

Electromagnetic Disruption Analysis

Methodology and Theoretical Evaluation & Update

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- **Build an ideal cylindrical model of the reactor space and apply the in house electromagnetic script (provided by Sri Avasarala).**
 - **Compare the contoured results to the classical theory for B field using the Curl operator.**
 - **Outline the derivation and assumptions used for this Electromagnetic analysis scripts currently in use.**
 - **Compare one MATLAB output file provided by Sri with the data supplied by OPERA data from R. Hatcher.**
 - **Compare the B field and B dot calculations resulting from ANSYS to the OPERA data at the same locations for the Outboard disruption on the Neutral Beam Armor model.**
 - **Update the Electromagnetic script to account for the revisions**
 - **Generate conclusions and recommendations**
 - **Identify alternate analysis methods to be investigated for comparison.**

ASSUMPTIONS

- The dell operator on the vector potential can be defined as zero
 - Variation of A in theta are zero due to symmetry (See slide #11)
 - Variation of A in vertical Z are zero due to symmetry (see slide #12)
 - Variation of A in the radial are defined inversely as a function of radius r
 - Note:** R. Feynman equation 18.23 does not make this assumption for Transient analysis

$$\nabla \cdot A = 0 = \frac{1}{r} \frac{\partial}{\partial r} (rA_r) + \frac{1}{r} \frac{\partial A_\theta}{\partial \theta} + \frac{\partial A_z}{\partial z}$$

$$\nabla \cdot A = 0 = \frac{1}{r} \frac{\partial}{\partial r} (rA_r) + \frac{1}{r} \frac{\partial A_\theta}{\partial \theta} + \frac{\partial A_z}{\partial z}$$

Note : Transient analysis $\nabla \cdot A + \frac{\partial \phi}{\partial t} = 0$ we assume then that : $\frac{\partial \phi}{\partial t} = 0$

Although Classical Physics : $\nabla \cdot A = \frac{1}{c^2} \frac{\partial \phi}{\partial t}$ R. Feynman eqn 18.23 Vol II Lectures on Physics

- The assumption of a long straight wire with a steady current applies for applying transient boundary conditions as provided in Volume II Lectures on Physics (R. Feynman) Equation 14.21
- The B Field in ANSYS is calculated based on the reduction of the Curl Operator as:

$$B = B_x + B_y + B_z = -\frac{\partial A_\theta}{\partial z} i - \frac{\partial A_z}{\partial r} j + \frac{1}{r} \frac{\partial (rA_\theta)}{\partial r} k \quad \text{See derivation provided below}$$

Script from Sri

```

timint,on
time,10.005
autots,on
deltim,.001,.0005,.002
kbc,0
*do,i,1,nmax
z=nz(i)
x=nx(i)
d,i,ay,vect5(x,z)
d,i,az,-0.5*BR*log(x*x)
*enddo
d,all,ax,0.
SOLVE

time,10.0055
autots,on
deltim,.0001,.00005,.0002
kbc,0
*do,i,1,nmax
z=nz(i)
x=nx(i)
d,i,ay,vect5(x,z)
d,i,az,-0.5*BR*log(x*x)
*enddo
d,all,ax,0.
SOLVE
    
```

Ay from Opera Tables

Az from assumption of infinite wire see derivation in slides below

Ax assumed = 0

The script applies only one value (Ay) from the Opera tables
Other values are calculated or assumed as zero

DERIVATION OF EQUATION

Ampere's Circuital Law

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I = \frac{I}{\epsilon_0 c^2} \quad I = \epsilon_0 c^2 B 2\pi r$$

$$j_z = \frac{I}{\pi a^2} \quad \text{uniform current density}$$

Assume: Infinite straight wire

$$A_z = \frac{-\pi a^2 J}{2\pi \epsilon_0 c^2} \ln(r) \quad A_z = -\frac{I}{2\pi \epsilon_0 c^2} \ln(r) \quad \text{REF: Feynman Eqn 14.21}$$

Substitute for I in terms of B:

$$A_z = \frac{\epsilon_0 c^2 B 2\pi r}{2\pi \epsilon_0 c^2} \ln(r) = Br \ln(r)$$

$$I = \left(\frac{130,000 \text{ Amps}}{\text{Turn}} \right) \left(\frac{12 \text{ Turns}}{TF} \right) \left(\frac{3TF}{\text{Turn}} \right)$$

$$A_z = \frac{I}{2\pi \epsilon_0 c^2} \ln(r) = \left(\frac{130,000 \text{ Amps}}{\text{Turn}} \right) \left(\frac{12 \text{ Turns}}{TF} \right) \left(\frac{3TF}{\text{Turn}} \right) \frac{2}{4\pi \epsilon_0 c^2}$$

$$A_z = \frac{2BR}{2} \ln(r) = \frac{(BR) \ln(r^2)}{2}$$

Addition of factor of 2 used since X coordinates in geometry must be > zero

Curl Operator Assumptions

$$B_x = \nabla X A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \quad \text{since: } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla X A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \quad \text{since: } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla X A_z = \frac{1}{r} \frac{\partial(rA_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial(rA_\theta)}{\partial r} \quad \text{since: } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program

$$B = B_x + B_y + B_z = -\frac{\partial A_\theta}{\partial z} i - \frac{\partial A_z}{\partial r} j + \frac{1}{r} \frac{\partial(rA_\theta)}{\partial r} k$$

The theoretical B field from the Curl Operator
 Is inconsistent with the resulting ANSYS contour plots

$$-4 < z = \text{Vertical Height} < +4$$

```

55.txt - Notepad
File Edit Format View Help
0      -4      -3.9     -3.8     -3.7     -3.6     -3.5     -3.4     -3.3     -3.2     -3.1     -3
-1.1   -1      -0.9     -0.8     -0.7     -0.6     -0.5     -0.4     -0.3     -0.2     -0.1     0
1.9    2      2.1      2.2      2.3      2.4      2.5      2.6      2.7      2.8      2.9      3
    
```

Radius r =

```

1.2    0      -0.00291  -0.00584  -0.00877  -0.0117357  -0.014763
-0.0457728 -0.0479648 -0.0497042 -0.0511955 -0.0530166 -0.0561604
-0.2677548 -0.2822218 -0.2891791 -0.2881221 -0.2787209 -0.2606143
-0.2528031 -0.2689699 -0.2762751 -0.2749428 -0.2652947 -0.2477786
-0.00282    -0.00431    -0.00794    -0.0118592  -0.0151395  -0.0174625
-0.00958    -0.00772    -0.00581    -0.00389    -0.00195    0
1.3    0      -0.00336  -0.00671  -0.0101215  -0.0135442  -0.0170185
-0.0537866 -0.056999  -0.0600047 -0.0629014 -0.0659146 -0.0693306
-0.307856  -0.3270459 -0.3377146 -0.3393086 -0.3321667 -0.3167975
-0.3085857 -0.3219789 -0.3269522 -0.32301    -0.3096951  -0.2876106
-0.0217773 -0.0215436 -0.0225121 -0.0238882 -0.0250526 -0.0257474
-0.0114797 -0.00922    -0.00694    -0.00464    -0.00233    0
1.4    0      -0.0038   -0.00767  -0.0115107  -0.0154294  -0.0194058  -0.0234
-0.0627038 -0.0670165 -0.0712677 -0.0754105 -0.0794069 -0.0829491
-0.3622543 -0.3845891 -0.3997258 -0.4036906 -0.3983756 -0.3857679
-0.3772448 -0.3878664 -0.3910394 -0.3856978 -0.3710884 -0.3420081
-0.0401559 -0.0388827 -0.0378753 -0.0369078 -0.0353073 -0.0333085
-0.0135692 -0.0108786 -0.00816    -0.00594    -0.00374    0
1.5    0      -0.00431  -0.00863  -0.01296    -0.01729    -0.02162    -0.0219041
-0.0723312 -0.0778737 -0.0834522 -0.0889974 -0.0942678 -0.0987343
-0.4376941 -0.4736372 -0.4924191 -0.491837    -0.4761401 -0.4694395
-0.4607023 -0.465424  -0.4790922 -0.4774638 -0.4562599 -0.4177592
-0.0599116 -0.0571361 -0.0541571 -0.0513007 -0.048568    -0.0458739
-0.0158266 -0.0126567 -0.00948    -0.00631    -0.00316    -8.49E-20
1.6    0      -0.00479  -0.00965  -0.0145061  -0.0194443  -0.0244531
-0.0825926 -0.0894396 -0.0964994 -0.1037115 -0.1108566 -0.1175193
-0.5296828 -0.5876625 -0.6194967 -0.6206817 -0.6023441 -0.5745652
-0.565804  -0.591765  -0.6080611 -0.6047737 -0.5705109 -0.5101157
-0.0821065 -0.0767165 -0.0713884 -0.0663251 -0.06164    -0.0572279
-0.0182487 -0.0145869 -0.0109002 -0.00727    -0.00365    0
    
```

Opera $\Rightarrow A_\theta$

TYPICAL DISRUPTION FILE

MATRIX IN ANSYS

$$-4 < z = \text{Vertical Height} < +4$$

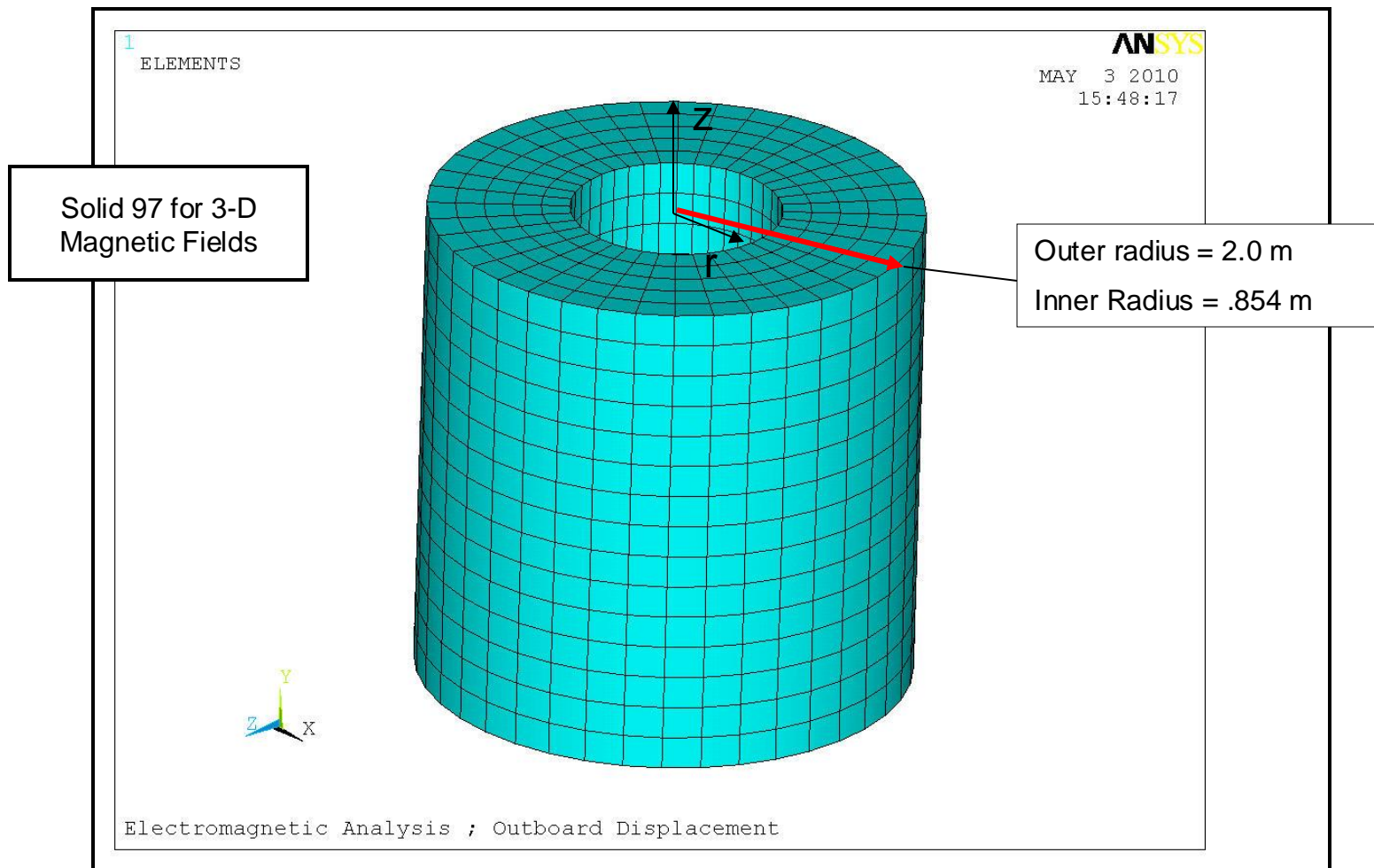
55.txt - Notepad
File Edit Format View Help

| | z | | | | | | | | |
|-----|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| | -0.4 | -0.3 | -0.2 | -0.1 | 0 | 0.1 | 0.2 | 0.3 | 0.4 |
| 0.9 | -0.160167 | -0.1485453 | -0.1400191 | -0.1346351 | -0.1324816 | -0.1335789 | -0.1378888 | -0.1453163 | -0.1556598 |
| 1 | -0.1746959 | -0.1616066 | -0.1518436 | -0.1456535 | -0.1431628 | -0.1444539 | -0.1494147 | -0.1578758 | -0.1695729 |
| 1.1 | -0.200521 | -0.1855423 | -0.1741501 | -0.1668848 | -0.1640096 | -0.1655843 | -0.1714682 | -0.1813962 | -0.1949001 |
| 1.2 | -0.239723 | -0.2221119 | -0.2085563 | -0.1998172 | -0.1963578 | -0.1983843 | -0.2056633 | -0.2176565 | -0.2336723 |
| 1.3 | -0.2944492 | -0.2731554 | -0.2564147 | -0.2455005 | -0.2412399 | -0.243957 | -0.2533102 | -0.2684834 | -0.2880901 |
| 1.4 | -0.3652584 | -0.3402059 | -0.3186082 | -0.3045239 | -0.2991931 | -0.30297 | -0.3154284 | -0.3353011 | -0.3586298 |
| 1.5 | -0.4472474 | -0.4198815 | -0.3945778 | -0.3766374 | -0.3697521 | -0.375017 | -0.3912821 | -0.4148743 | -0.4404785 |
| 1.6 | -0.5395105 | -0.502837 | -0.4715897 | -0.4505645 | -0.4426378 | -0.4489681 | -0.468217 | -0.4978654 | -0.5327199 |
| 1.7 | -0.6398557 | -0.5858224 | -0.5432602 | -0.5160564 | -0.5060545 | -0.5144429 | -0.5399219 | -0.5808571 | -0.6330433 |

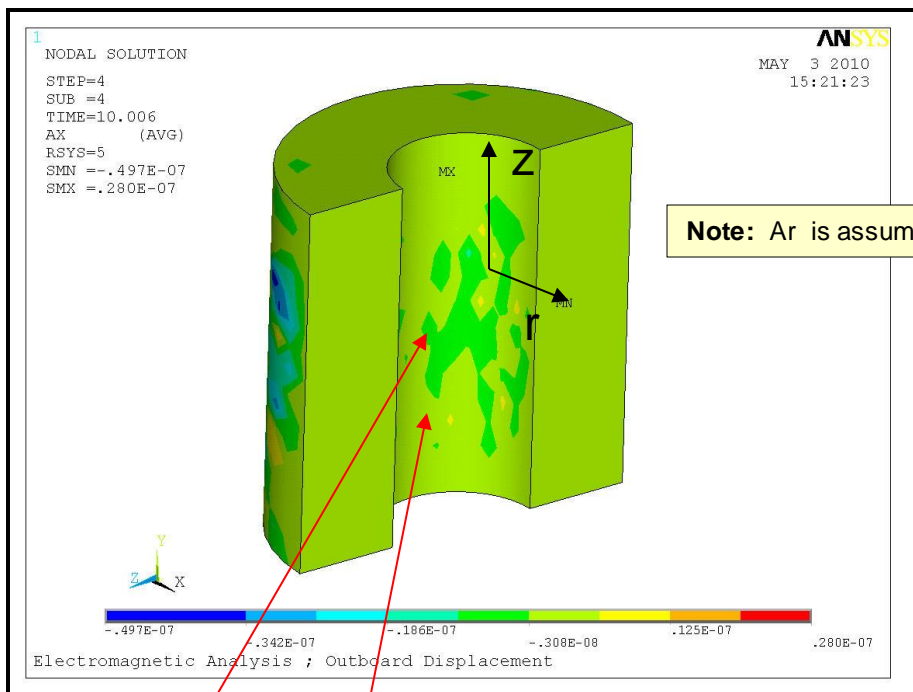
Radius r =

Opera $\Rightarrow -0.45 < A_\theta < -0.432$ at $r = 1.577$ $Z = -0.14$

FE Model For Field Result Comparison



A simplified model of the Reactor space as a cylinder for comparison of the field calculations using the Electromagnetic Script



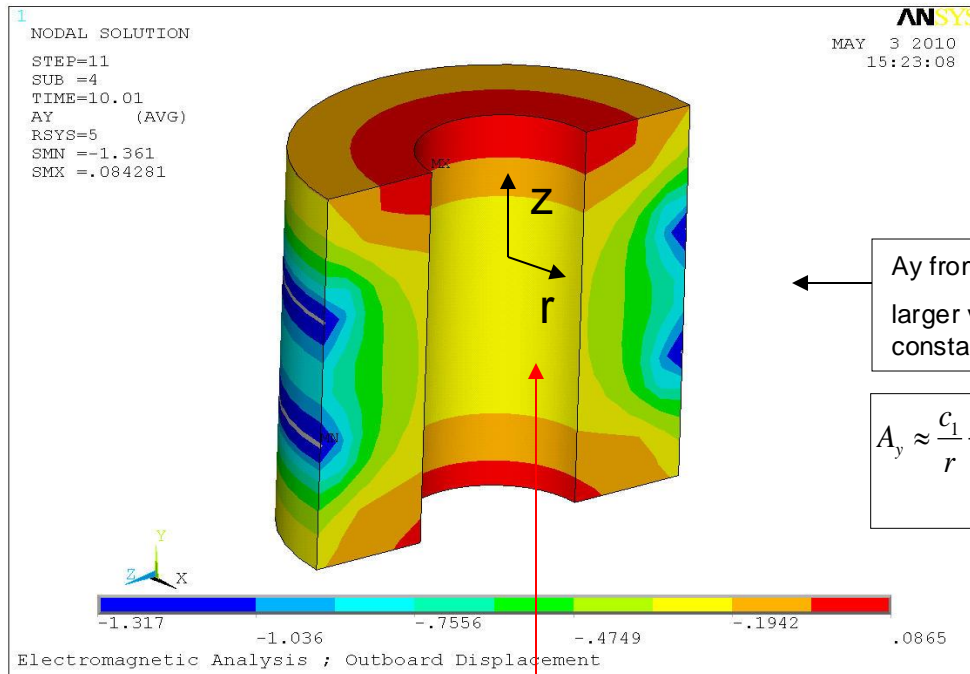
Note: Ar is assumed uniform, constant and zero with the script

$$B_x = \nabla X A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \quad \text{since: } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla X A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \quad \text{since: } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla X A_z = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} \quad \text{since: } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program



Ay from **Opera** is not a simple function of 1/r
larger values of r approach a negative constant

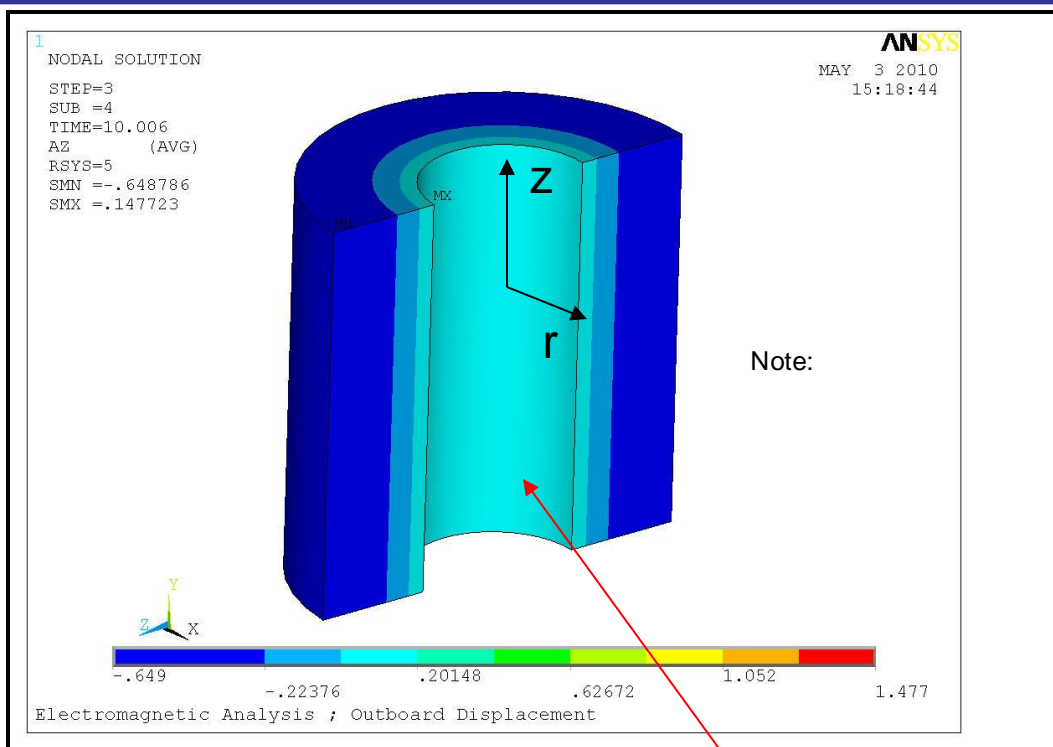
$$A_y \approx \frac{c_1}{r} - f(1/r, z) \quad f(1/r, z) \approx -.2 \quad \text{if } z=0$$

$$B_x = \nabla \times A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \quad \text{since: } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla \times A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \quad \text{since: } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla \times A_z = \frac{1}{r} \frac{\partial(rA_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial(rA_\theta)}{\partial r} \quad \text{since: } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program

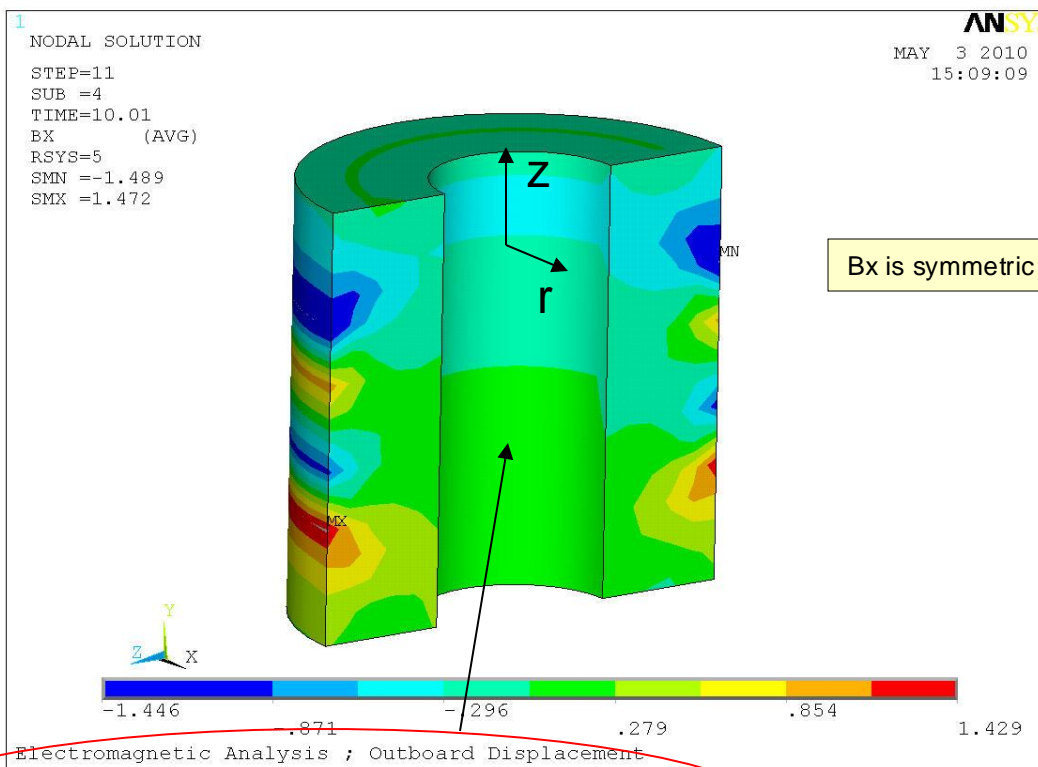


$$B_x = \nabla \times A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \quad \text{since: } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla \times A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \quad \text{since: } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla \times A_z = \frac{1}{r} \frac{\partial (rA_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial (rA_\theta)}{\partial r} \quad \text{since: } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program

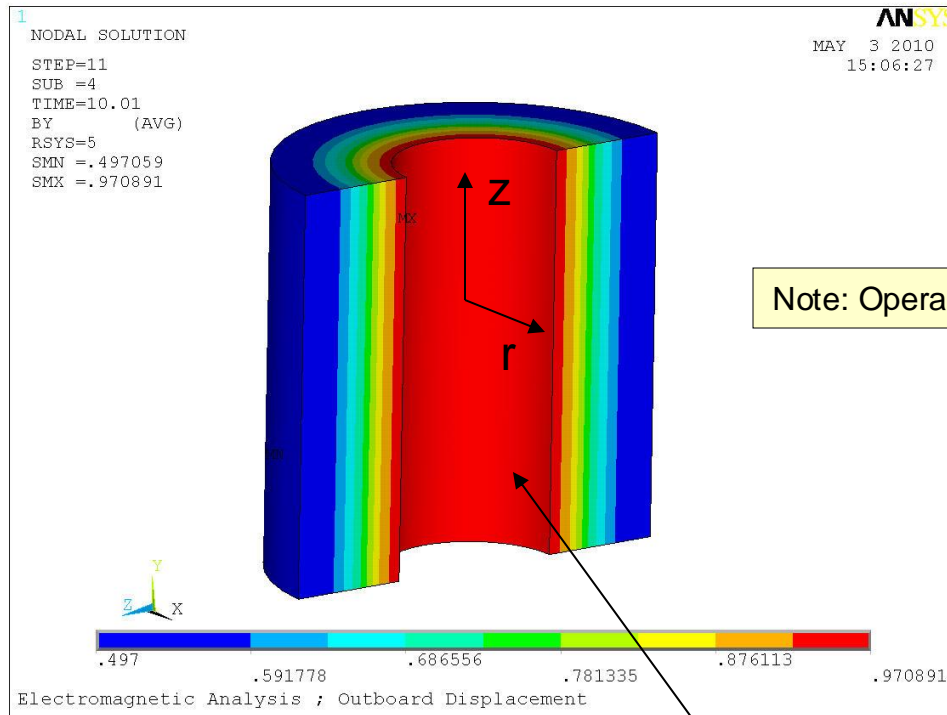


$$B_x = \nabla \times A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \text{ since } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla \times A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \text{ since } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla \times A_z = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} \text{ since } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program

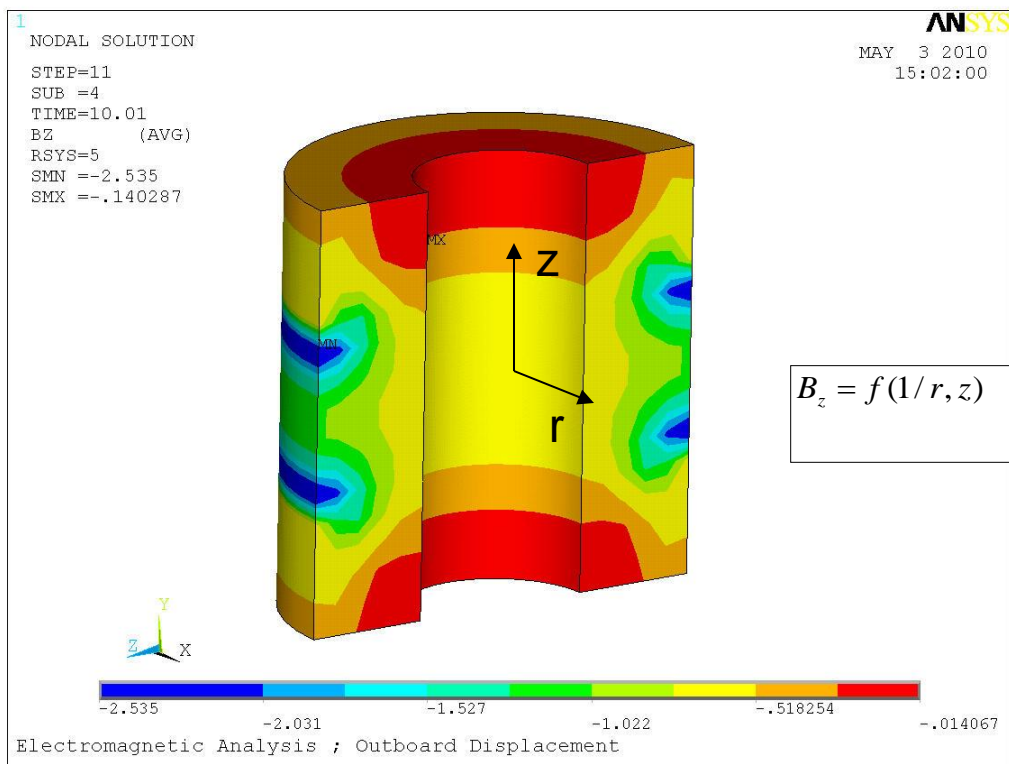


$$B_x = \nabla X A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \quad \text{since: } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla X A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \quad \text{since: } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla X A_z = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} \quad \text{since: } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program



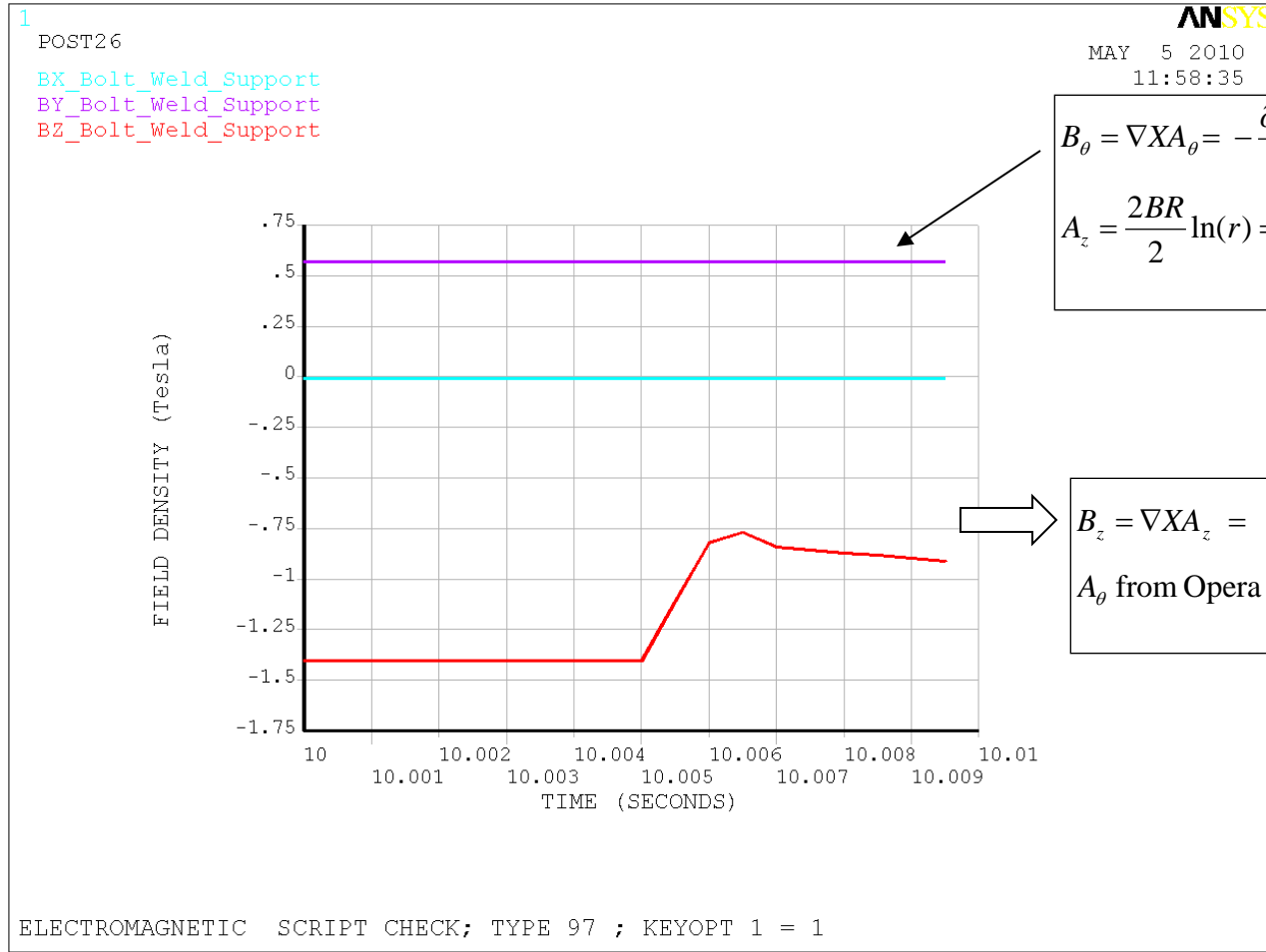
$$B_z = f(1/r, z) \quad f(1/r, z) \approx -.518 \quad \text{if } z = 0$$

$$B_x = \nabla X A_r = \frac{1}{r} \frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z} = -\frac{\partial A_\theta}{\partial z} \quad \text{since: } A_z \neq f(\theta); \text{ for symmetric profiles}$$

$$B_\theta = \nabla X A_\theta = \frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r} = -\frac{\partial A_z}{\partial r} \quad \text{since: } A_r \neq f(z); \text{ for symmetric profiles}$$

$$B_z = \nabla X A_z = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} - \frac{1}{r} \frac{\partial A_r}{\partial \theta} = \frac{1}{r} \frac{\partial (r A_\theta)}{\partial r} \quad \text{since: } A_r \neq f(\theta) \text{ for symmetric profiles}$$

A_θ from Opera program



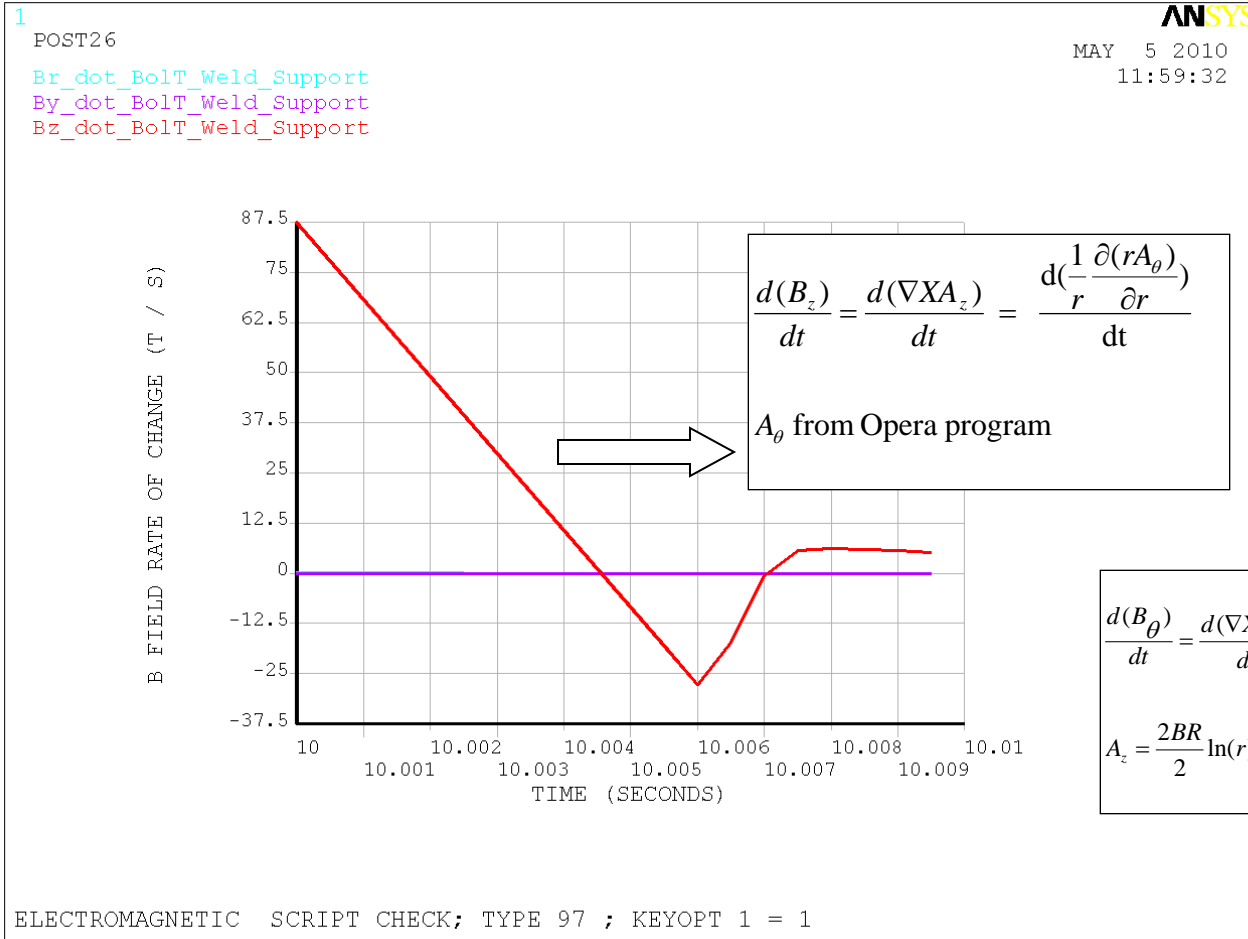
$$B_{\theta} = \nabla X A_{\theta} = -\frac{\partial A_z}{\partial r}$$

$$A_z = \frac{2BR}{2} \ln(r) = \frac{(BR)Ln(r^2)}{2}$$

$$B_z = \nabla X A_z = \frac{1}{r} \frac{\partial (rA_{\theta})}{\partial r}$$

A_{θ} from Opera program

The Flux rate (Bdot) from the Ideal Cylinder shows Bz dot is the largest contributor
 By from the infinite wire has a very small relative impact

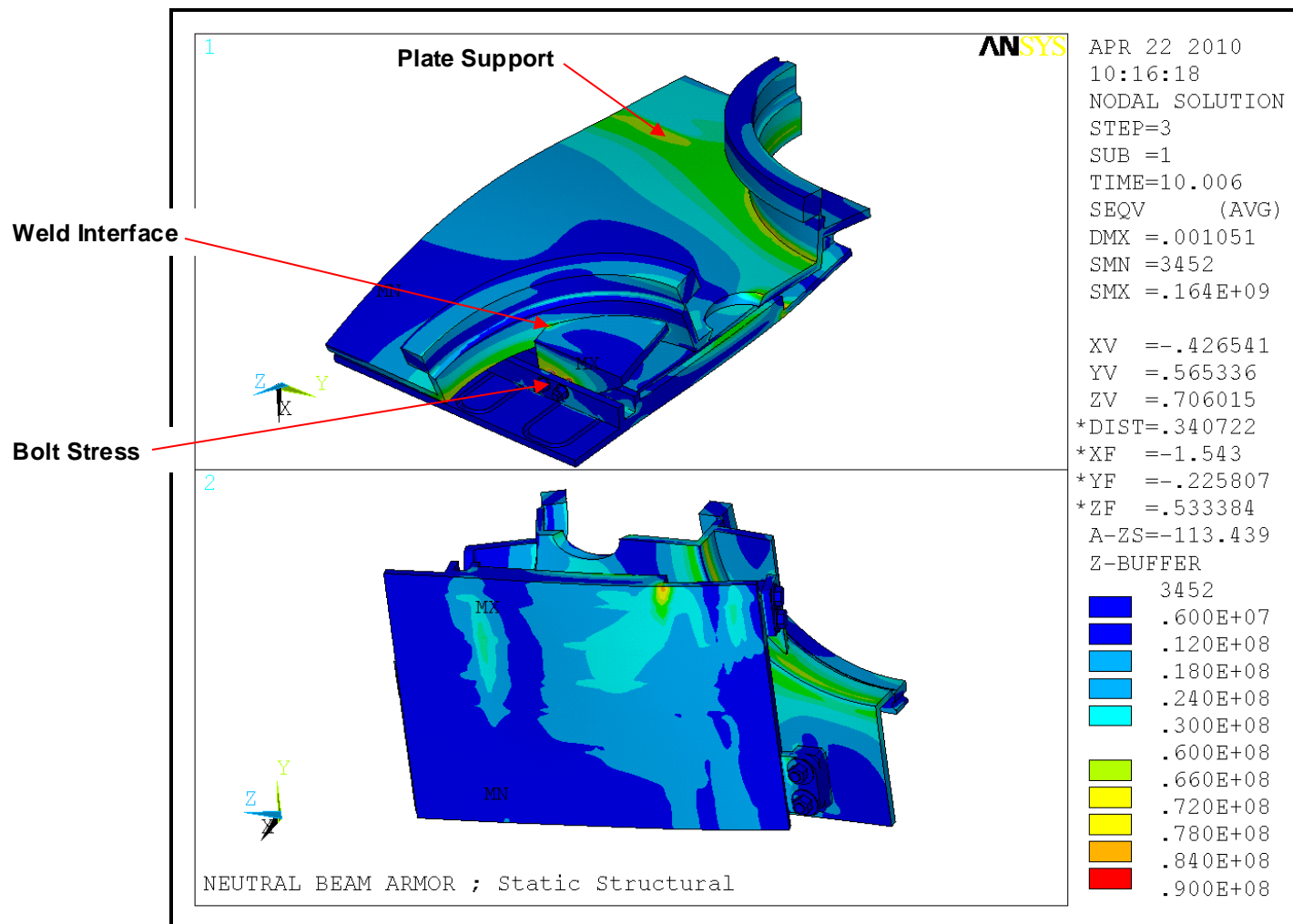


The Flux rate (Bdot) from the Ideal Cylinder shows Bz dot is the largest contributor
 By from the infinite wire has a very small relative impact

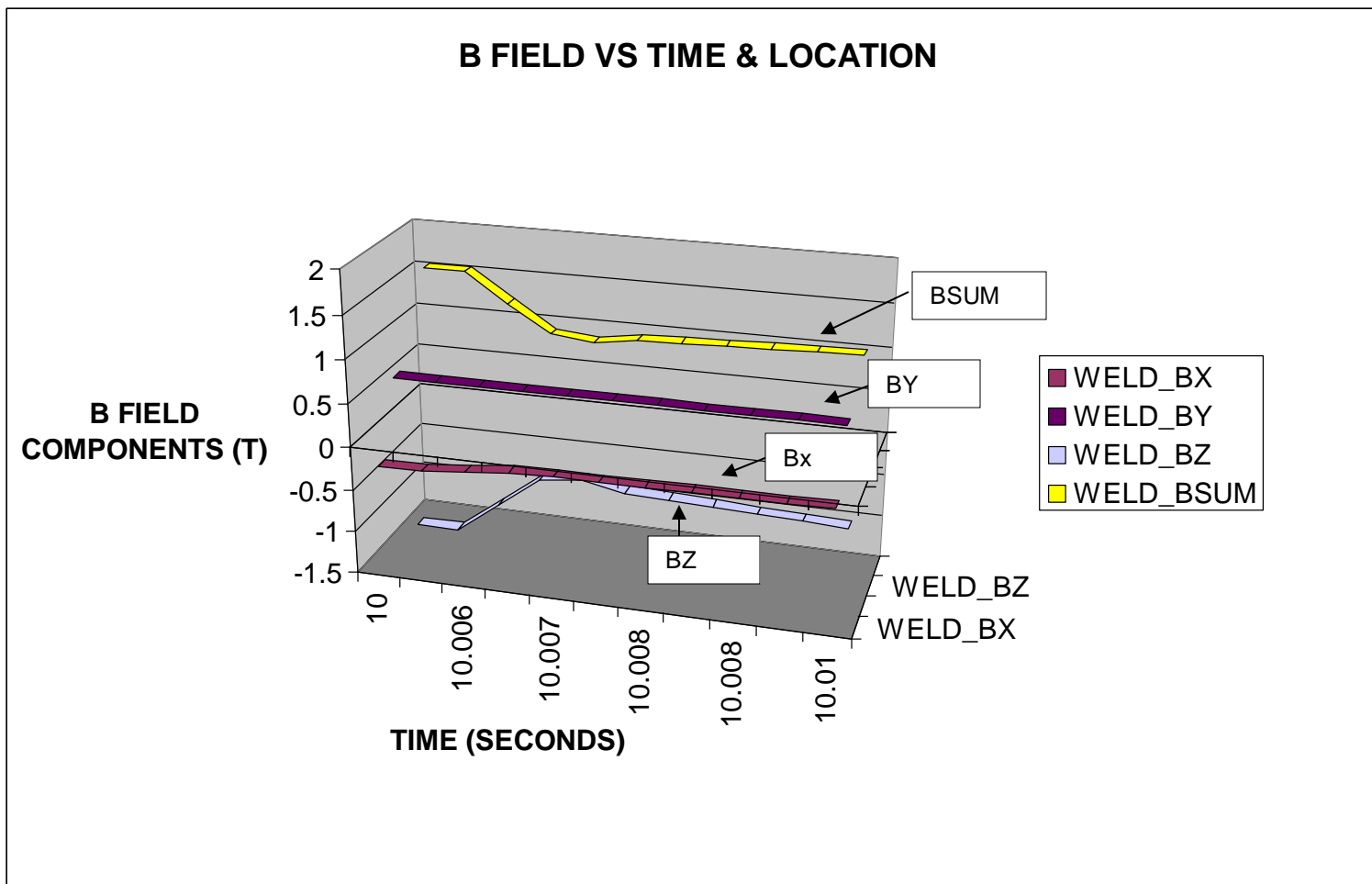
ARMOR MODEL DATA RESULTS

Comparison to

OPERA



B FIELD COMPARISON



Three Locations Identified for B OBD Field from ANSYS program
Data shows Bz is the largest contributor

B FIELD COMPARISON

| TIME | B X | B X | B X | B Y | B Y | B Y | B Z | B Z | B Z |
|--------|-----------|-------------|-------------|-----------|-------------|-------------|-----------|-------------|-------------|
| | Bolt Weld | Armor Plate | Armor Plate | Bolt Weld | Armor Plate | Armor Plate | Bolt Weld | Armor Plate | Armor Plate |
| 10 | -0.254524 | -0.257837 | -0.441618 | 0.592054 | 0.606551 | 0.594702 | -1.40825 | -1.38778 | -1.48148 |
| 10.005 | -0.254524 | -0.257837 | -0.441618 | 0.592054 | 0.606551 | 0.594702 | -1.40825 | -1.38778 | -1.48148 |
| 10.006 | -0.204063 | -0.191579 | -0.338777 | 0.592153 | 0.606672 | 0.594863 | -1.03435 | -1.0366 | -1.23867 |
| 10.006 | -0.151308 | -0.123944 | -0.236554 | 0.592255 | 0.606796 | 0.595024 | -0.665195 | -0.689504 | -0.989148 |
| 10.007 | -0.136419 | -0.107519 | -0.214723 | 0.592282 | 0.606828 | 0.595058 | -0.604015 | -0.631578 | -0.934217 |
| 10.007 | -0.141459 | -0.11699 | -0.230224 | 0.592269 | 0.606815 | 0.595034 | -0.698978 | -0.720783 | -0.987923 |
| 10.008 | -0.137178 | -0.113564 | -0.224289 | 0.592275 | 0.606825 | 0.595043 | -0.720506 | -0.741341 | -0.999644 |
| 10.008 | -0.133354 | -0.110439 | -0.218653 | 0.59228 | 0.606834 | 0.595052 | -0.741778 | -0.761762 | -1.01292 |
| 10.008 | -0.129929 | -0.107591 | -0.21331 | 0.592284 | 0.606842 | 0.59506 | -0.762448 | -0.781686 | -1.02701 |
| 10.009 | -0.126866 | -0.105006 | -0.208308 | 0.592288 | 0.60685 | 0.595068 | -0.782342 | -0.800923 | -1.04141 |
| 10.01 | -0.124124 | -0.102667 | -0.203665 | 0.592292 | 0.606858 | 0.595075 | -0.801397 | -0.819396 | -1.05582 |

Highlighted Data Graphed & Compared to OPERA next Slide

| NODE | R | Y | Z | |
|--------|--------|---------|----------|---------------|
| 29680 | 1.5776 | -151.95 | -0.14623 | BOLT WELD |
| 38971 | 1.5388 | -153.70 | -0.17847 | PLATE |
| 103492 | 1.5703 | -171.92 | -0.39053 | PLATE SUPPORT |

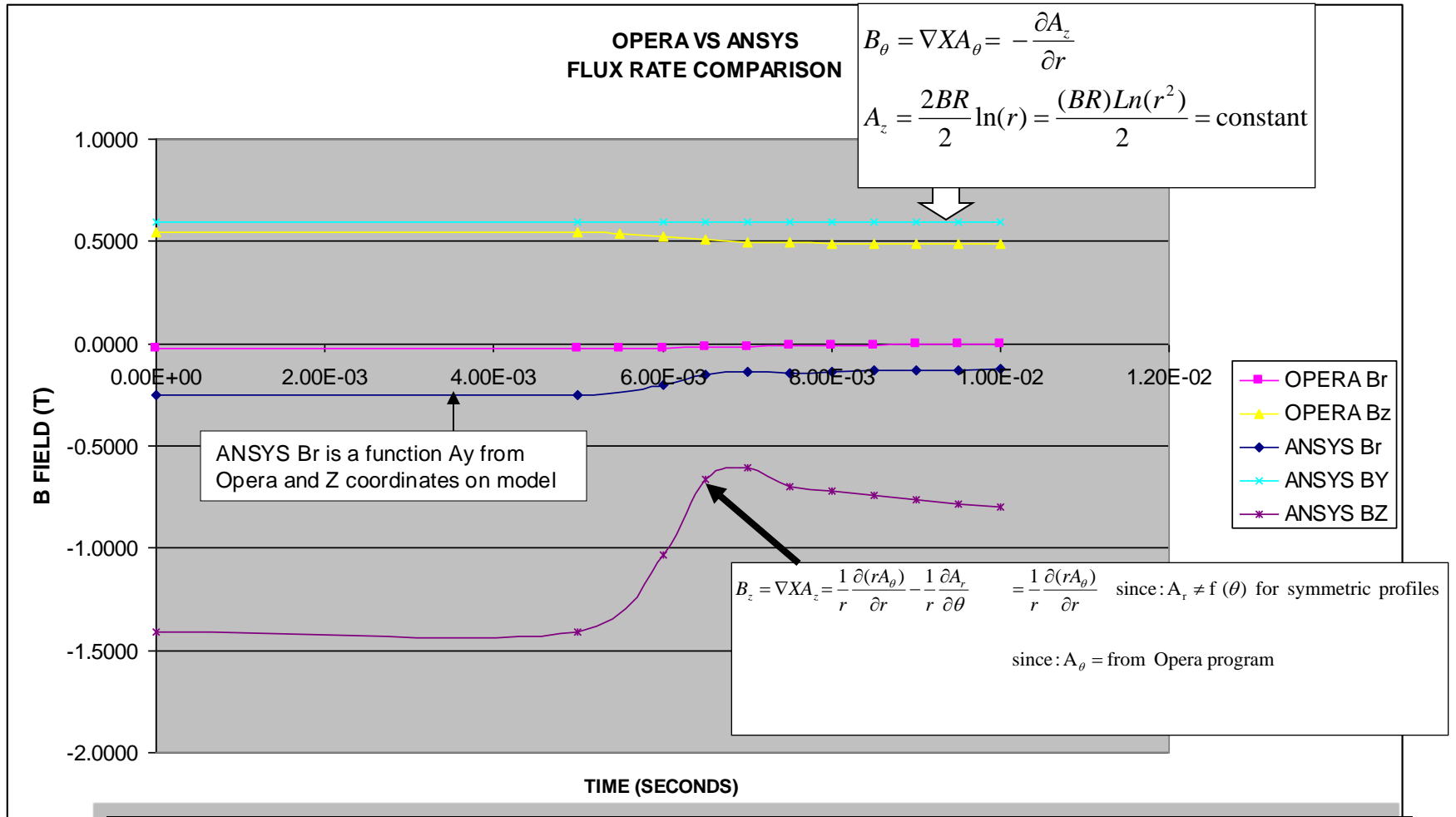
Three Locations Identified for B OBD Field from ANSYS program
Data shows BZ is the largest contributor during disruptions

OPERA FIELD & FLUX RATE For OBD R. HATCHER 5-3-10 ($r=1.5776$ m $Z=-.014623$ m)

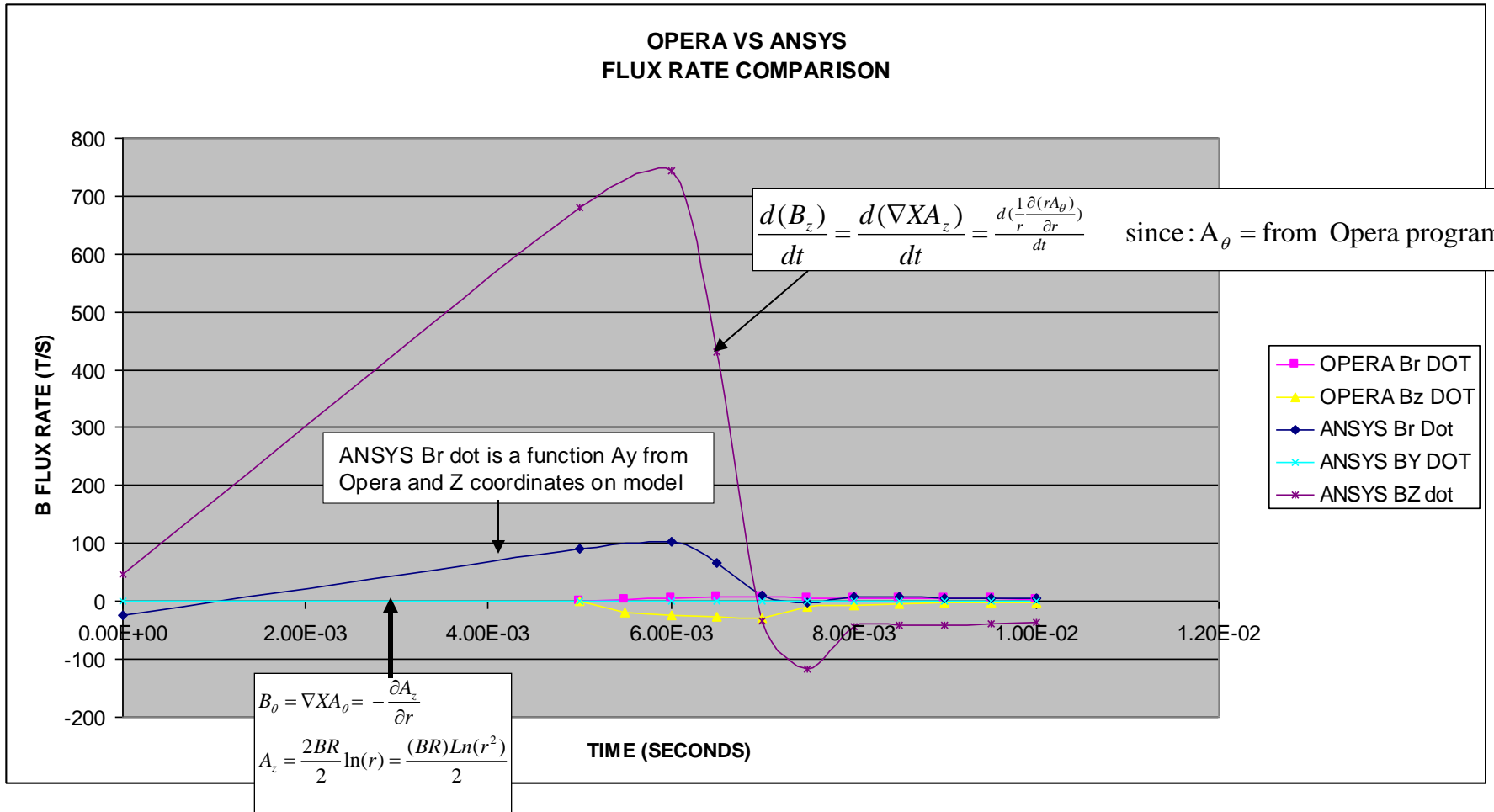
| T [s] | Br [T] | Bz [T] | B | dBr/dt | dBz/dt | d B /dt |
|----------|---------|--------|--------|--------|--------|---------|
| 0.00E+00 | -0.0260 | 0.5472 | 0.5478 | | | |
| 5.00E-03 | -0.0260 | 0.5472 | 0.5478 | 0.00 | 0.00 | 0.00 |
| 5.50E-03 | -0.0241 | 0.5374 | 0.5379 | 3.89 | -19.74 | -19.89 |
| 6.00E-03 | -0.0212 | 0.5255 | 0.5259 | 5.63 | -23.79 | -24.00 |
| 6.50E-03 | -0.0177 | 0.5124 | 0.5127 | 7.00 | -26.05 | -26.29 |
| 7.00E-03 | -0.0135 | 0.4985 | 0.4987 | 8.40 | -27.92 | -28.17 |
| 7.50E-03 | -0.0108 | 0.4942 | 0.4944 | 5.41 | -8.46 | -8.59 |
| 8.00E-03 | -0.0084 | 0.4914 | 0.4915 | 4.98 | -5.68 | -5.77 |
| 8.50E-03 | -0.0060 | 0.4895 | 0.4895 | 4.69 | -3.88 | -3.95 |
| 9.00E-03 | -0.0038 | 0.4881 | 0.4882 | 4.47 | -2.64 | -2.68 |
| 9.50E-03 | -0.0016 | 0.4873 | 0.4873 | 4.28 | -1.73 | -1.76 |
| 1.00E-02 | 0.0004 | 0.4868 | 0.4868 | 4.12 | -1.05 | -1.06 |

ANSYS FLUX RATE FROM OUTBOARD 4-30-10

| ANSYS DERIVATIVE RESULTS | | | | |
|--------------------------|---------------------|---------------------|---------------------|----------|
| TIME | 20 DERI Br dot B | 21 DERI BY dot B | 22 DERI BZ dot B | |
| 0 | | -22.9381 | -3.59E-02 | 47.5091 |
| 0.005 | | 91.747 | 0.179558 | 679.825 |
| 0.006 | | 103.216 | 0.201101 | 743.056 |
| 0.0065 | | 67.6443 | 0.129268 | 430.333 |
| 0.007 | | 9.84905 | 1.42E-02 | -33.7834 |
| 0.0075 | | -0.759602 | -7.01E-03 | -116.492 |
| 0.008 | | 8.10563 | 1.07E-02 | -42.7997 |
| 0.0085 | | 7.24953 | 9.41E-03 | -41.9419 |
| 0.009 | | 6.48747 | 8.31E-03 | -40.5637 |
| 0.0095 | | 5.8049 | 7.35E-03 | -38.9491 |
| 0.01 | | 5.12233 | 6.40E-03 | -37.3344 |



ANSYS & OPERA Provide Similar Br Fields
 By field is added field from the infinite wire assumption
 Bz is the largest component during disruption – based on Opera Ay



ANSYS disruption is primarily controlled by Bz dot which is derived from the A_y input from Opera – The relative contribution of By is small

CONCLUSIONS

- The Electromagnetic script used for processing the ANSYS models has been checked and evaluated for input and theoretical values.
- The ANSYS Field calculations for B_x is similar to OPERA, however, the ANSYS B_z is significantly different from the OPERA values for the disruption file provided by Sri for the OBD disruption.
- The previously undocumented equation for Vector Potential A_z was reverse engineered and shown to match the assumptions of an infinite wire.
- The results demonstrated that changes to the script were necessary in order to assure consistency with the OPERA electromagnetic data.
- An APDL script (ESYSTEM-MODIFY) was constructed to include an automatic generation of an element system that corresponds with the cylindrical nodal coordinate system 5. The script selects the users defined element types and modifies each one separately while maintaining the previously define values for Real, Mat, and Type numbers.
 - Each user will need to independently verify that their all of their FE model elements have this element system defined and that each element has been rotated into this system.
- With the changes to the script we determined for the OPERA field results:
 - B_r are close and differences could be explained with small position differences.
 - B_z results are significantly different due to differences in the theory and perhaps some mistake in the generation of the disruption profiles.
 - ANSYS B_z is calculated based on input of A_y from Opera and is the largest rate contributor.
 - OPERA B_z is calculated based on additional coils that we do not model or include.
 - ANSYS B_y is a constant as input from the script (Infinite Wire) Opera does not have B_y value
- Without adding the rotated element coordinate system the B_Y and B_Z filed values are switched in the result output.

RECOMMENDATIONS

- Previous runs using the in house Electromagnetic script should be re-checked to verify that results are consistent with the new element coordinate system addition.
- The attached APDL script (ESYSTEM-MODIFY) can be used to generate the proper cylindrical coordinate stem and change all of the elements in the model to include this change.
- Consider evaluating the influence of discretization error by investigating Ron Hatchers mesh.
- Given that the B_z and B_z -dot field calculations are significantly different, we need to establish a more robust central data base for cataloging the disruption files.
 - Text Headers should be added to each disruption file to assure that we have a traceable record for each data set.
- Every disruption analysis data set evaluated by the stress group should include or have added a side by side comparison of the OPERA filed and rate comparison along with the analysts results.