How to model offset wagon loads in Vampire

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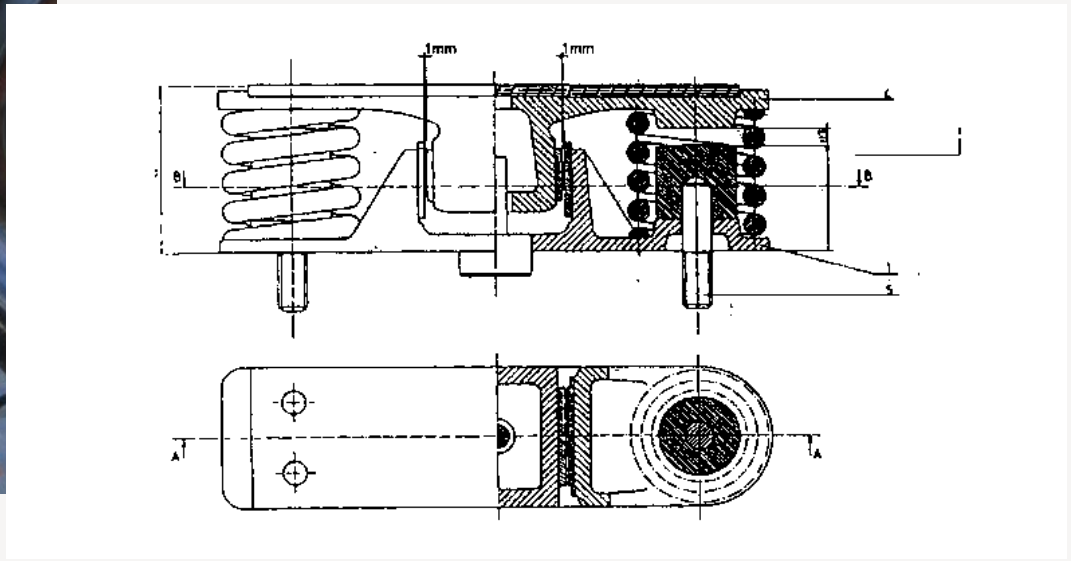
How are static loads normally calculated in Vampire models?

- Static loads in weight-bearing elements are automatically calculated by Vampire
- If there are parallel load paths, load distributed according to stiffness
- Static loads not automatically used for normal loads on friction elements
- PRELOAD keyword in bumpstop adjusts characteristic but does not normally change the actual static load in the element

Example - UIC centre pivot and sidebearers



- When wagon assembled, sidebearers contact first and load up to 16 kN each before centre pivot comes into contact

Example - UIC centre pivot and sidebearers

- Sidebearer spring vertical stiffness = 0.285 MN/m, so 1.14 MN/m per bogie
- Centre pivot stiffness could be 100 MN/m
- Assume 200 kN pivot load
- Actual loads are 16 kN per sidebearer and 168 kN on pivot
- Calculated according to stiffness only:
  - Load per sidebearer = 200 x 0.57 / (1.14 + 100) = 1.127 kN
  - Load on pivot = 200 x 100 / (1.14 + 100) = 197.746 kN

Example - UIC centre pivot and sidebearers

- Model sidebearer bumpstop characteristic as follows (assuming 12 mm gap):

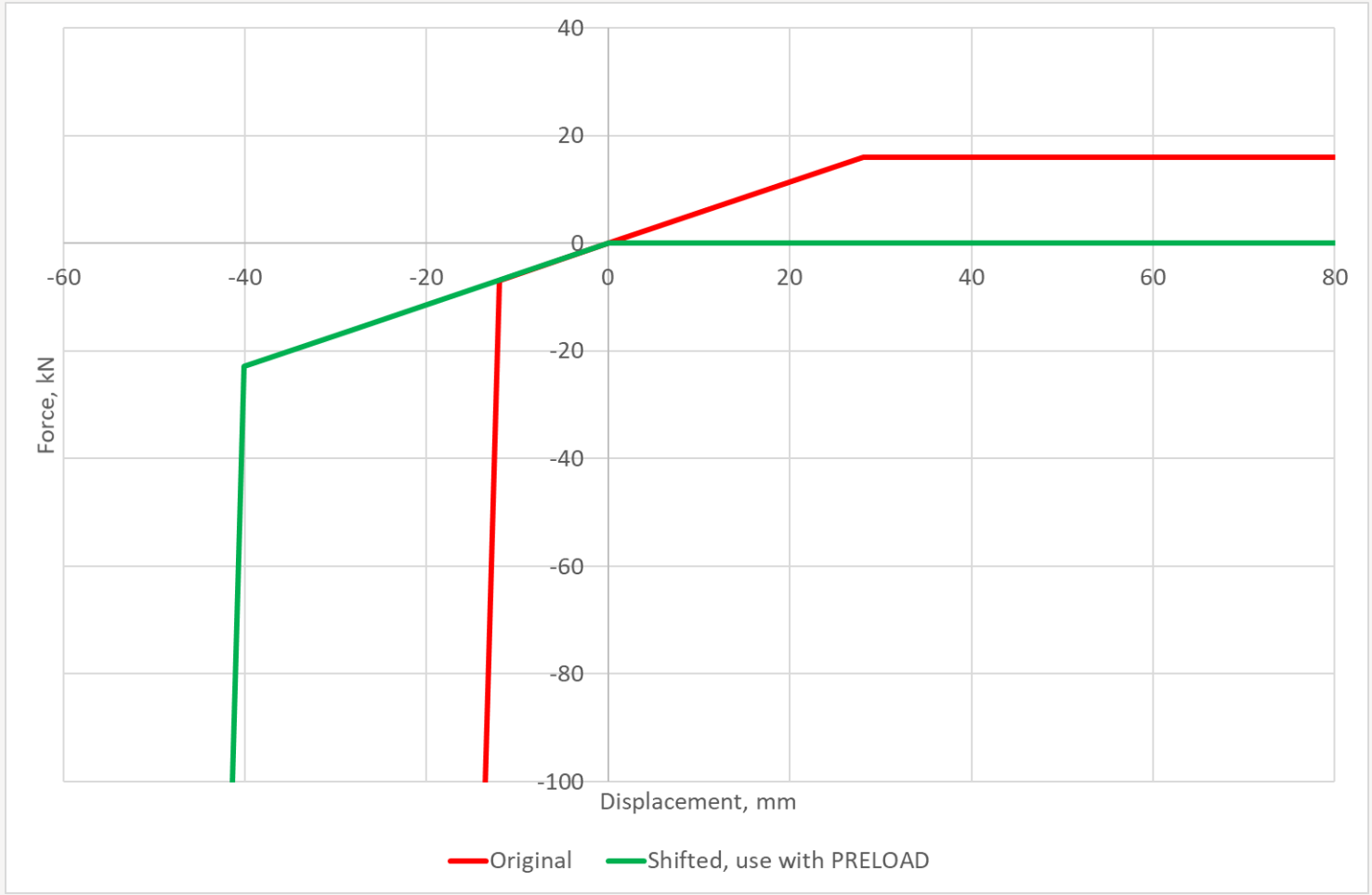
DISPLACEMENT	-22.00	-12.00	0.00	28.07	100.00
FORCE	-606.84	-6.84	0.00	16.00	16.00

- This is equivalent to:

DISPLACEMENT	-50.07	-40.07	-28.07	0.00	71.93
FORCE	-622.84	-22.84	-16.00	0.00	0.00
PRELOAD	16.0				

- This means that if 16 kN is removed from the sidebearer it will lose contact, but there is only 1.127 kN on it, so it will reach 14.873 kN TENSION before releasing

Example - UIC centre pivot and sidebearers



Example - UIC centre pivot and sidebearers

- To force the preload to be 16 kN add STIC OVERRIDE:

```
DISPLACEMENT    -50.07     -40.07     -28.07       0.00      71.93
FORCE          -622.84     -22.84     -16.00       0.00       0.00
PRELOAD          16.0
STATIC        OVERRIDE
```

- Unless the centre pivot is also adjusted this will lead to an imbalance in the model as the sidebearers will carry 16 kN each but the centre pivot will still carry 197.746 kN so the total load carried will be 229.746 kN

Example - UIC centre pivot and sidebearers

- Assume centre pivot is modelled with a 100 MN/m STIFFNESS element
- Displacement under 168 kN load would be 168 / 100 = 1.68 mm or 0.00168 m
- If free height is 0.100 m then installed height would be 0.100 – 0.00168 = 0.09832 m
- Model like this:

```
STIFFNESS        100.00
FREELENGTH         0.100
STATIC         OVERRIDE
**
POSITION           8.000      0.000    0.79832
                   8.000      0.000      0.700
```

Example - UIC centre pivot and sidebearers

- Makes very little difference to model behaviour
- Friction static normal loads are defined separately
- Does affect total load on each element- check using BSTnn and KSTnn output mnemonics
- Total bumpstop load:

  BST01+B01

- Total stiffness load:

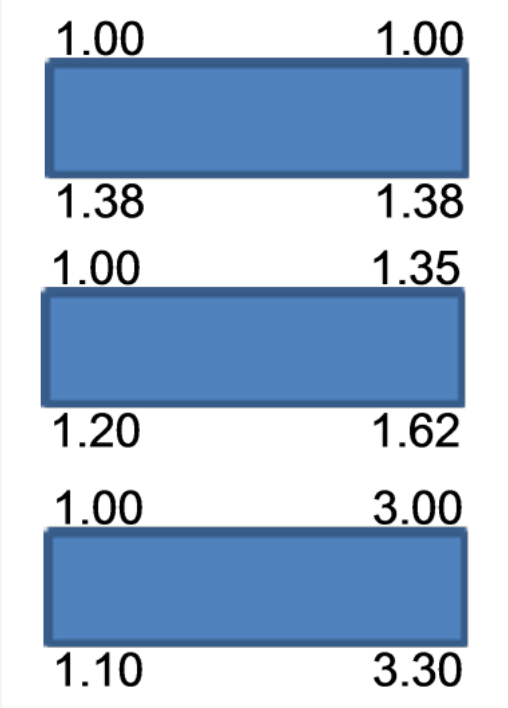
  KST01+K01

Why are we concerned about static loads in models?

- Parallel load paths such as three-axle bogies
- Load distribution affected by body or bogie twist
- Loadings with offset centres of gravity, especially with non-linear and multi-stage suspensions where elements come into contact at different loads
- Example- new offset container load cases in GMRT2141 issue 4.1

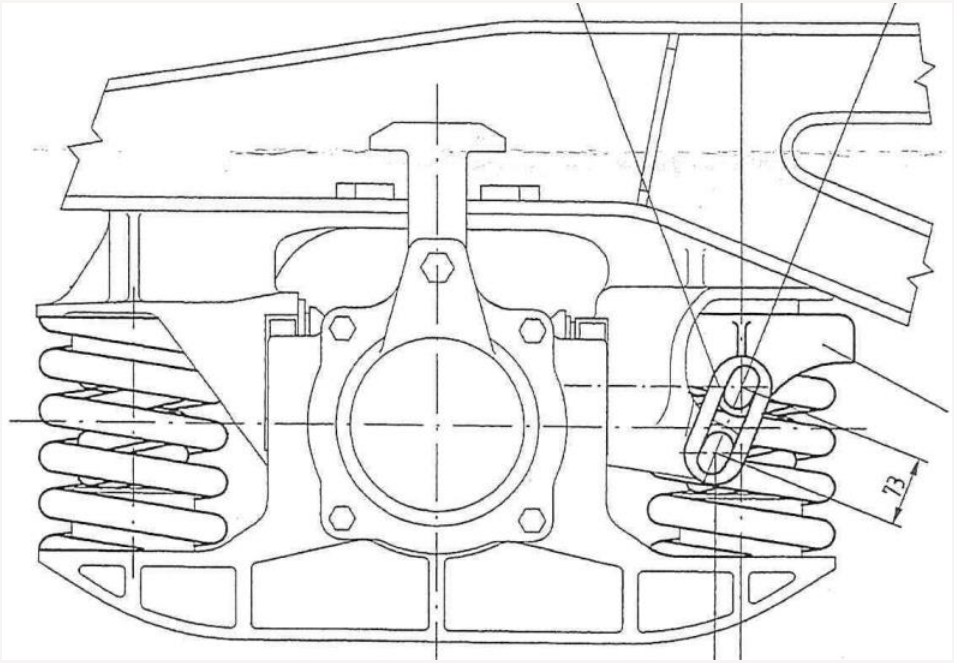
GMRT2141 issue 4.1 offset container loads

- Following Camden Road derailment in 2013 three offset container loading cases introduced to GMRT2141 Issue 4 (now 4.1) for delta Q/Q (and potentially Y/Q) assessment
- Case a- lateral offset
- Case b- combined offset 1
- Case c- combined offset 2

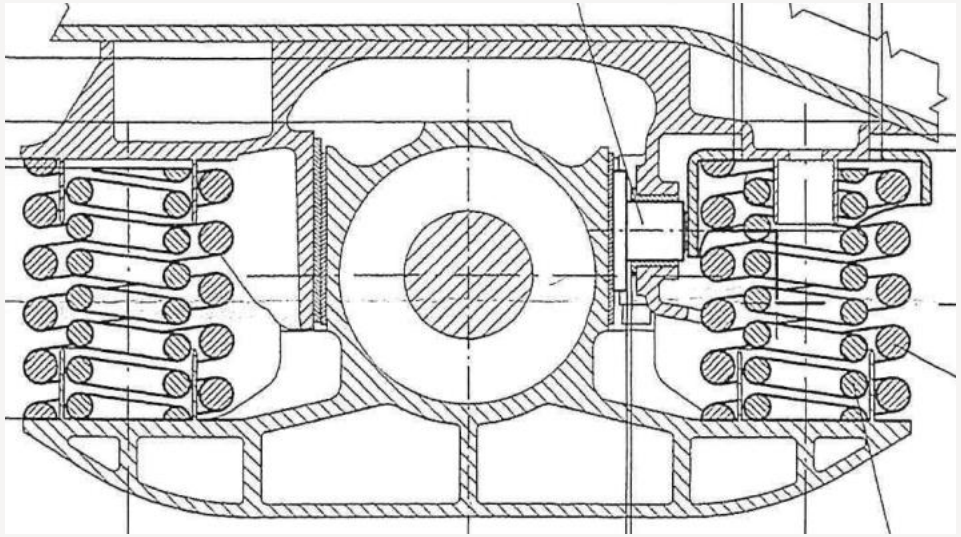


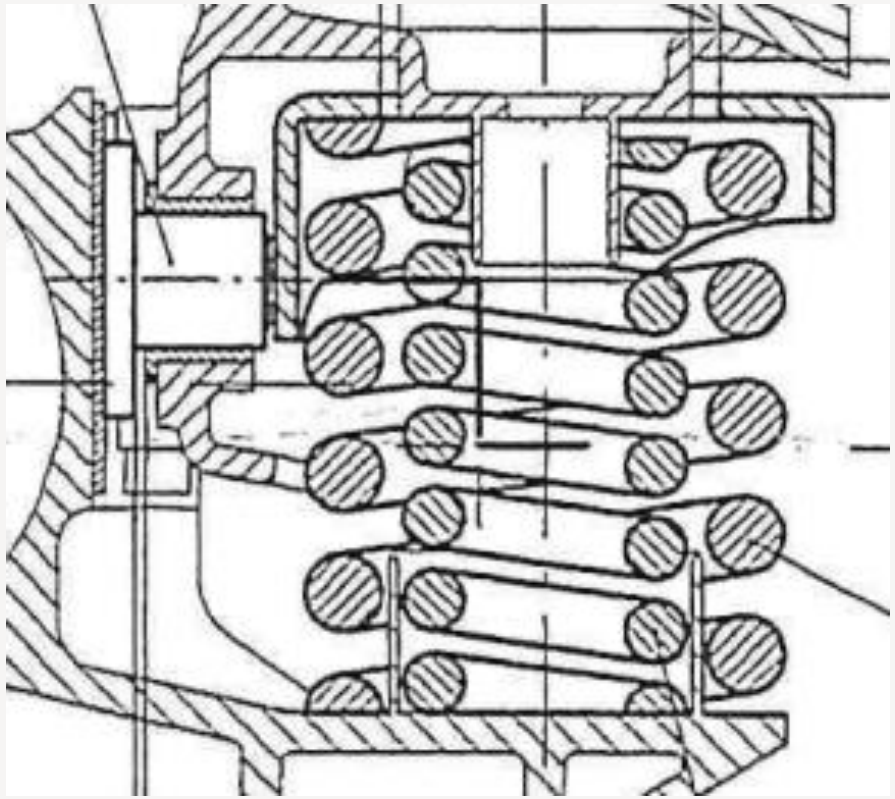
GMRT2141 issue 4.1 offset container loads

- How to model these accurately with correct static loads in sidebearers and primary tare and laden springs and Lenoir links (assuming a Y series bogie)?



GMRT2141 issue 4.1 offset container loads





GMRT2141 issue 4.1 offset container loads

- Body could roll on pivots, closing sidebearer gaps on one side, possibly as far as metal contact
- Bogie could drop and roll, increasing loads in Lenoir links and friction plungers and could drop and roll enough to contact laden springs on one or both sides
- The static loading could be precalculated manually but this seems very tedious when Vampire can do it for you!

GMRT2141 issue 4.1 offset container loads

- Create a tare model including elements with defined static loads
- Use parameters such as:

```
d1 = 0.00000 m      Drop at end 1
d2 = 0.00000 m      Drop at end 2
r1 = 0.00000 rad    Bogie roll at end 1
r2 = 0.00000 rad    Bogie roll at end 2
```

GMRT2141 issue 4.1 offset container loads

- Model shear springs with FREELENGTH and STATIC OVERRIDE:

```
*SHEAR
** Tare springs
STIFFNESS      0.500     0.500     0.800     0.001     0.001      0.001
FREELENGTH     0.300
STATIC      OVERRIDE
POSITION            x     1.000   0.56319-d1-1*r1     0.300     2     4
POSITION            x    -1.000   0.56319-d1+1*r1     0.300     2     4
** Laden springs
STIFFNESS      0.300     0.300     1.500     0.001     0.001      0.001
FREELENGTH     0.255
STATIC      OVERRIDE
POSITION            x     1.000   0.56319-d1-1*r1     0.300     2     4
POSITION            x    -1.000   0.56319-d1+1*r1     0.300     2     4
```

GMRT2141 issue 4.1 offset container loads

- With d1 = r1 = 0, tare spring load will be:

  1000 x 0.8 x (0.3 – (0.56319 – 0.3) = 800 x 0.03681 = 29.448 kN

- Laden spring load will be 0 as installed height is less than free height

GMRT2141 issue 4.1 offset container loads

- Create a ‘setup’ model by setting friction to very low values (Vampire often doesn’t like it set to zero)
- Apply offset container loads to setup model using static program
- All loads will be carried by springs, not friction

GMRT2141 issue 4.1 offset container loads

```
STATIC LOAD EXAMPLE
*******************
..\D01 Vehicle models\Example_setup
**
*STATIC
*******
DQ          0.000001
STAGE 1
** Apply load
F01Z          38.001
F01T          18.210
F01P        -101.221
**
```

GMRT2141 issue 4.1 offset container loads

```
*OUTPUT
*******
Primary drop, bogie 1                    m
D02Z-(D04Z+D05Z)/2
Primary drop, bogie 2                    m
D03Z-(D06Z+D07Z)/2
Roll, bogie 1                          rad
D02T-(D04T+D05T)/2
Roll, bogie 2                          rad
D03T-(D06T+D07T)/2
*
```

GMRT2141 issue 4.1 offset container loads

- Read results from STATIC section of lis file:

```
*STATIC DATA:-
CH  1     Primary drop, bogie 1                    m
   1.049E-02
CH  2     Primary drop, bogie 2                    m
   1.271E-03
CH  3     Roll, bogie 1                            rad
   2.842E-03
CH  4     Roll, bogie 2                            rad
   2.834E-03
```

GMRT2141 issue 4.1 offset container loads

- Use the results to set the parameters in the laden vehicle model:

```
d1 = 0.01049 m      Drop at end 1
d2 = 0.00127 m      Drop at end 2
r1 = 0.00284 rad    Bogie roll at end 1
r2 = 0.00283 rad    Bogie roll at end 2
```

- The example spring loads will then be as follows:

Tare right 1000 x 0.8 x (0.3 – (0.56319 – 0.01049 – 0.00284 - 0.3) = 40.112 kN

Tare left 1000 x 0.8 x (0.3 – (0.56319 – 0.01049 + 0.00284 - 0.3) = 35.568 kN

Laden right 1000 x 1.5 x (0.255 – (0.56319 – 0.01049 – 0.00284 - 0.3) = 7.710 kN

Laden left 0 as height is greater than free height

GMRT2141 issue 4.1 offset container loads

- For a full Y series bogie model need to define the following:
  - Static bogie and plunger drops
  - Static body and bogie rolls
  - Axlebox pitch angles (because of Lenoir links), both bogies, both sides
  - Lenoir link preloads, both bogies, both sides
  - Friction normal loads (plungers), both bogies, both sides
  - Sidebearer and centre pivot loads

GMRT2141 issue 4.1 offset container loads

- Also need loads in tare and laden springs in order to calculate their shear stiffnesses as these are load-dependent
- Can use INCLUDE files to add these parameters to the model

GMRT2141 issue 4.1 offset container loads

```
** EXAMPLE
** *******
*PARAMETER
**********
** Static drops and rolls
** ***********************
          d1 =      0.01049 m     Bogie 1 drop
          d2 =      0.00127 m     Bogie 2 drop
          p1 =      0.01022 m     Bogie 1 plunger drop
          p2 =      0.00124 m     Bogie 2 plunger drop
          r1 =      0.00284 rad   Bogie 1 roll
          r2 =      0.00283 rad   Bogie 2 roll
          rb =      0.01110 rad   Body roll
```

GMRT2141 issue 4.1 offset container loads

```
a1R =    -0.00053 rad   Axlebox 1 right pitch
a1L =    -0.00030 rad   Axlebox 1 left pitch
a2R =     0.00052 rad   Axlebox 2 right pitch
a2L =     0.00030 rad   Axlebox 2 left pitch
a3R =    -0.00016 rad   Axlebox 3 right pitch
a3L =     0.00006 rad   Axlebox 3 left pitch
a4R =     0.00016 rad   Axlebox 4 right pitch
a4L =    -0.00006 rad   Axlebox 4 left pitch
```

*

GMRT2141 issue 4.1 offset container loads

```
** EXAMPLE
** *******
*PARAMETER
**********
          k0801 =    0.367 MN/m  Bogie 1 tare spring shear stiffness
          k0802 =    0.362 MN/m  Bogie 2 tare spring shear stiffness
*

** EXAMPLE
** *******
*PARAMETER
**********
          k0901 =    0.347 MN/m  Bogie 1 laden spring shear stiffness
          k0902 =    0.347 MN/m  Bogie 2 laden spring shear stiffness
*
```

GMRT2141 issue 4.1 offset container loads

- Can even add container load using an INCLUDE file:

```
** EXAMPLE
** *******
*MASS
*****
            INERTIA       4.100     16.610  113.220  105.477
M 19+M      POSITION                X+D*0      D*0              2.054-0.5*d1-0.5*d2-0*rb
            SIZE        X-6.096     -1.219   0.995-(d1+d2)/2           ~
                        X+6.096      1.219   3.586-(d1+d2)/2
            COLOUR              0         0       255
**
```

GMRT2141 issue 4.1 offset container loads

```
*BUMPSTOP
*********
            DISPLACEMENT        -10.000     0.000  100.000
            FORCE              -600.000     0.000    0.000
            PRELOAD              10.052
B 73        POSITION        X+D*5.992    D*1.13   1.045-1.31*d1+0.31*d2-1.13*rb    20
                            X+D*5.992    D*1.13   0.945-1.31*d1+0.31*d2-1.13*rb     1
            DISPLACEMENT        -10.000     0.000  100.000
            FORCE              -600.000     0.000    0.000
            PRELOAD              10.052
B 74        POSITION        X+D*5.992   D*-1.13   1.045-1.31*d1+0.31*d2+1.13*rb    20
                            X+D*5.992   D*-1.13   0.945-1.31*d1+0.31*d2+1.13*rb     1
            DISPLACEMENT        -10.000     0.000  100.000
            FORCE              -600.000     0.000    0.000
            PRELOAD              10.052
B 75        POSITION        X+D*-5.992   D*1.13   1.045+0.31*d1-1.31*d2-1.13*rb    20
                            X+D*-5.992   D*1.13   0.945+0.31*d1-1.31*d2-1.13*rb     1
            DISPLACEMENT        -10.000     0.000  100.000
            FORCE              -600.000     0.000    0.000
            PRELOAD              10.052
B 76        POSITION        X+D*-5.992  D*-1.13   1.045+0.31*d1-1.31*d2+1.13*rb    20
                            X+D*-5.992  D*-1.13   0.945+0.31*d1-1.31*d2+1.13*rb     1
**
```

GMRT2141 issue 4.1 offset container loads

```
*BUSH
*****
            STIFFNESS   50.000    50.000    0.001    0.000    0.000    0.000
            DAMPING      0.045     0.045    0.045    0.000    0.000    0.000
P 13        POSITION   X+D*5.992   D*1.13     0.995-1.31*d1+0.31*d2-1.13*rb      1      20
P 14        POSITION   X+D*5.992  D*-1.13     0.995-1.31*d1+0.31*d2+1.13*rb      1      20
P 15        POSITION   X+D*-5.992  D*1.13     0.995+0.31*d1-1.31*d2-1.13*rb      1      20
P 16        POSITION   X+D*-5.992 D*-1.13     0.995+0.31*d1-1.31*d2+1.13*rb      1      20
*
```

GMRT2141 issue 4.1 offset container loads

- Reference the INCLUDE files in the model like this:

```
*INCLUDE
********
          FILE  Example part 1.VAMParam
**
```

- Check the model and check the loads in the .slc file to make sure they are as intended and that they give the right masses for every mass and wheelset in the model

How can the process be automated?

- Create and check the tare model and create the low friction ‘setup’ version
- Create a macro-enabled Excel workbook
- Define loading in terms of container size, position and mass properties
- Excel can create and save the static run file and read the results from the lis file
- Excel can create and save the INCLUDE files
- Excel can edit the tare vehicle model to create the laden model, just by changing the title and references to INCLUDE files

Summary

- In some situations it is important to define the static loads in a Vampire vehicle model
- It is important to check the static balance when this is done as it is possible to create models that do not balance
- The process can be automated, but this requires extreme care
- A lot to take in here- I am happy to answer questions later if needed!

Thank you

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