SDLL102 - Gantry subjected to electrodynamic forces

Summary:

This test is a three-dimensional problem of direct transitory dynamic calculation with forces distributed of electrodynamic origin applied to a gantry (bars on 3 insulating columns of a switchyard).

This test was provided by the Center of Studies of Transport network (EDF-DEPT). It was supplemented since by a benchmark international bench starting from experimental measurements (results of several foreign codes): test CIGRE-structure D.

It makes it possible to compare results of displacements compared to those obtained by other industrial codes using a method finite elements or finished differences.

This test contains a modeling with elements of the type SEG2.
1 Problem of reference

1.1 Geometry

![Diagram]

Cross sections of beams:

- frame support

  \[ \begin{align*}
  S1 & : \quad A = 1.2061 \times 10^{-2} \text{m}^2 & \quad I_z = 2.3681 \times 10^{-5} \text{m}^4 \\
  S5 & : \quad A = 1.4621 \times 10^{-2} \text{m}^2 & \quad I_z = 2.8709 \times 10^{-5} \text{m}^4 \\
  S9 & : \quad A = 1.5530 \times 10^{-2} \text{m}^2 & \quad I_z = 3.0493 \times 10^{-5} \text{m}^4 \\
  \end{align*} \]

- insulating columns

  \[ \begin{align*}
  S2 & : \quad A = 3.1428 \times 10^{-2} \text{m}^2 & \quad I_z = 4.5070 \times 10^{-5} \text{m}^4 \\
  S6 & : \quad A = 3.2592 \times 10^{-2} \text{m}^2 & \quad I_z = 4.6738 \times 10^{-5} \text{m}^4 \\
  S10 & : \quad A = 3.3416 \times 10^{-2} \text{m}^2 & \quad I_z = 4.7927 \times 10^{-5} \text{m}^4 \\
  \end{align*} \]

- connections

  \[ \begin{align*}
  S3, S11 & : \quad A = 3.1944 \times 10^{-2} \text{m}^2 & \quad I_z = 1.15 \times 10^{-5} \text{m}^4 \\
  S7 & : \quad A = 4.2130 \times 10^{-2} \text{m}^2 & \quad I_z = 1.15 \times 10^{-5} \text{m}^4 \\
  \end{align*} \]

- drivers

  \[ \begin{align*}
  S4, S8 & : \quad \text{circular } R = 6.055 \times 10^{-2} \text{m} & \quad e = 6.2 \times 10^{-3} \text{m} \\
  \end{align*} \]

1.2 Material properties

\[ \begin{align*}
  M1 & : \quad E = 2.1 \times 10^{11} \text{Pa} & \quad \rho = 8000 \text{kg/m}^3 \quad \text{(frame support)} \\
  M2 & : \quad E = 5.1 \times 10^{10} \text{Pa} & \quad \rho = 2500 \text{kg/m}^3 \quad \text{(insulating column)} \\
  M3 & : \quad E = 7.1 \times 10^{10} \text{Pa} & \quad \rho = 2700 \text{kg/m}^3 \quad \text{(connection and conducting aluminium)} \\
  \end{align*} \]
1.3 Boundary conditions and loadings

Points $A$, $E$, $I$: embedding
Points $D$, $L$: not-continuity of $u_x$, $\theta_x$, $\theta_z$
Forces of Laplace on the drivers $DH$, $HL$;

- two-phase current $\phi = \omega = 100 \, m$
- infinite drivers separated from $1 \, m$

$$I = I_{\text{eff}} \sqrt{2} (\cos (\omega t + \phi) - e^{-\tau t} \cos \phi)$$

$I_{\text{eff}}$: effective intensity of the current
$\tau$: time-constant

- two short-circuit with reset

<table>
<thead>
<tr>
<th>$t$</th>
<th>$0 &lt; t \leq 0.135$</th>
<th>$0.135 &lt; t &lt; 0.580$</th>
<th>$0.580 \leq t \leq 0.885$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{\text{eff}}$</td>
<td>$15.6 , kA$</td>
<td>$0$</td>
<td>$15.6 , kA$</td>
</tr>
<tr>
<td>$\tau$</td>
<td>$0.066 , s$</td>
<td>$-$</td>
<td>$0.062 , s$</td>
</tr>
</tbody>
</table>

1.4 Initial conditions

$t = 0$, speed and zero acceleration.

2 Reference solution

2.1 Method of calculating used for the reference solution

- experimental measurements,
- digital methods Finished Differences or Finite elements.

$$I = I_{\text{eff}} \sqrt{2} (\cos (\omega t + \phi) - e^{-\tau t} \cos \phi)$$

2.2 Uncertainty on the solution

The dispersion of the computed values is regarded as understood enters 5% and 10%.

2.3 Bibliographical references

1) G. DEVESA: “Calculation of the electrodynamic strains on structures of drivers rigid of the electric stations: establishment in the mechanical computer code *Aster* and Validation”. Note HM-72/5904
3 Modeling A

3.1 Characteristics of modeling

Modeling POU_D_E

Discretization:

- elements $AB$, $EF$, $IJ$ : 10 meshes: SEG2
- elements $BC$, $FG$, $JK$ : 10 meshes: SEG2
- elements $CD1$, $GH1$, $KL1$ : 1 mesh: SEG2
- elements $D2H1$, $H2L1$ : 30 meshes: SEG2

Dynamic evolution on 1s discretized in step of time of $5 \times 10^{-4}$ s with the algorithm of NEWMARK ($a=0.25$, $d=0.5$).

Storage of the results all 20 pas de time is $10^{-2}$ s.

3.2 Characteristics of the grid

Many nodes: 126
Many meshes and types: 123 meshes SEG2

3.3 Sizes tested and results

<table>
<thead>
<tr>
<th>Identification</th>
<th>Reference test</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t=0.12$ s</td>
<td></td>
</tr>
<tr>
<td>$u_y$ in $C2$</td>
<td></td>
</tr>
<tr>
<td>$M_x$ in $S1$</td>
<td>$-3140$. Nm</td>
</tr>
<tr>
<td>$M_x$ in $S2$</td>
<td>$-10150$. Nm</td>
</tr>
<tr>
<td>$M_x$ in $S3$</td>
<td>$-3130$. Nm</td>
</tr>
<tr>
<td>$M_z$ in $C2$</td>
<td>$1431$. Nm</td>
</tr>
<tr>
<td>$t=0.70$ s</td>
<td></td>
</tr>
<tr>
<td>$u_y$ in $C2$</td>
<td></td>
</tr>
<tr>
<td>$M_x$ in $S1$</td>
<td>$-6080$. Nm</td>
</tr>
<tr>
<td>$M_x$ in $S2$</td>
<td>$-19670$. Nm</td>
</tr>
<tr>
<td>$M_x$ in $S3$</td>
<td>$-6060$. Nm</td>
</tr>
<tr>
<td>$M_z$ in $C2$</td>
<td>$2746$. Nm</td>
</tr>
</tbody>
</table>

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Maximum obtained with $t=0.12\,s$ (1st short-circuit) or $t=0.70\,s$ (2nd short-circuit) or reset (conformity test-calculation).

3.4 Remarks

Results got by Code_aster are satisfactory compared to the other codes. They are almost always lower than measurements (effects of the frames $AB$, $EF$, $IJ$ overestimated). The maximum ones are chopped because of periodic storage.

Contents of the file results:

Displacements all them $10^{-2}\,s$ and efforts in the elements at times $t=0.12\,s$, $t=0.27\,s$, $t=0.70\,s$. 
4 Modeling B

A modeling B was added to test the elements of beam with warping POU_D_TG. The additional coefficients were arbitrarily selected:

\[ AY = AZ = 1.0 \]
\[ EY = EZ = JG = 0.0 \]

4.1 Sizes tested and results

<table>
<thead>
<tr>
<th></th>
<th>Reference test</th>
<th>References of not-regression</th>
<th>% tolerance tests/not regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t = 0.12 , s )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( u_x ) in ( C2 )</td>
<td>( 60.5 , \text{mm} )</td>
<td>( 3108. , \text{Nm} )</td>
<td>( 2.0/0.1 )</td>
</tr>
<tr>
<td>( M_x ) in ( S1 )</td>
<td>( -3140. , \text{Nm} )</td>
<td>( -3108. , \text{Nm} )</td>
<td>( 2.0/0.1 )</td>
</tr>
<tr>
<td>( M_x ) in ( S2 )</td>
<td>( -10150. , \text{Nm} )</td>
<td>( -9255. , \text{Nm} )</td>
<td>( 9.0/0.1 )</td>
</tr>
<tr>
<td>( M_x ) in ( S3 )</td>
<td>( -3130. , \text{Nm} )</td>
<td>( -2948. , \text{Nm} )</td>
<td>( 3.0/0.1 )</td>
</tr>
<tr>
<td>( M_z ) in ( C2 )</td>
<td>( 1431. , \text{Nm} )</td>
<td>( 1304. , \text{Nm} )</td>
<td>( 9.0/0.1 )</td>
</tr>
</tbody>
</table>

| \( t = 0.70 \, s \) |                |                              |                                 |
| \( u_x \) in \( C2 \) | \( 118.9 \, \text{mm} \) | \( 6150. \, \text{Nm} \) | \( 2.0/0.1 \) |
| \( M_x \) in \( S1 \) | \( -6080. \, \text{Nm} \) | \( -6150. \, \text{Nm} \) | \( 2.0/0.1 \) |
| \( M_x \) in \( S2 \) | \( -19670. \, \text{Nm} \) | \( -18523. \, \text{Nm} \) | \( 6.0/0.1 \) |
| \( M_x \) in \( S3 \) | \( -6060. \, \text{Nm} \) | \( -5928. \, \text{Nm} \) | \( 3.0/0.1 \) |
| \( M_z \) in \( C2 \) | \( 2746. \, \text{Nm} \) | \( 2602. \, \text{Nm} \) | \( 6.0/0.1 \) |
5 Summary of the results

The results are acceptable compared to the test results and locate values produced by Code_Aster in good place among ten results of other software.