Wheelset torsion mode

Assume a mode of vibration; left and right wheel:

$$\beta_l = \begin{pmatrix} whe_k \cdot z_l \\ 0. \\ -whe_k \cdot x_l \end{pmatrix} \qquad \begin{matrix} -\sqrt{(r^2 - x_l^2)} \le z_l \le \sqrt{(r^2 - x_l^2)} \\ \\ -\sqrt{(r^2 - z_l^2)} \le x_l \le \sqrt{(r^2 - z_l^2)} \end{matrix}$$

$$\beta_r = \begin{pmatrix} -whe_k \cdot z_r \\ 0. \\ whe_k \cdot x_r \end{pmatrix} \qquad \begin{matrix} -\sqrt{(r^2 - x_l^2)} \le z_r \le \sqrt{(r^2 - x_l^2)} \\ \\ -\sqrt{(r^2 - z_l^2)} \le x_r \le \sqrt{(r^2 - z_l^2)} \end{matrix}$$

Where: whe_k is the pitch angle of the wheels.

Mass-orthonormalize one wheel:

$$\iint (\beta_l^T \, dM_l \beta_l) = \iint (\beta_l^T \rho b \, \beta_l) \; dx_l \, dz_l = J_x \cdot whe_k^2 = 1$$

Where: $dMl = \rho \cdot b \cdot dx_l \cdot dz_l$

ρ = Density

b = Wheel thickness

Mass-orthonormalize the whole wheelset gives:

$$J_x \cdot 2 \cdot whe_k^2 = 1 \quad => \quad whe_k = \frac{1}{\sqrt{(2 \cdot J_x)}}$$

The contact points of the wheels are located at:

$$x_l = x_r = 0.$$
$$z_l = z_r = r_o$$

Which gives the mass-orthonormalized amplitude in contact point:

$cpl_x = \dfrac{r_o}{\sqrt{(2 \cdot J_x)}}$ Left wheel

$cpr_x = \dfrac{-r_o}{\sqrt{(2 \cdot J_x)}}$ Right wheel

Wheelset bending mode

Assume a mode of vibration; left and right wheel:

$$\beta_l = \begin{pmatrix} 0. \\ -whe_f \cdot z_l \\ 0. \end{pmatrix} \qquad -r \le z_l \le r$$

$$\beta_r = \begin{pmatrix} 0. \\ whe_f \cdot z_r \\ 0. \end{pmatrix} \qquad -r \le z_r \le r$$

Where: whe_f is the roll angle of the wheels.

Mass-orthonormalize the whole wheelset gives:

$$J_\varphi \cdot 2 \cdot whe_f^2 = 1 \quad => \quad whe_f = \frac{1}{\sqrt{(2 \cdot J_\varphi)}}$$

The contact points of the wheels are located at:

$$x_l = x_r = 0.$$
$$z_l = z_r = r_o$$

Which gives the mass-orthonormalized amplitude in contact point:

$$cpl_y = \frac{r_o}{\sqrt{(2 \cdot J_\varphi)}} \qquad \text{Left wheel}$$

$$cpr_y = \frac{-r_o}{\sqrt{(2 \cdot J_\varphi)}} \qquad \text{Right wheel}$$

The axle-boxes are located at:

$$\begin{cases} x_r = 0. \\ y_r = B_{kzba} - B_o \\ z_r = 0. \end{cases}$$

$$\begin{cases} x_l = 0. \\ y_l = -y_r \\ z_l = 0. \end{cases}$$

Which gives the mass-orthonormalized amplitude in the primary suspension:

$$kzba_z = \frac{B_{kzba} - B_o}{\sqrt{(2 \cdot J_\varphi)}} \qquad \text{Left wheel}$$

$$kzba_z = \frac{B_{kzba} - B_o}{\sqrt{(2 \cdot J_\varphi)}} \qquad \text{Right wheel}$$

Wheelset torsion and bending mode in gensys

Define two vibration modes:

```
mass m_flex_1 axl_111
     fq_torsion damp_torsion
     fq_bending damp_bending
```

Add coupling series flexibilities:

```
coupl m_flex_1 cp1_111l end_2
               cplx  0.  0.
               0.   cply 0.

coupl m_flex_1 cp1_111r end_2
               cprx  0.  0.
               0    cpry 0.

coupl m_flex_1 kzba_111l  end_2
               0. 0. 0.    0. 0. 0.
               0. 0. kzbaz 0. 0. 0.

coupl m_flex_1 kzba_111r  end_2
               0. 0. 0.    0. 0. 0.
               0. 0. kzbaz 0. 0. 0.

coupl m_flex_1 czba_111l  end_2
               0. 0. 0.    0. 0. 0.
               0. 0. kzbaz 0. 0. 0.

coupl m_flex_1 czba_111r  end_2
               0. 0. 0.    0. 0. 0.
               0. 0. kzbaz 0. 0. 0.
```