Belt modelling in LS-DYNA

A review of new features for belt modelling in LS-DYNA

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Paper

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- Paper: https://www.dynalook.com/conferences/16th-international-ls-dyna-conference/aerospace-01-2/t1-2-b-aerospace-148.pdf
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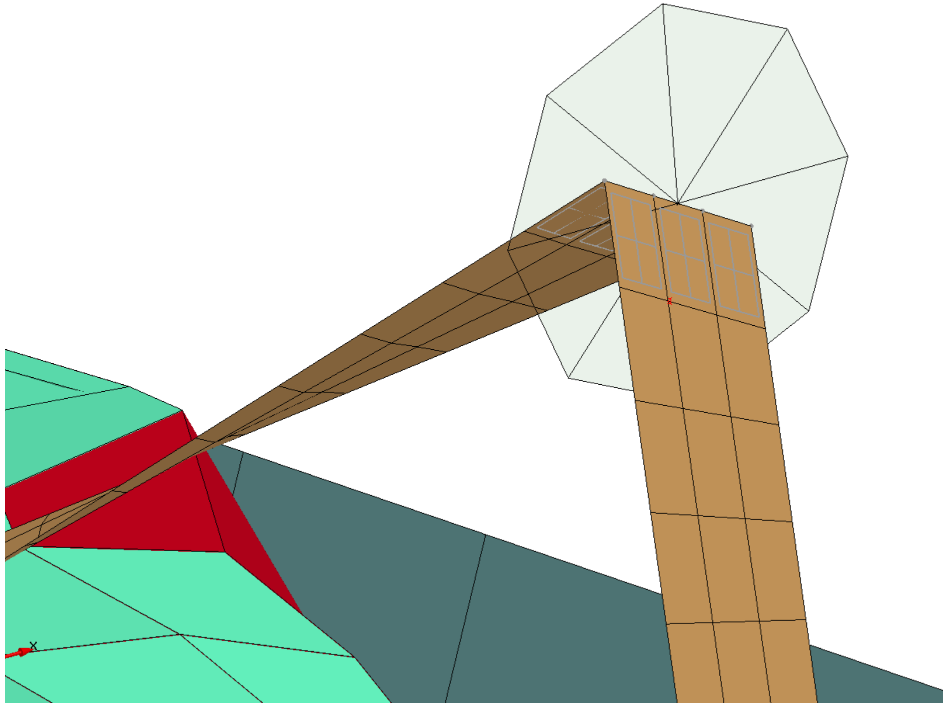
Outline

- Background
- Current issues with 2D belts
- Coating functionality
- Results
- Input parameters when using coating
- Other new features for 2D belts
  - Orthotropic membrane material behavior
  - Strain rate effects
  - Orthotropic friction properties (SOFT=2 contact) NEW!
- Conclusions
- Future

Background

- Belt modelling has in the past and the closest future included sliprings, which are points in space where the belt elements pass through
- Typically these points are located at sharp directional changes in the belt routing, e.g. B-pillar, D-ring and buckle tongue



Background

- Modelling physical sliprings is also possible, but the contact situation put requirements on element size and timestep size in the simulation model
- Hence the use of sliprings is still standard in most automotive simulations
- Belt modelling in LS-DYNA has evolved over time from 1D seatbelts to 2D seatbelts and hybrids variations
- A risk with hybrid belts is to run out of belt elements at sliprings, which will affect the results and likely cause an error termination

Background

- Currently 2D belt elements are frequently used and recommended
- 2D belt elements is a combination of 1D-belt elements along the length direction of the belt and 2D membrane elements made of *MAT_FABRIC
- The 2D membrane elements are made internally by LS-DYNA from *MAT_SEATBELT input
- Both 1D and 2D belt elements are assigned *MAT_SEATBELT, which is the only material compatible with sliprings
- It is the slipring functionality that inhibits users from using an ordinary element and material of their own selection to model the belt

Current issues with 2D belts

- Today, crash simulations that include a belted dummy are versatile
- It may include airbags, out of position occupants, secondary impact etc
- To meet the requirements dummy models get more refined and are discretized with decreasing element size
- In order to capture all effects in the crash, and still use sliprings, a decision was made to extend the 2D belt functionality in LS-DYNA

Current issues with 2D belts

- A first step was to decrease the element size of the belt to match dummy models, which would give better belt-to-dummy interaction

- However, decreasing the element size of a 2D belt will mean that it will collapse more easily since 2D belt elements (and 1D) are membrane and does not carry bending loads

- A decision was therefore made to port the coating functionality of *MAT_FABRIC to *MAT_SEATBELT_2D

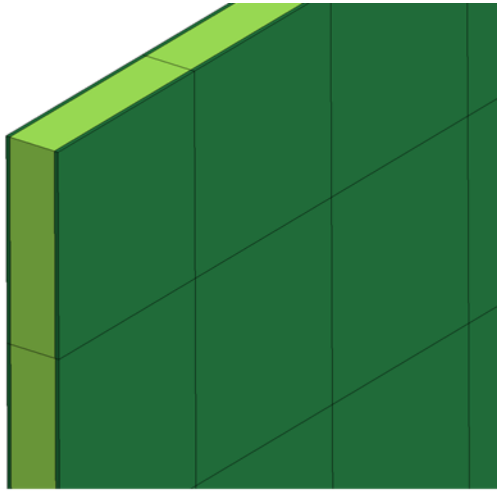
Additional card for FORM = -14.

Card 7	1	2	3	4	5	6	7	8
Variable	LCAA	LCBB	H	DT		ECOAT	SCOAT	TCOAT
Type	I	I	F	F		F	F	F

*MAT_FABRIC coating

Coating functionality

- In *MAT_FABRIC coating can be added to the membrane elements if FORM=-14 is used
- The new extension of *MAT_SEATBELT_2D in LS-DYNA utilize the coating functionality of MAT_FABRIC, FORM=-14
- The coating can be visualized as an added layer of elasto-plastic material on the surfaces of the membrane element
- This new layer enables the membrane to transfer bending loads

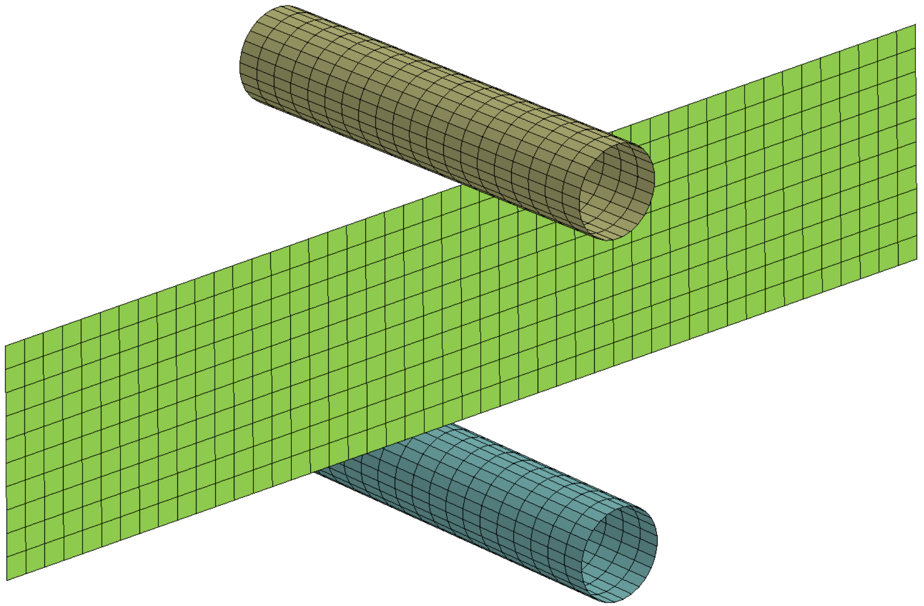


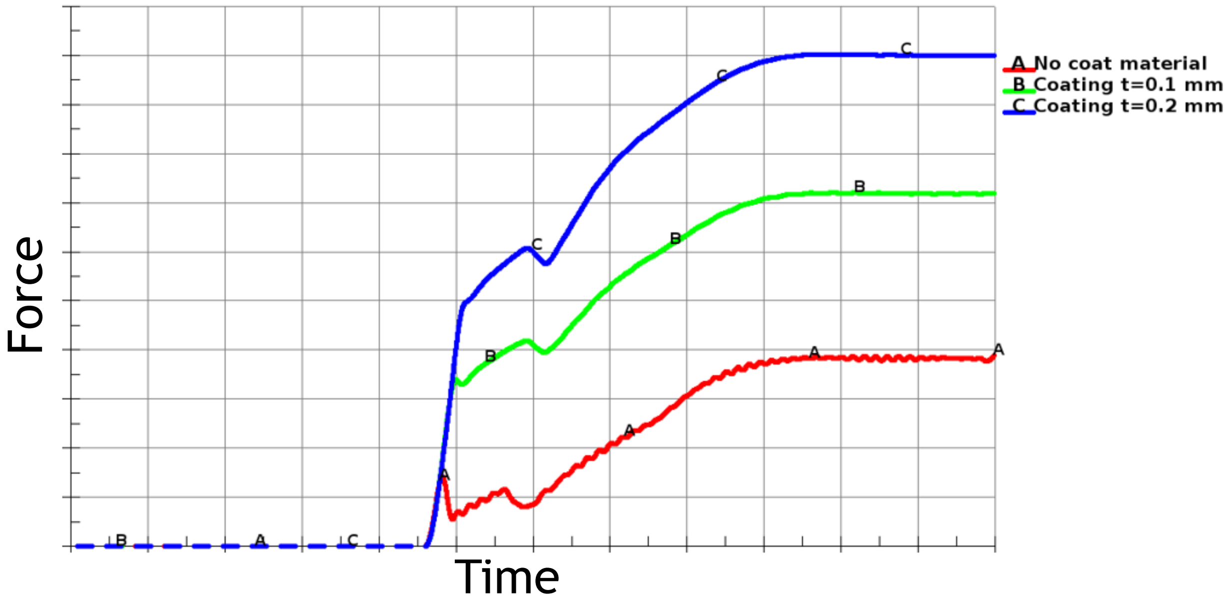
TCOAT is applied on both sides

Coating functionality

- The isotropic elasto-plastic hardening properties of the coating are defined by thickness, Young’s modulus and yield strength parameters

- A proposed set-up for determining the parameters are shown below. The belt should be loaded in tension at a typical load level found during crash





Results

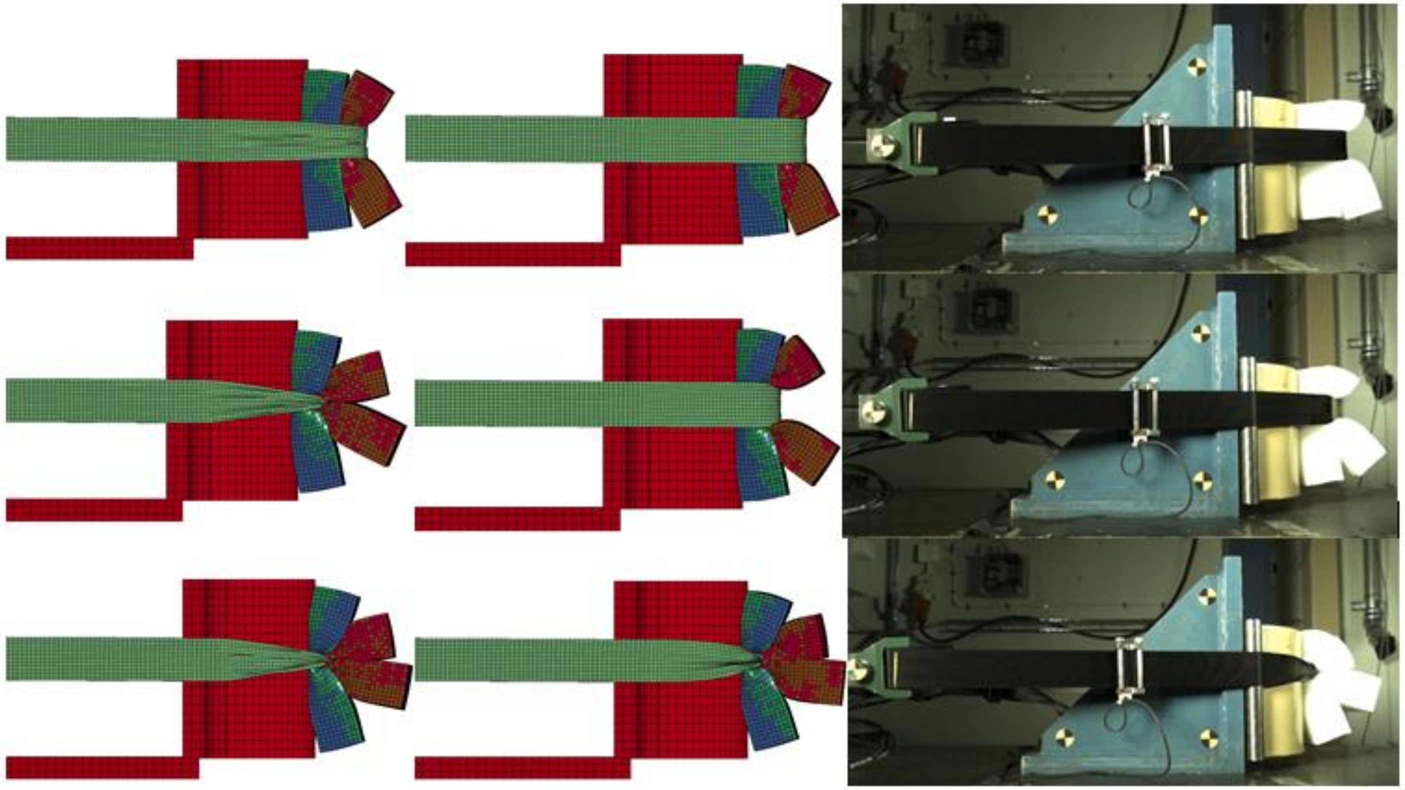
- The two major results achieved by adding coating to the belt are
  - 1) improved performance in bending over the width of the belt
  - 2) more stable unloading behavior

- The effect becomes more obvious if the belt is finely meshed

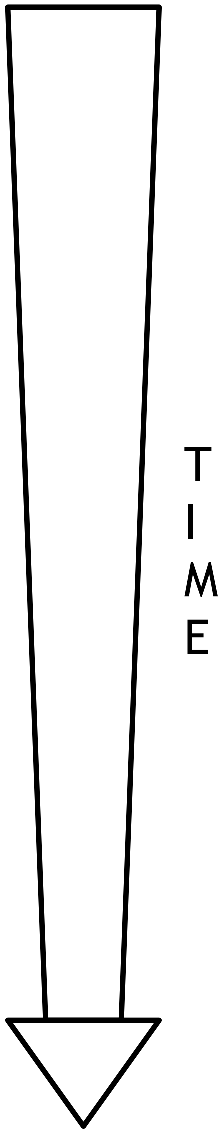
- Added coating in combination with finer mesh belt clearly improves the interaction between belt and dummy

Results

- Loading of belt into foam blocks at three instants in time

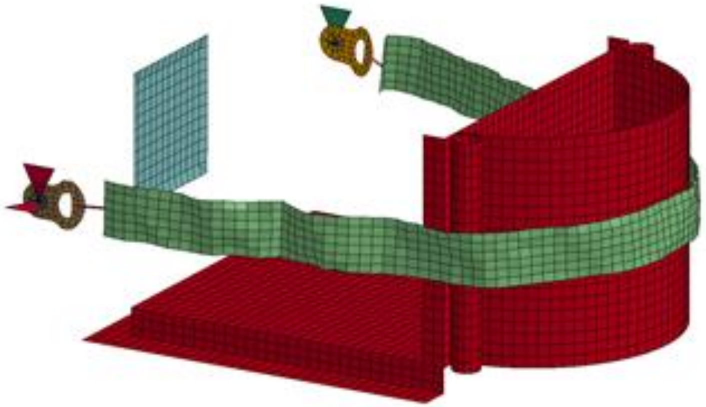


FORM=0	FORM=-14 with coating	Physical test

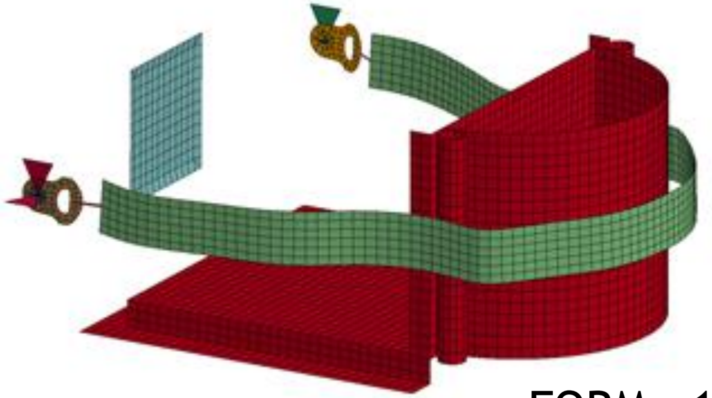


Results

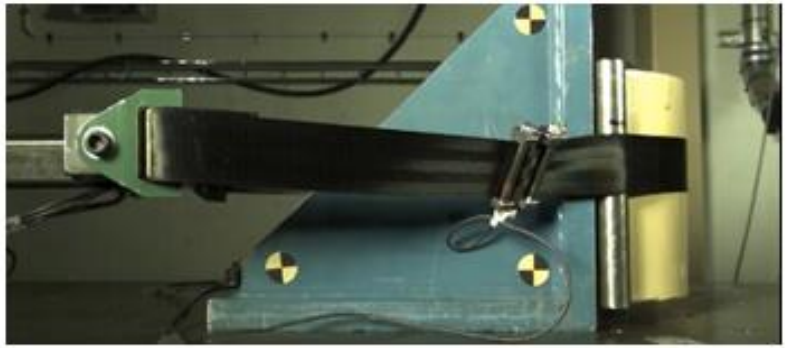
- After peak load behavior



FORM=0



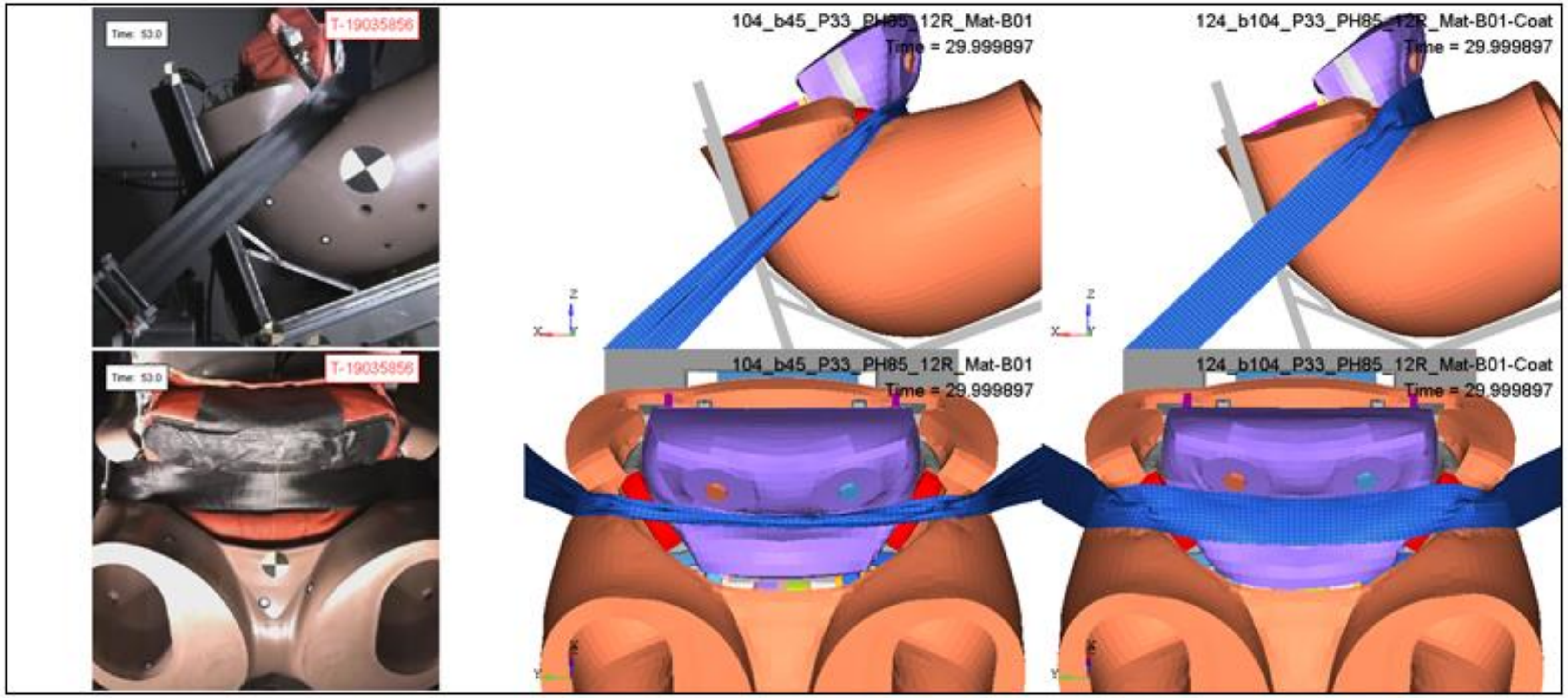
FORM=-14 with coating



Physical test

Results

- Belt-to-dummy interaction at 30 ms into the event



Physical test FORM=0 FORM=-14 with coating

Input parameters when using coating

- *SECTION_SHELL

	1	2	3	4	5	6	7	8
Card 1	SECID	ELFORM	~~SHRF~~	~~NIP~~	~~PROPT~~	~~QR/IRID~~	ICOMP	~~SETYP~~
Card 2	T1	T2	T3	T4	~~NLOC~~	~~MAREA~~	~~IDOF~~	EDGSET
Card 3	B1	B2						

- When using FORM=-14 set ICOMP=1 (it will invoke Card 3)
- Set B1=0 and B2=90
- The under-integrated membrane element (ELFORM=5) is recommended
- T1 is the thickness of the belt

Input parameters when using coating

- *MAT_SEATBELT_2D

	1	2	3	4	5	6	7	8
Card 1	MID	MPUL	LLCID	ULCID	LMIN	CSE	DAMP	~~E~~
Card 2	~~A~~	~~I~~	~~J~~	~~AS~~	~~F~~	~~M~~	~~R~~	
Card 3	P1DOFF	FORM	ECOAT	TCOAT	SCOAT	EB	PRBA	PRAB
Card 3	GAB							

- FORM=-14 for coating functionality
- It is recommended to use all three parameters E, T and SCOAT for coating
- ECOAT – Young's modulus of coat material
- TCOAT – Thickness of coat material
  - Coating will add to membrane in-plane stresses unless TCOAT is set to a negative value
- SCOAT – Yield stress of coat material

Other new features for 2D belts

- Orthotropic membrane material behavior
- Strain rate effects
- Orthotropic friction properties

Orthotropic membrane material behavior

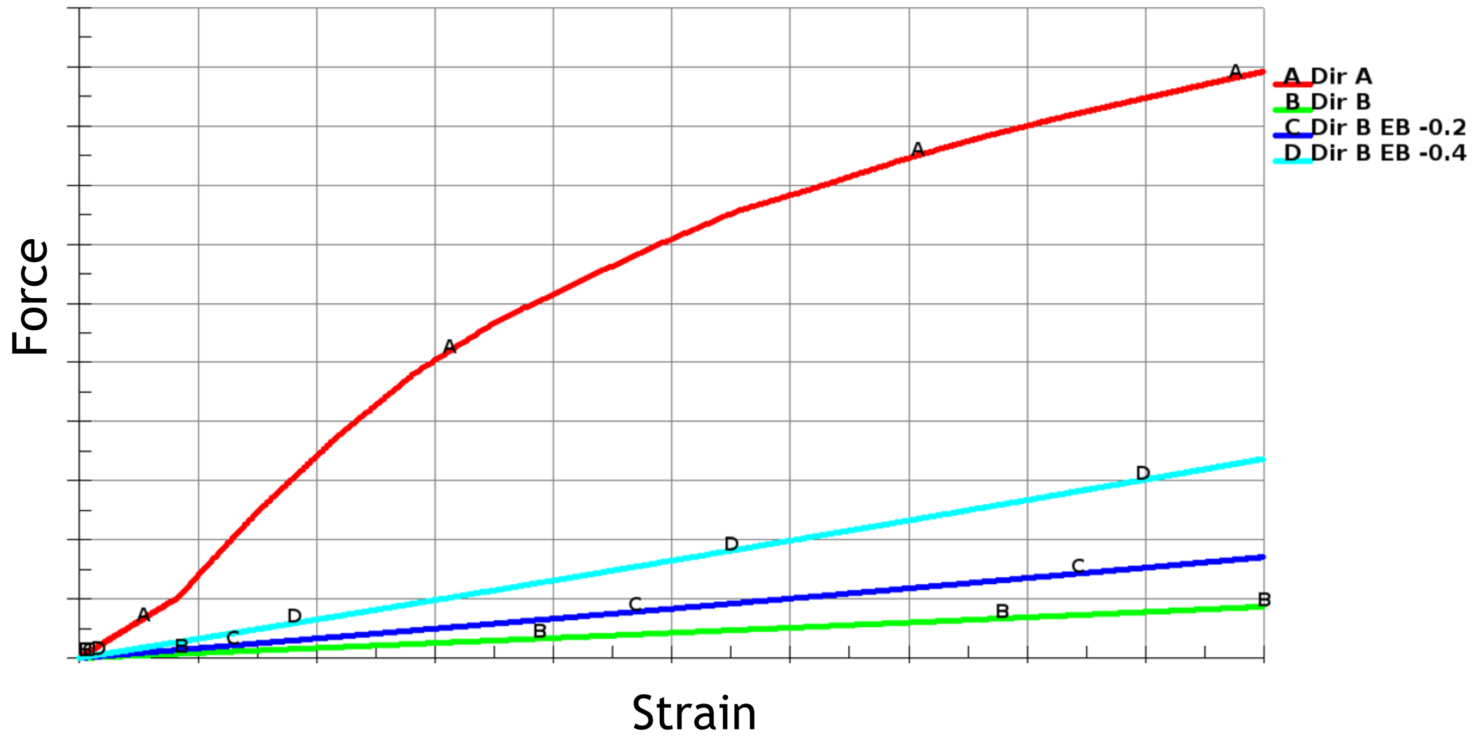
- A real belt has orthotropic membrane properties

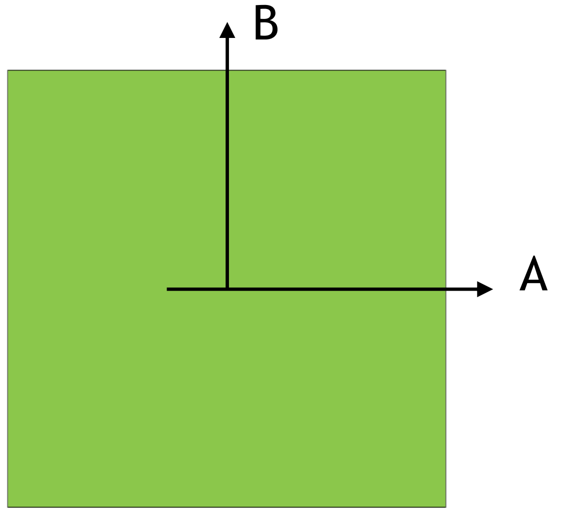
- With the new parameters EB, PRAB, PRBA and GAB on *MAT_SEATBELT_2D the user can control the material properties to be applied in the perpendicular direction of the 2D belt

*MAT_SEATBELT_2D

	1	2	3	4	5	6	7	8
Card 1	MID	MPUL	LLCID	ULCID	LMIN	CSE	DAMP	~~E~~
Card 2	~~A~~	~~I~~	~~J~~	~~AS~~	~~F~~	~~M~~	~~R~~	
Card 3	P1DOFF	FORM	ECOAT	TCOAT	SCOAT	$\boxed{\text{EB}}$	$\boxed{\text{PRBA}}$	$\boxed{\text{PRAB}}$
Card 3	$\boxed{\text{GAB}}$							

Orthotropic membrane material behavior

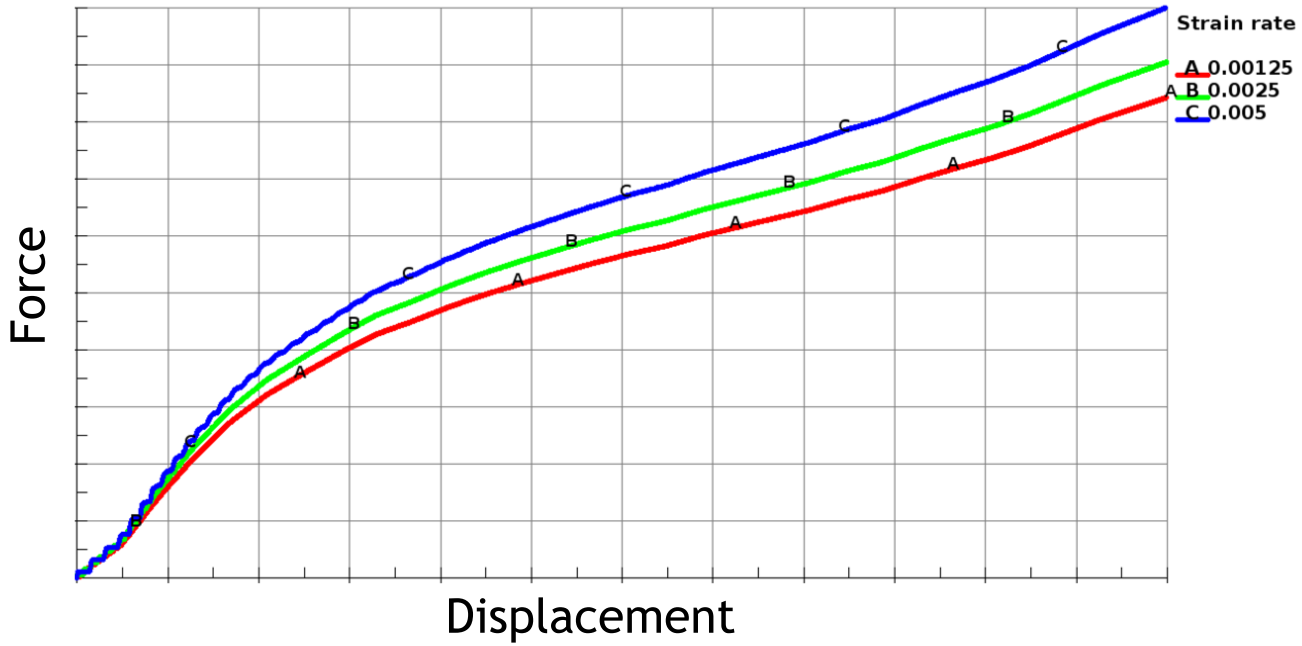


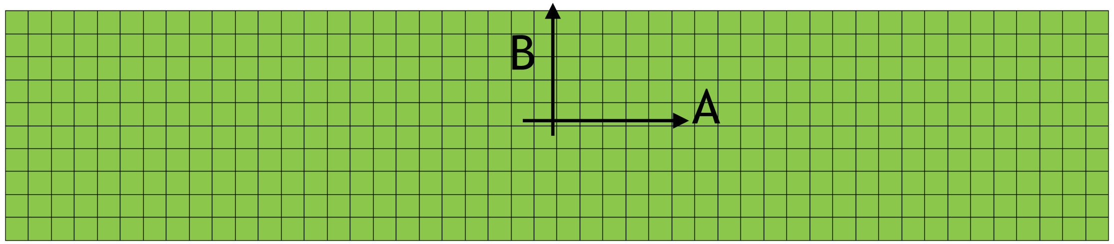


Strain-rate effects

- Strain-rate effects has been available for 1D belt elements
- Recently strain-rate dependency was made available also for 2D belt elements
- It is applied in the length direction of the belt only
- Strain-rate effects enables to capture the behavior and injury levels at different impact speeds
- Strain-rate dependency is applied by referencing a table ID on LLCID (MAT_SEATBELT_2D)

Strain-rate effects





Orthotropic friction properties

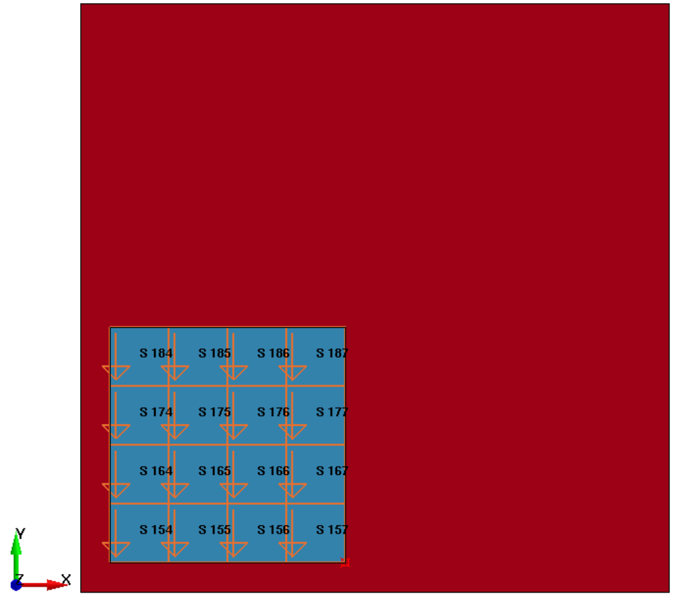
- A new option for “ORTHO_FRICTION” when using SOFT=2 contact
- If master surface static properties are set to zero for both the 1 and 2 direction, then the slave surface properties and sliding direction on the slave surface is used to determine Coulomb friction values
- The zeroed values must be FS1_M, LC1_M, FS2_M, and LC2_M

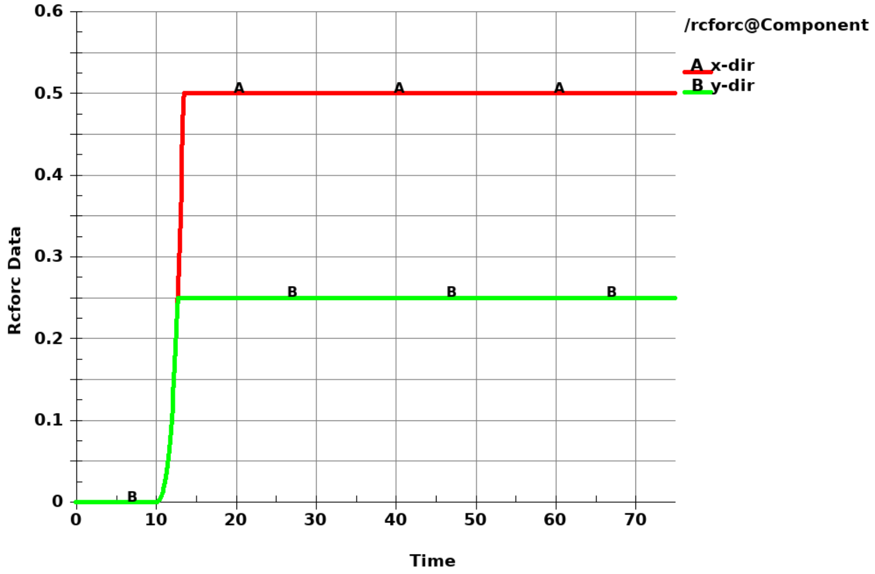
Orthotropic friction properties

Slave side is belt

```
*CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_ORTHO_FRICTION_ID
$#     cid                                                                 title
         1Belt-to-dummy contact
$#    ssid      msid     sstyp     mstyp    sboxid    mboxid       spr       mpr
         1         2         0         0         0         0         0         0
$#      fs        fd        dc        vc       vdc    penchk        bt        dt
       0.0       0.0       0.0       0.0      10.0         0       0.0       0.0
$#     sfs       sfm       sst       mst      sfst      sfmt       fsf       vsf
       1.0       1.0       1.0       1.0       0.0       0.0       0.0       0.0
$#   fs1_s     fd1_s     dc1_s     vc1_s     lc1_s    oacs_s      lcfs      lcps
      0.25      0.25       0.0       0.0         0         0         0         0
$#   fs2_s     fd2_s     dc2_s     vc2_s     lc2_s
       0.5       0.5       0.0       0.0         0
$#   fs1_m     fd1_m     dc1_m     vc1_m     lc1_m    oacs_m      lcfm      lcpm
       0.0       0.0       0.0       0.0         0         0         0         0
$#   fs2_m     fd2_m     dc2_m     vc2_m     lc2_m
       0.0       0.0       0.0       0.0         0
$#    soft    sofscl    lcidab    maxpar     sbopt     depth     bsort    frcfrq
         2       0.0         0       0.0       3.0         5         1         0
$#  penmax    thkopt    shlthk     snlog      isym     i2d3d    sldthk    sldstf
       0.0         0         0         0         0         0       0.0       0.0
$#    igap    ignore    dprfac    dtstif    unused    unused    flangl   cid_rcf
         0         0     0.001       0.0                             0.0         0
$#   q2tri    dtpchk     sfnbr    fnlscl    dnlscl      tcso    tiedid    shledg
         0       0.0       0.0       0.0       0.0         0         0         1
```

Master friction properties are zero





Conclusions

The new implementation of *MAT_SEATBELT_2D allows for

- orthotropic membrane behavior (R12.0)
- isotropic bending behavior (R10_dev, R11_dev, R12.0)
- strain-rate effects (R12.0)
- use of sliprings

By using coating functionality for 2D belt elements the following was found

  - 1) improved performance in bending over the width of the belt
  - 2) more stable unloading behavior

- A new feature allows for orthotropic friction based on belt directions (R12_dev)

Future

- It has been foreseen that in the future and for detailed analysis of sliprings a traditional model utilizing normal contact definition will be used
- Then the use of *MAT_SEATBELT will not be mandatory
- Hence a need for a coupled material/element model to separate bending/tension will be desirable
- Currently this is accomplished with double layer elements. Membrane/shell for in-plane/bending properties, respectively

Thank you!

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