Presented at the COMSOL Conference 2008 Boston

Structural Modeling of a Cooling Catheter Using COMSOL Multiphysics

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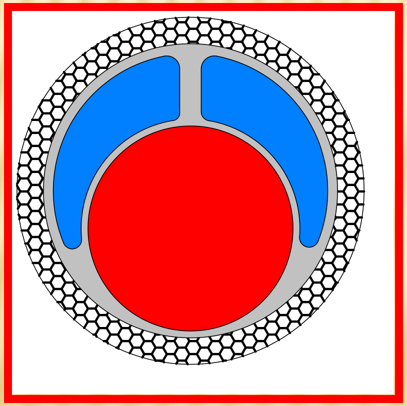
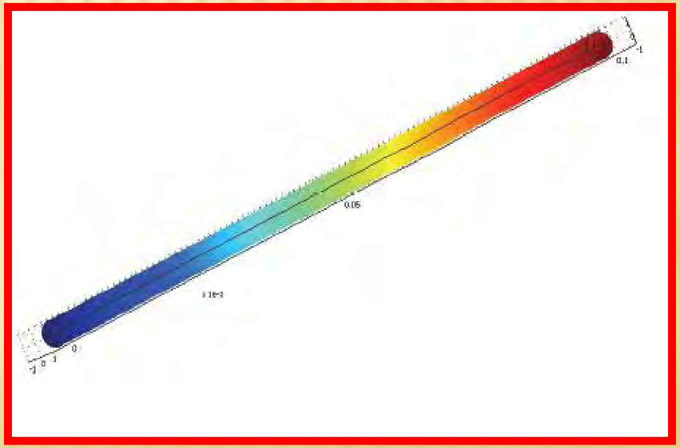




October 9th, 2008

BLUEPRINT

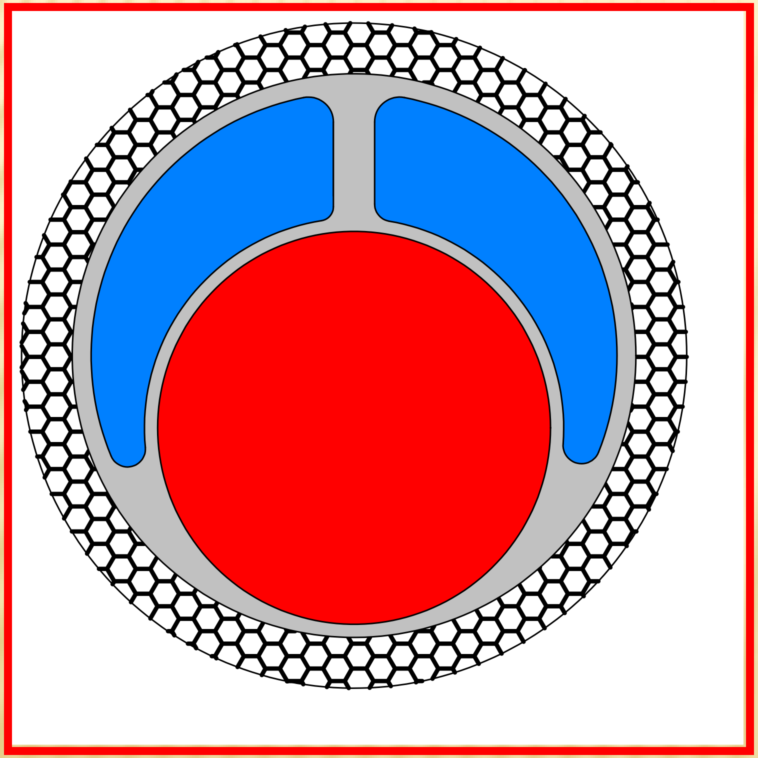
- Clinical Problem
- Background Information
- Objective
- Analytical Procedure
- Comsol Procedure
- Results
- Future Work

THE CLINICAL PROBLEM

- Ischemic tissue damage from 800,000 heart attacks per year and 700,000 strokes per year.
- Tissue damage and resulting patient outcome are highly time sensitive.
- Reperfusion therapy is the preferred primary treatment. Many experts believe we have reached the maximum benefit from reperfusion - adjunct therapies are needed

CURRENT DESIGN

Our multi-lumen design leaves little space for catheter walls. Catheters walls provide torsional strength to allow proper placement inside the body



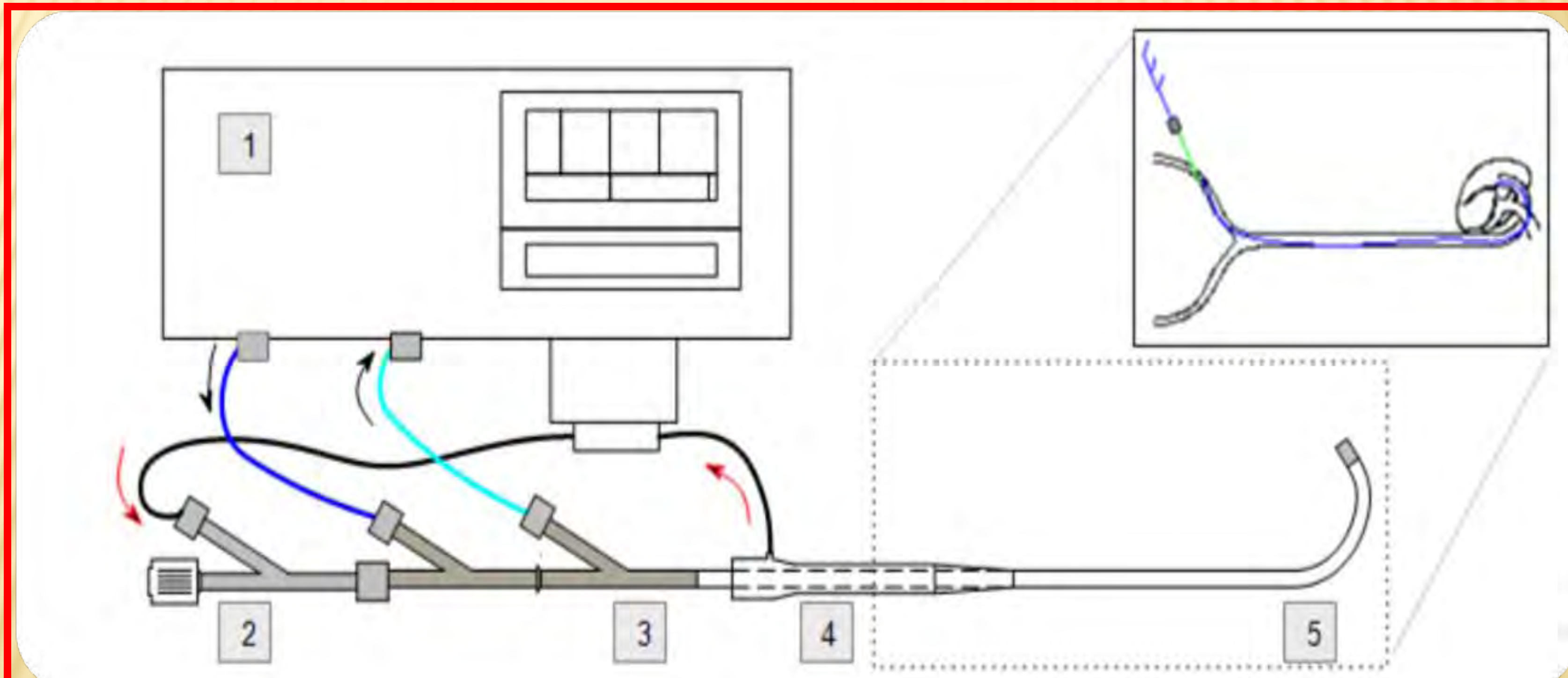
Blue – Coolant pathways (closed circuit)

Red – Blood

Grey- Teflon

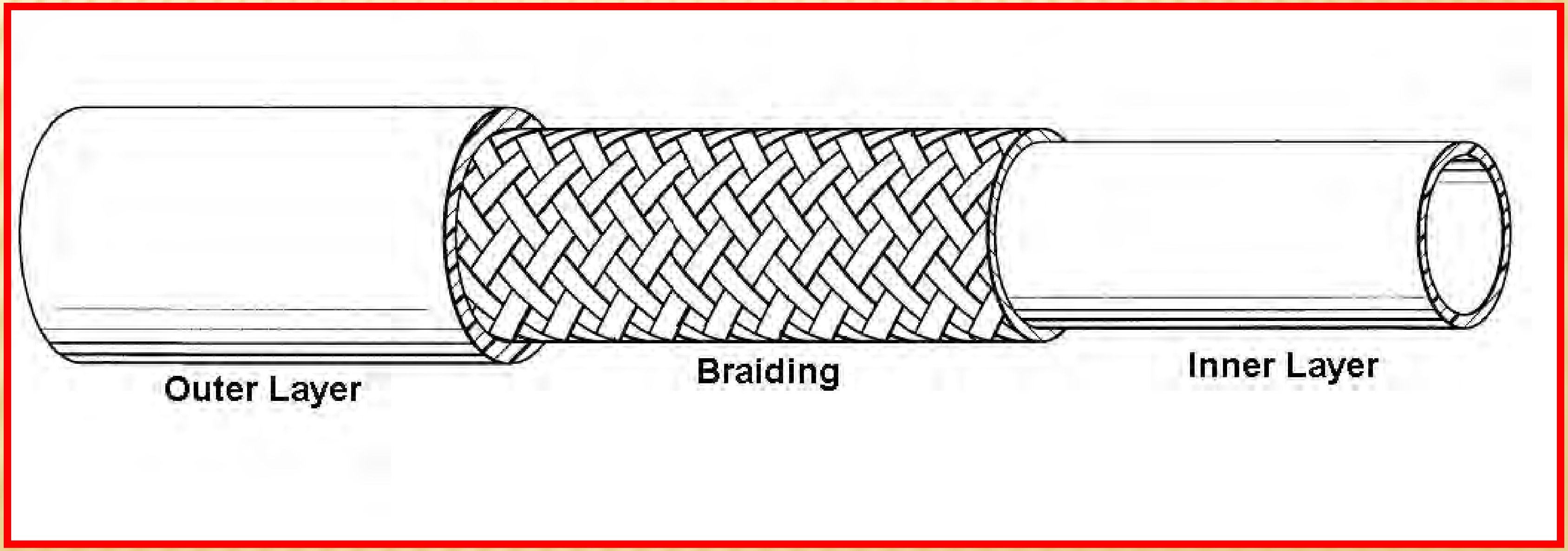
Mesh – Stainless steel-Pebax composite

SCHEMATIC OF CATHETER SYSTEM



TRADITIONAL CATHETER DESIGN

Braided composite walls displace room that is needed for multiple lumens.

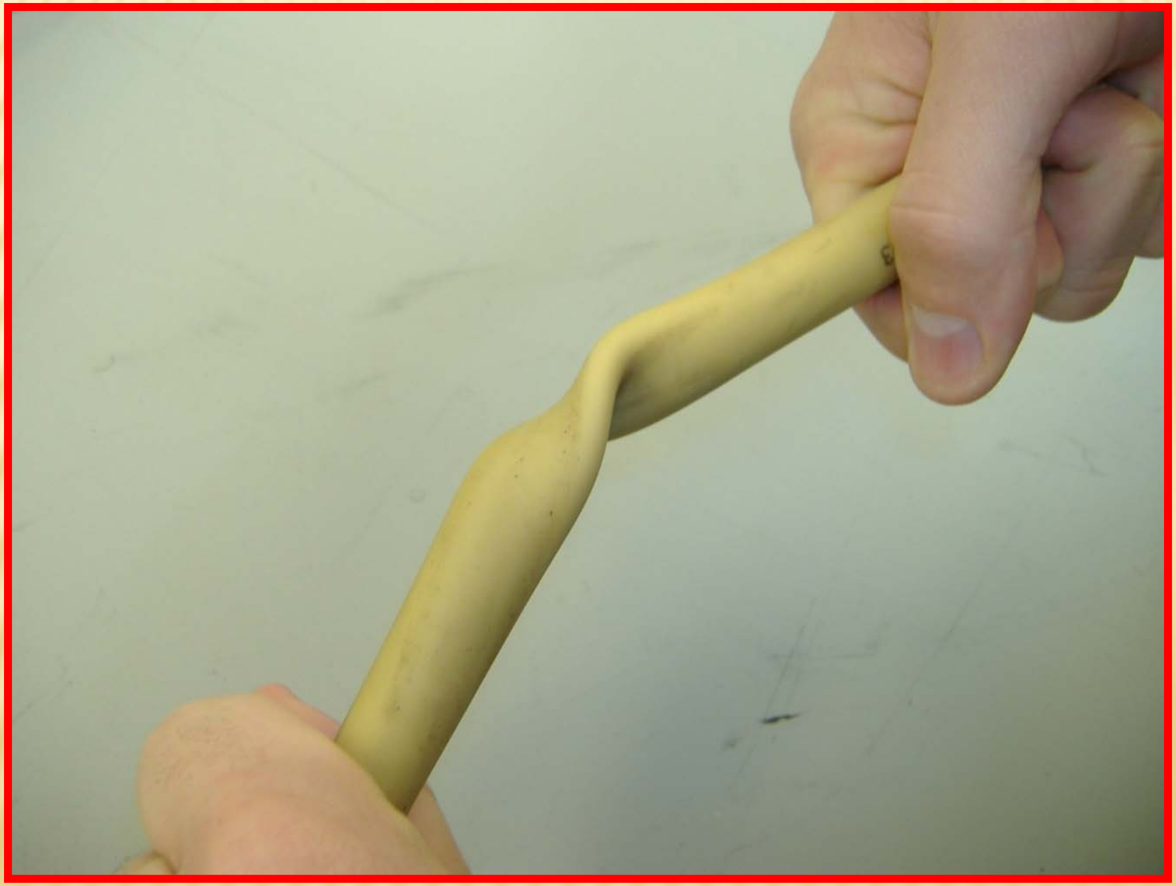


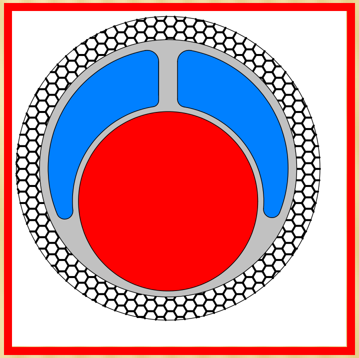
DESIGN GOALS

- Design a blood cooling catheter that maximizes available flow pathway cross sections. Higher flows → higher blood cooling → higher tissue cooling → more tissue saved.
- In terms of acceptable twist angles, our goal is to create a design that is within 10-20% of the braided twist angle for identical applied torques.

TORSIONAL BUCKLING OF A TUBE

Catheter buckling will stop blood and coolant flow





SIMPLIFYING ASSUMPTIONS

- Constant diameter down the length of the catheter
- Single lumen (channel)
- No pressurized coolant flowing throughout the catheter

EQUATIONS

$$J = \frac{\pi}{2}\left(R_{out}{}^{4} - R_{in}{}^{4}\right)$$

$$\phi = \frac{TL}{GJ}$$

J – Polar moment of inertia [m^4]

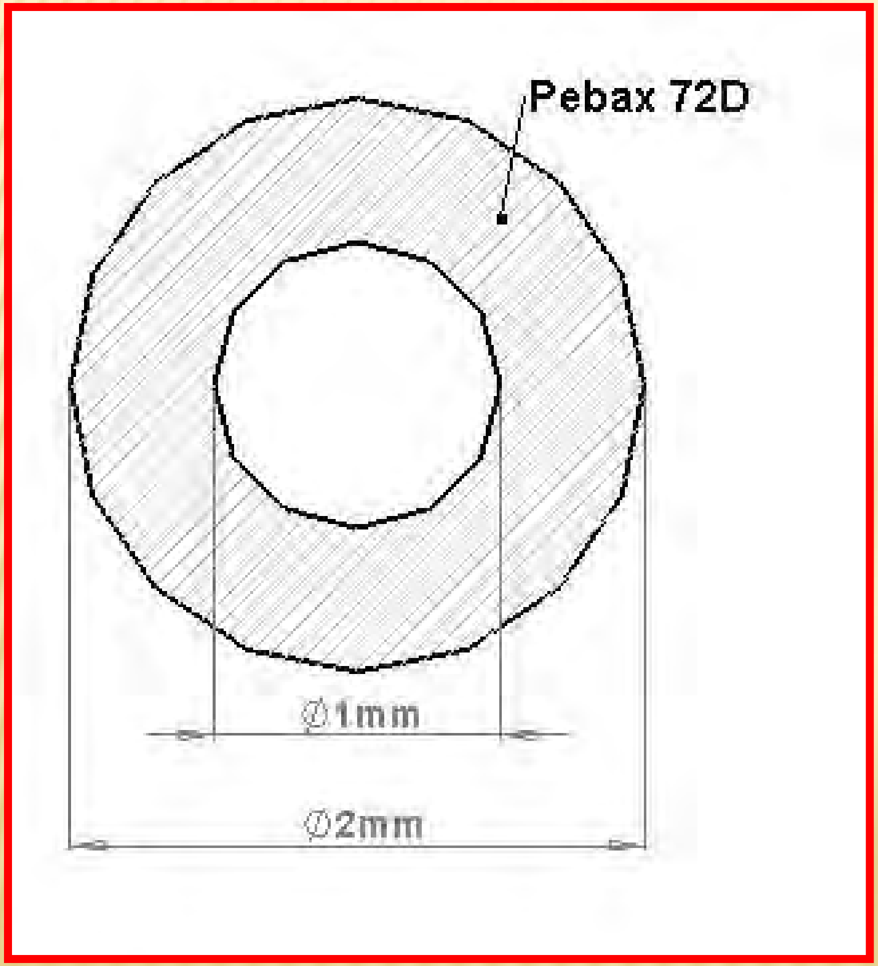
Φ – Angular Deflection [rad]

T – Applied Torque [N-m]

L – Length [cm]

G – Shear modulus [Pa]

ANALYTICAL SOLUTION
HOMOGENOUS TUBE



Material: Pebax 72D

G = 434 MPa

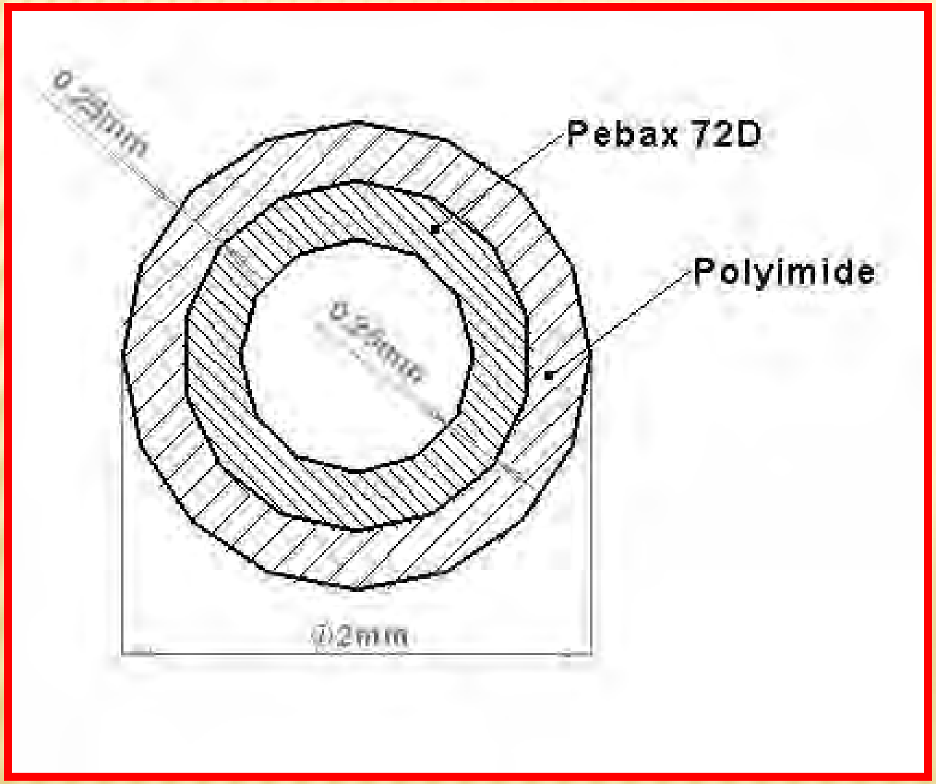
L = 5 cm

J = 1.47×10^{-12} m^4

Torque = 0.003 N-m

Angular Deflection: 0.235 rad

ANALYTICAL SOLUTION
COMPOSITE TUBE



Inner Layer: Pebax 72D
Outer Layer: Polyimide

G_{eff} = 9.99 GPa

L = 5 cm
J = 1.47×10^{-12} m^4

Torque = 0.003 N-m

Angular Deflection: 0.0373 rad

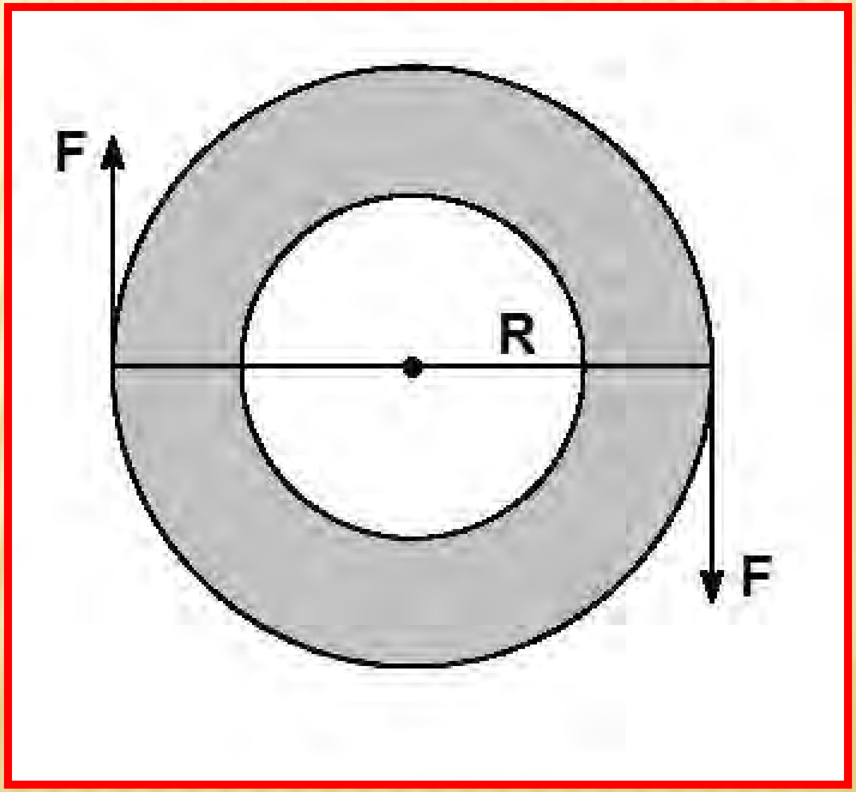
COMSOL (POINT SETTINGS)

$$T = 2 \cdot R \cdot F$$

F = Coupler Forces [N]

R = Radius of catheter [m]

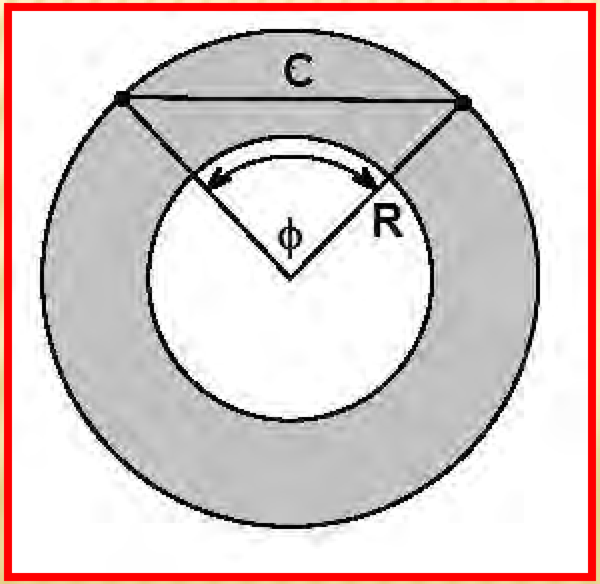
T = Applied torque or moment [N-m]



ANGULAR DEFLECTION

$$C = \sqrt{u^2 + v^2}$$

$$R = \sqrt{X^2 + Y^2}$$



C – Total Displacement [m]

u – Displacement in the x-direction [m]

v – Displacement in the y-direction [m]

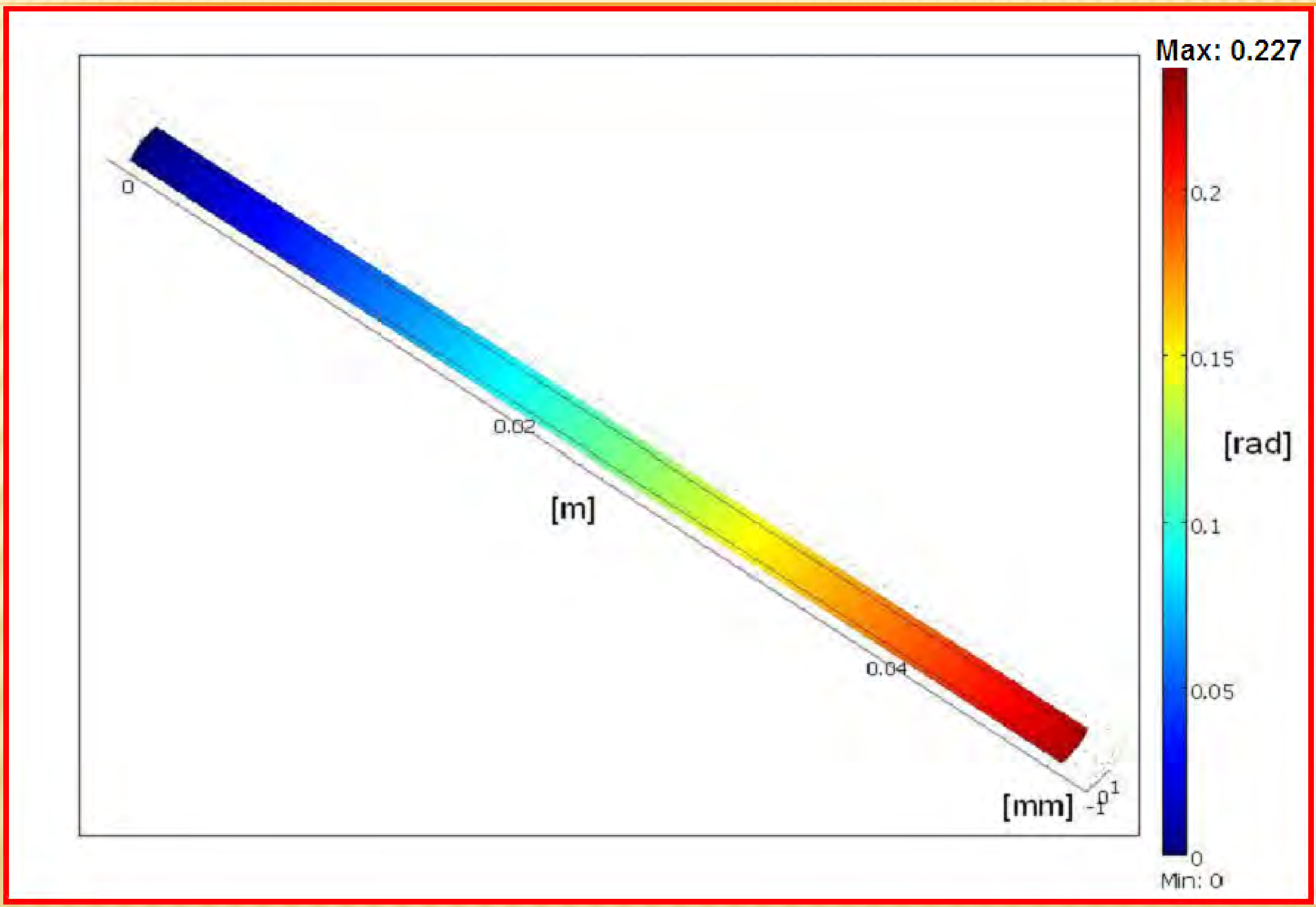
R – Radius of catheter [m]

X – Initial x coordinate of the point [m]

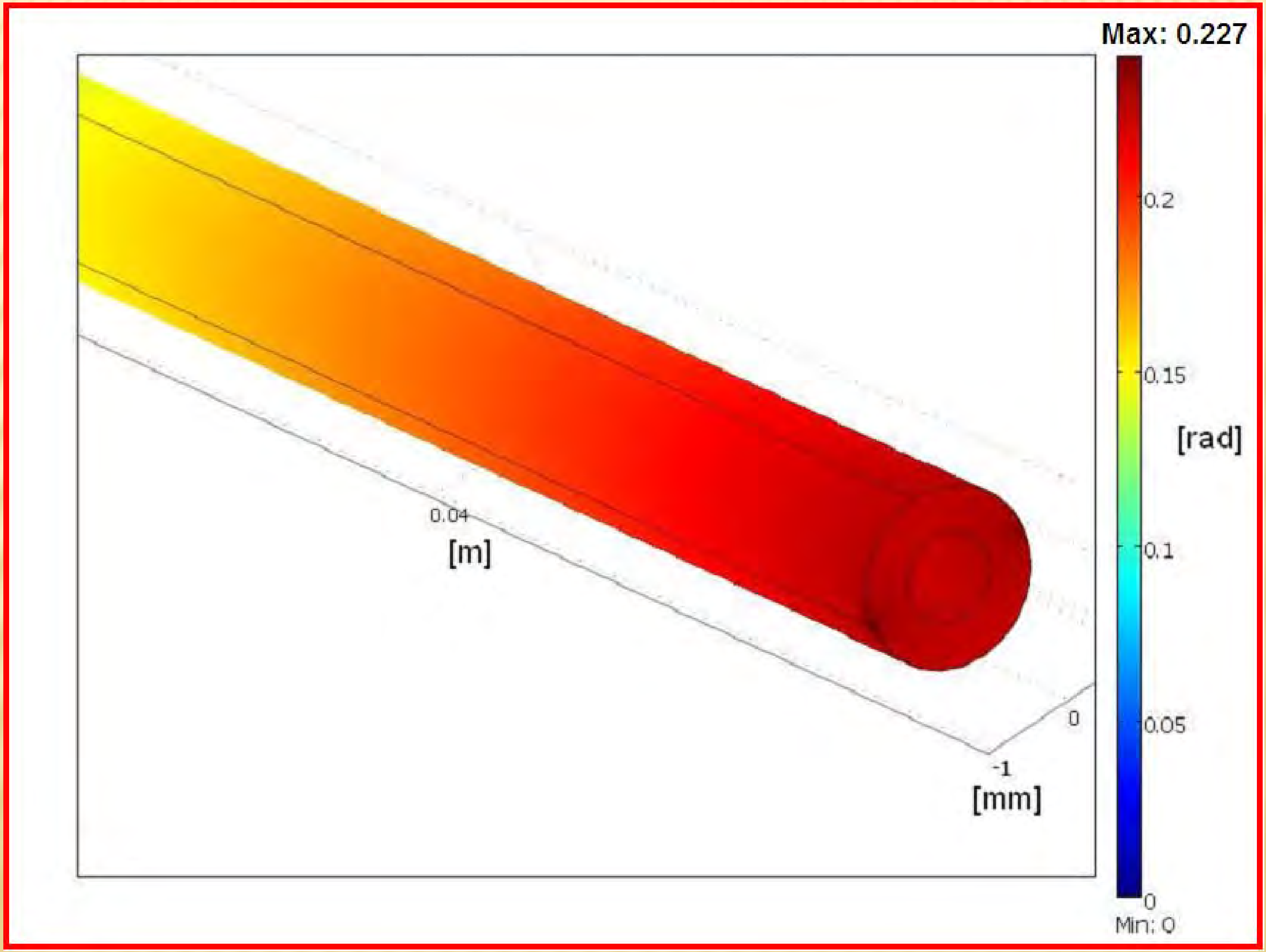
Y – Initial y coordinate of the point [m]

$$\phi = 2 \cdot \sin^{-1}\left(\frac{C}{2R}\right)$$

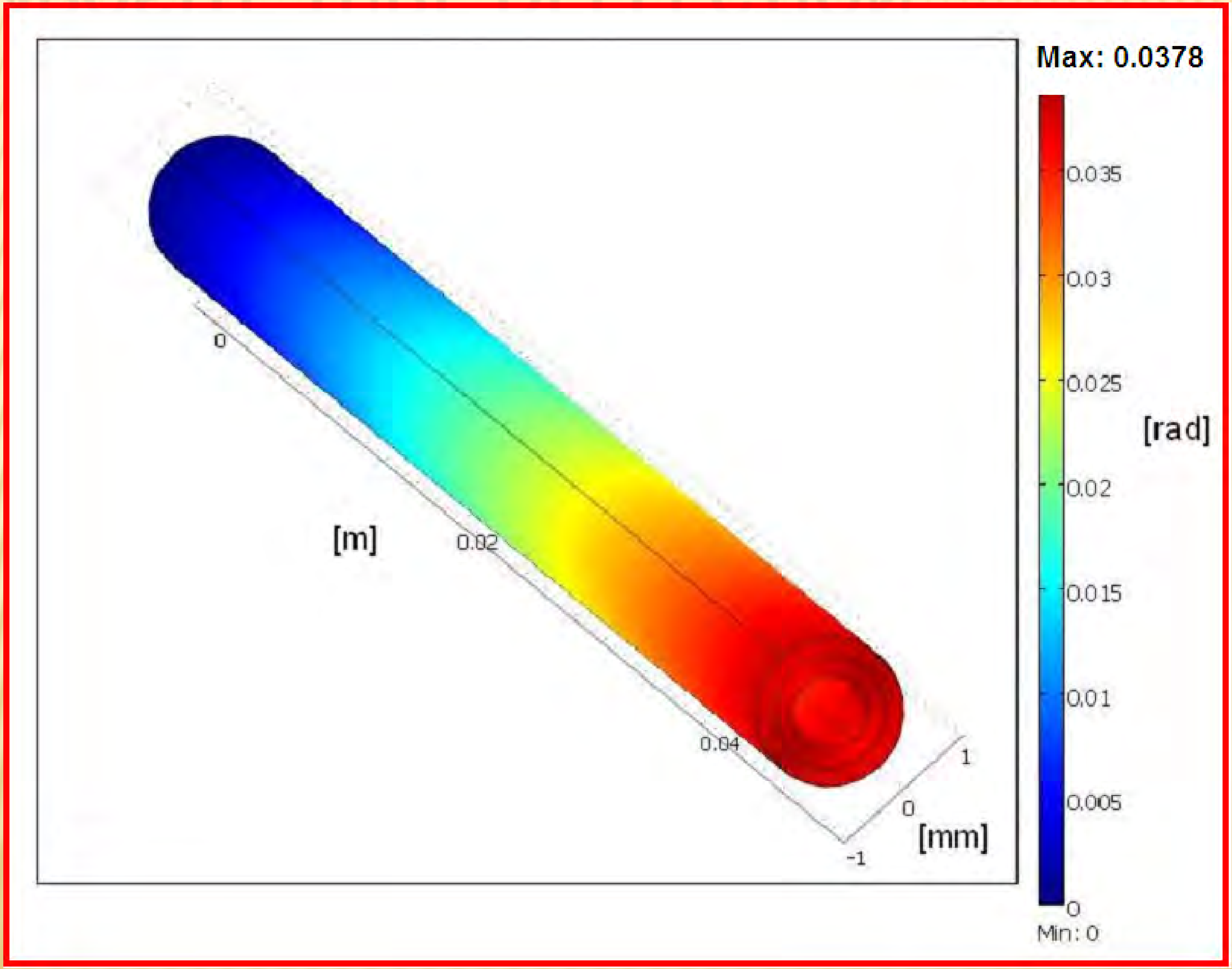
HOMOGENOUS TUBE DEFLECTION



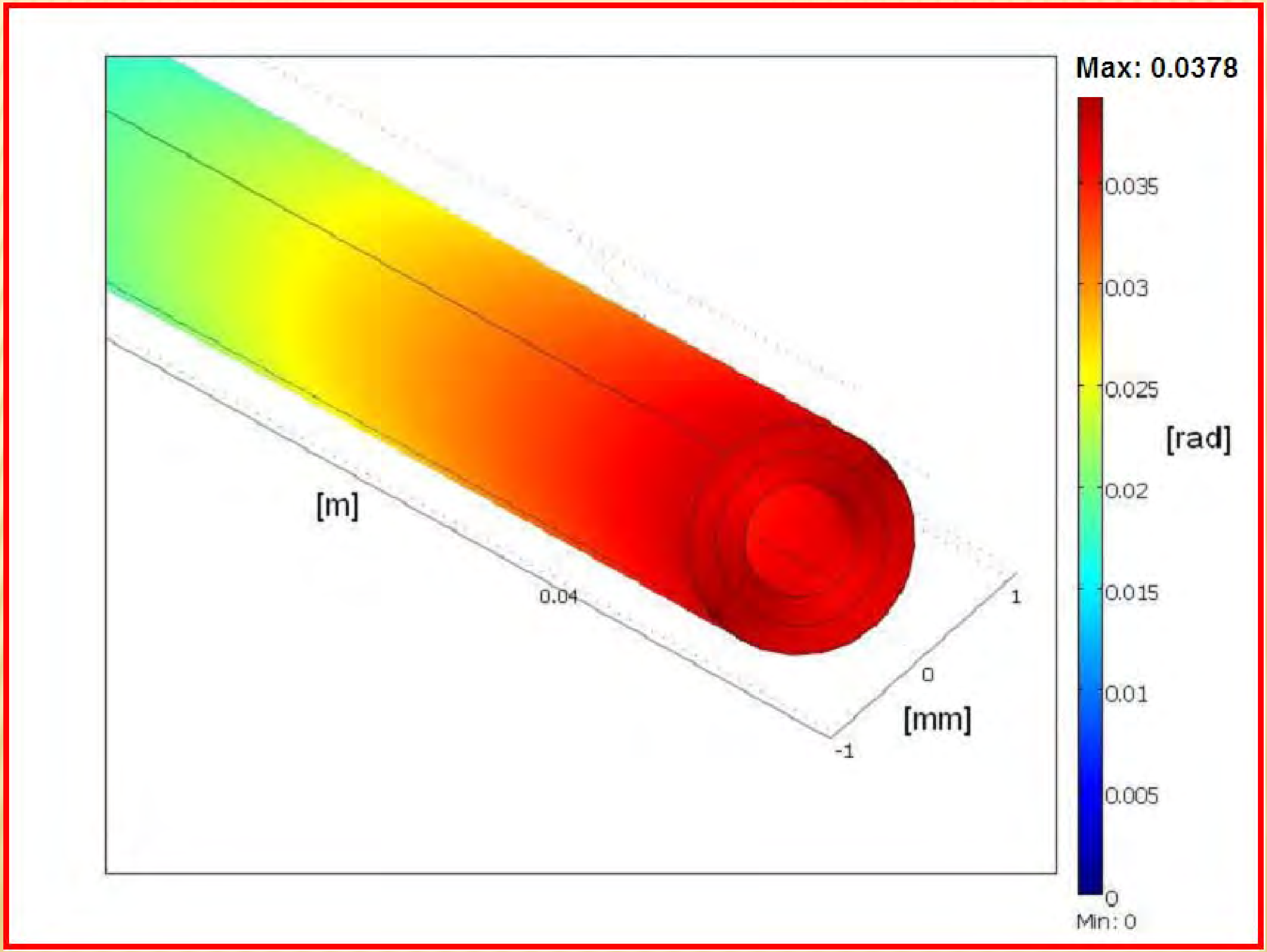
HOMOGENEOUS TUBE DEFLECTION



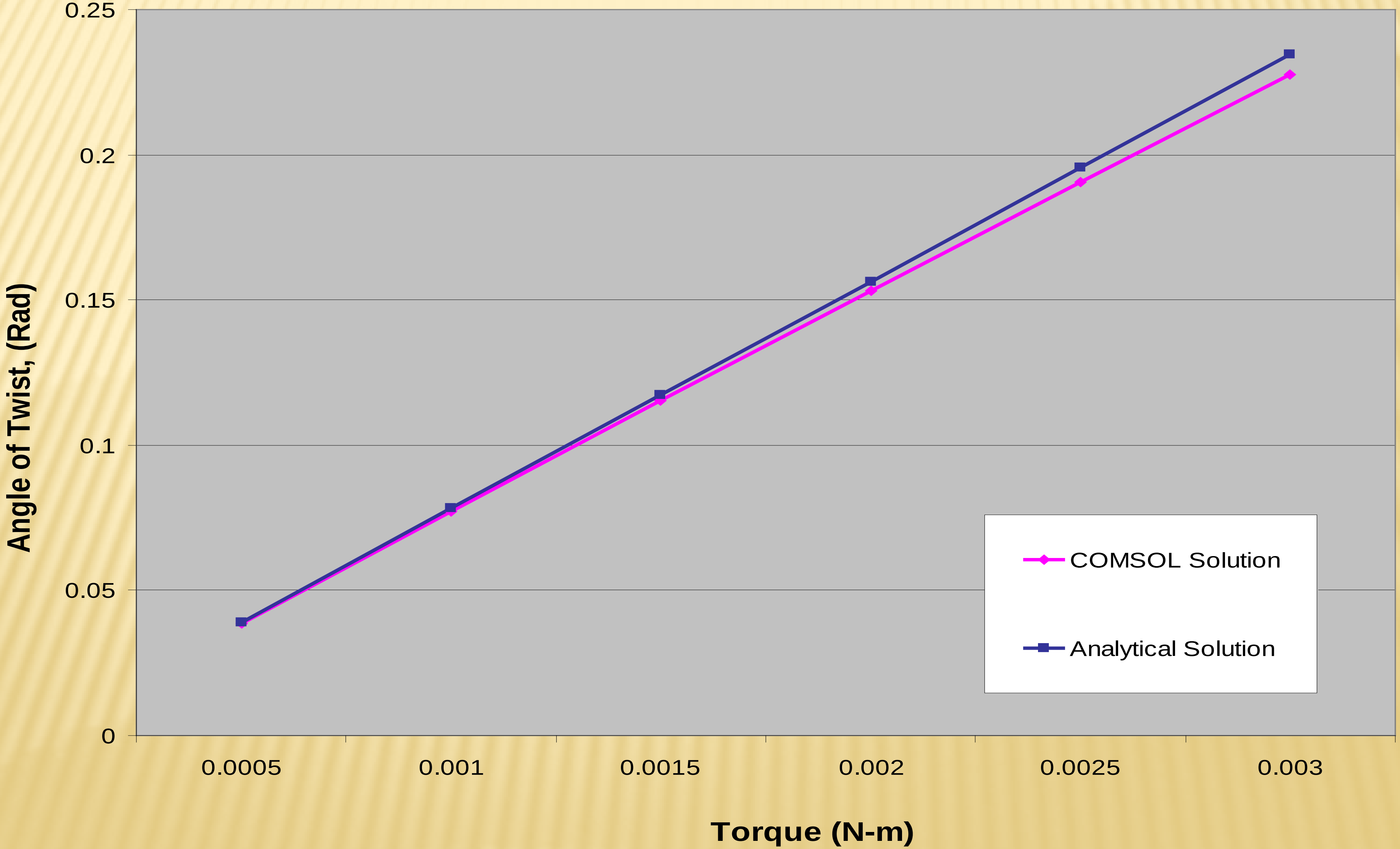
COMPOSITE TUBE DEFLECTION



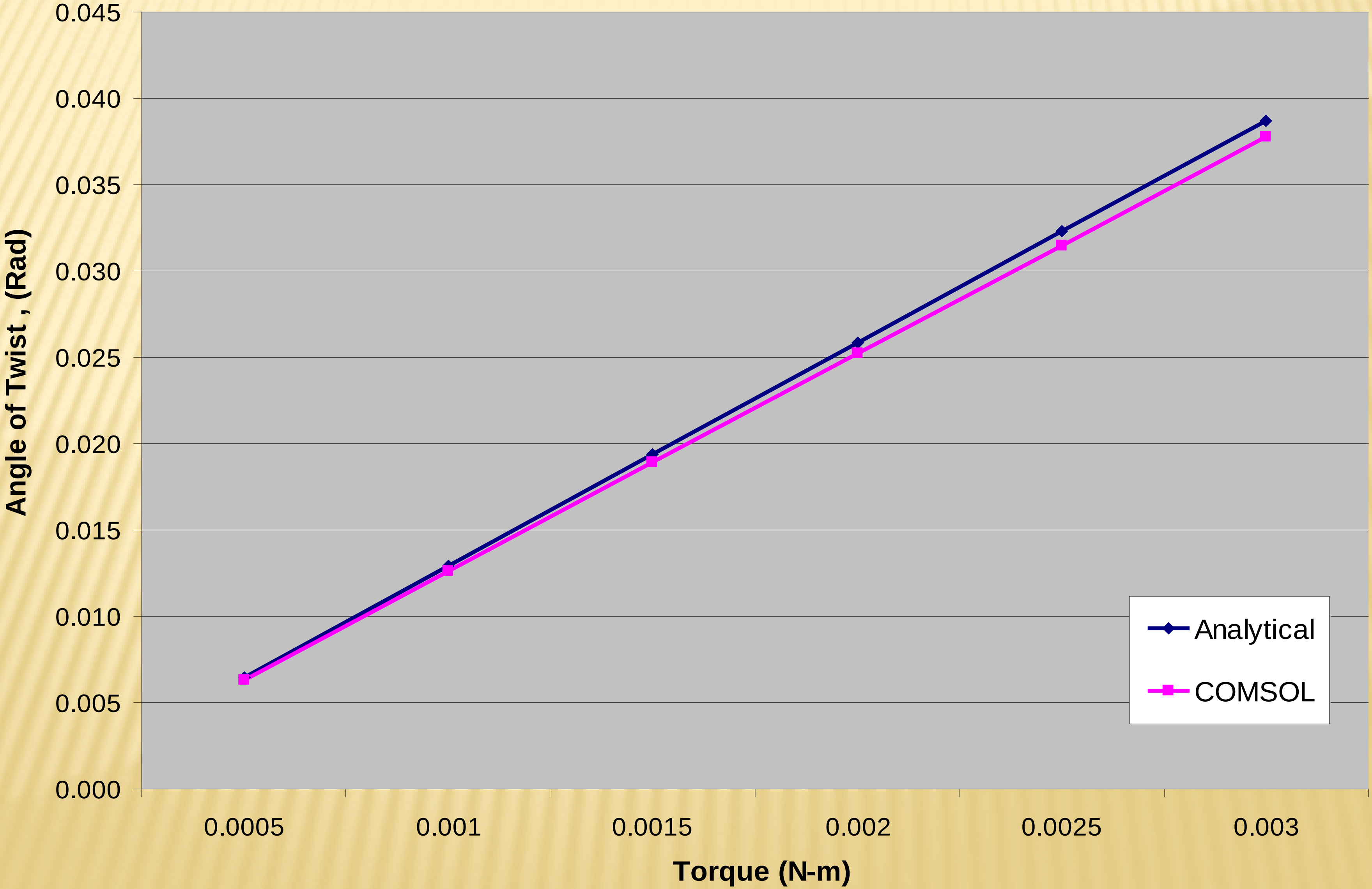
COMPOSITE TUBE DEFLECTION



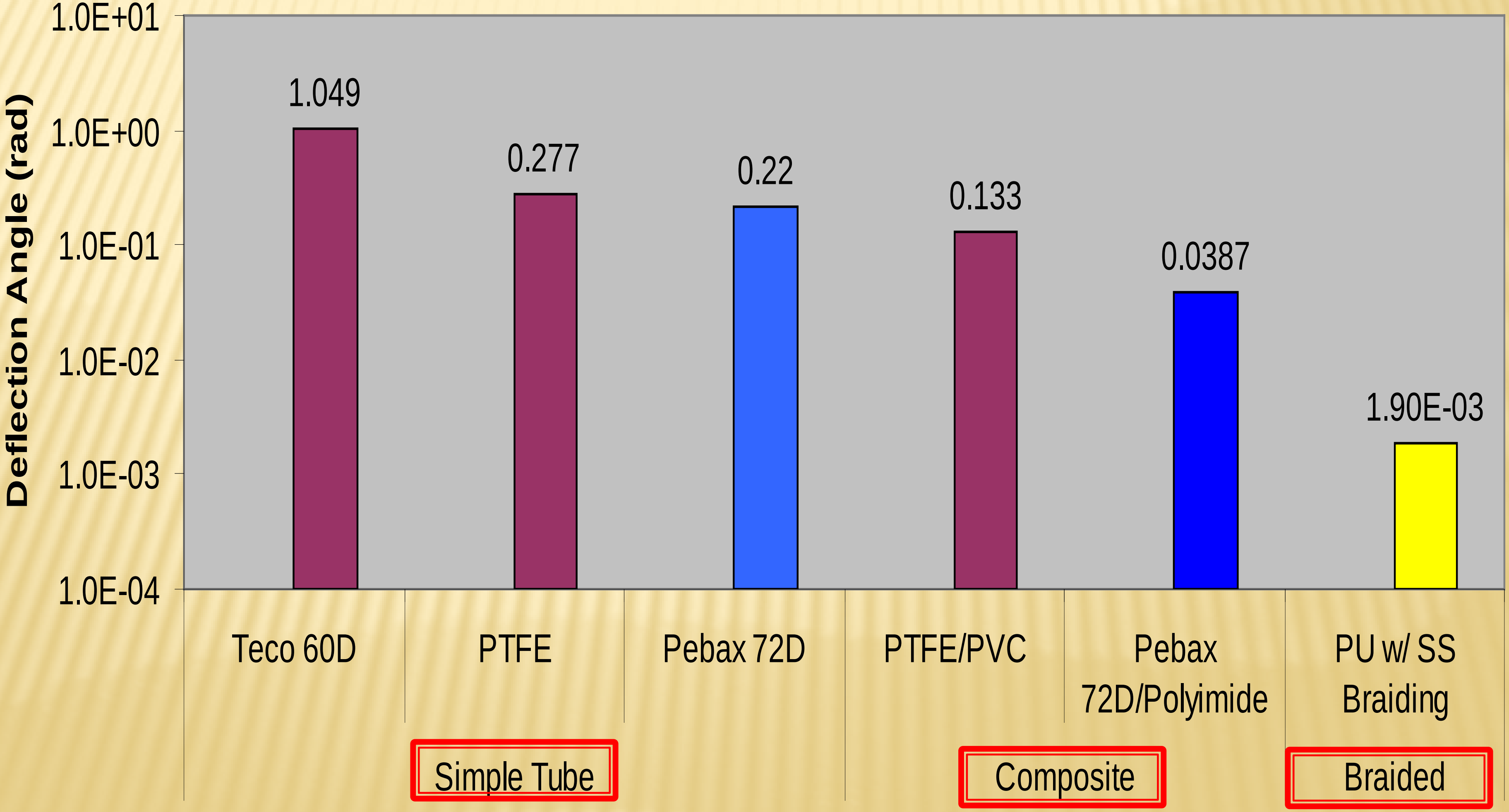
HOMOGENEOUS ANGULAR DEFLECTION



COMPOSITE ANGULAR DEFLECTION

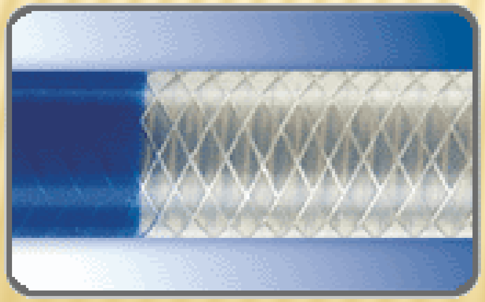


ANGULAR DEFLECTION OF DIFFERENT CATHETER MATERIALS



FUTURE WORK

- Explore other two component composite designs.
- Explore the use of different braided materials that may minimize flow cross section impact.
- Explore the impact of internal high pressure coolant flow on torsional properties.



This work is supported by NIH Grant # R44HL088789. The content is solely the responsibility of the authors and does not represent the official views of NIH.