Effect of pipe twisting on coiled tubing fatigue

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ICoTA Calgary Round Table
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Introduction

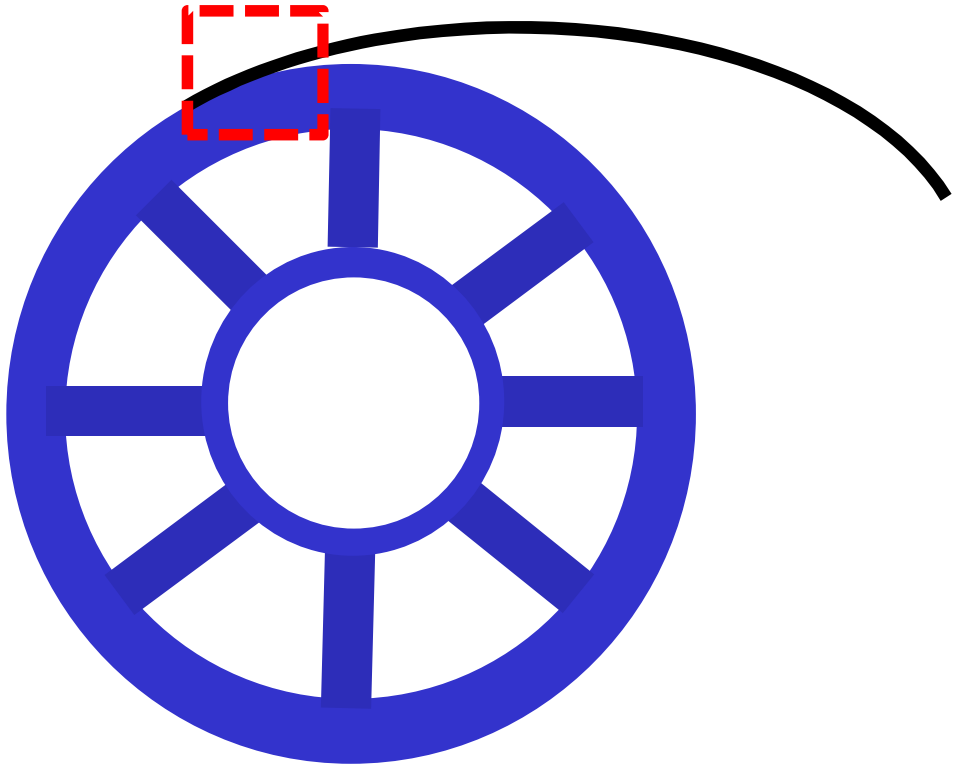
- CT Fatigue Refresher
- Theory on Pipe Twist's Effect
- Fatigue Modeling with Pipe Rotation/Twist
- Tracking of Pipe Rotation / Twist
- Diameter Growth Modeling

Sources of CT Fatigue

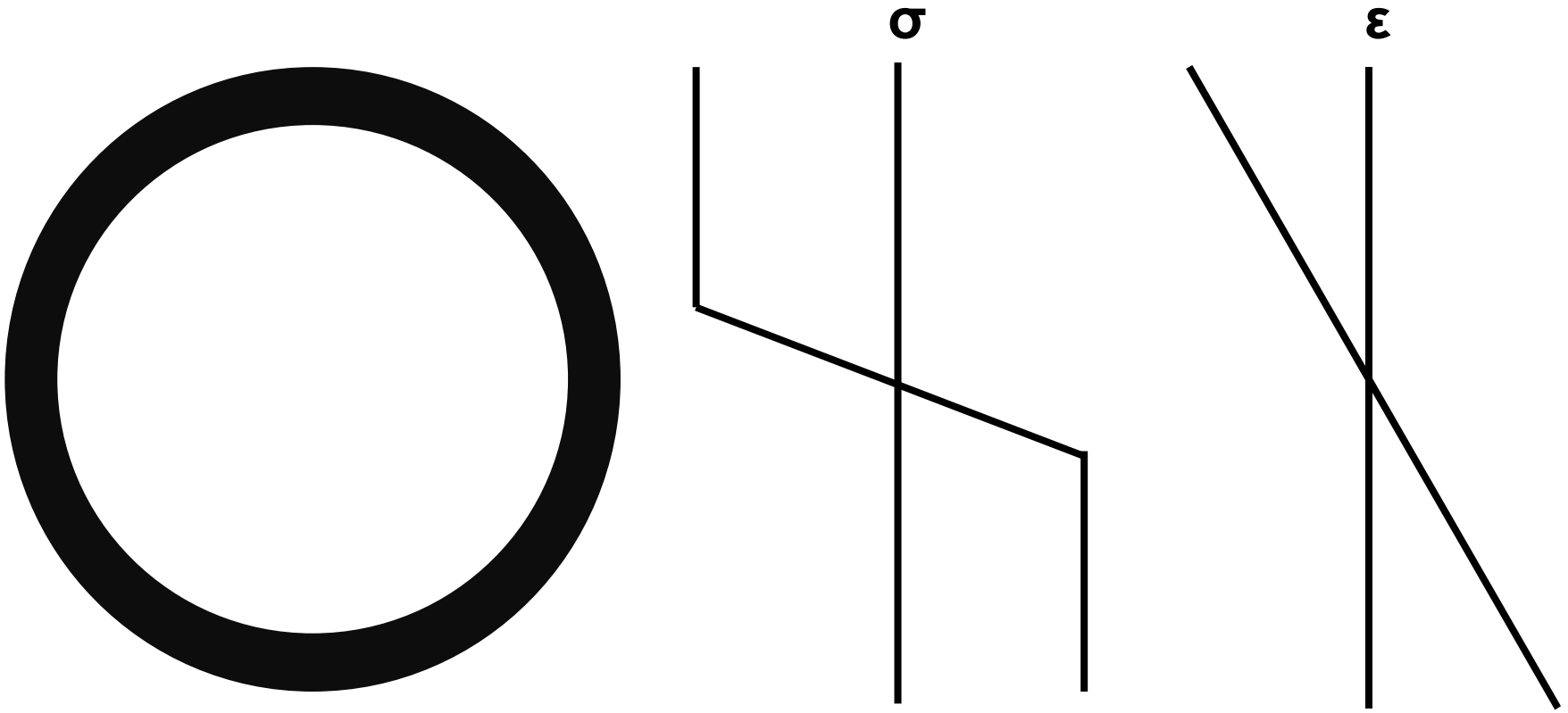
CT Fatigue Dependencies

- Bending Strain (Geometry)
  - $\varepsilon = r/R$
- Stress due to pressure
  - Von Misses Stress or Hoop Stress
- Tubing Material Properties
- Previous Fatigue Accumulation

Bending Stress / Strain relationship

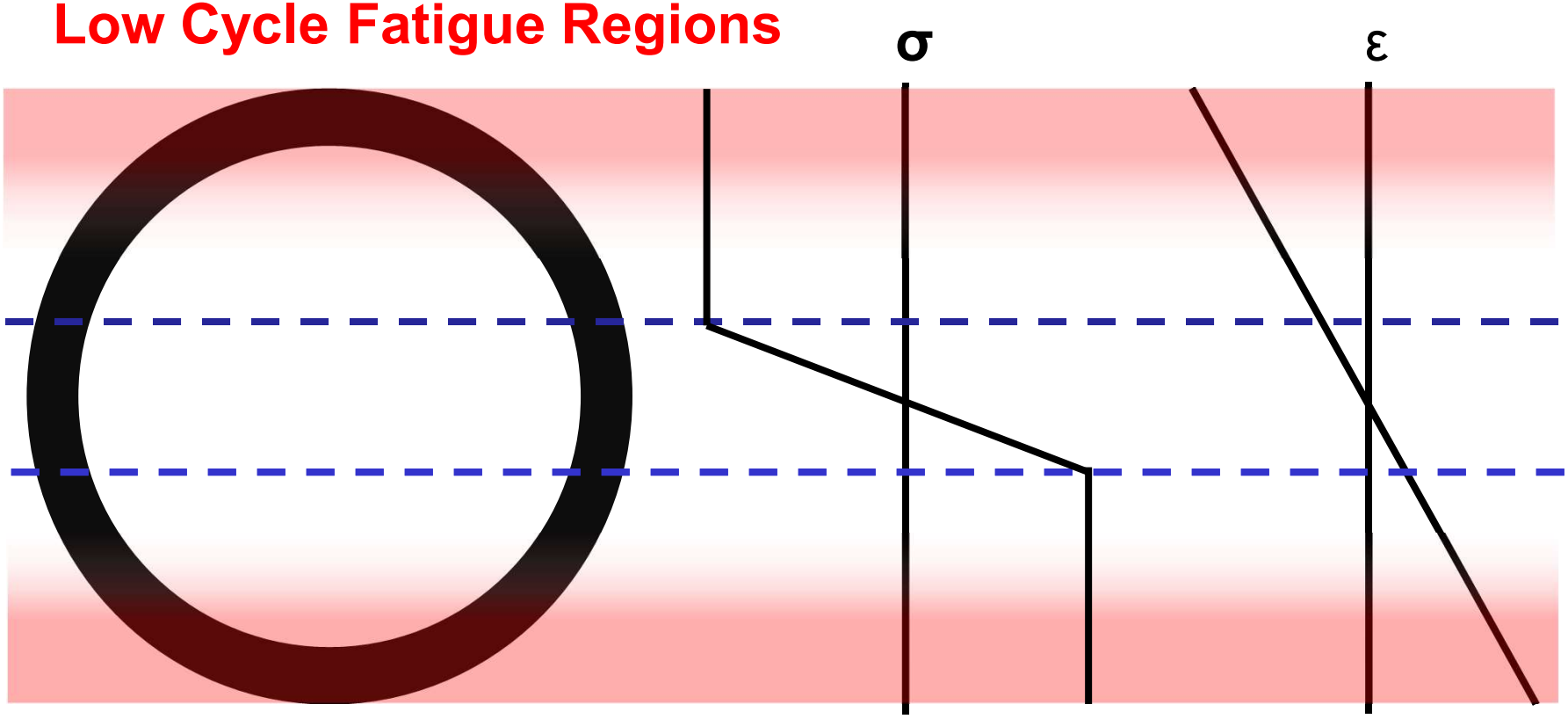


Bending Stress / Strain relationship



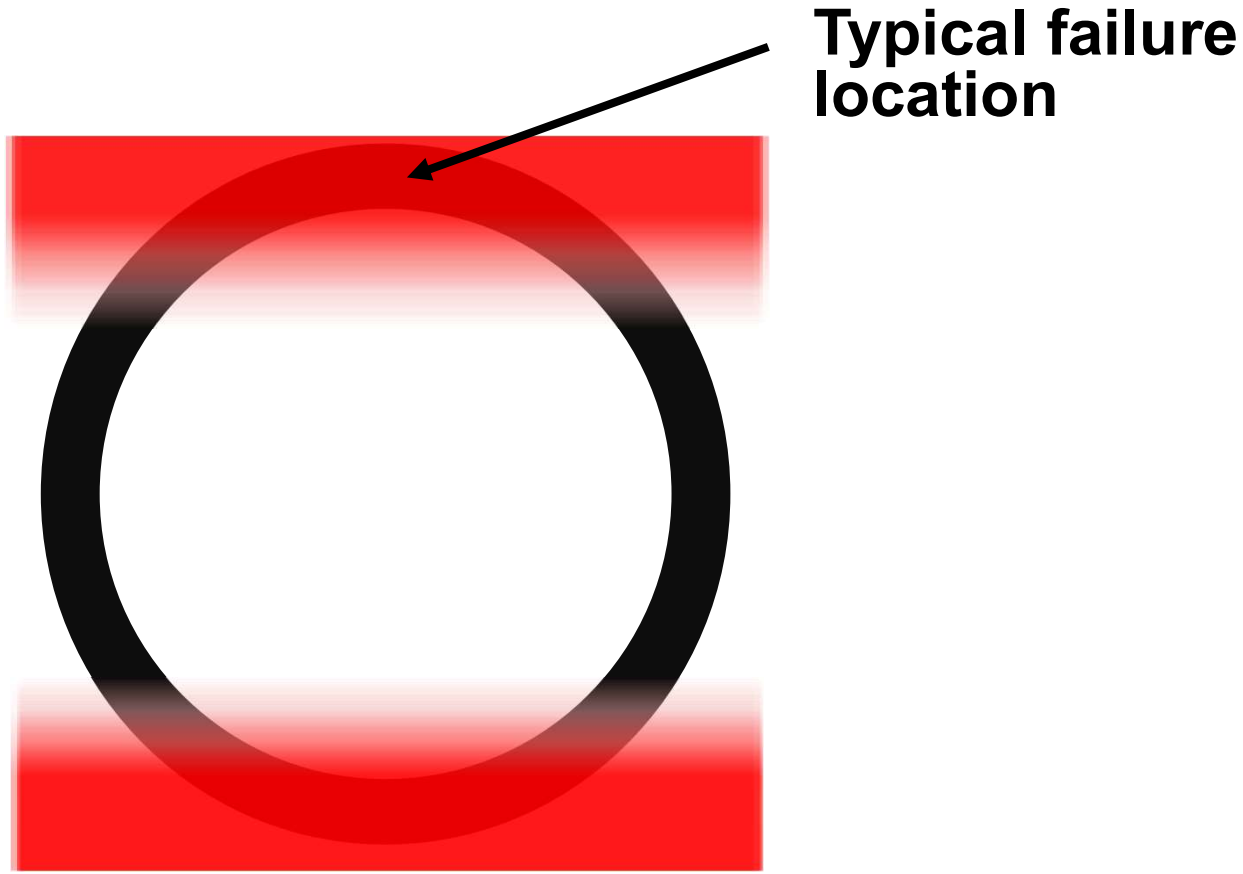
Plastic Deformation Due to Bending

Low Cycle Fatigue Regions

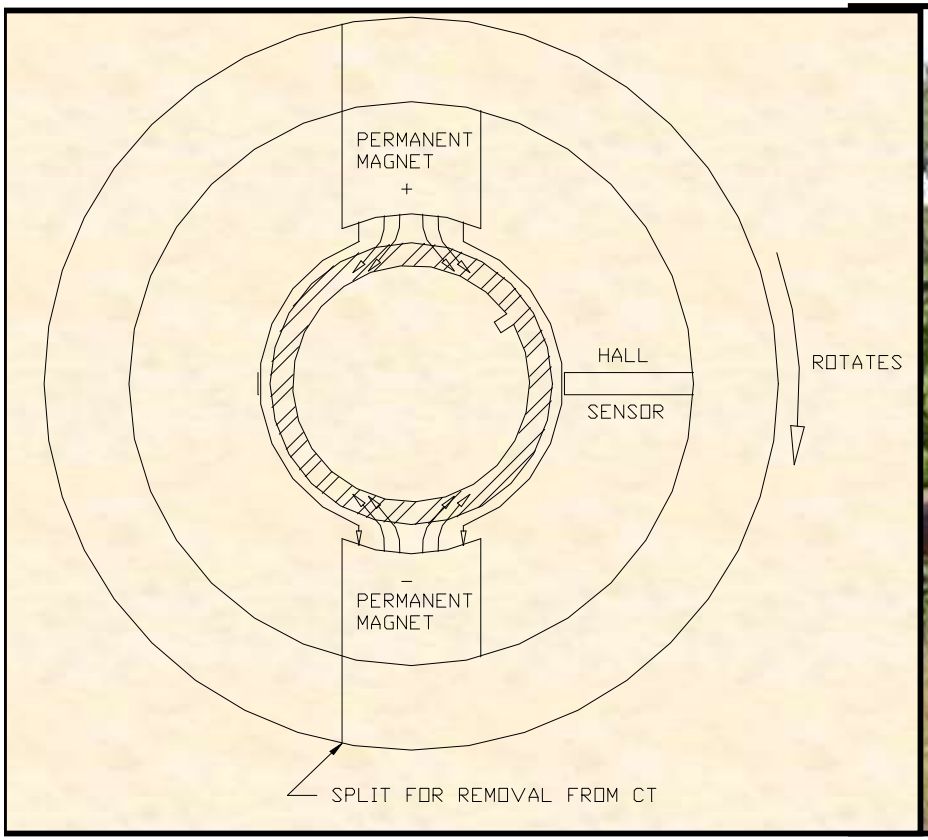


Standard CT Fatigue Testing

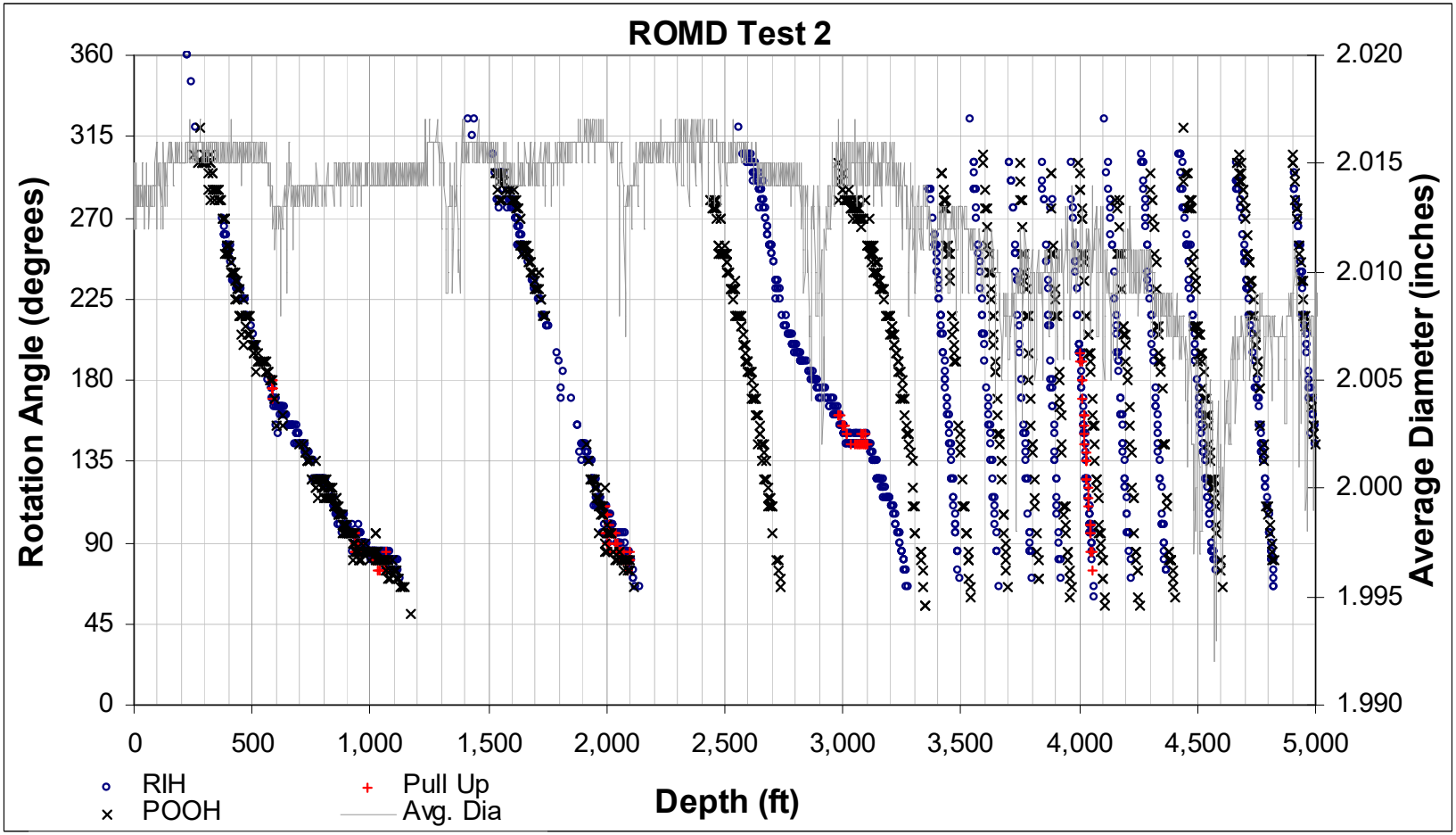
Fatigue Damage Accumulation
Standard CT Fatigue Testing



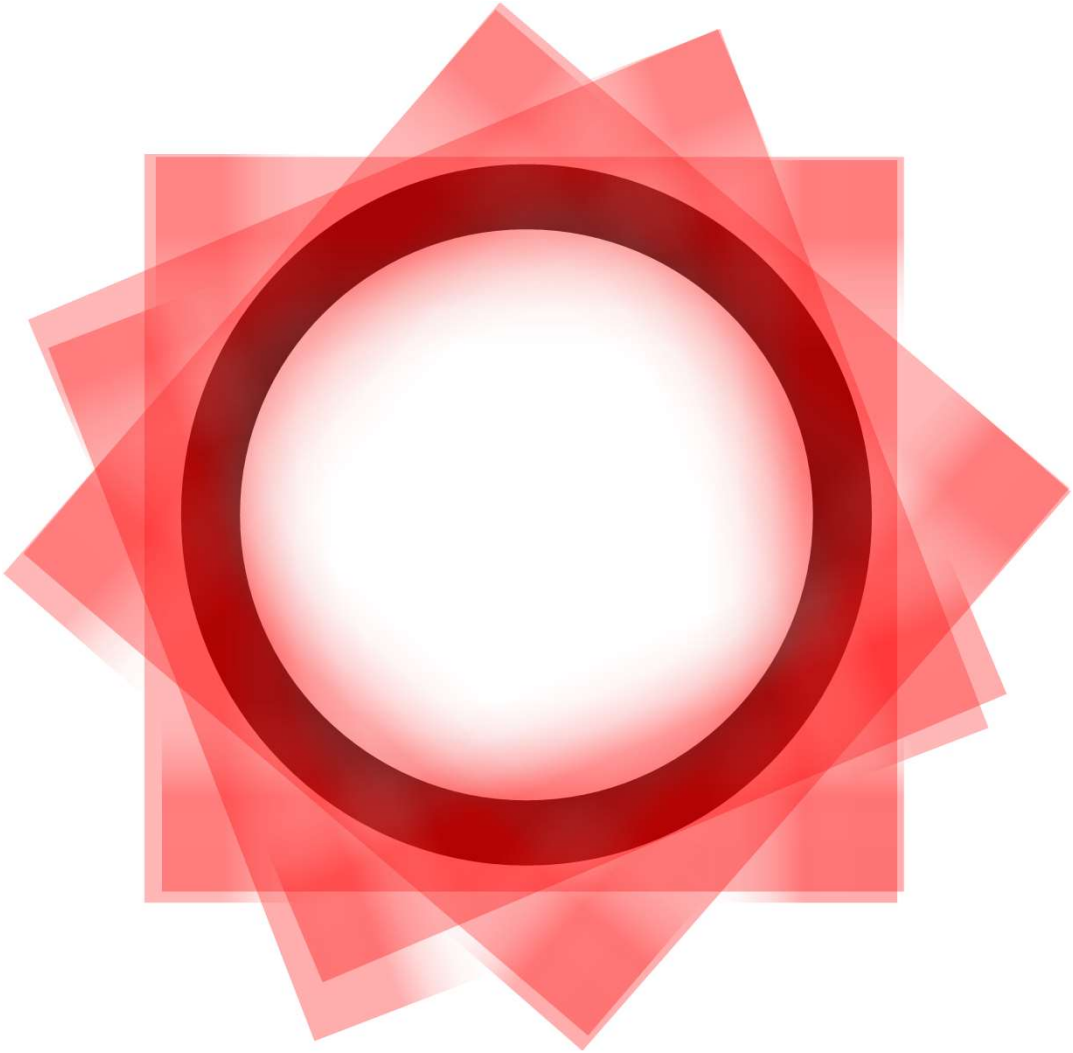
Rotational Orientation Measuring Device (ROMD)



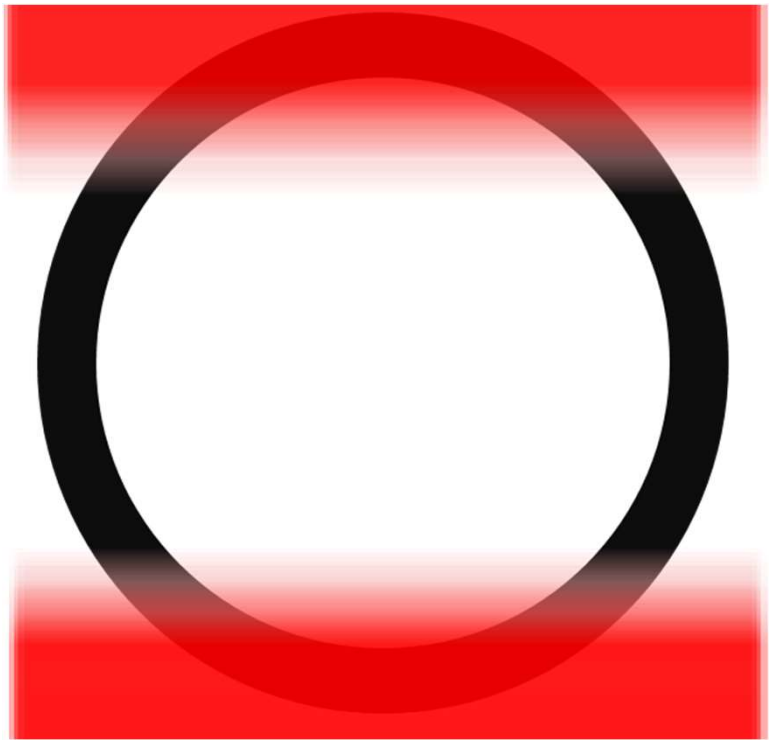
Pipe Twist – Seam weld tracking

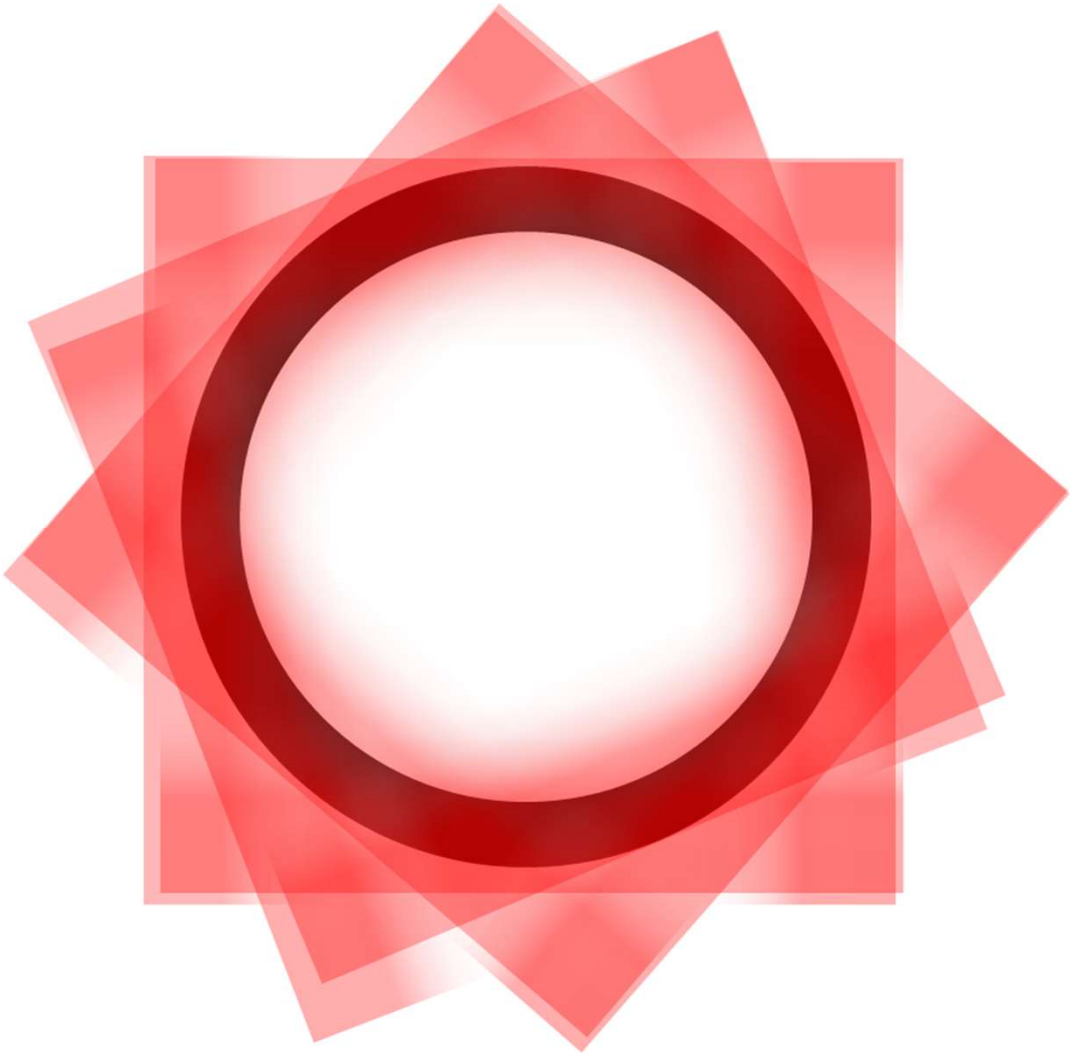


Fatigue Damage Accumulation with evenly distributed twist



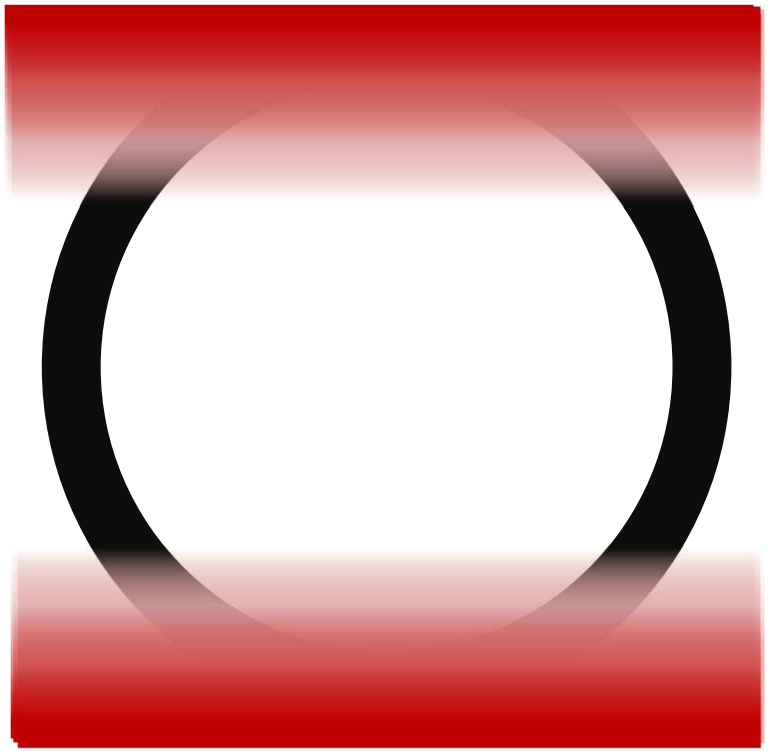
Comparison of accumulations





Fatigue Damage Accumulation with 180 degree twist

Alternating Reversed Bends



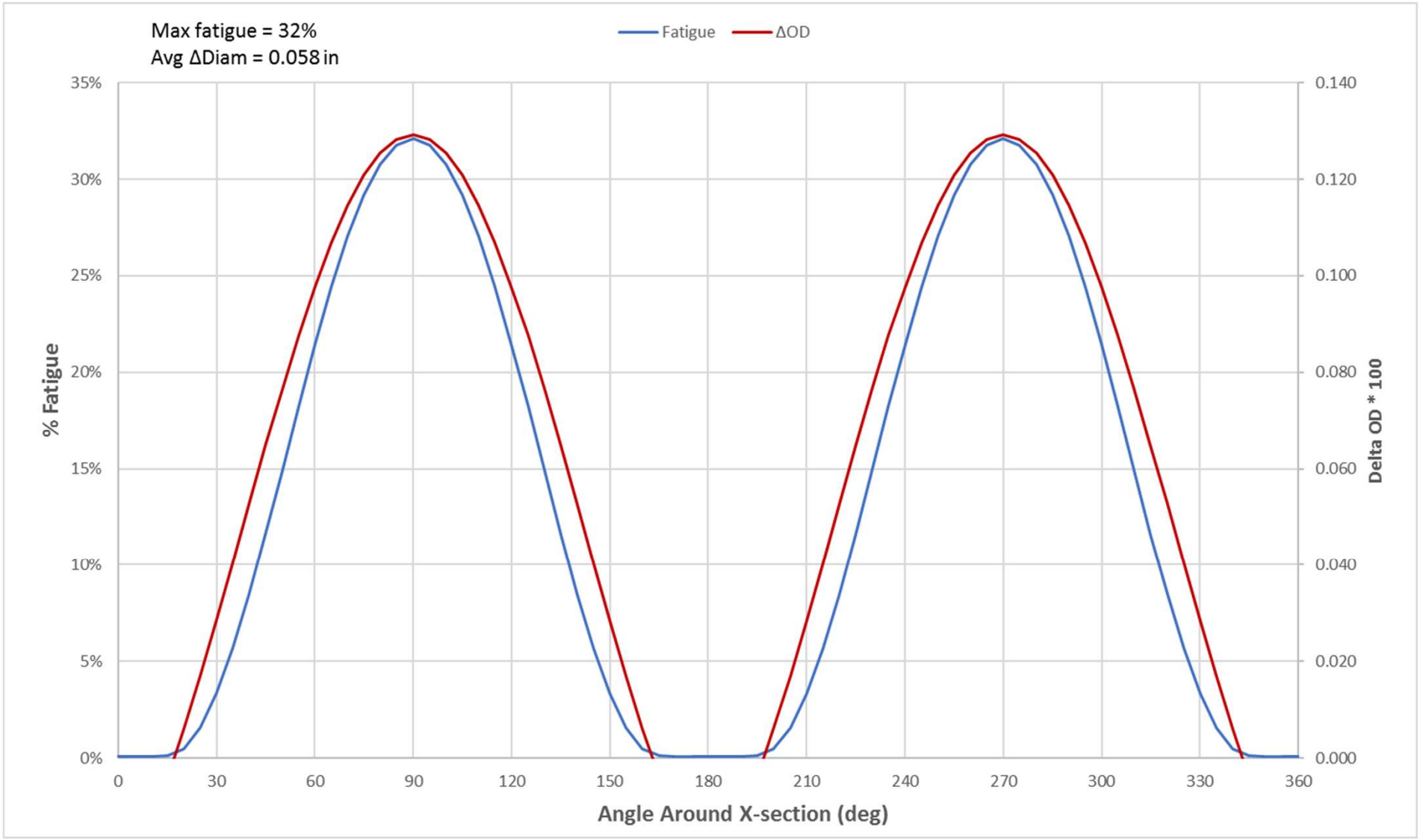
CT Fatigue and Deformation

- Athena has developed a fatigue model that includes rotation and diameter growth
- In 1990's Radovan Rolovic developed a CT plasticity model called "CTdef"
- These models are being used in this work

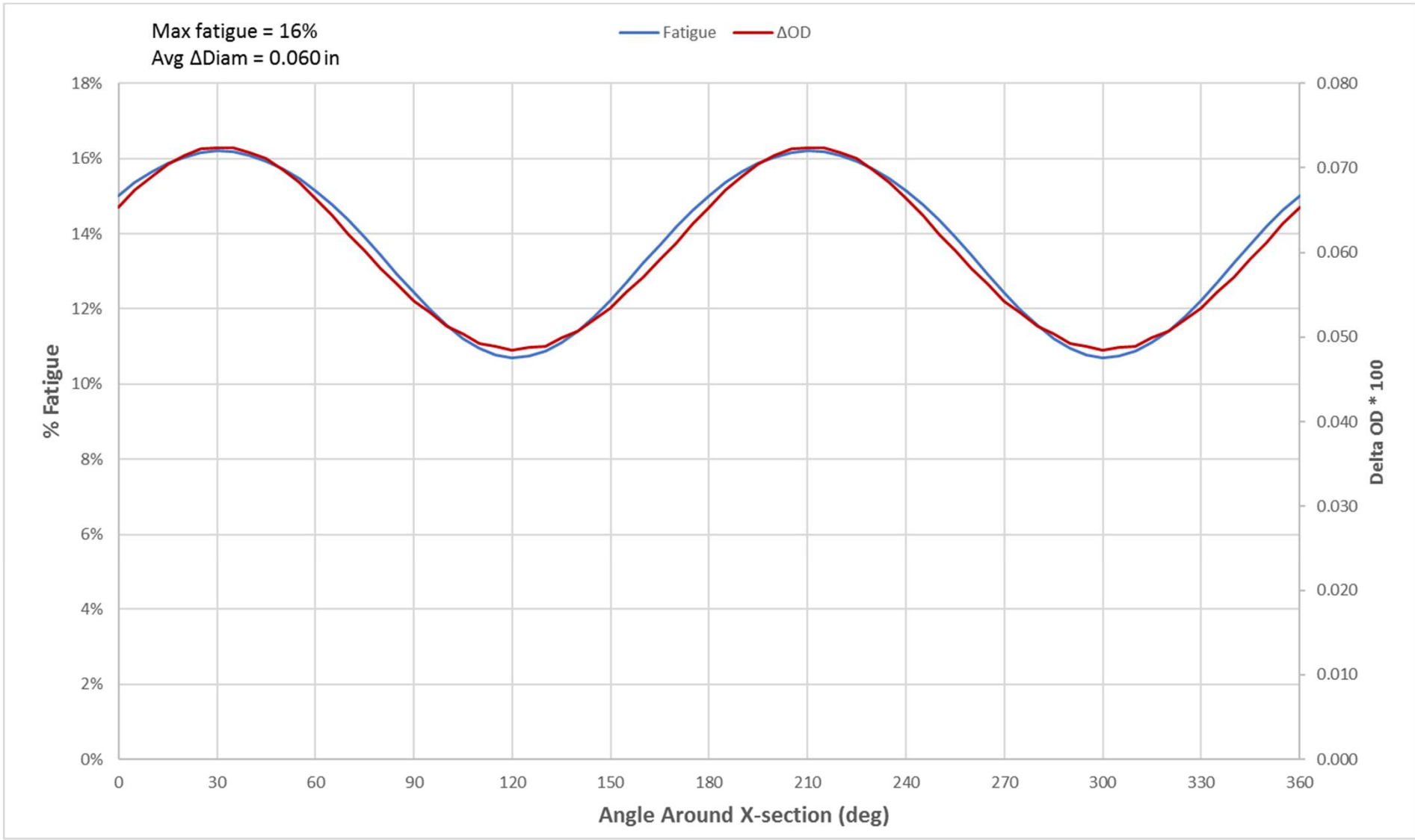
Fatigue with Rotation Base Case

- 2” X .203” 90 Grade CT
- 5,000 psi internal pressure
- No axial force
- 72” guide arch
- 96” reel diameter
- 30 trips
- Rotation once per trip

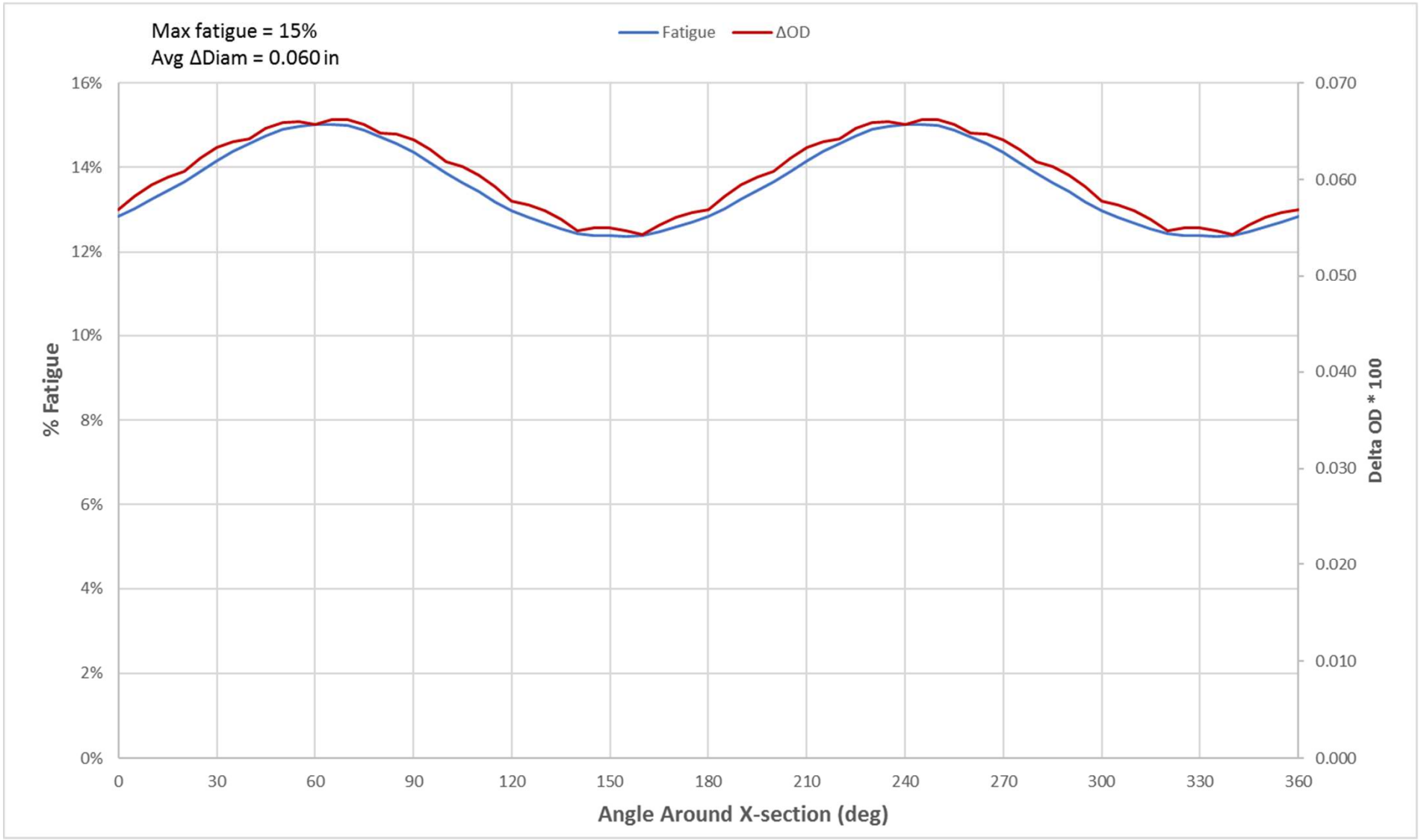
No Rotation


Max fatigue = 32%
Avg ΔDiam = 0.058 in
Fatigue
ΔOD
% Fatigue
Delta OD * 100
Angle Around X-section (deg)
35%
30%
25%
20%
15%
10%
5%
0%
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0
30
60
90
120
150
180
210
240
270
300
330
360

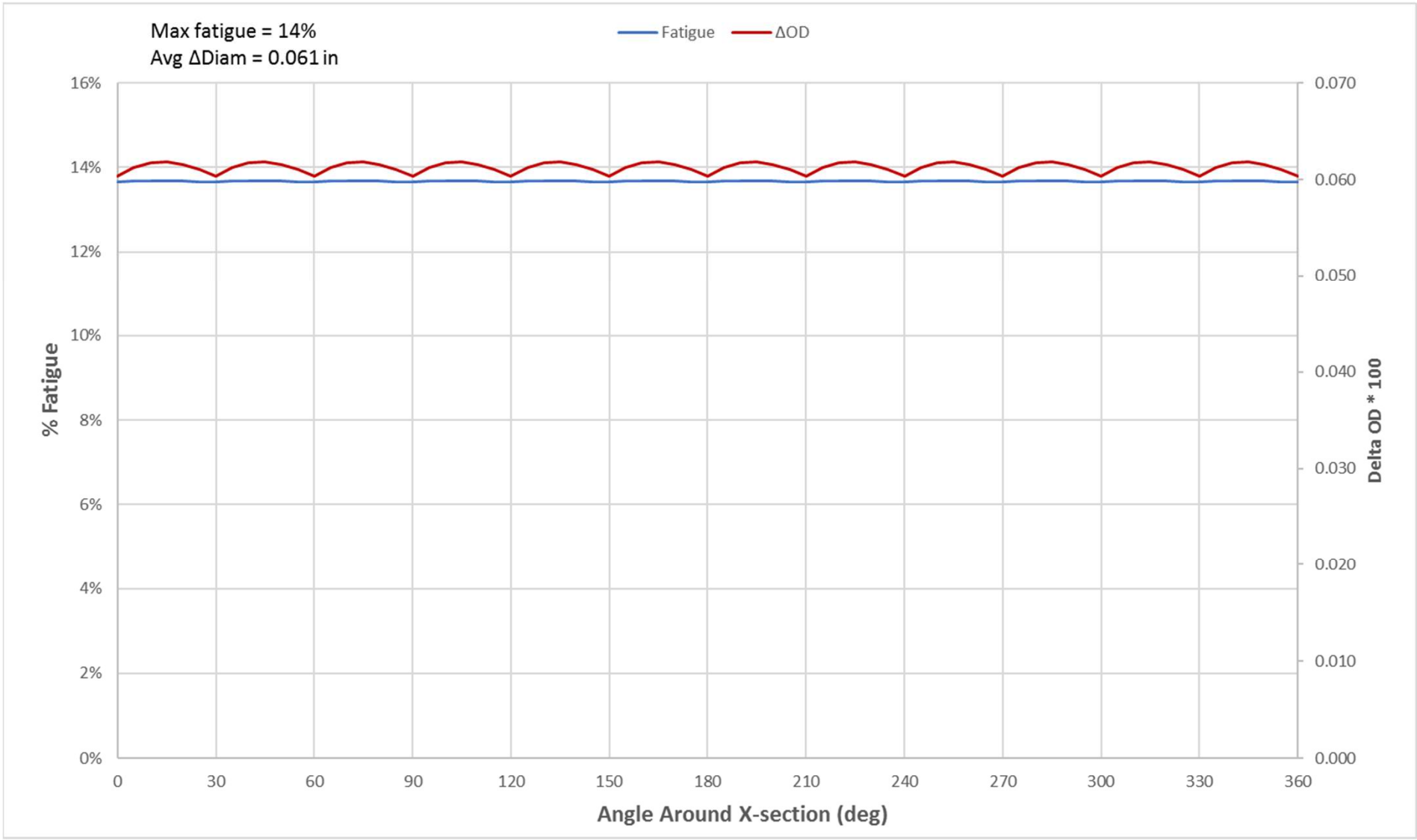
Rotation 10 deg/trip



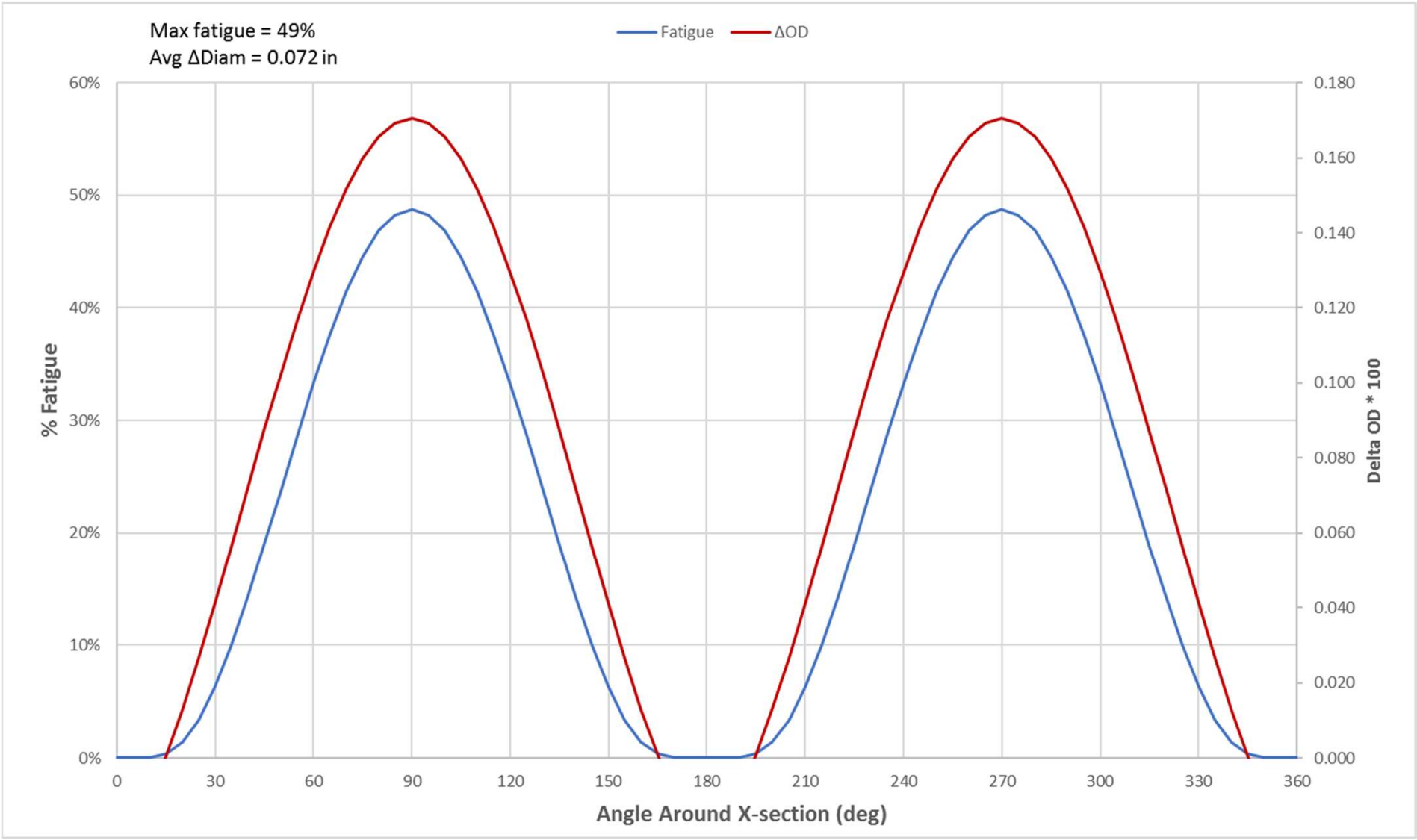
Rotation 20 deg/trip



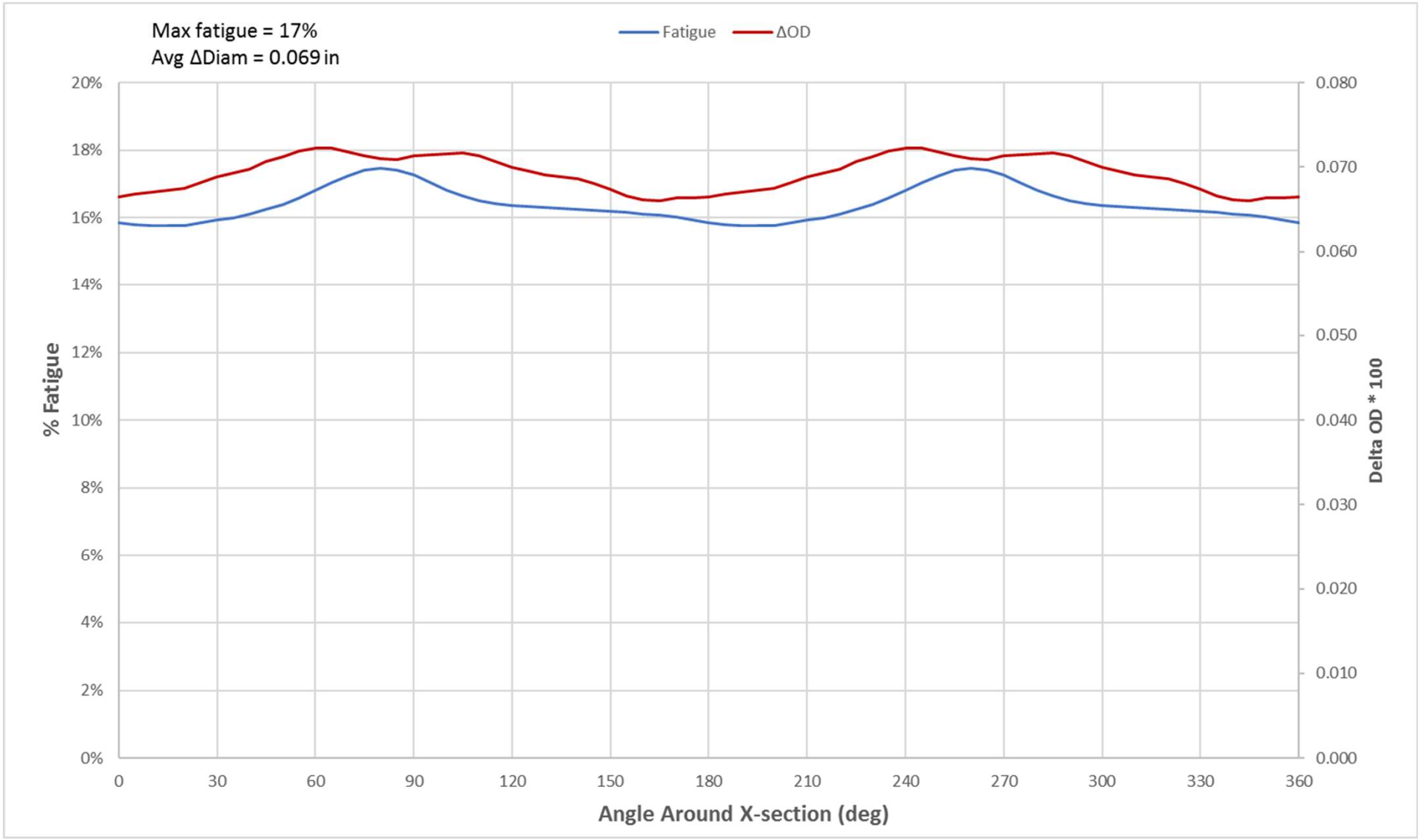
Rotation 30 deg/trip



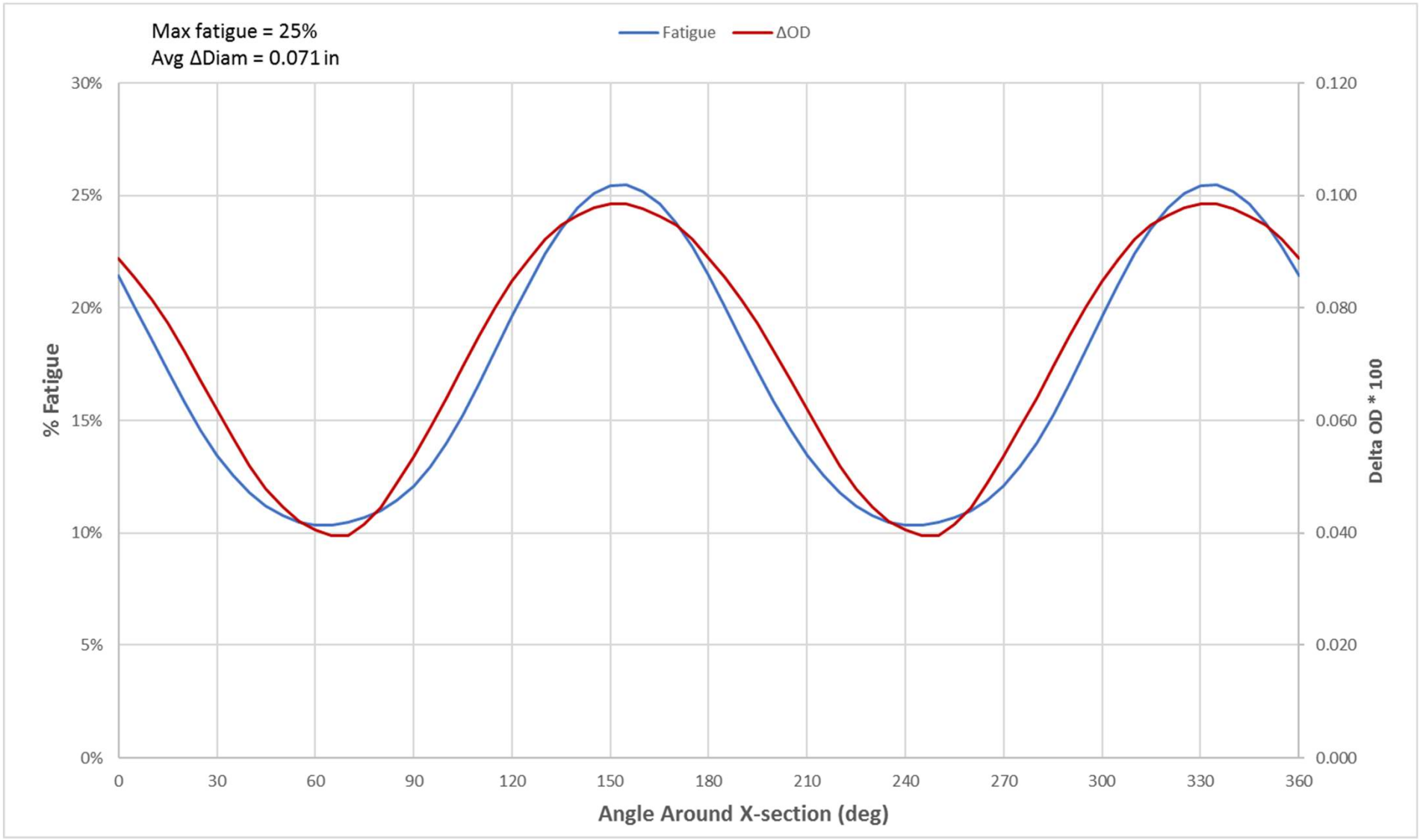
Rotation 180 deg/trip



Random Rotation



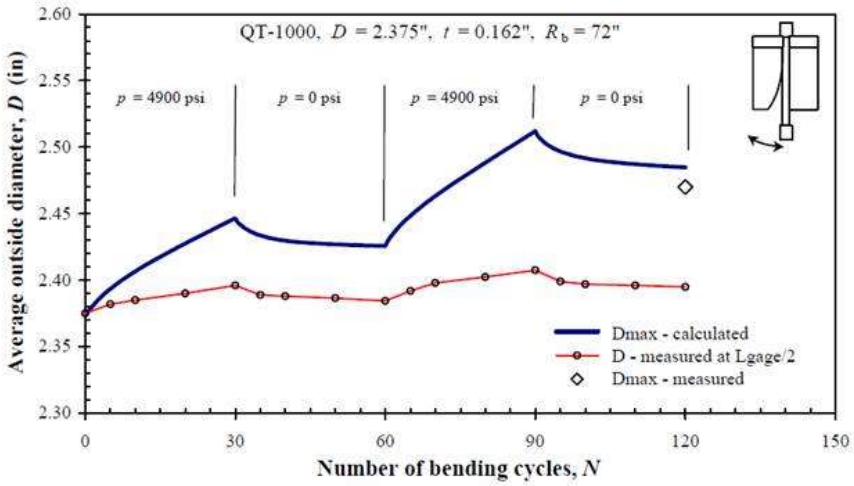
Random Rotation

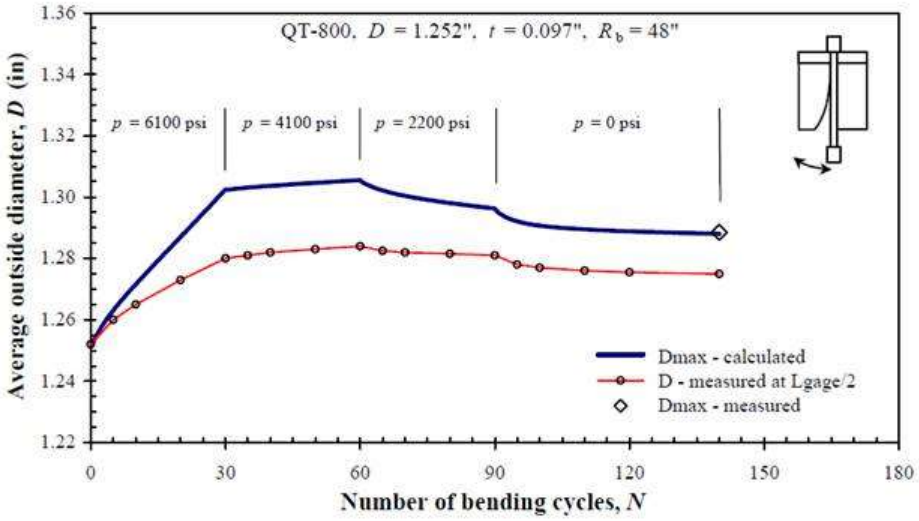


CT Deformation
Diameter Growth

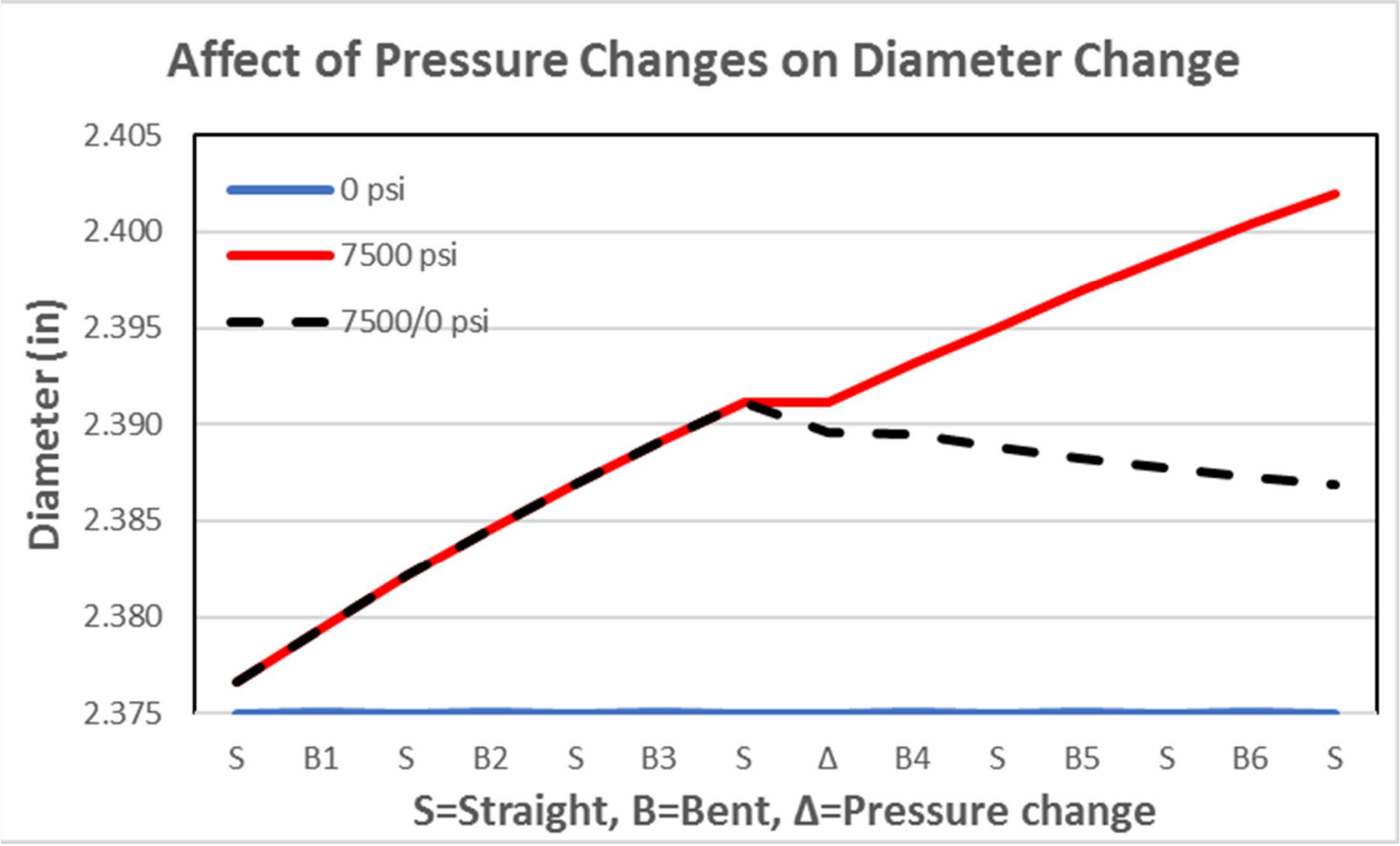
- Diameter growth models have been developed based on diameters measured from fatigue test data
- These models are implemented in programs like Cerberus to predict diameter growth along the length of the CT string
- The predictions from these models tend to over predict the growth when compared to measured data in the field
- The purpose of this analysis is to determine why these models over predict the diameter growth

Variation in Internal Pressure





Varying Pressure



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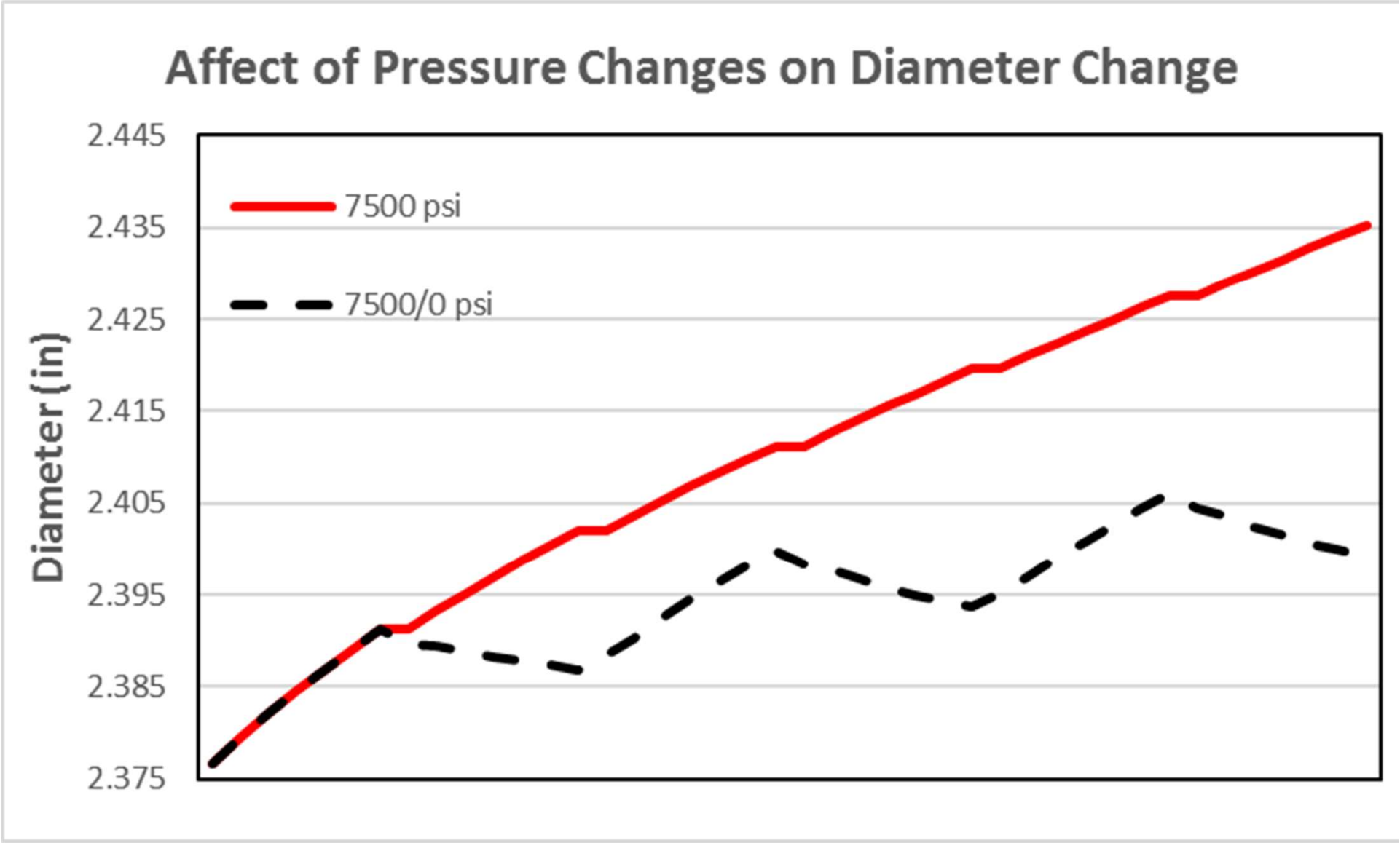
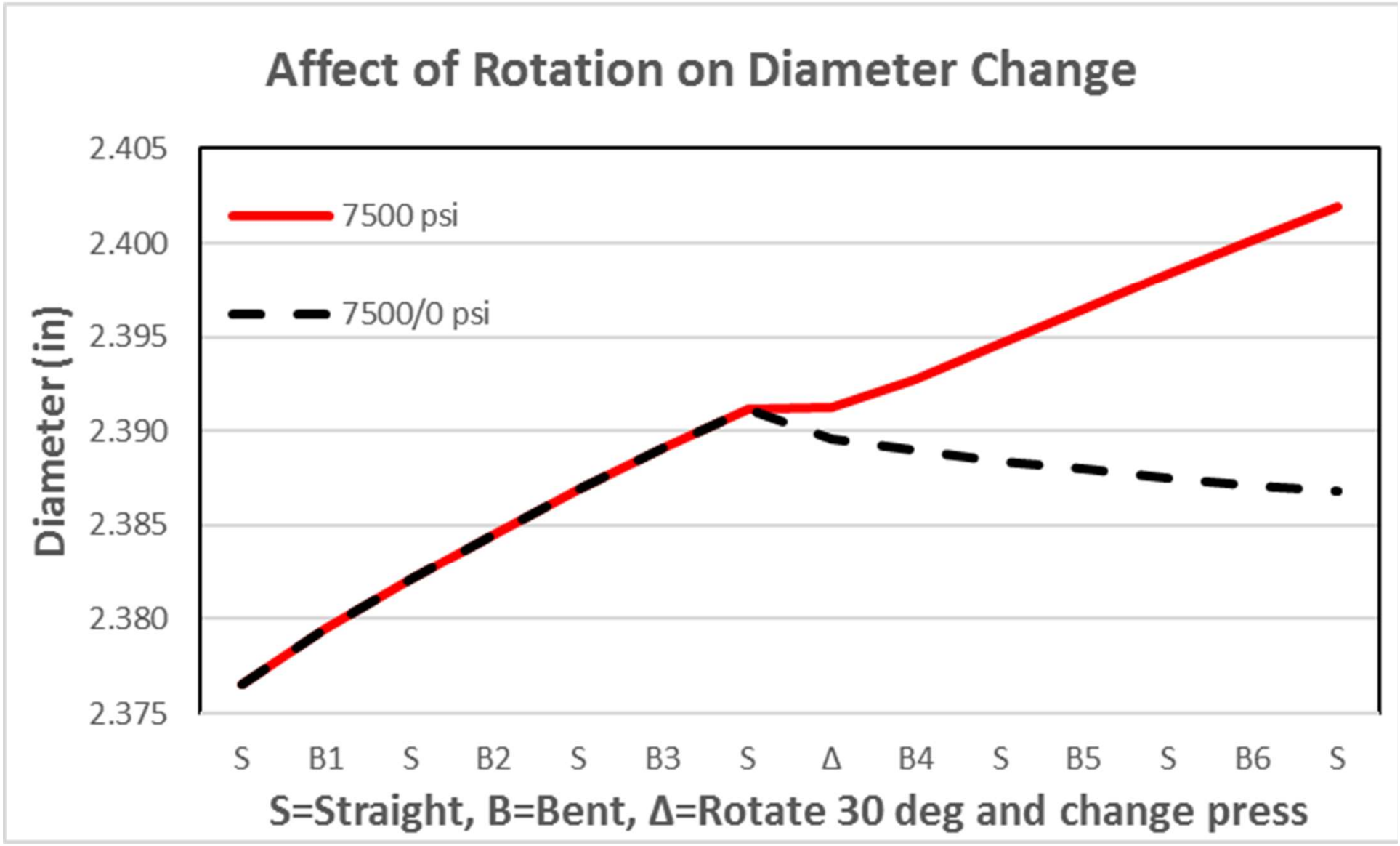
Varying Pressure



Affect of Rotation on Diameter

- The Athena model and the CTdef model were used to model the affect of rotation on diameter growth.
- Surprisingly, both models predicted that rotation would have a minimal impact on diameter growth

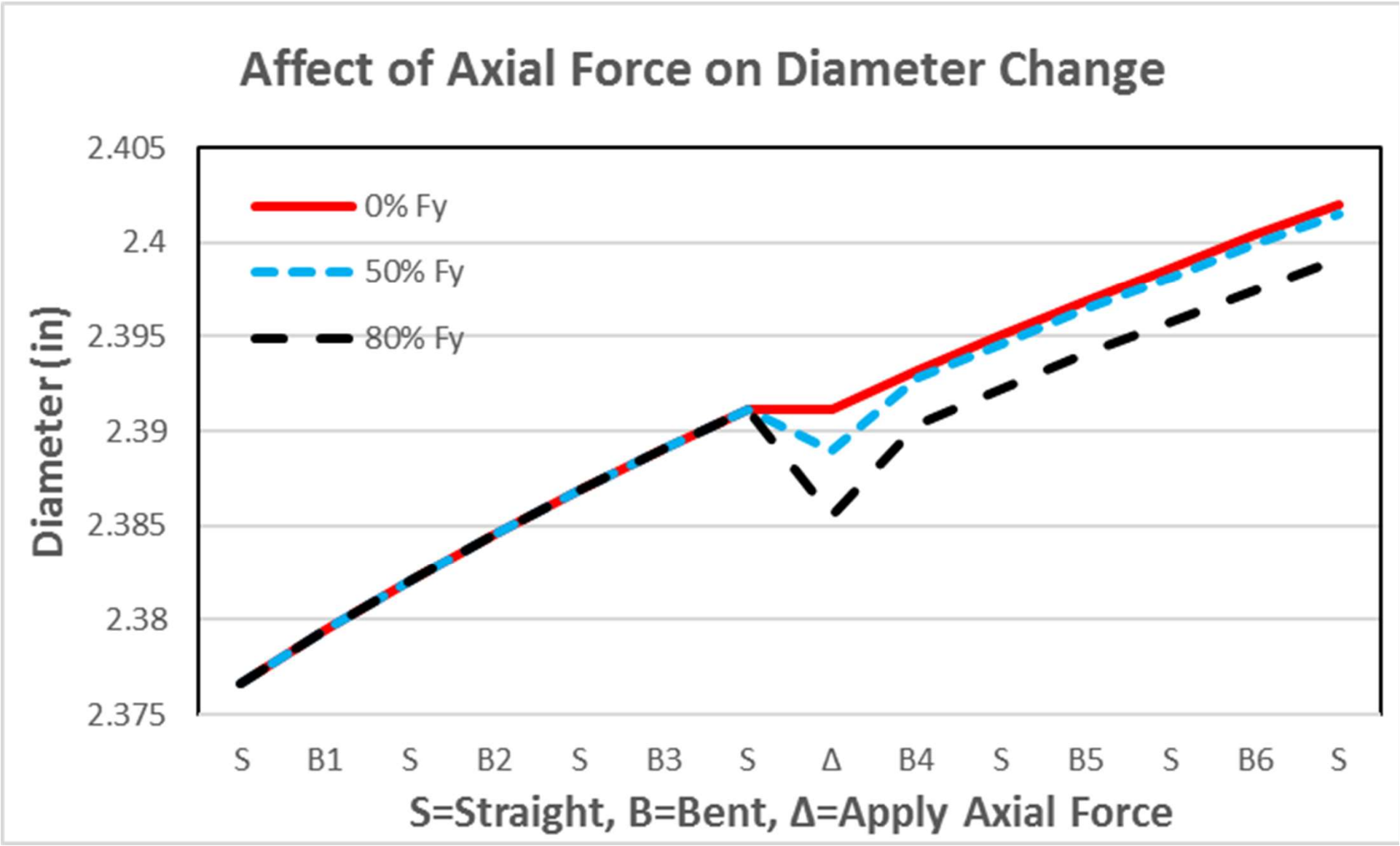
Rotation


Affect of Rotation on Diameter Change
Diameter (in)
2.405
2.400
2.395
2.390
2.385
2.380
2.375
7500 psi
7500/0 psi
S
B1
S
B2
S
B3
S
Δ
B4
S
B5
S
B6
S
S=Straight, B=Bent, Δ=Rotate 30 deg and change press

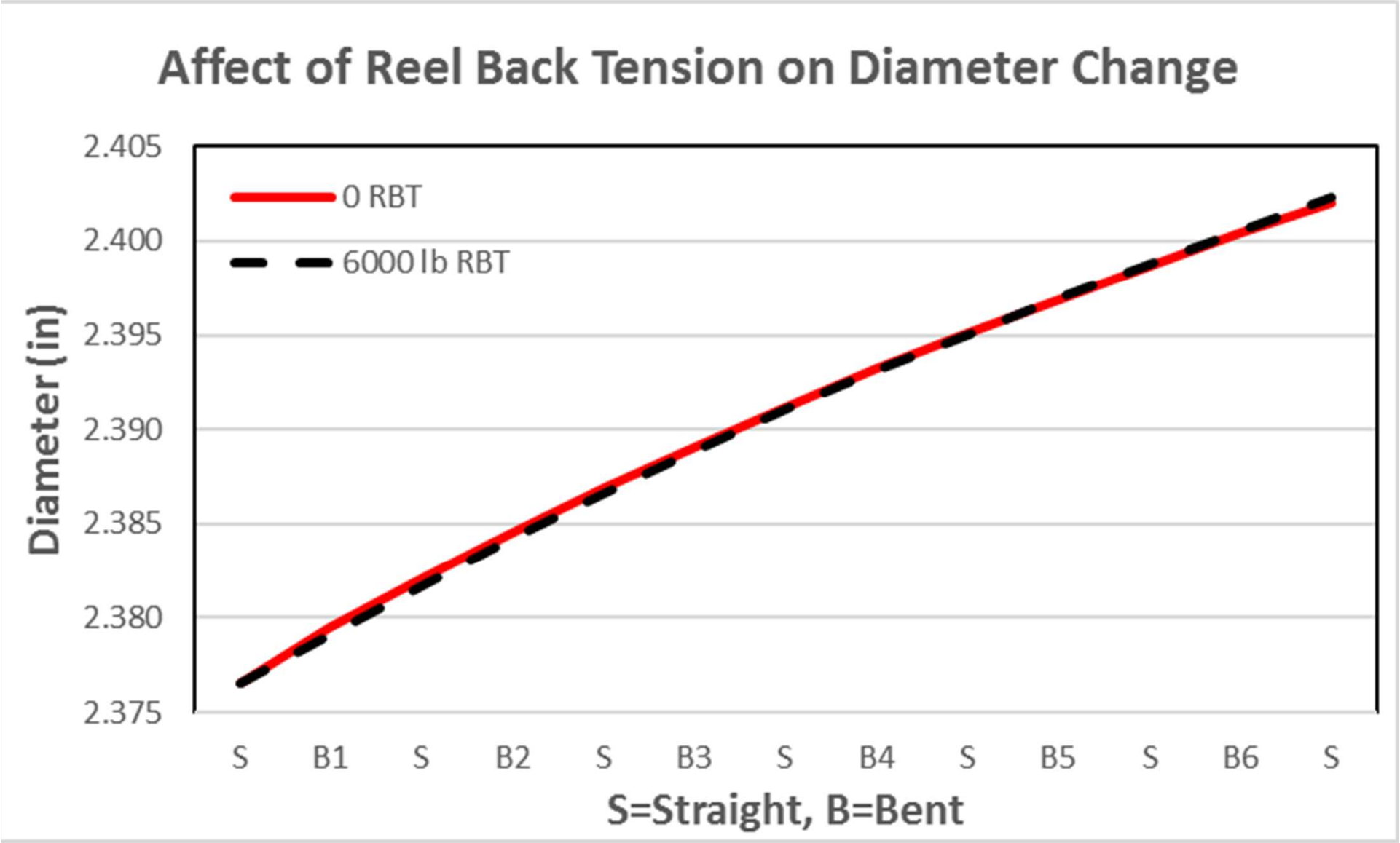
Affects of Axial Force on Diameter Change

- There are two types of axial force which are applied to the CT.
  - Axial force in the well. This can be a large force, up to 80% of the yield force
  - Reel Back Tension (RBT) – this is a fairly small force applied between the reel and the guide arch to keep the CT from springing off the reel

Large Weight Force Applied in the Well



Reel Back Tension



Summary for Diameter Growth

- As Radovan showed 20 years ago, the changing of internal pressure while bending has a significant impact on diameter growth
- Rotation of the CT has minimal impact on diameter growth
- Weight, while the CT is in the well, has some impact when the weights are high
- Reel back tension has no significant affect
- Radovan did some testing that proved the first point above
- Athena in in the process of doing some testing which will hopefully validate some of the other points.

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Thank You

Questions?