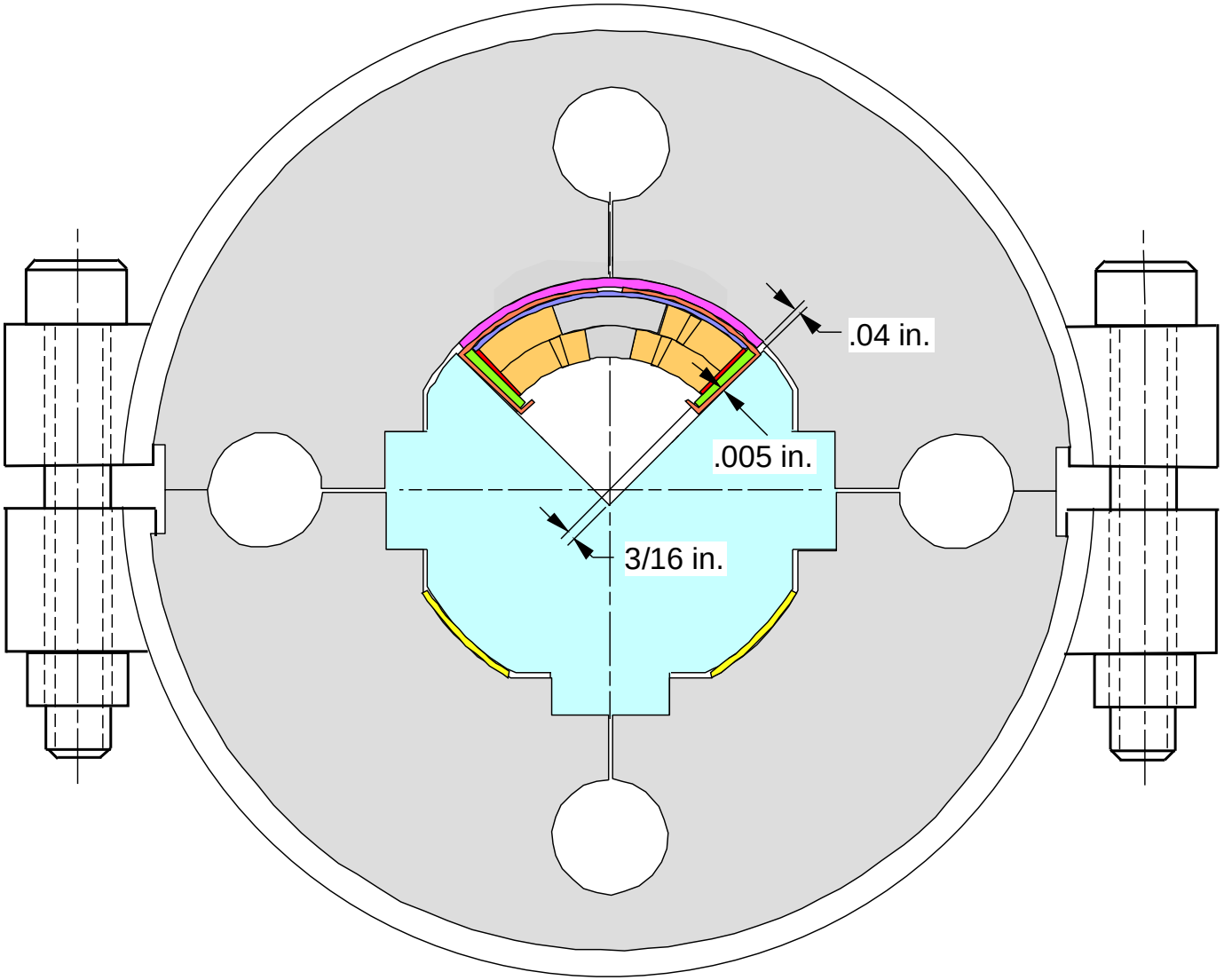
HQM AZ Pole Gauge under LF action

Igor Novitski

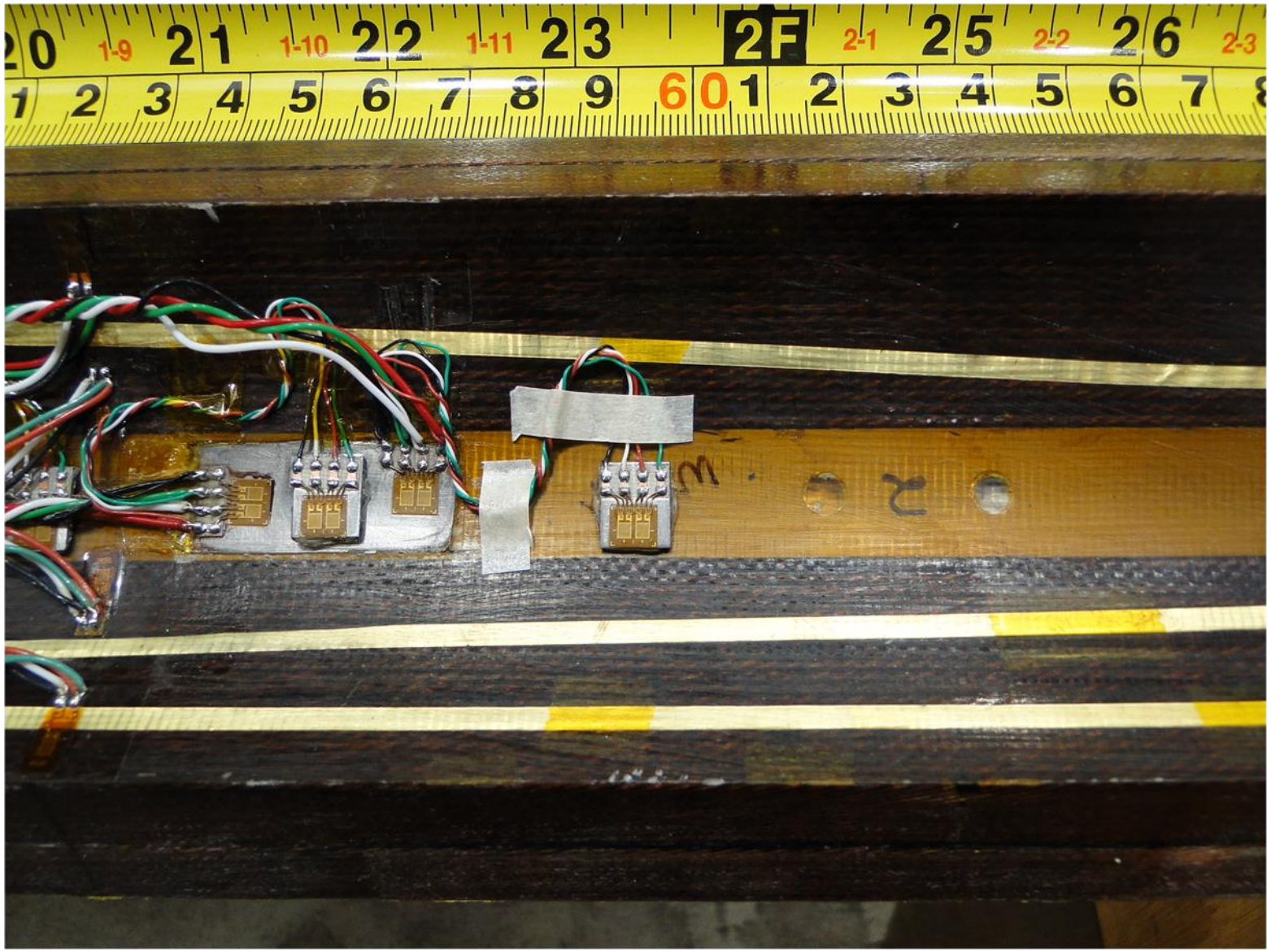
MDP modeling working group meeting

10-20-2020

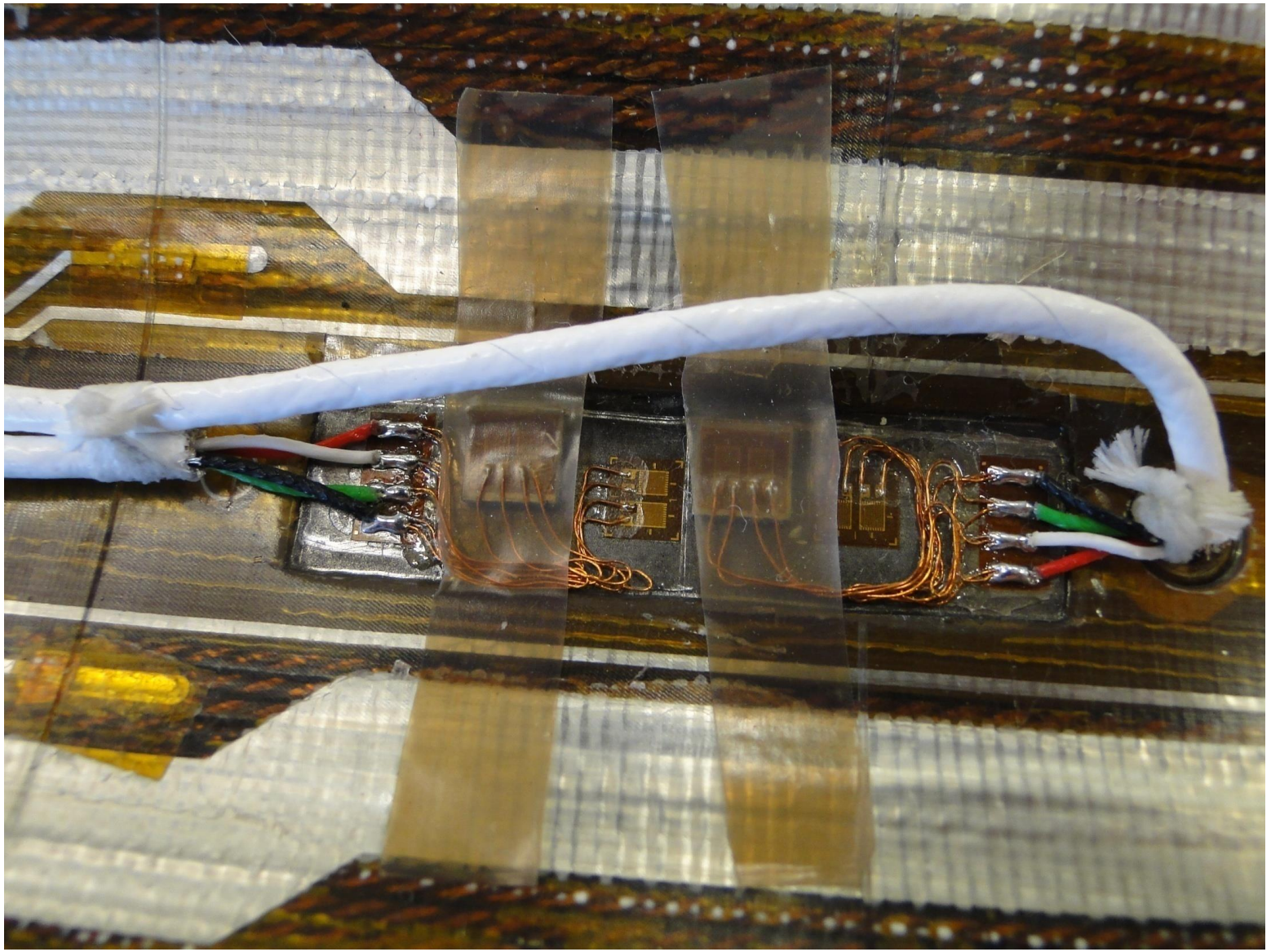
HQ Mirror Design



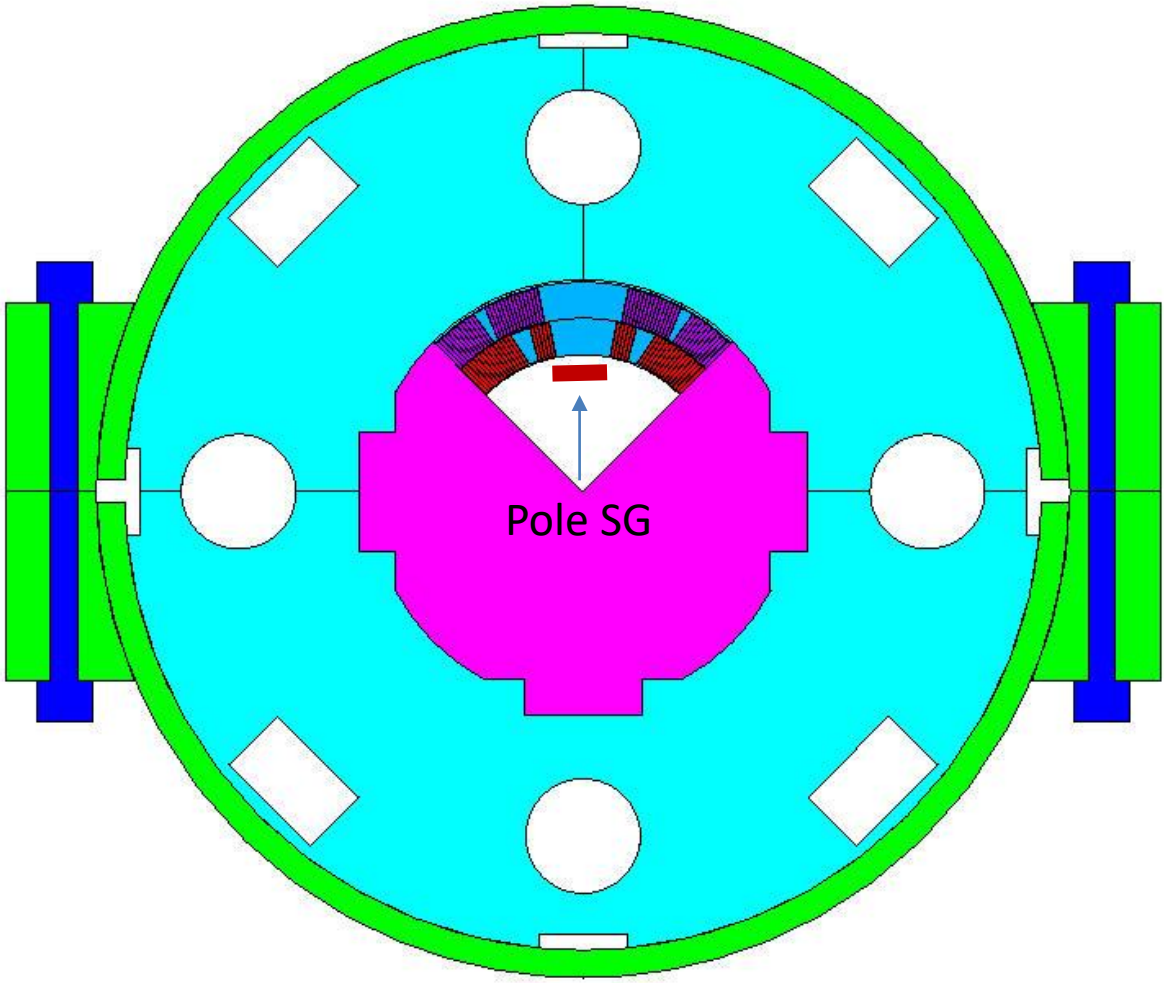
Strain Gauge placement on Coil 35



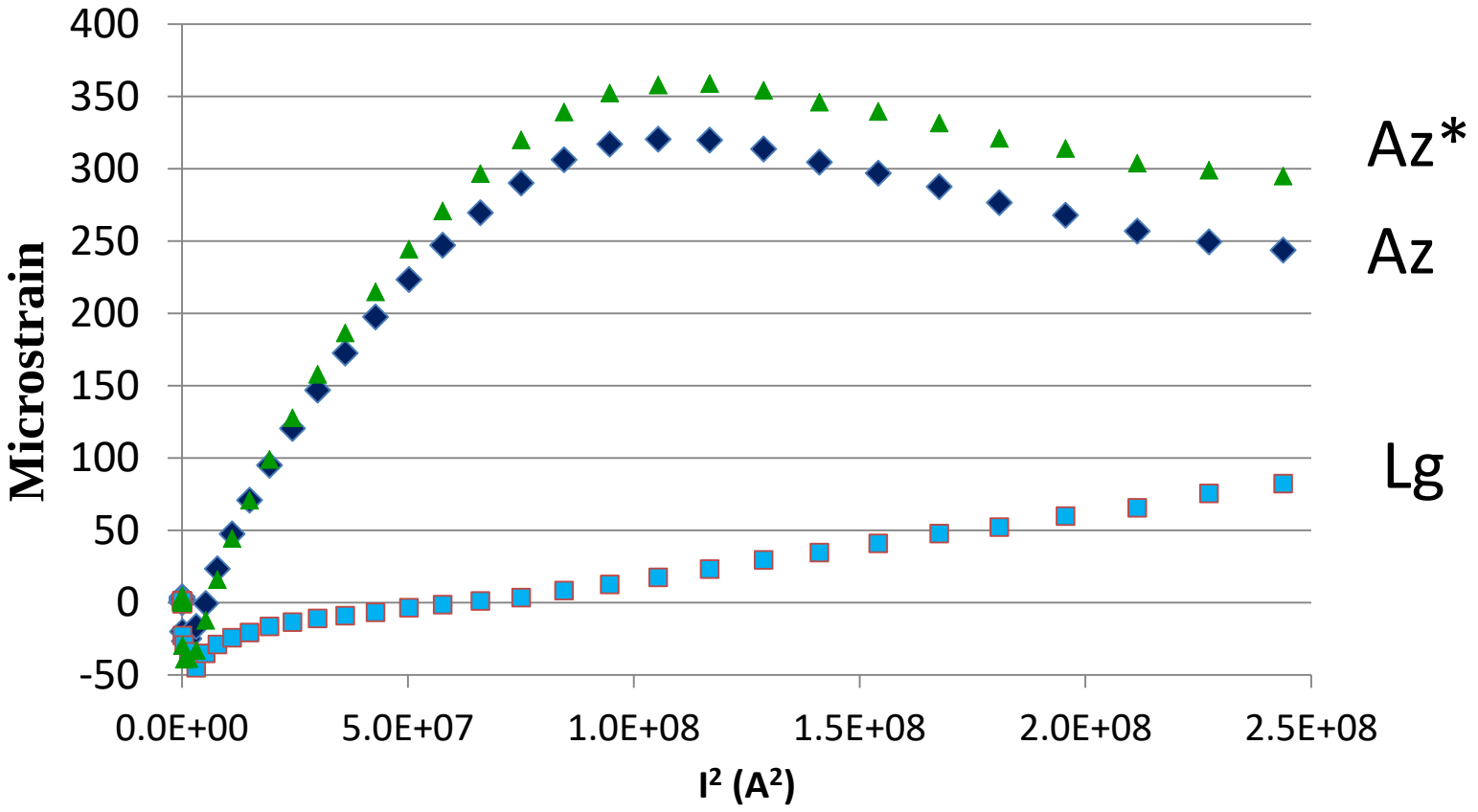
HQM01-02



HQ Mirror FEA Model



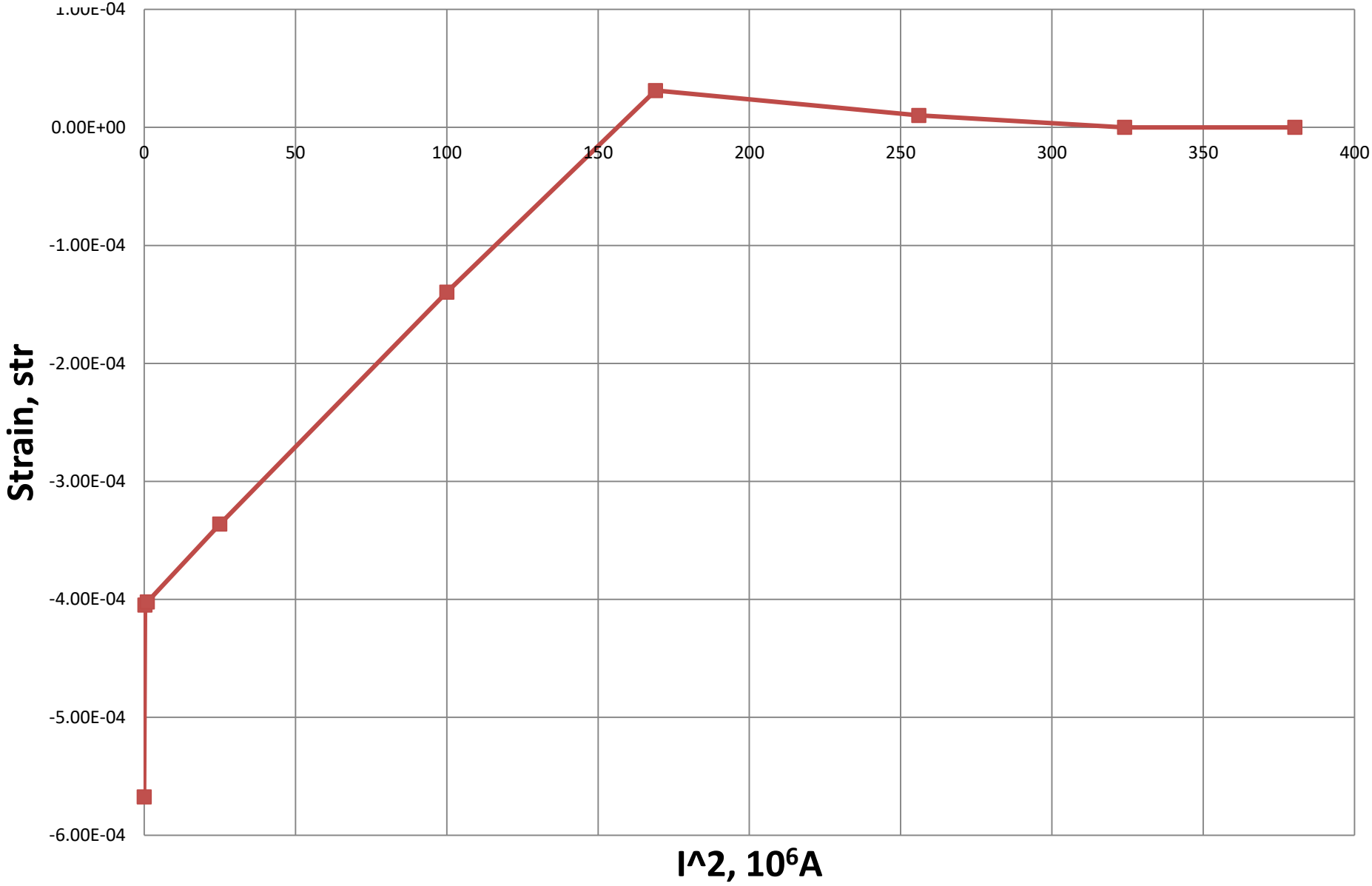
Pole SG Measurements



$Az^*=(Az+Kp*Lg)/(1-Kp*Kp)$ Rd=0

FEA

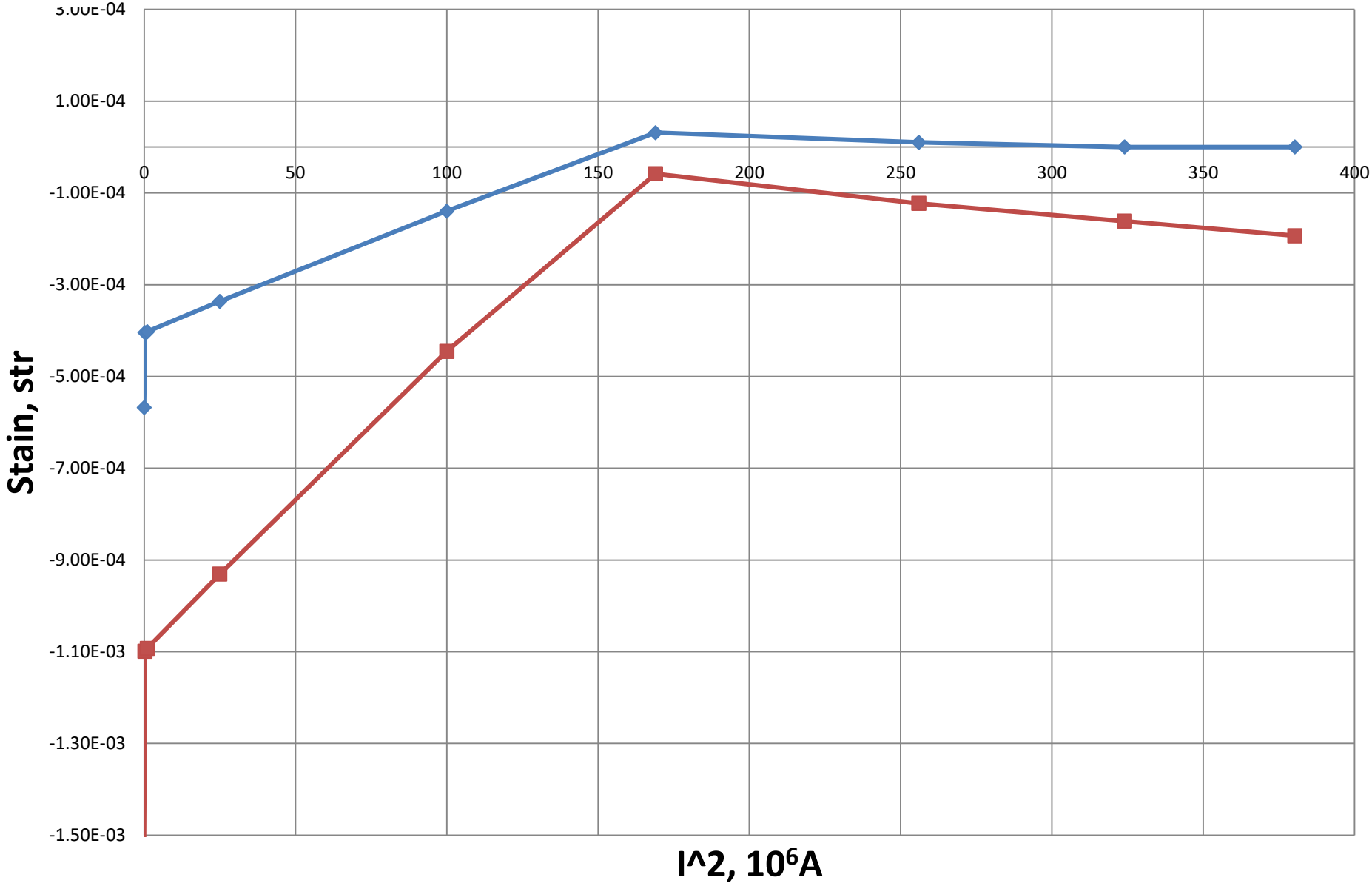
Pole Az Strain



Ec=44GPa, Ep=120GPa

FEA

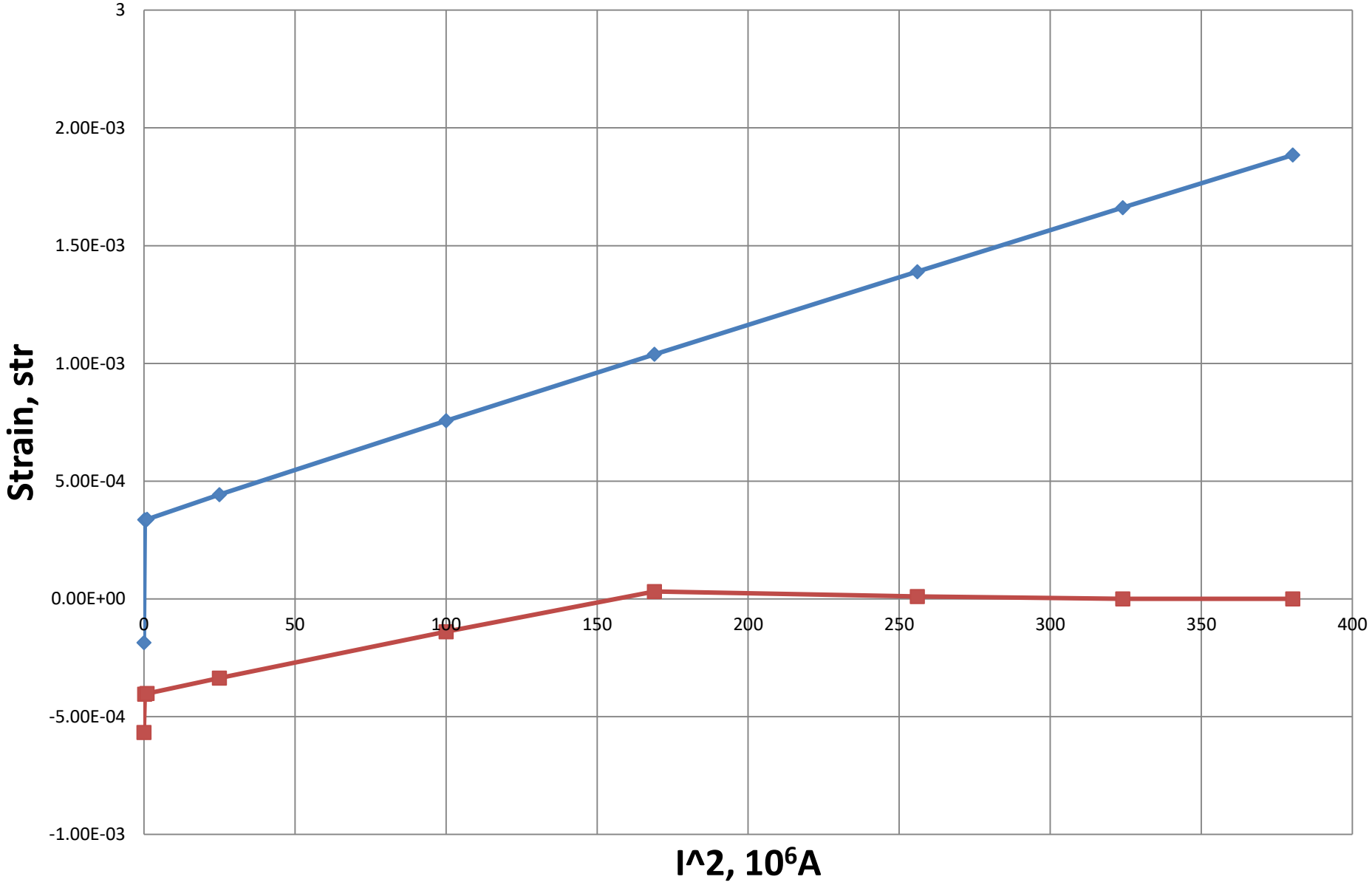
Pole Az Strain



Ec=44GPa, Ep=120GPa

FEA

Pole Az Strain



Ecoil=44GPa, Ep=120GPa

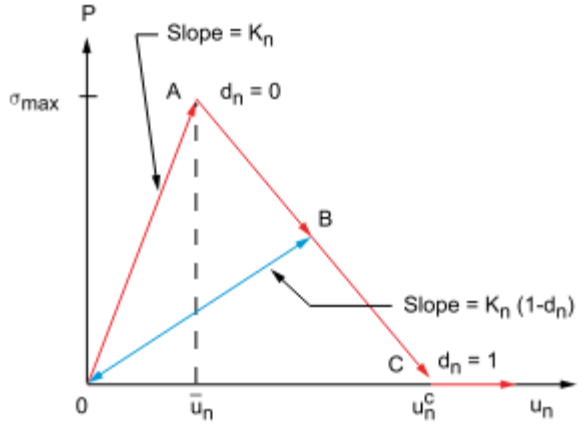
Contact at the coil-pole azimuthal interface defined by ANSYS

```
!
!*****************************************
!       CONTACT 169-172 PROP
!*****************************************
!
!REAL CONSTANT ANS KEY OPTION FOR THE CONTACT ELEMENTS
!KEYOPT(12)=0 STANDARD (SEPARATION - SLIDING)
!KEYOPT(12)=1 ROUGH (SEPARATION - NO SLIDING)
!KEYOPT(12)=2 NO SEPARATION (SLIDING)
!KEYOPT(12)=5 BONDED (NO SEPARATION - NO SLIDING)
!KEYOPT(9)=1 EXCLUDE BOTH INITIAL PENETRATION OR GAP
!KEYOPT(9)=0 INCLUDE BOTH INITIAL PENETRATION OR GAP
!KEYOPT(9)=3 INCLUDE OFFSET ONLY (CONTACT REAL CONSTANT,
!POSITIVE BEING INTERF), EXCLUDE BOTH INITIAL PENETRATION OR GAP
!
! REAL CONSTANTS:
!
!R1,    -TARGET CIRCLE RADIUS
!R2,    -TARGET CIRCLE RADIUS
!FKN,   -NORMAL PENALTY STIFFNESS FACTOR
!FTOLN, -PENETRATION TOLERANCE FACTOR
!ICONT, -INITIAL CONTACT CLOSURE
!PINB,  -PINBALL REGION
!PMAX,  -UPPER LIMIT OF INITIAL ALLOWABLE PENETRATION
!PMIN,  -LOWER LIMIT OF INITIAL ALLOWABLE PENETRATION
!TAUMAX,-MAXIMUM FRICTION STRESS
!CNOF,  -CONTACT SURFACE OFFSET
!FKOP,  -CONTACT OPENING STIFFNESS OR CONTACT DAMPING
!FKT,   -TANGENT PENALTY STIFFNESS FACTOR
!COHE,  -CONTACT COHESION
!TCC,   -THERMAL CONTACT CONDUCTANCE
!FHTG,  -FRICTIONAL HEATING FACTOR
!SBCT,  -STEFAN-BOLTZMANN CONSTANT
!RDVF,  -RADIATION VIEW FACTOR
!FWGT,  -HEAT DISTRIBUTION WEIGHING FACTOR
!ECC,   -ELECTRIC CONTACT CONDUCTANCE
!FHEG,  -JOULE DISSIPATION WEIGHT FACTOR
!FACT,  -STATIC/DYNAMIC RATIO
!DC,    -EXPONENTIAL DECAY COEFFICIENT
!SLTO,  -ALLOWABLE ELASTIC SLIP
!TNOP,  -MAXIMUM ALLOWABLE TENSILE CONTACT PRESSURE
!TOLS   -TARGET EDGE EXTENSION FACTOR
!
!*****************************************************
```

Cohesive Zone Material for Interface Elements and Contact Elements

Mode I Debonding

Mode I debonding defines a mode of separation of the interface surfaces where the separation normal to the interface dominates the slip tangent to the interface. The normal contact stress (tension) and contact gap behavior is plotted in *Figure 4.36: Normal Contact Stress and Contact Gap Curve for Bilinear Cohesive Zone Material*. It shows linear elastic loading (*OA*) followed by linear softening (*AC*). The maximum normal contact stress is achieved at point *A*. Debonding begins at point *A* and is completed at point *C* when the normal contact stress reaches zero value; any further separation occurs without any normal contact stress. The area under the curve *OAC* is the energy released due to debonding and is called the critical fracture energy. The slope of the line *OA* determines the contact gap at the maximum normal contact stress and, hence, characterizes how the normal contact stress decreases with the contact gap, i.e., whether the fracture is brittle or ductile. After debonding has been initiated it is assumed to be cumulative and any unloading and subsequent reloading occurs in a linear elastic manner along line *OB* at a more gradual slope.



ANSYS tutorials

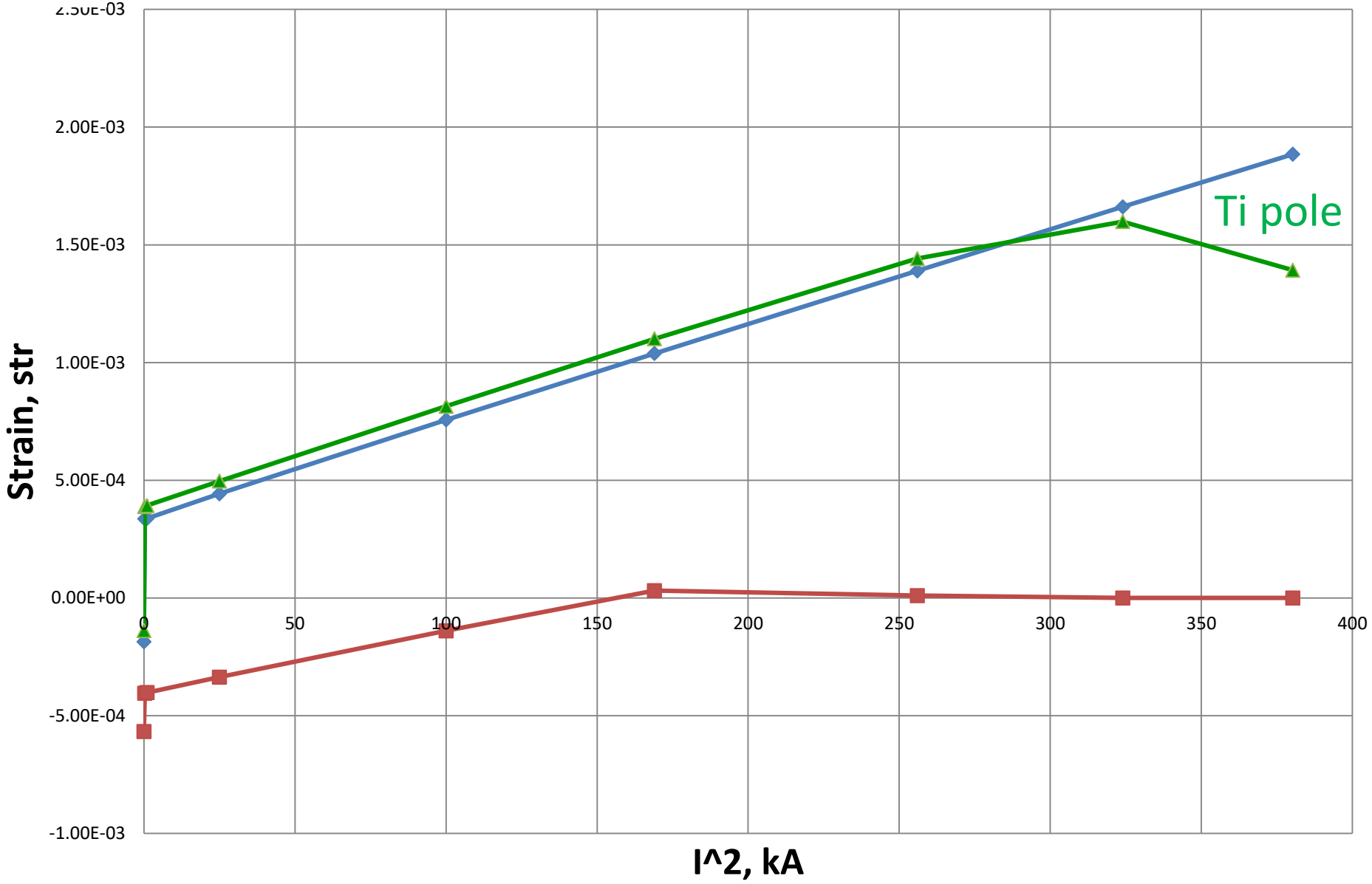
```
! This is a linear elastic material behavior with linear softening characterized by maximum traction and maximum
separation.
! To define this material, use the TB,CZM command with TBOPT = CBDD.
!
! C1- smax maximum normal contact stress - tension
! C2- contact gap at the completion of debonding
! C3- tmax maximum equivalent tangential contact stress
! C4- tangential slip at the completion of debonding
! C5- ? artificial damping coefficient
! C6- ß flag for tangential slip under compressive normal contact stress

TB,CZM,23,2,,CBDD       ! Activate bilinear material model with tractions and separation distances
TBTEMP,4.2              ! Define first temperature
TBDATA,1,30e6,1e-6,,,.1 !,tmax, ,?,ß  ! Define material constants at temp 1
TBTEMP,293              ! Define second temperature
TBDATA,1,30e6,1e-6      !,tmax, ,?,ß  ! Define material constants at temp 2
```

Tension limit
30 MPa

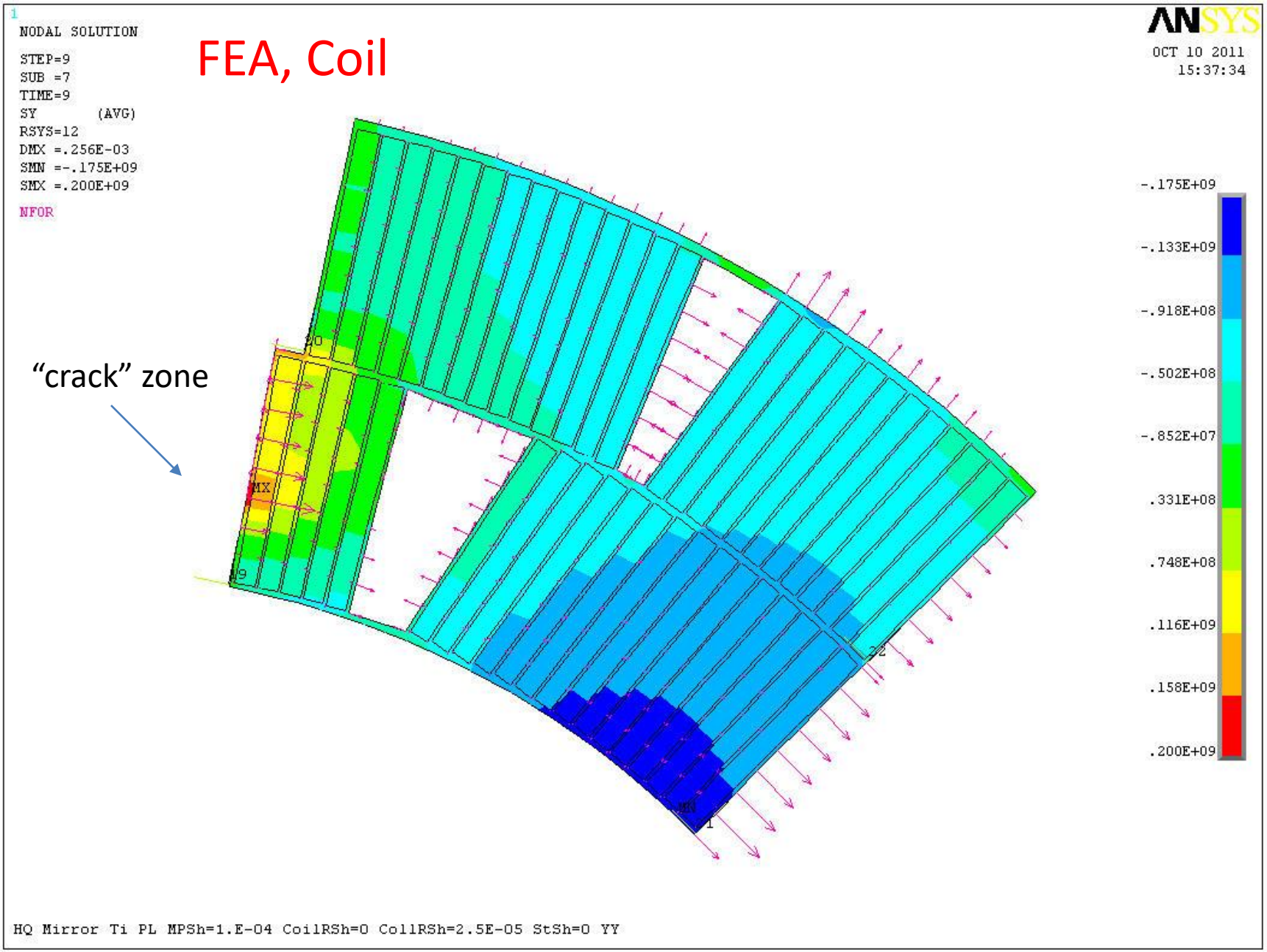
FEA

Pole Az Strain



Ecoil=44GPa, Epole=120GPa, Sn=30MPa

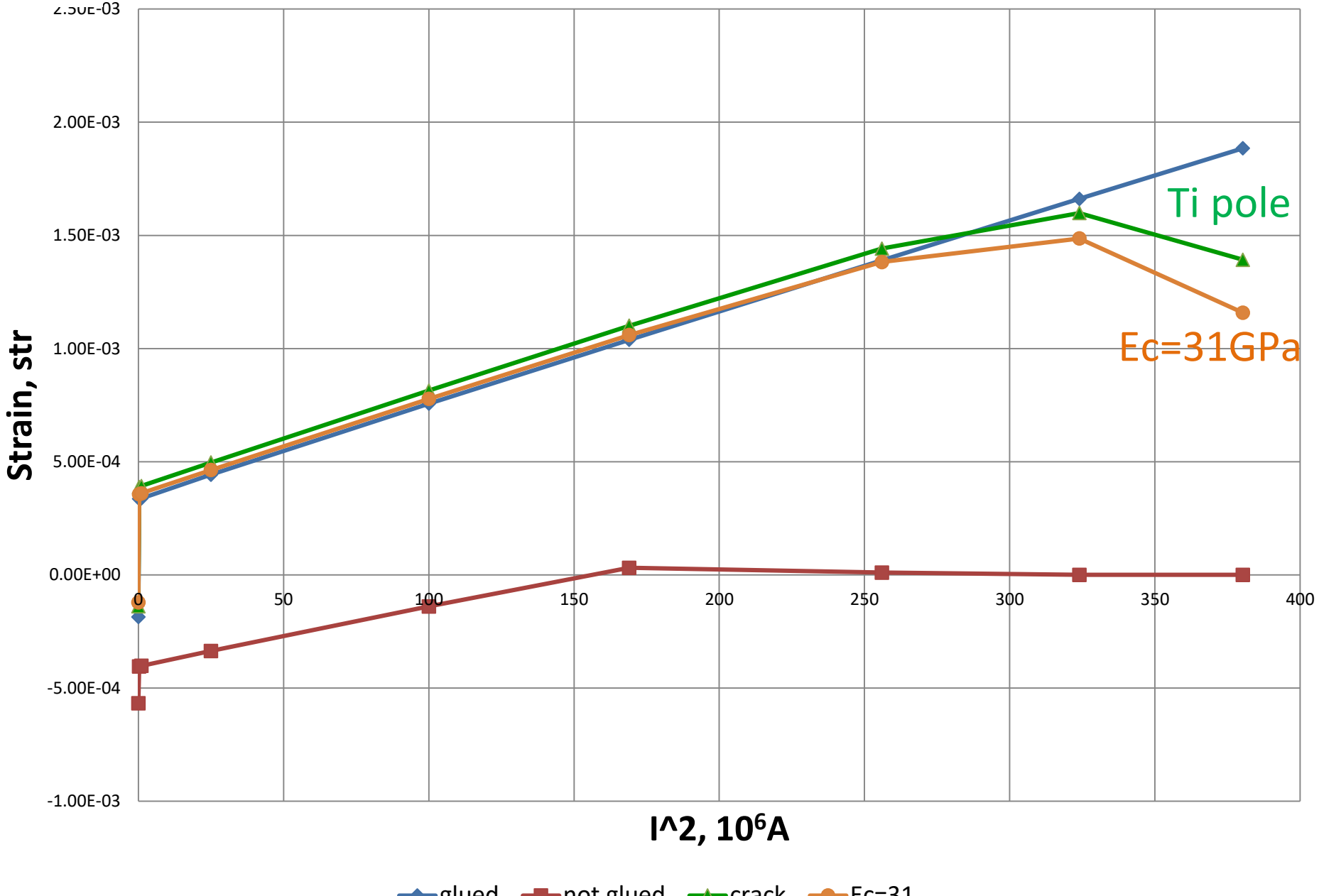
FEA, Coil



"crack" zone

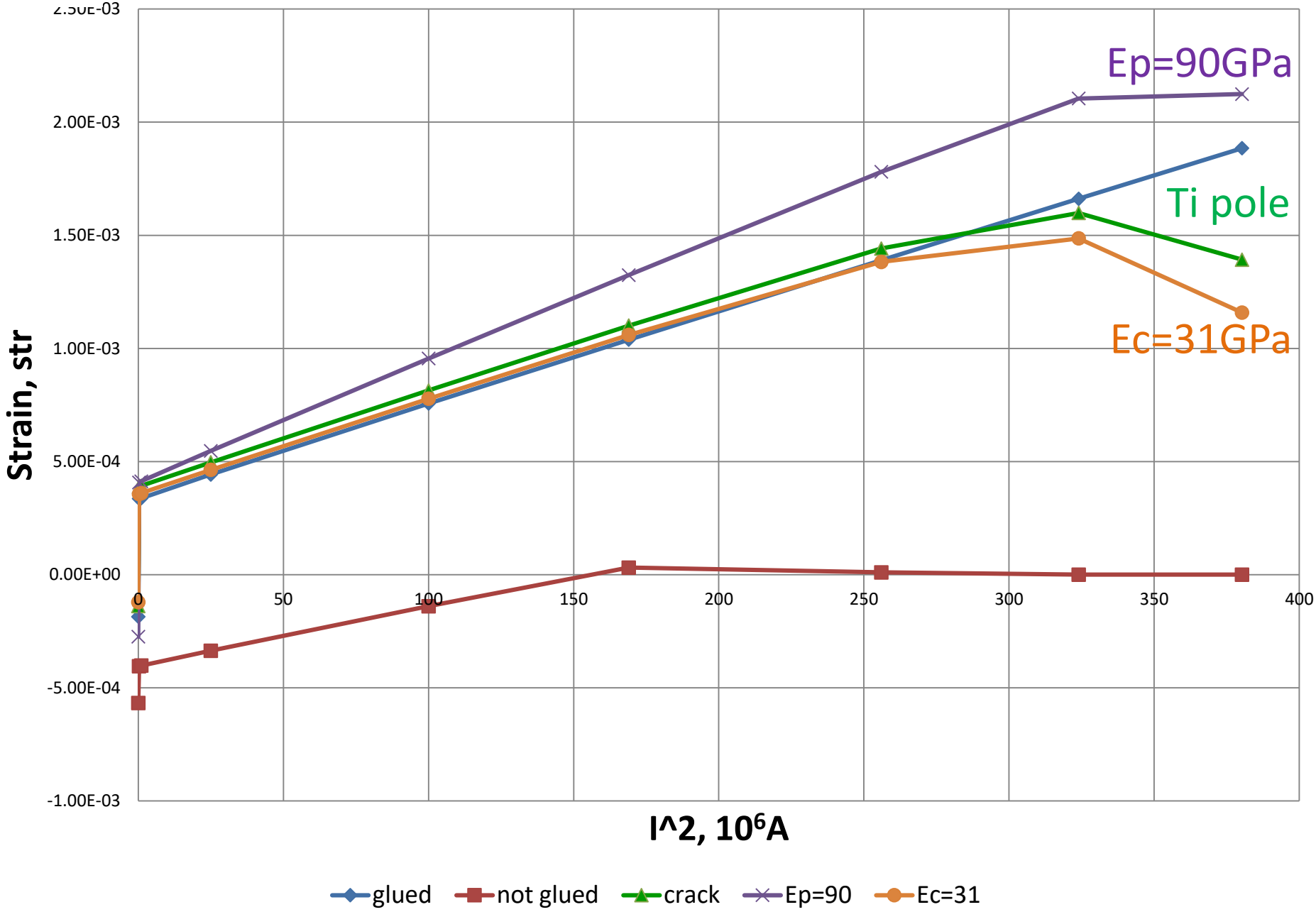
FEA

Pole Az Strain



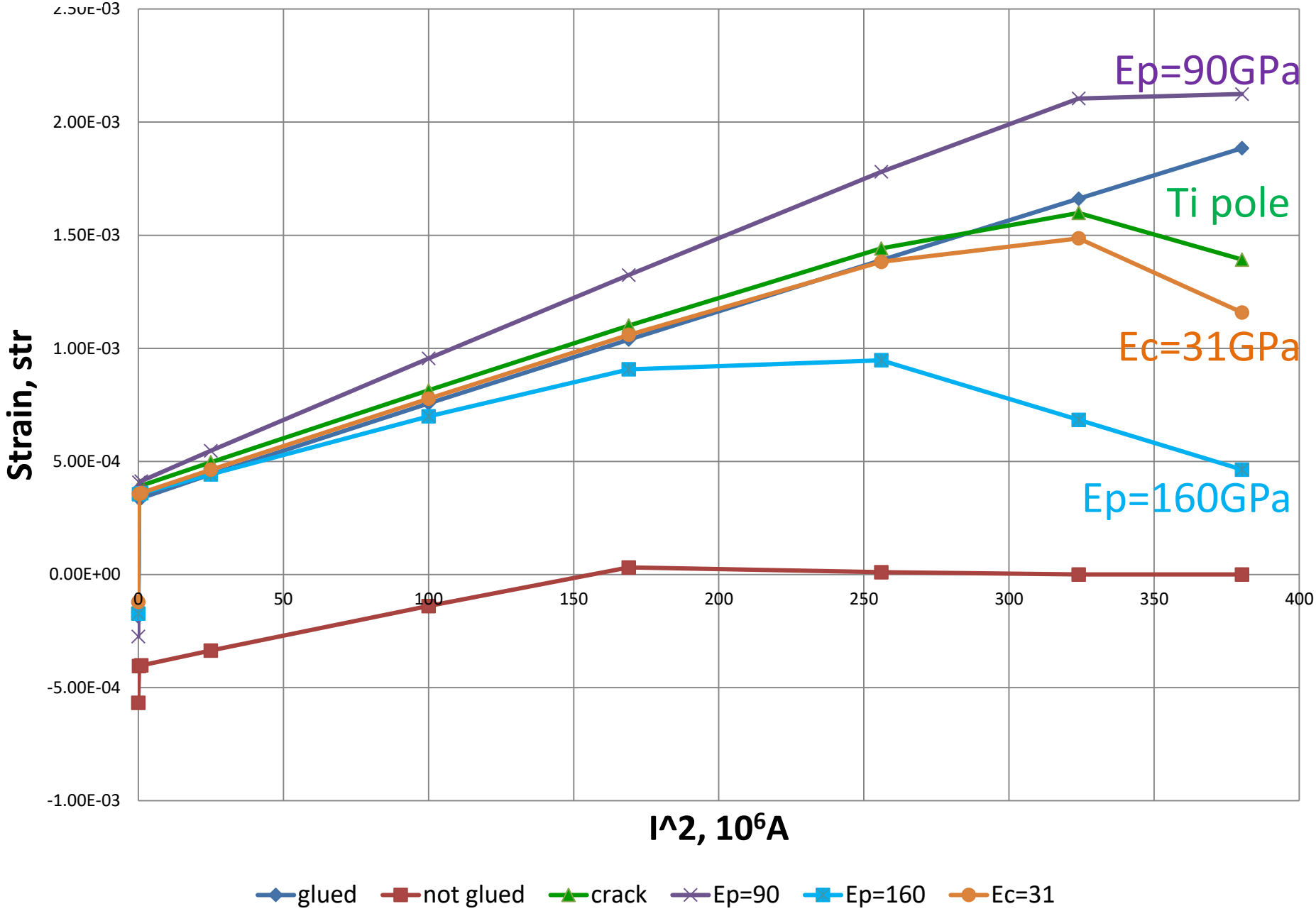
FEA

Pole Az Strain



FEA

Pole Az Strain



Summary

ANSYS contact element with a combination of the “cohesive zone material” may predict interface debonding behavior for the 2D analysis with a proper tuning.