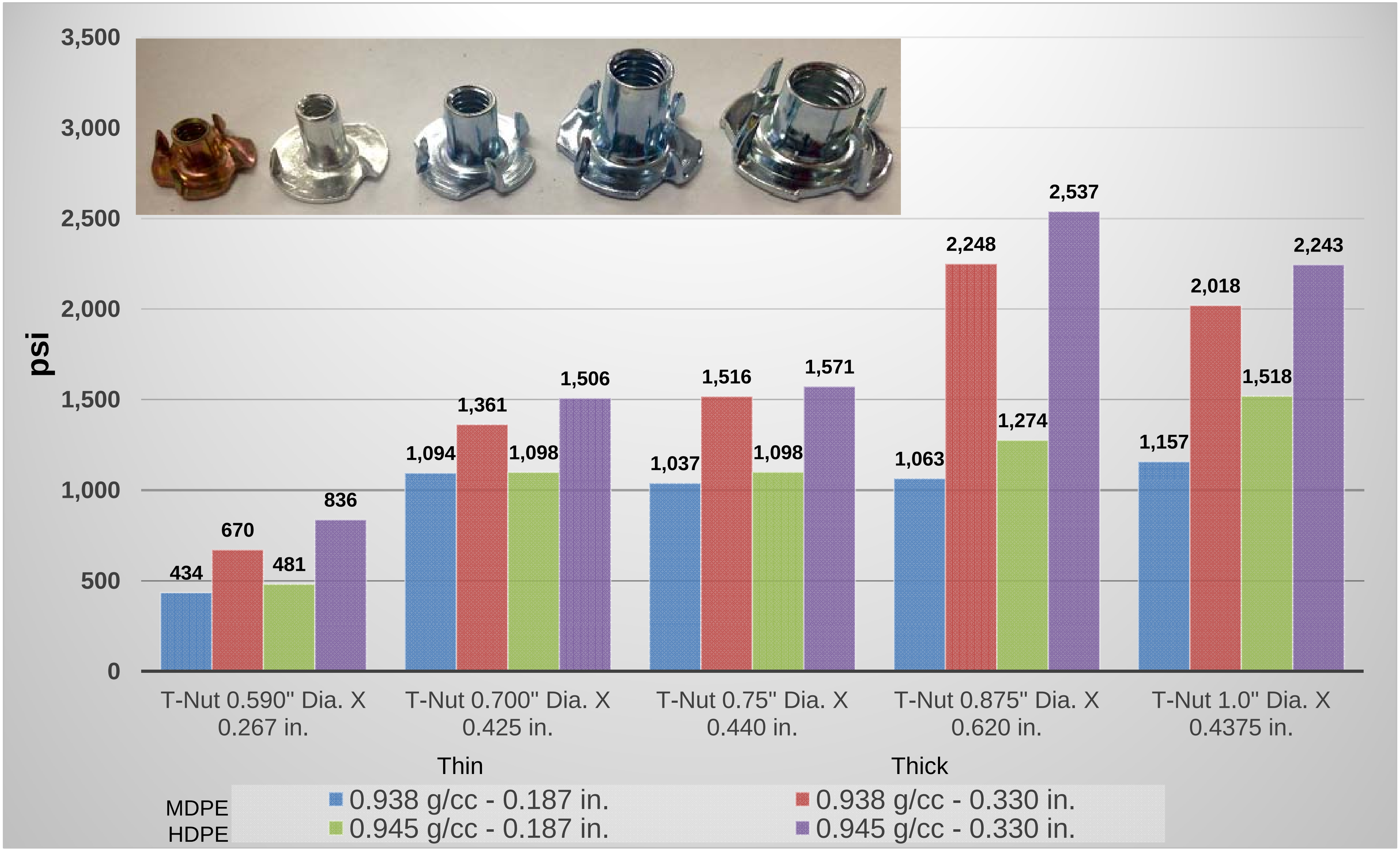
Size 4 Size 6 Size 8 Size 10

Rotaloc® Geoserts Pull-out Tensile

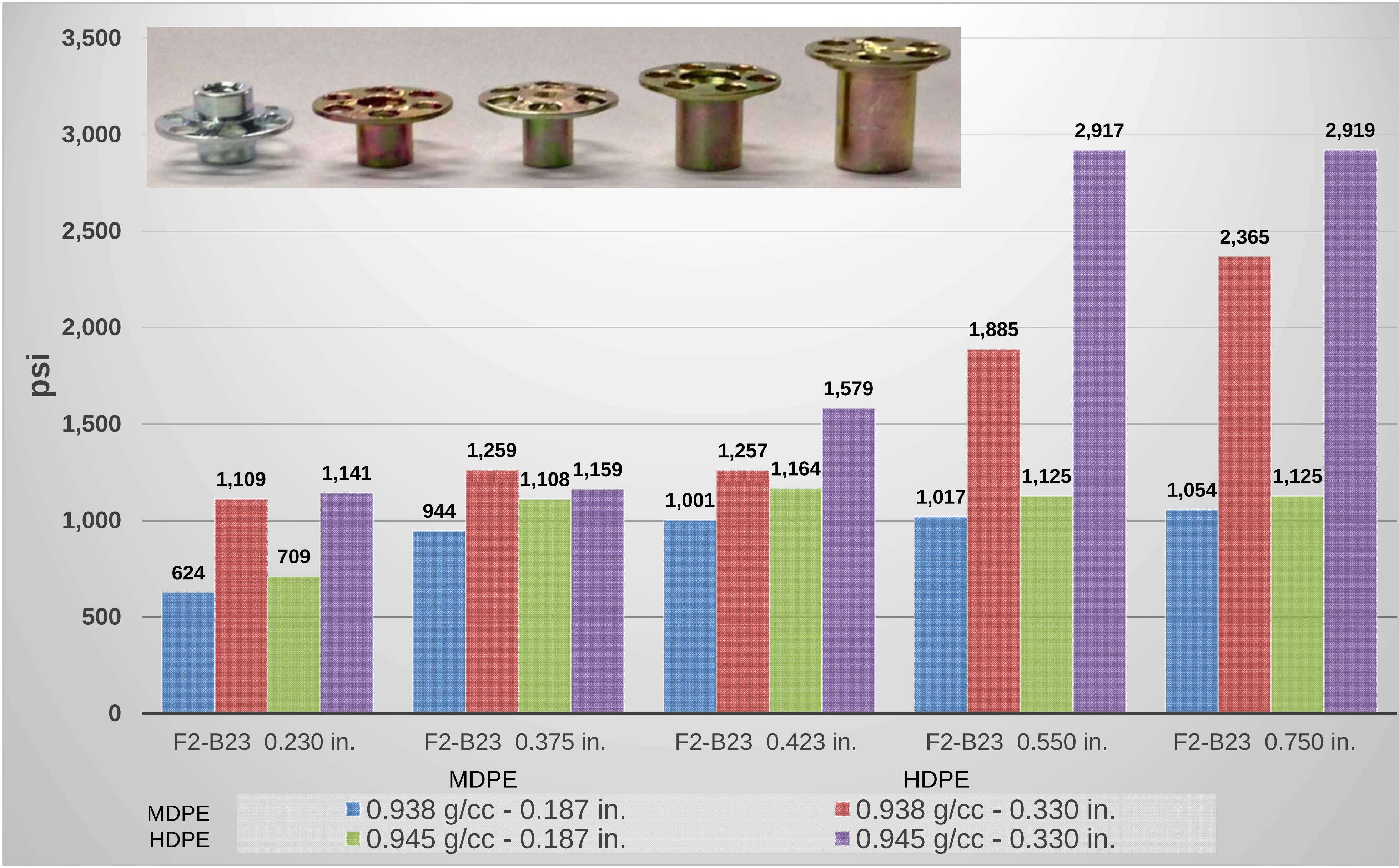


T- Nut Pull-out Tensile

(Barrel Ht.)



Offset Rotaloc® Pull-out Tensile



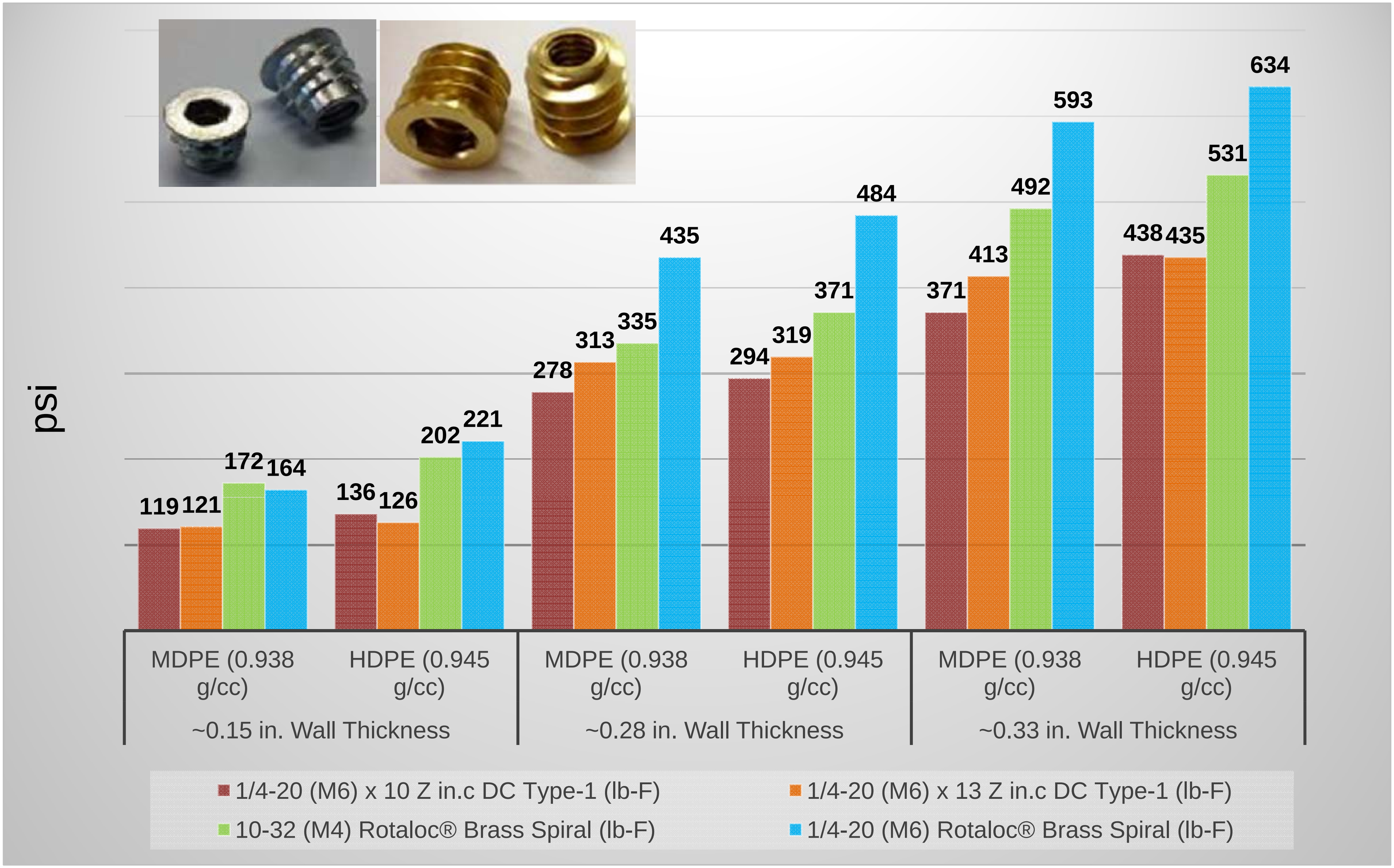
Conclusions - Molded-in inserts
Pull-Out Tensile

- **Rotaloc® Geoserts**
  - Thickness and density have less effect on smaller geoserts
  - Best tensile with high density grade with tensile over **1700** psi
  - Thicker wall significantly improves maximum tensile required for pull out
- **T-Nut**
  - Known for leaking if over torqued
  - Best tensile draw with high density grade over **2500** psi
  - Higher density does improve tensile required for pull out
  - Thicker wall significantly improves tensile required for pull out
- **Rotaloc® Bonding Fasteners**
  - Best tensile draw with high density near **3000** psi
  - Higher density does improve performance especially with larger inserts
  - Thicker wall significantly improves tensile for pull out
  - Correlated with FEA showing higher surface area leads to stronger tensile

Screw-in Inserts (post molding)




Post Applied inserts in Rotationally Molded Polyethylene - Tensile



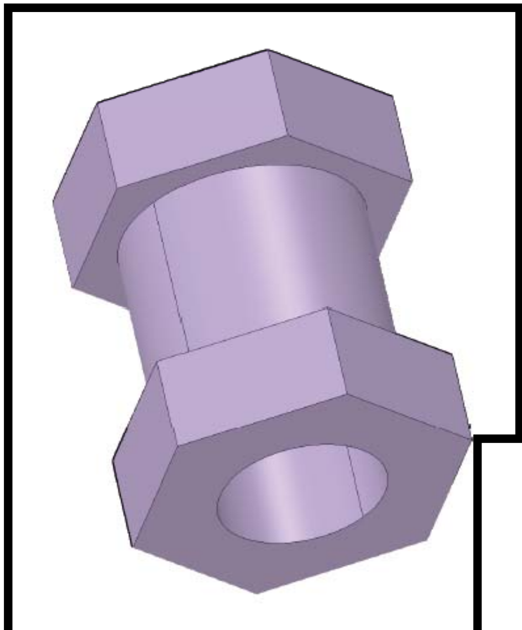
Conclusions - Post Molded inserts Pull-Out Tensile

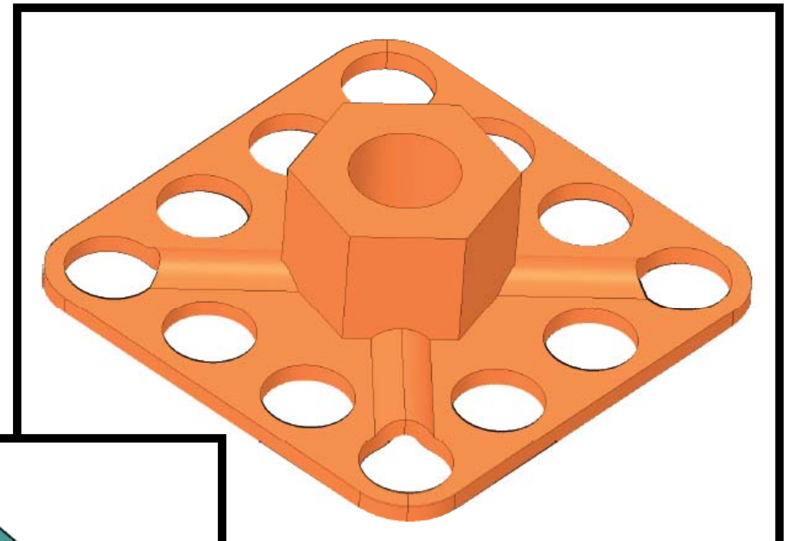
- Thickness and density have less effect on smaller post applied inserts
- New design appears to have better tensile strength when compared to previous design
- Best pull-out tensile with high density grade over **600** psi

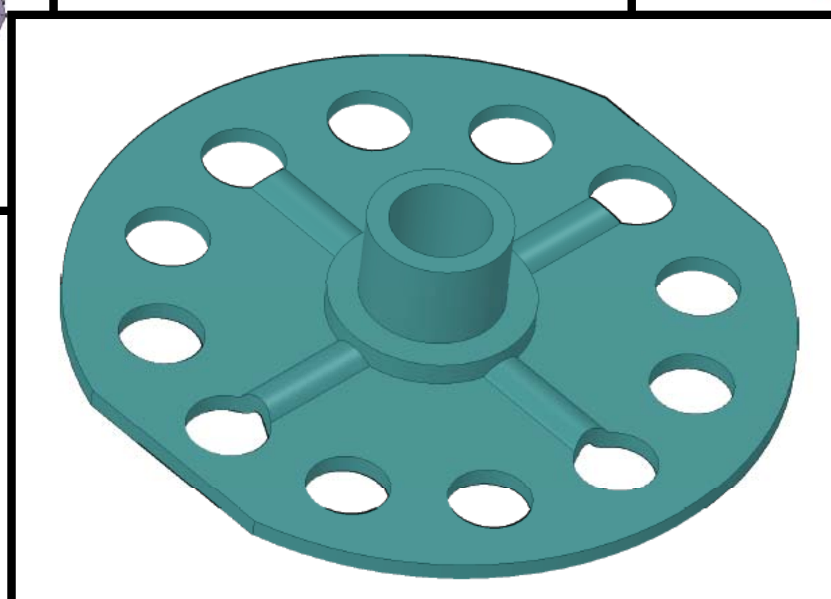
Torque Study

Molded-in insert Simulation
Torque Performance

Material : Marlex® HMN TR-938 Polyethylene
Process: Rotational molding







Rotaloc® Bonding Fasteners

Molded-in Insert Simulation Torque Performance

- **Chose two roto grades**
  - 0.938 g/cc / 3 MI
  - 0.945 g/cc / 6 MI
- **Inserts molded into parts at two different thickness**
  - Thin = 0.187 in.
  - Thick = 0.330 in.
- **Perform torque test on inserts**
- **Record maximum torque to turn insert inside part or bolt/insert fails**

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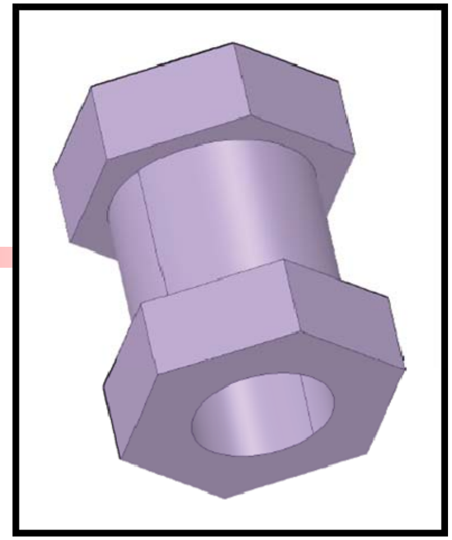
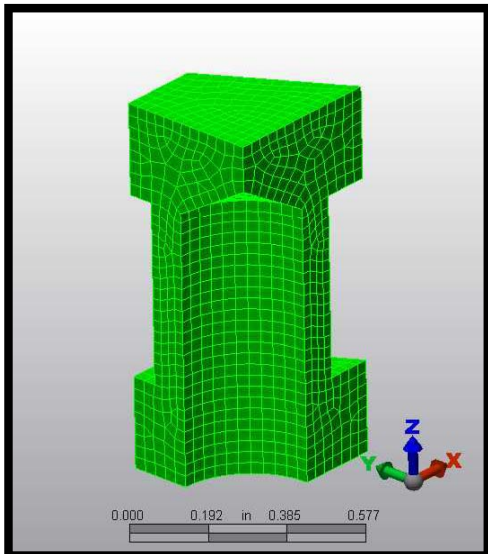
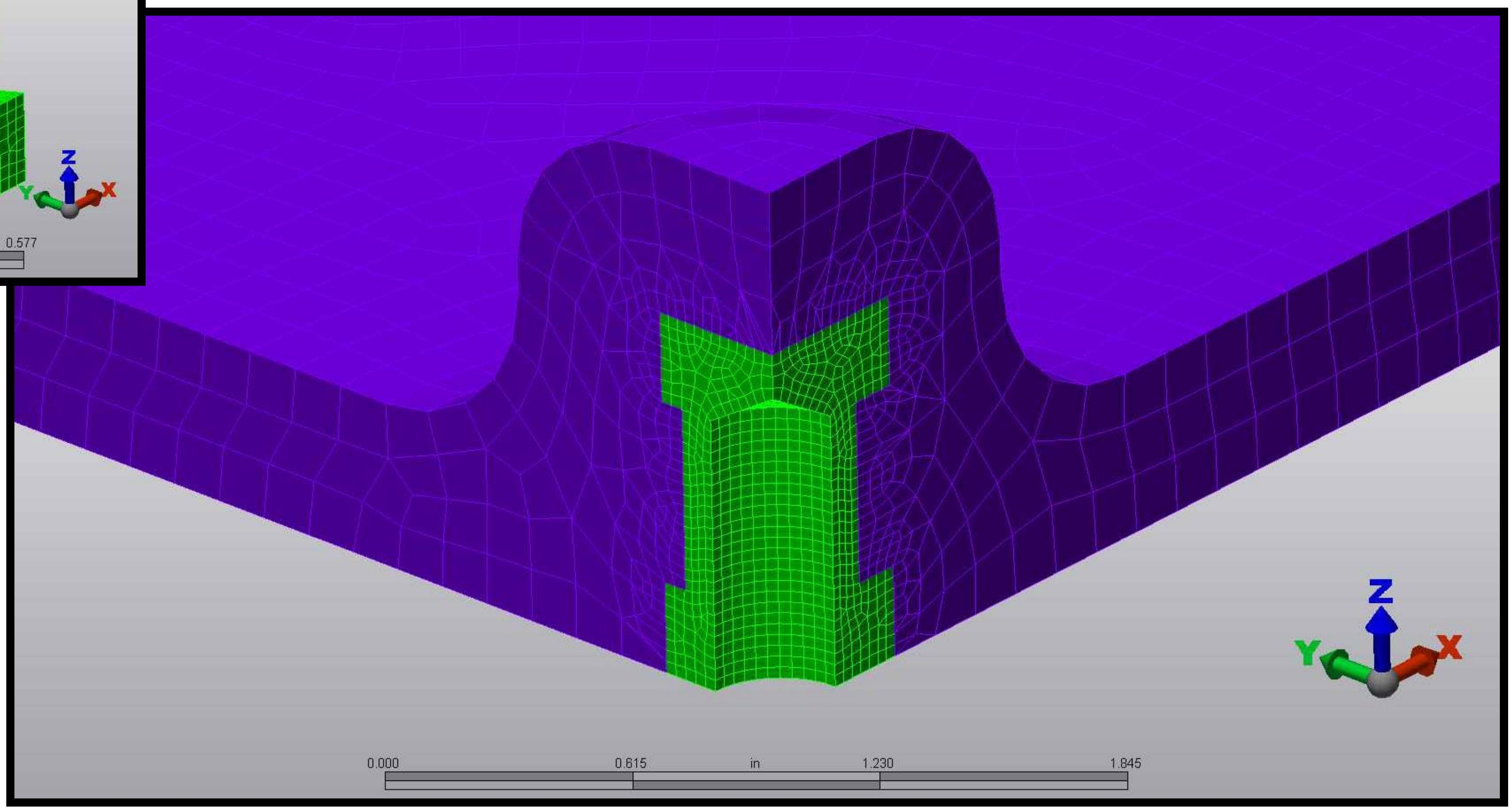
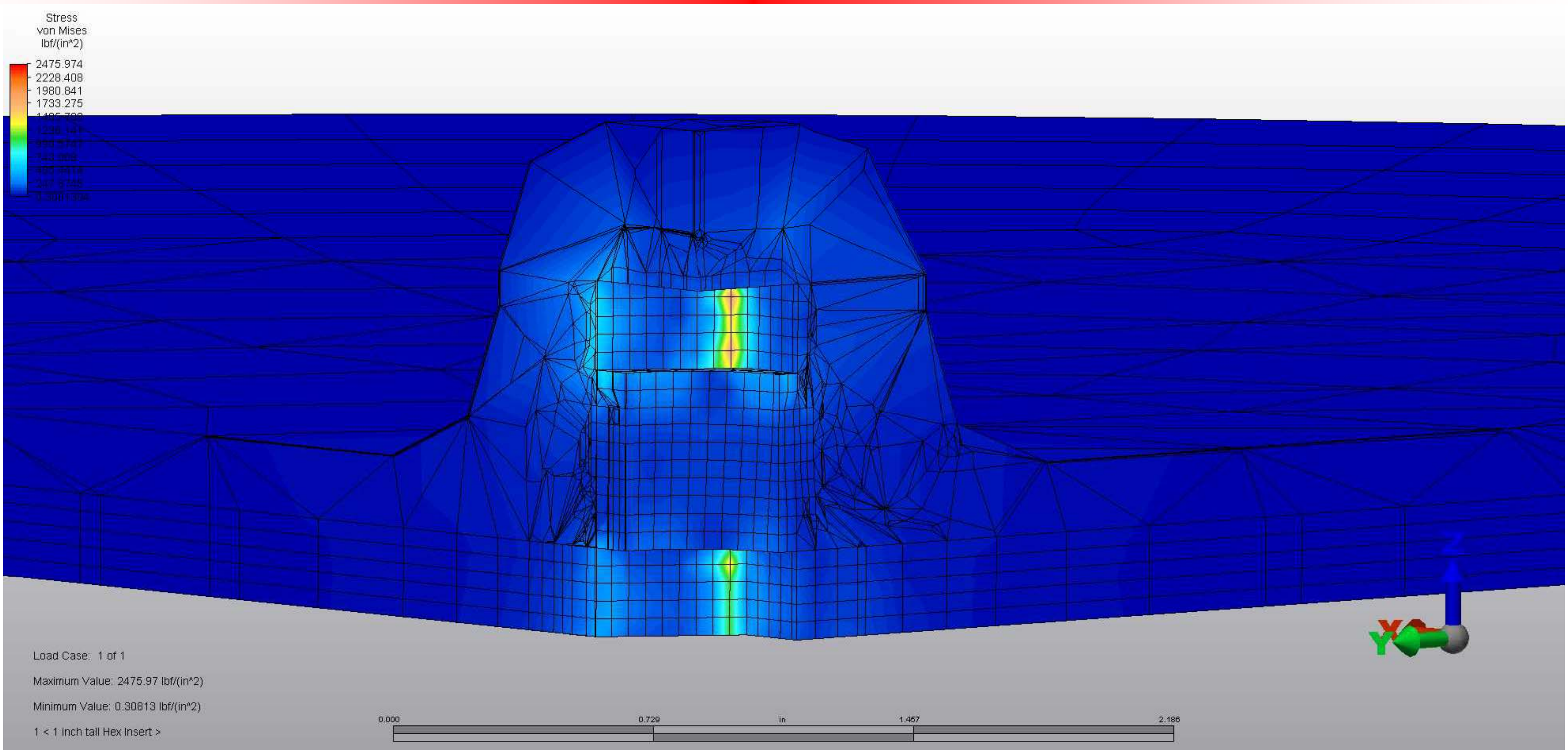
1 Inch X ¾ Inch Hex Insert





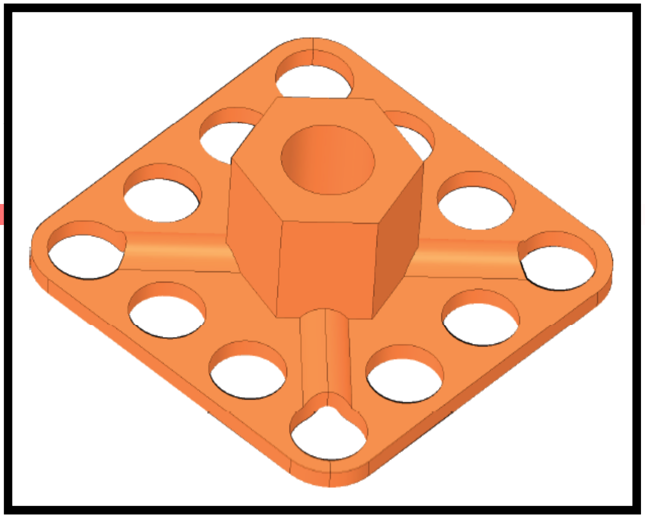


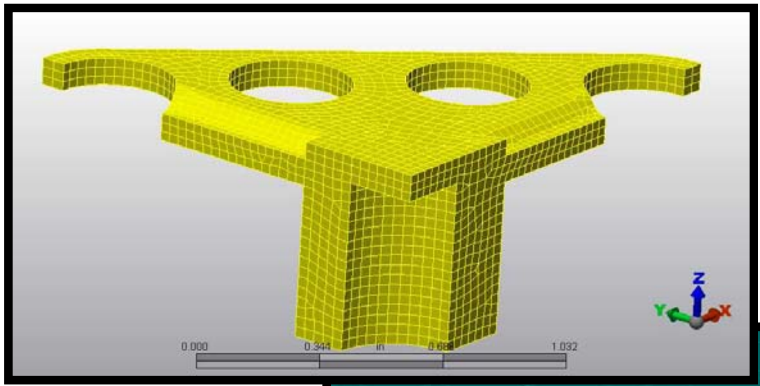
1 Inch X ¾ Inch Hex Insert Torque Analysis Results

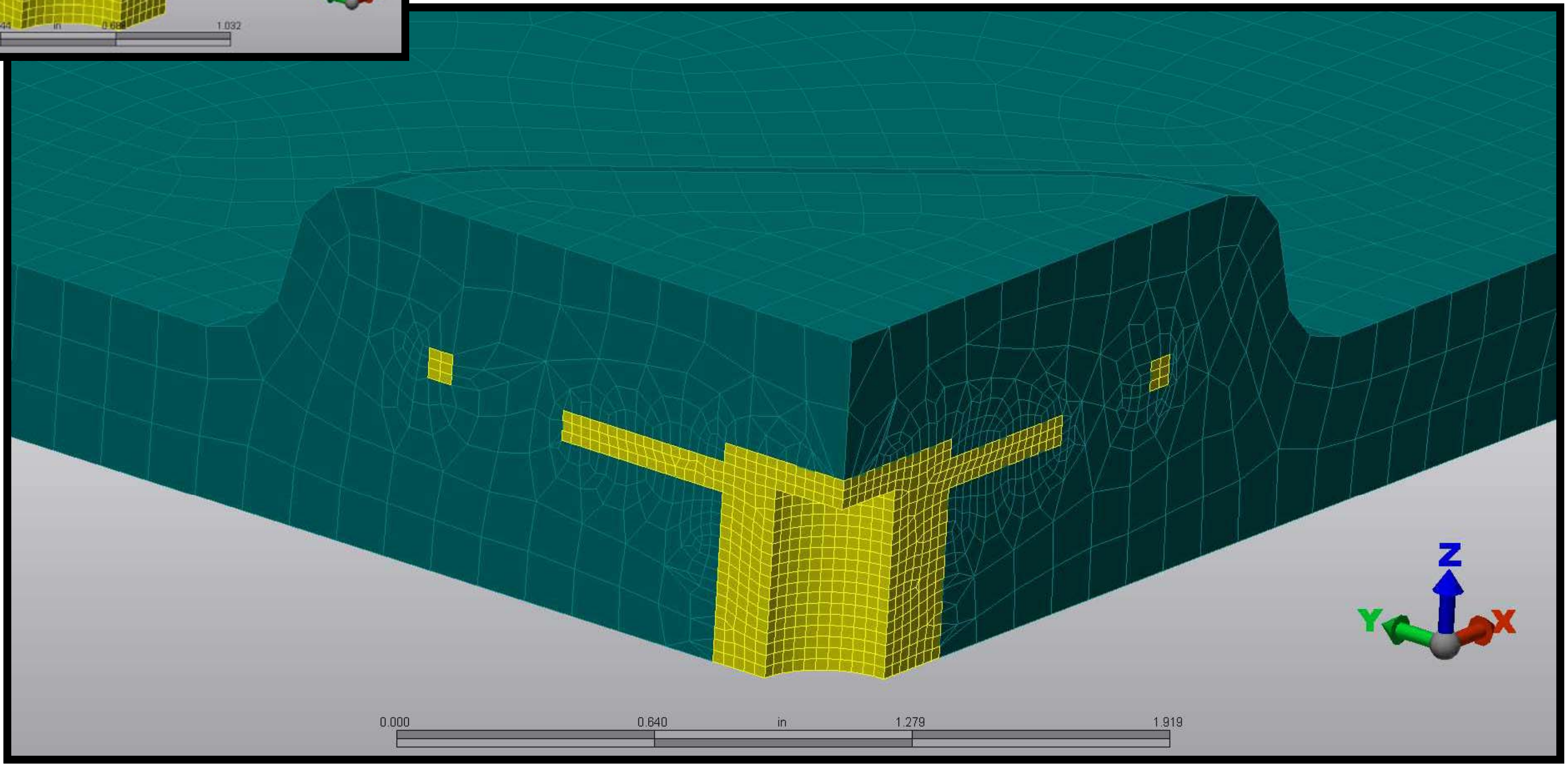


- **The highest stresses are concentrated at the edge of the Hex feature.**
- **The applied force of 300 lbf resulted in a stress of 2,475 psi which is slightly lower than the strength of the resin. (2500 psi) (The metal insert is not shown.)**

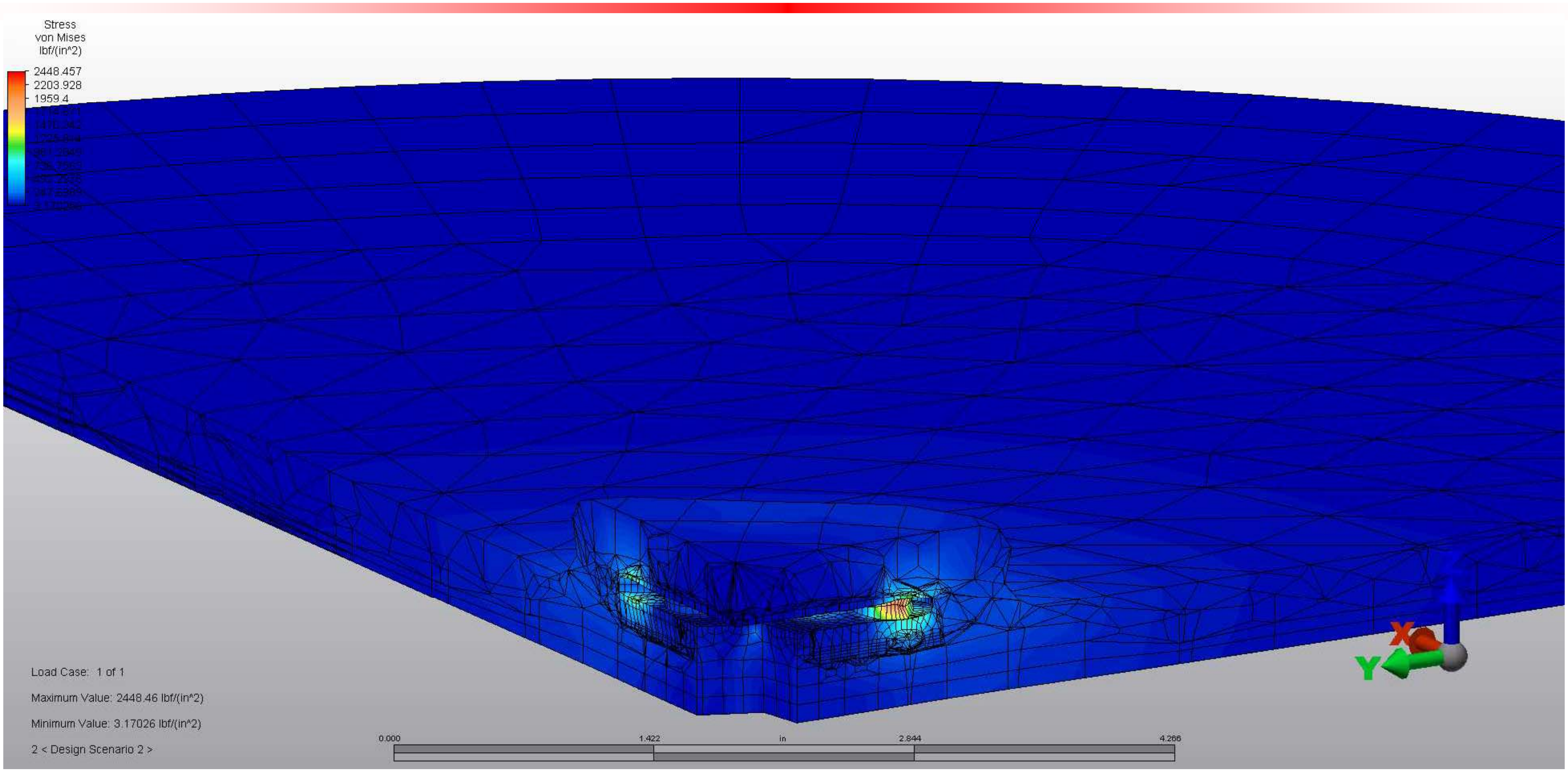
2 Inch Square Insert





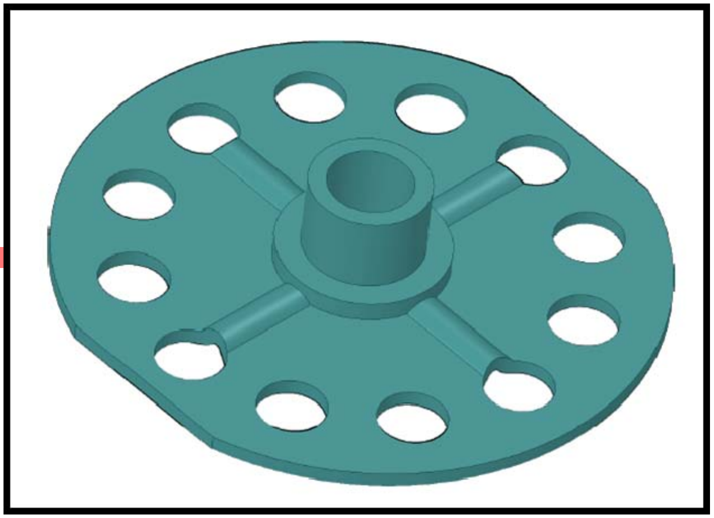


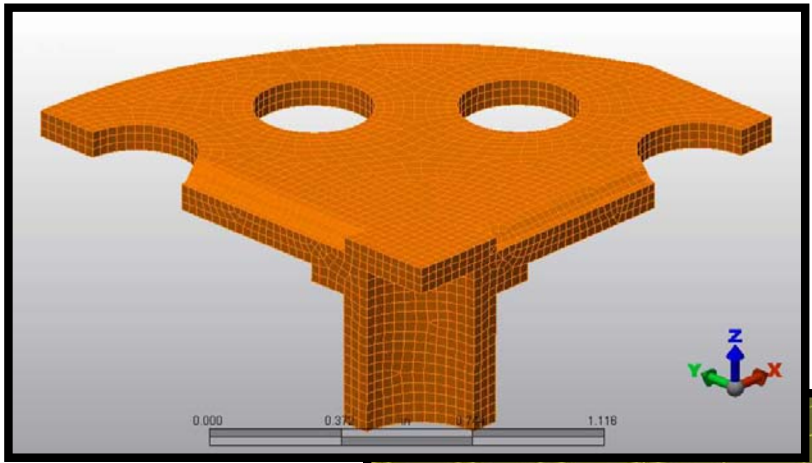
2 Inch Square insert
Torque Analysis Results

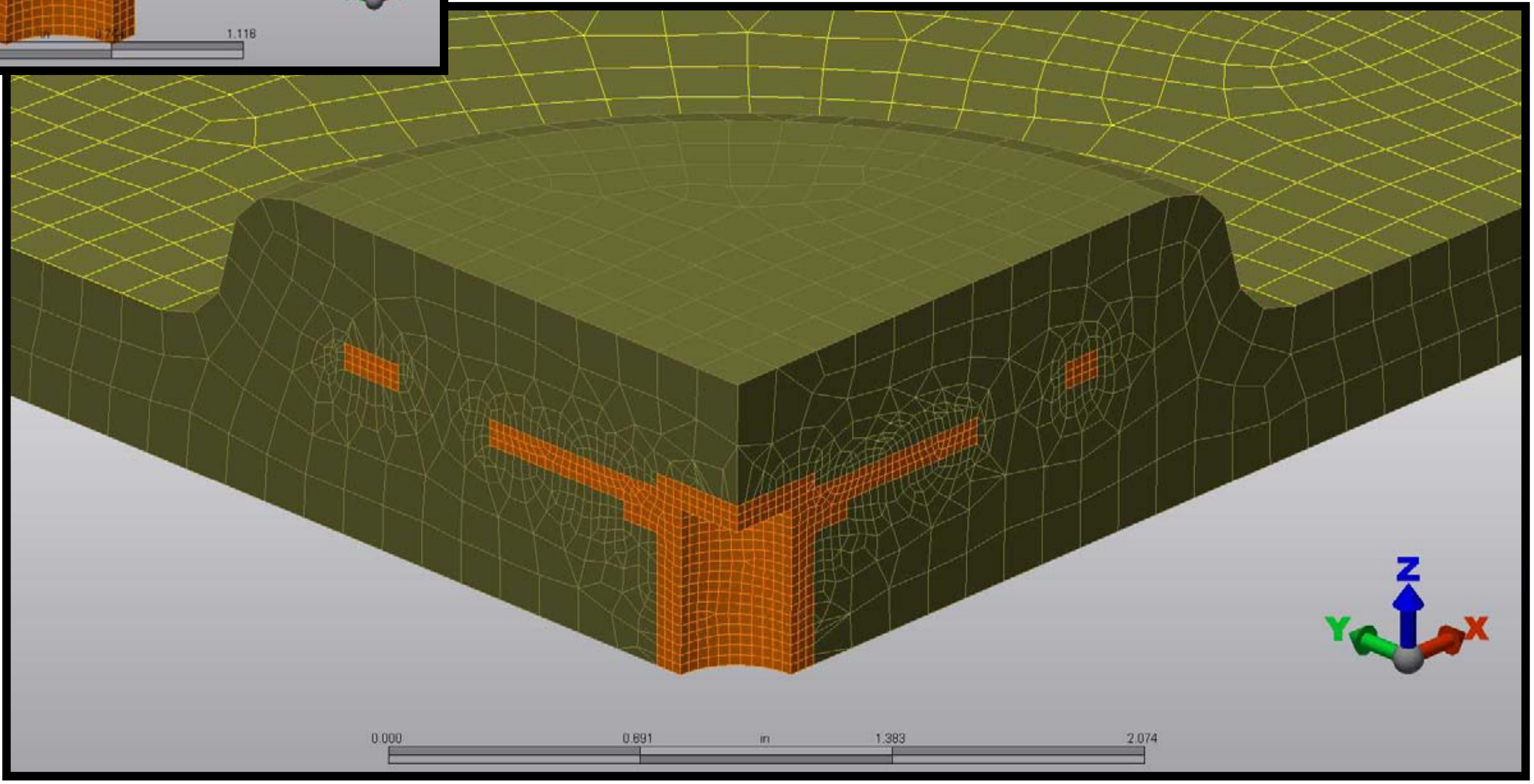


The applied force of 3400 lbf resulted in a stress of 2,448 psi which is slightly lower than the strength of the resin (2500 psi) (The metal insert is not shown.)

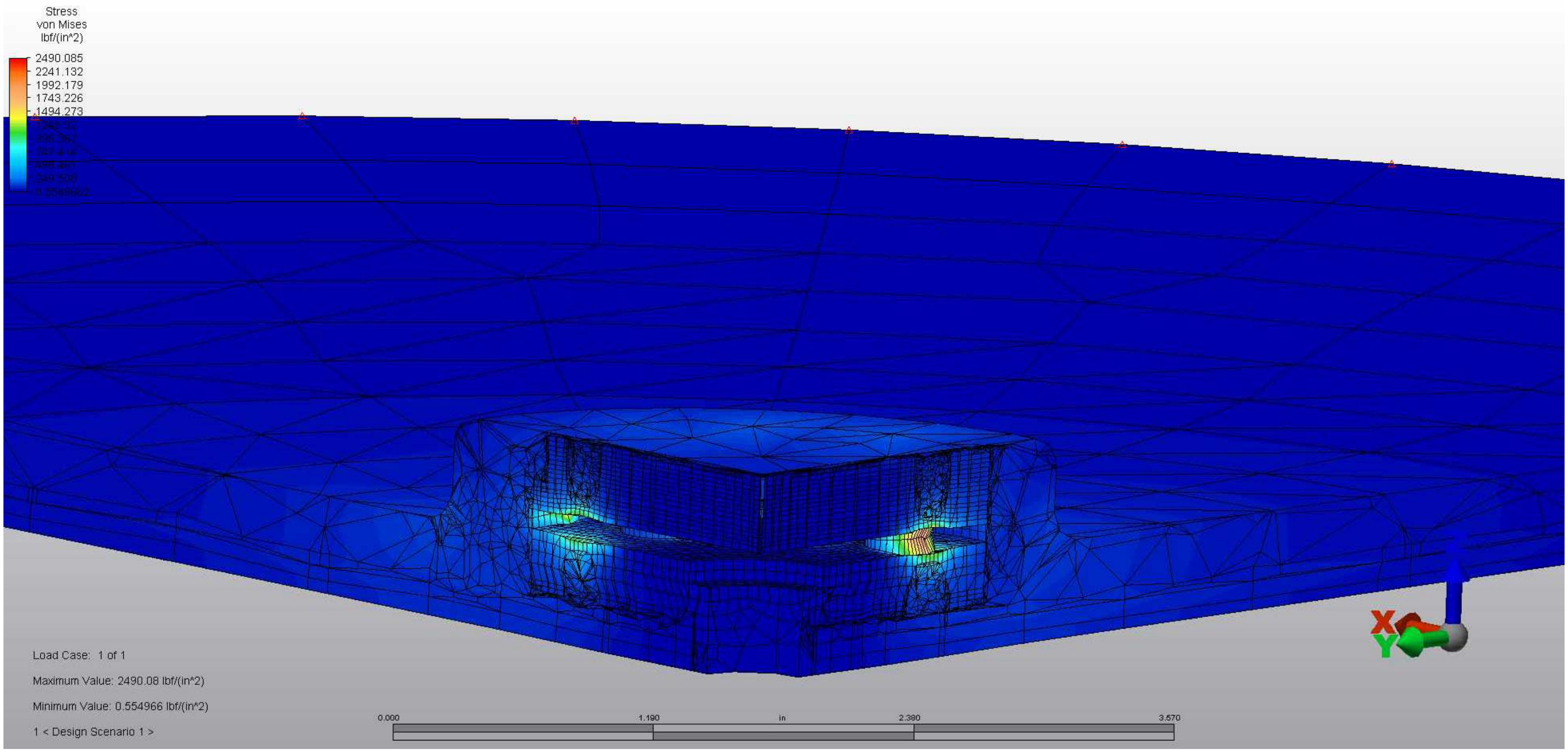
3 Inch Round Insert







3 Inch Round Insert
Torque Analysis Results



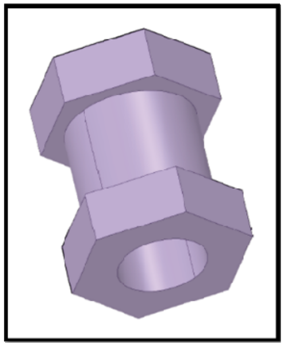
The applied force of 3650 lbf resulted in a stress of 2,490 psi which is slightly lower than the strength of the resin (2500 psi) (The metal insert is not shown.)

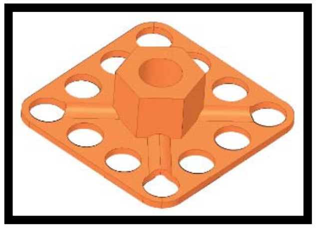
Summary of FEA

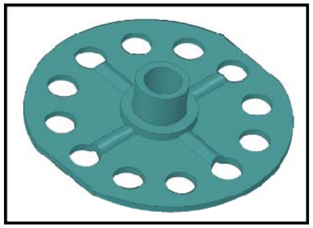
Insert Design	Force Applied (lbf)	Resulting Stress (psi)
Hex body	300	2475
2 in. square shoulder w/Hex body	3400	2448
3 in. round shoulder	3650	2490

Conclusion - Torque Performance Simulation

- FEA confirmed that the design of an insert is significant to the torque performance
- More surface area to mechanically bond to the material dramatically increases torque properties
- HDPE grades with higher tensile properties will yield higher torque performance
- Higher density does improve performance especially with larger inserts
- The applied force of 300 lbf resulted in a stress of 2,475 psi
- The applied force of 3400 lbf to a 2 in. Square Bonding Fastener resulted in a stress of 2,448 psi
- The applied force of 3650 lbf to a 3 in. Round Bonding Fastener resulted in a stress of 2,490 psi







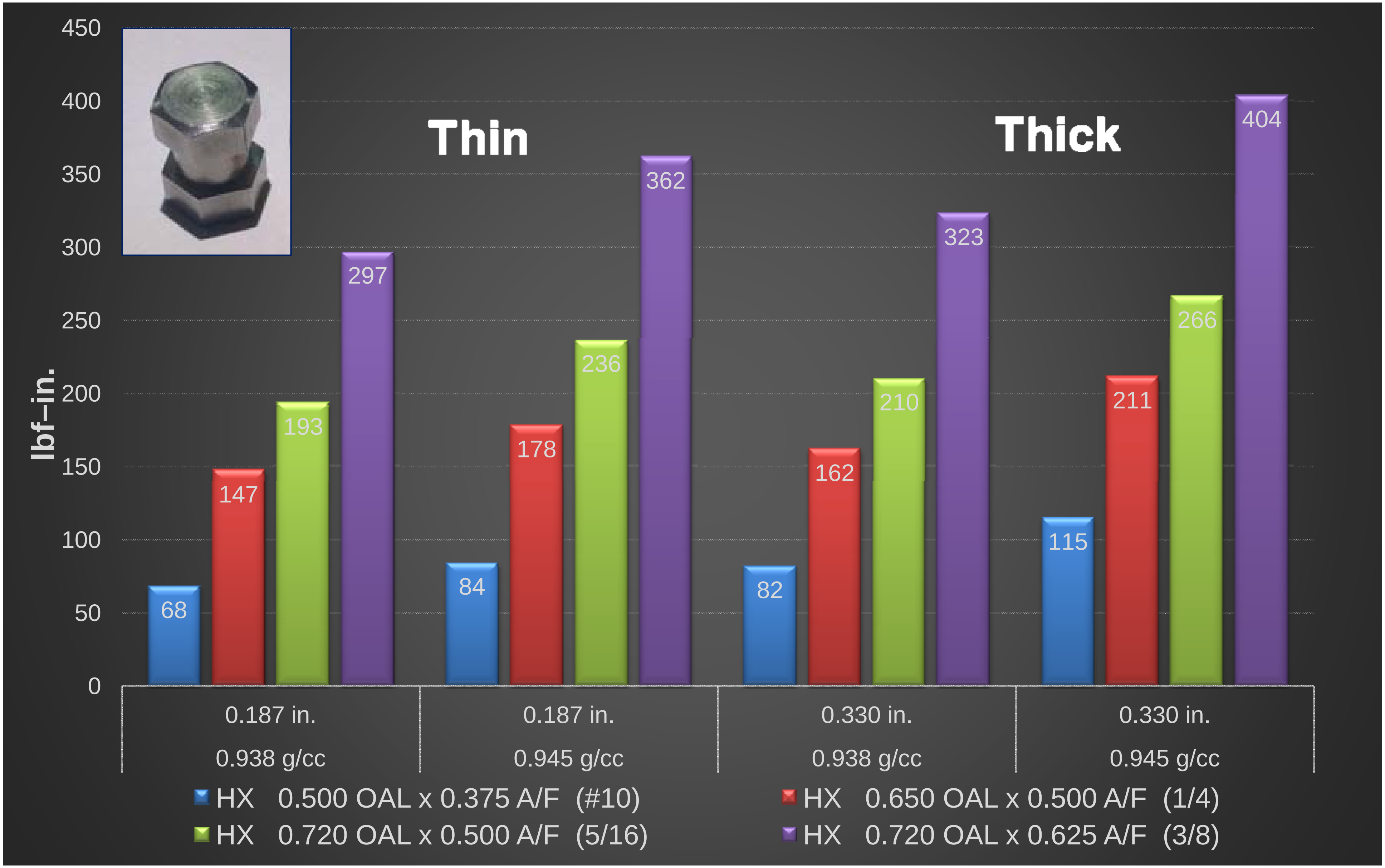
* Tensile strength assumed at a maximum of 2500 psi

Torque Performance

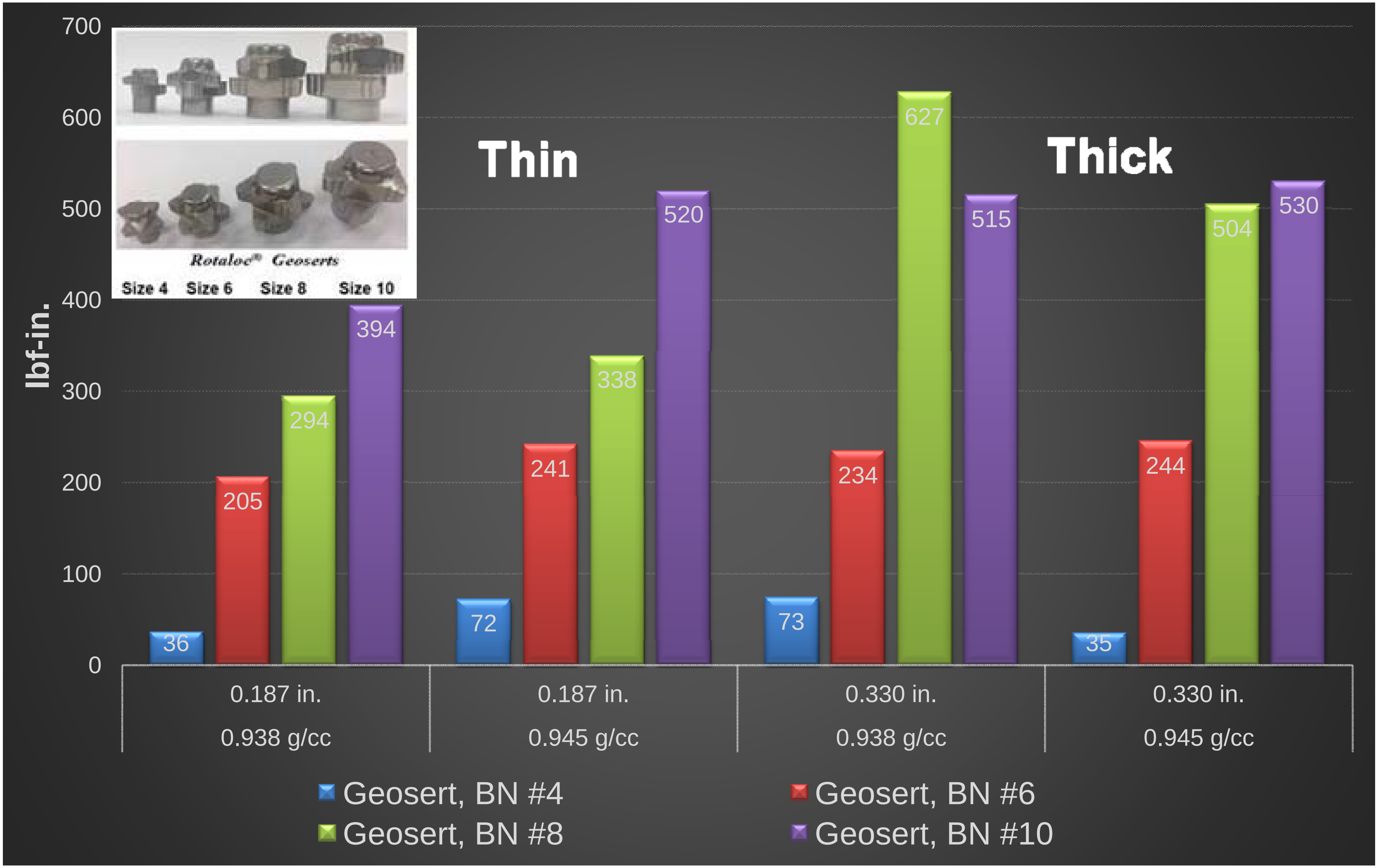
Real World

(limited data)

Maximum Torque (lbf–in.)
HEX Inserts



MaximumTorque (lbf–in.)
GEOSERTS



Conclusion - Molded-in inserts Torque Performance

- A significant torque improvement can be achieved with better insert designs
- HDPE offers a strength benefit over MDPE
- Thicker walls with larger inserts improve torque strength
- Inserts with larger surface area to bond with the material, offer significant improvement in torque performance
- Rotaloc® Geoserts
  - Thickness and density have less effect on smaller Geoserts
  - Thicker wall significantly improves maximum torque
  - Best torque performance with thick wall and:
    - Geoserts # 8 / MDPE - 627 lbf-in.
    - Geoserts #10 / HDPE - 530 lbf-in.

Summary

Summary - Pull-Out Tensile

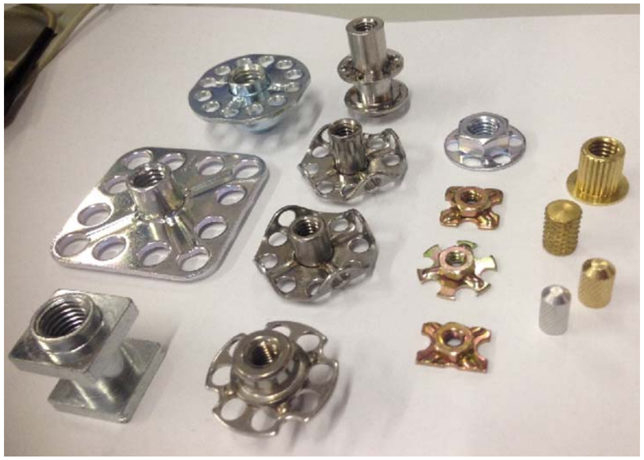
- Best simulation tensile draw with 3 in. round insert, HDPE and a thick wall reduced the applied stress by 72% over the best performance of a hex insert
- Molded-in offset inserts gave the best performance with HDPE and a thick wall with pull-out strength just under **3000 psi** (0.550 in. and 0.750 in. sizes)
- Post molded inserts performed best with HDPE and thick walls but only delivered a pull out strength just over **600 psi**
- Design with most surface area to mechanically bond to the material gave best results – simulated and real world
- HDPE grade with higher tensile properties gave the best results – real world
- Increased wall thickness gave best properties – real world

Summary - Torque Performance

- Best torque performance with Geoserts # 8, MDPE and thick wall at 627 lbf-in. - real world.
- The 3 in. round insert with HDPE and thickest walls gave the best simulated torque performance at 3650 lbf-in.
- Simulated torque performance is greater than the torques specifications for some bolts. Beware of breaking bolts!
- Design with most surface area to bond to the material gave best results – simulated and real world.
- MDPE and HDPE grades gave the best results with the thick wall – real world.
- Increased wall thickness gave best properties – real world.

Next Steps

- **Directly compare actual thickness with inserts to FEA analysis.**
- **Perform FEA with HDPE.**
- **Provide more torque data for large surface area inserts.**
- **Provide torque response with different inserts with:**
  - Hardened bolts
  - Stainless steel bolts
- **Review flow characteristics of materials with different melt indices around inserts**
- **Review flow characteristics using different pigments additives.**
- **Review sources of molding failures.**
  - Blowholes
  - Voids
  - Contamination on insert surface (oils , dirt, etc.)
  - Effects of under curing / over curing



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Questions?