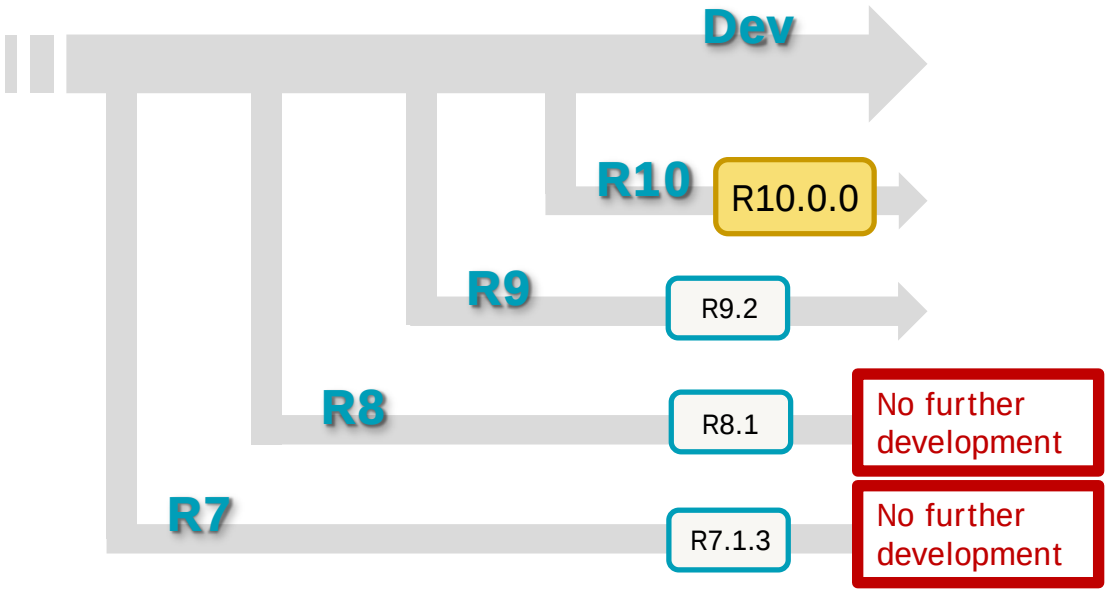
LS-DYNA – Crash and Impact, Explicit

J. Forsberg

LS-DYNA Explicit Crash Code

- Single precision
- MPP
- R7.1.3 → R9.x?



- R10 or DEV used for evaluation of new features and concepts.

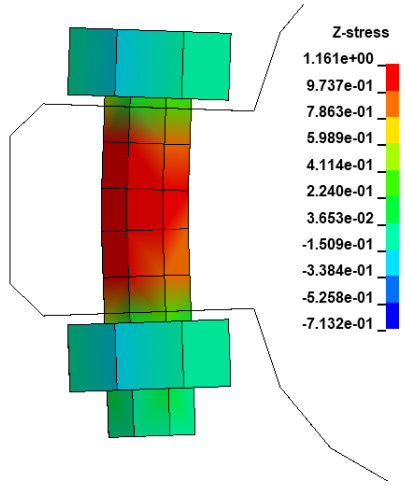
- Gaining interest
  - Hybrid version of LS-DYNA.
  - Double precision version due to increased number of cycles.
  - Hardware support on CPU:s – AVX2 and AVX512

Selected topics

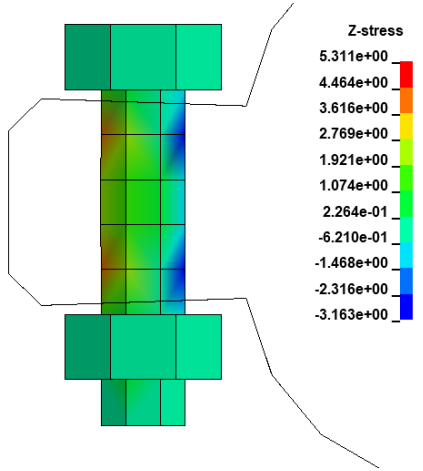
- How to initialize your model – some selected features
  - *INITIAL_STRESS_SECTION
  - *INITIAL_STRESS
  - *INITIAL_FOAM_REFERENCE_GEOMETRY
  - *INITIAL_VELOCITY_GENERATION
  - *CONSTRAINED_JOINT_xxx
- Possibilities with decomposition of your model
  - CONTROL_MPP_PFILE
- Airbag options
- Contact
- MAT_SPOTWELD

Bolt prestress using solid element models

- INITIAL_STRESS_SECTION
  - Functionality:
    - The cut element is shortened in the normal direction.
    - Contact between bolt heads and sheets gives arise to stress – in the normal direction.
    - Problem – no stiffness in shear for the shortened element.



  - IZSHEAR parameter:
    - Added to handle shear when performing a pre-stress of a solid element.



*INITIAL_STRESS/STRAIN(_BEAM/_SHELL_SOLID)

***INITIAL_STRESS[_BEAM|_SHELL|_SOLID]**
***INITIAL_STRAIN[_SHELL|_SOLID]**

- Initialise the state of stress and strain in elements.
- Normally used to carry results obtained in one simulation to another.
  - Multistage forming
  - Forming -> Crash
- Typically stored in a file called ‘dynain’ which is created by
  - Post-processor from a ‘d3plot’ file. OBS! The d3plot files may contain too few history variables for the material in order to create the same stress state in a re-initialization.
  - By LS-DYNA using
    - CONSTRUCTION_STAGES functionality – really offer automation of multistage simulation.
      - *CONTROL_CONSTRUCTION_STAGES
      - *DEFINE_CONSTRUCTION_STAGES
      - *DEFINE_STAGED_CONSTRUCTION_PART
    - *INTERFACE_SPRINGBACK_LSDYNA/NASTRAN/SEAMLESS_THICKNESS/NOTHICKNESS

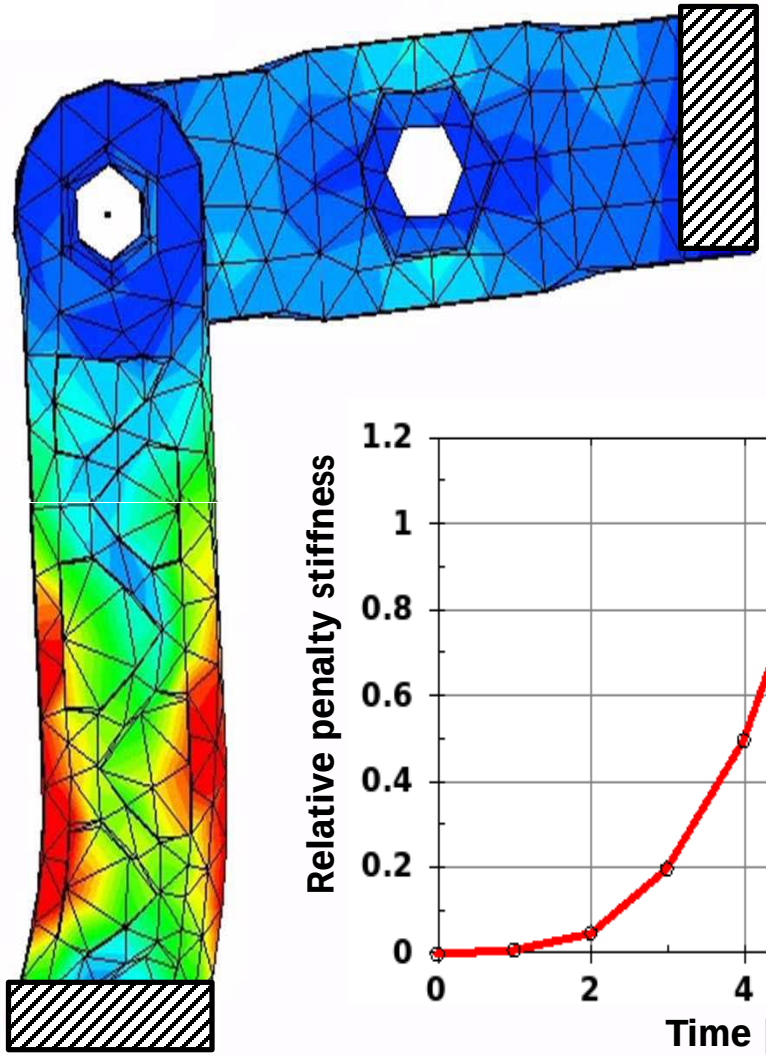
*INITIAL_FOAM_REFERENCE_GEOMETRY

- Hyper – formulated materials
  - FOAMS
  - RUBBERS
- New features
  - Improved precision of initial deformation
  - Added parameter: ndtrrg
    - Solid elements with reference geometry will ‘restore’ its reference geometry in ndtrrg steps.

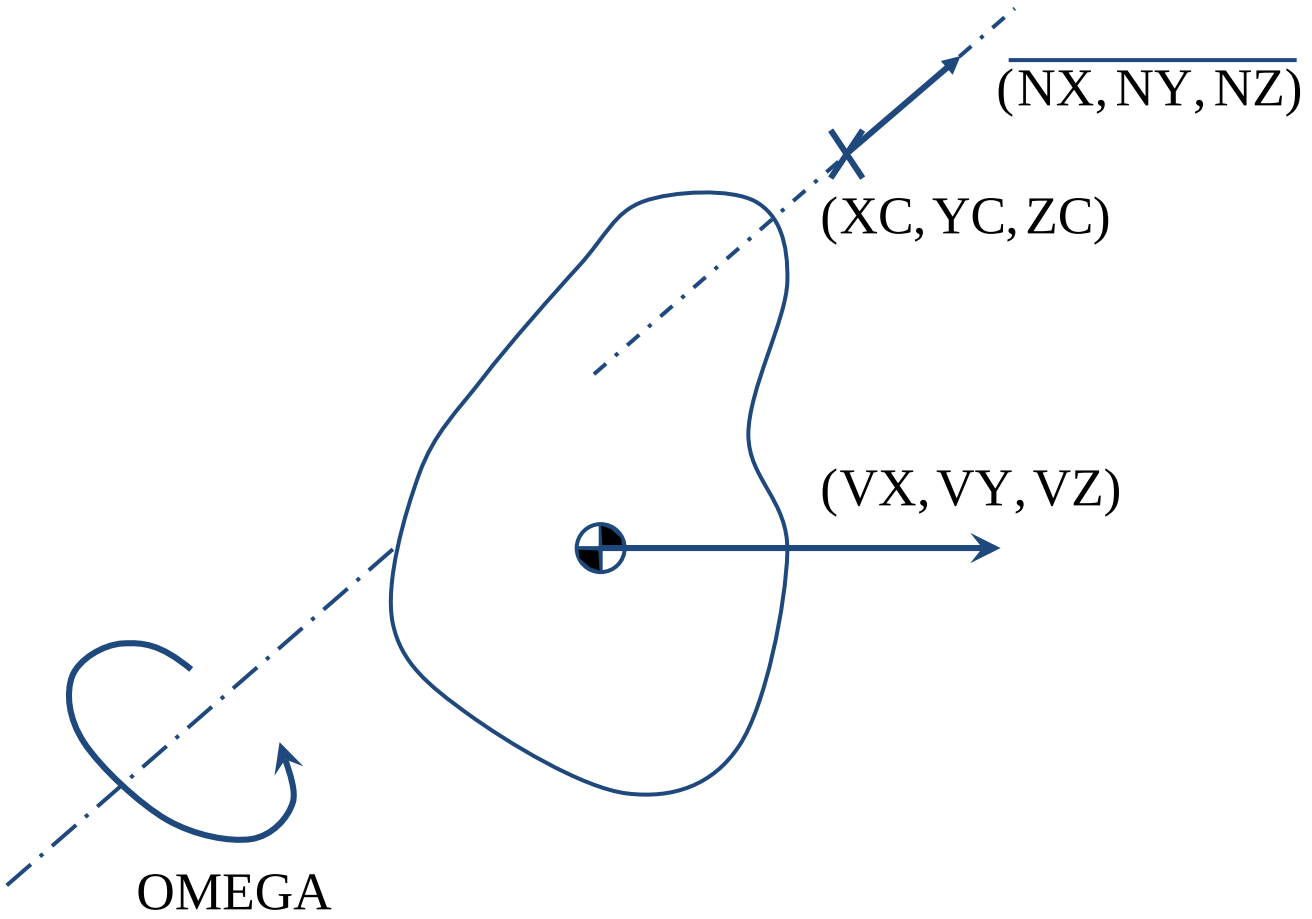
*CONSTRAINED_JOINT…

- For penalty-based joints, relative penalty stiffness can now be defined as time dependent value given by load curve (option RPS<0)
- Nodal points of connected parts must not coincide initially anymore
- For pre-stressing of joint connections
- Works for options…
  - SPHERICAL,
  - REVOLUTE,
  - CYLINDRICAL

- CONSTRAINED_JOINT_STIFFNESS
  - Add error termination if CIDA and CIDB not defined.
  - Support large loadcurve ID for for FMPH, FMT, FMPS.



*INITIAL_VELOCITY_GENERATION



*INITIAL_VELOCITY_GENERATION

*INITIAL_VELOCITY_GENERATION

Card 1	1	2	3	4	5	6	7	8
Variable	ID	STYP	OMEGA	VX	VY	VZ	IVATN	ICID
Type	I	I	F	F	F	F	I	I

Card 2	1	2	3	4	5	6	7	8
Variable	XC	YC	ZC	NX	NY	NZ	PHASE	IRIGID
Type	I	I	F	F	F	F	I	I
Setting	-	-	0.0	0.0	0.0	0.0	0	0

- ID Selected entities
- STYP type ID (node/part set)
- OMEGA Rotational velocity
- Vi Translational velocities
- IVATN How to treat slaved entities
- ICID Local coordinate sys
- XC-ZC Point on axis of rotation
- NX-NZ Define rotation axis
- PHASE Relates to dynamic relaxation
- IRIGID How to treat rigid entities velocity

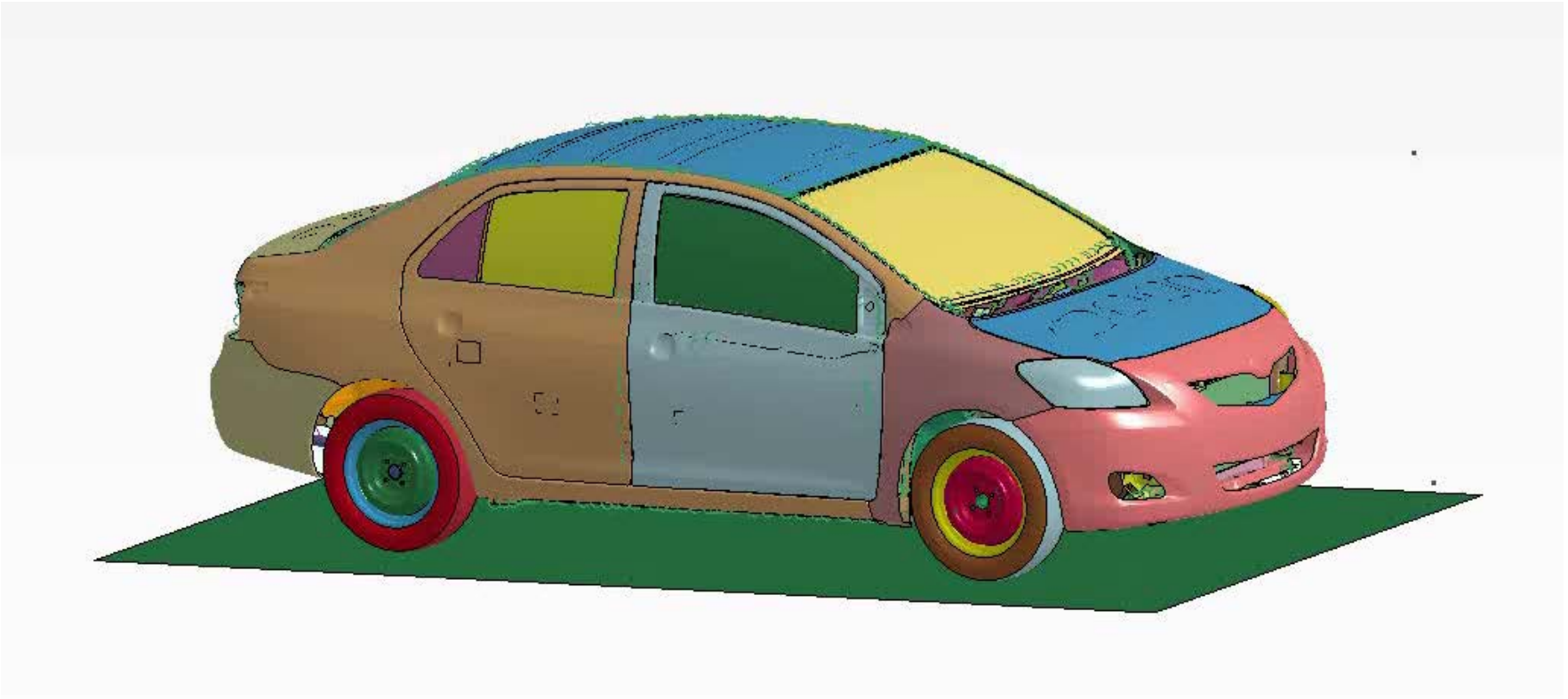
- Initial translational and rotational velocities for bodies.
- Can not be combined with INITIAL_VELOCITY[_NODE].
- Multiple definitions overwrite previous keywords.
- More used today since wheels need rotational velocity!

Applying velocity…

- Cumbersome part about velocities in LS-DYNA
  - Any _INERTIA the velocities given on that card – make use of IRIGID parameter.
  - Dynamic relaxation – if to (or not to) be applied here – PHASE parameter.
  - On restart (e.g. after dynamic relaxation) care needs to be taken such that correct velocities are applied for rigid entities in the model.
  - For rigid entities the body motion is given, the nodal velocities are then re-calculated accordingly. Hence, differences may or may not be noticeable.
  - If there are several *INITIAL_VELOCITIES applied to same part/nodes – last one will prevail.

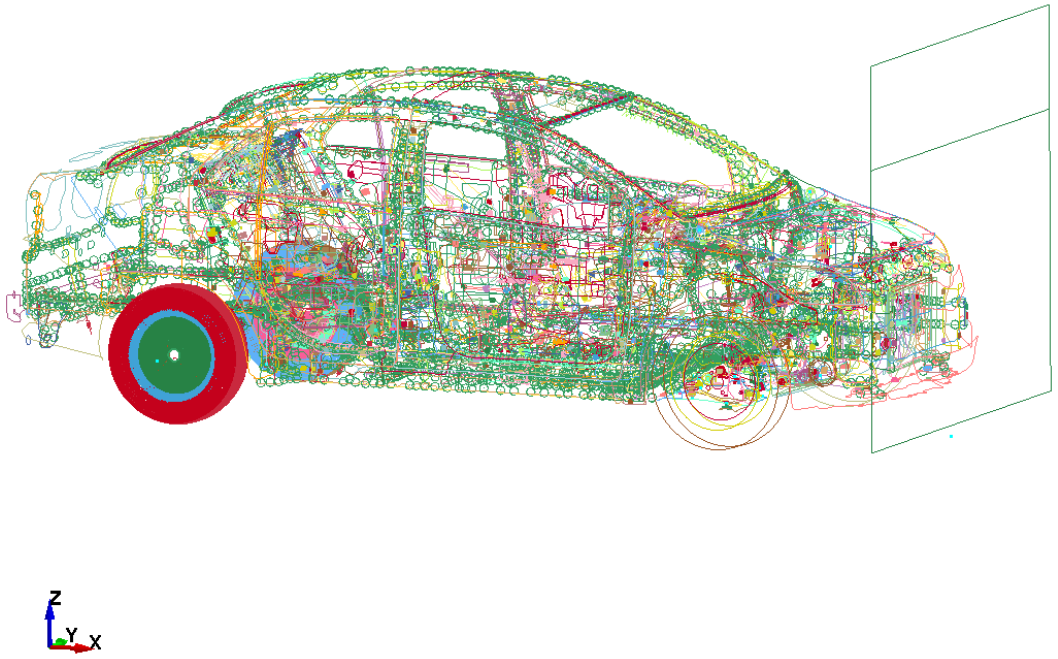
INITIAL_VELOCITY_GENERATION - Example

- Public model Toyota Yaris with interior from ccsa.
- ~1.5M elements

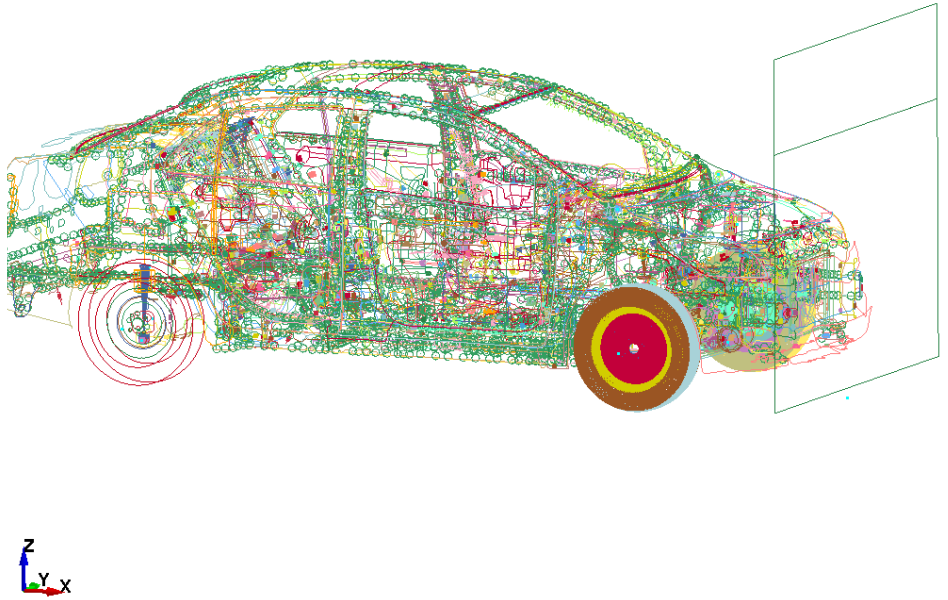


Each wheel need to be rotating

TOYOTA YARIS DETAILED MODEL (CCSA V02)



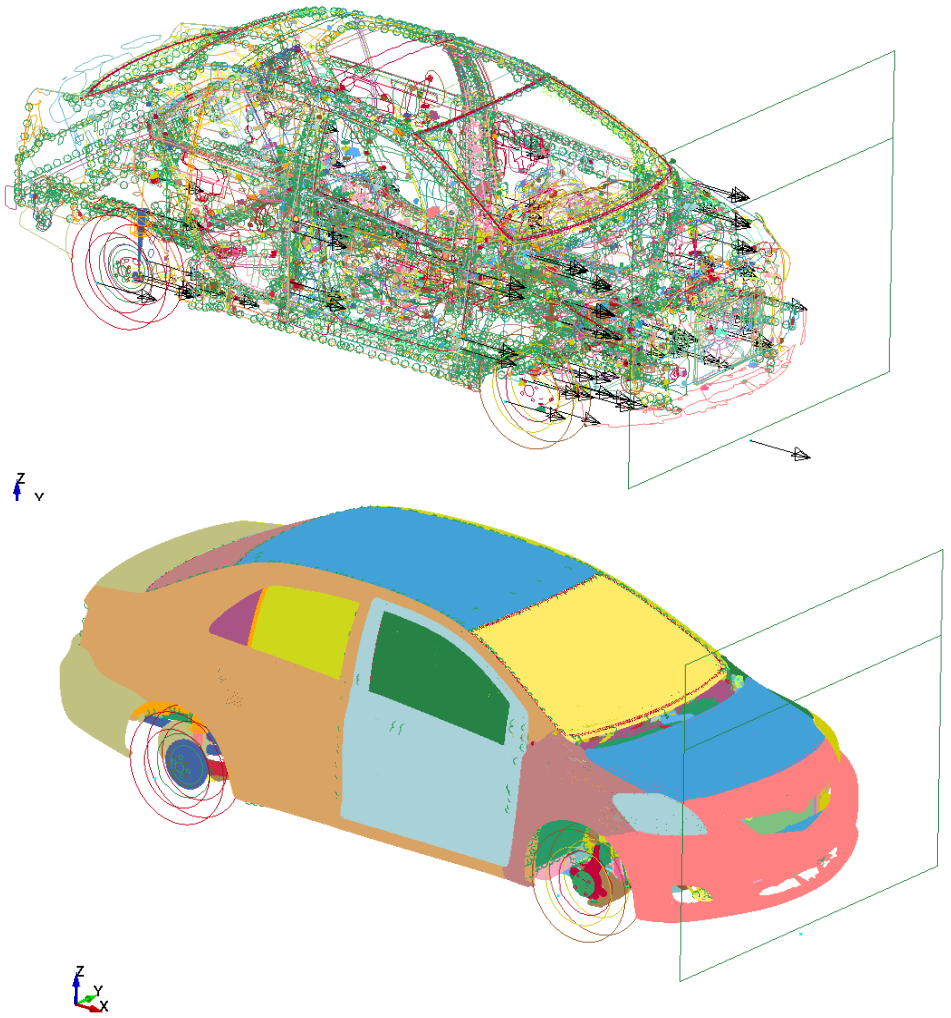
YOTA YARIS DETAILED MODEL (CCSA V02)



- PHASE=IVATN=IRIGID=0
  No dynamic relaxation and no *xxx_INERTIA

All translational velocities with 2 *INITIAL_VELOCITY_GENERATION

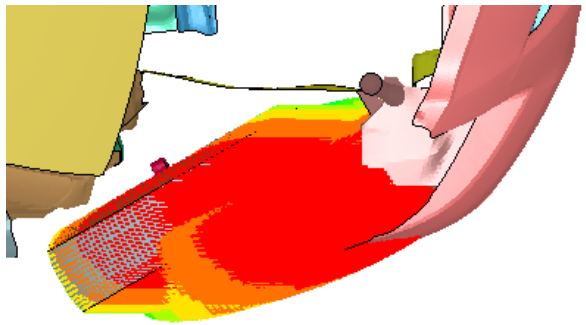
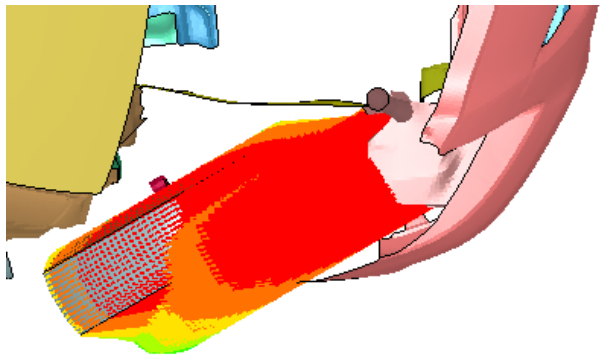
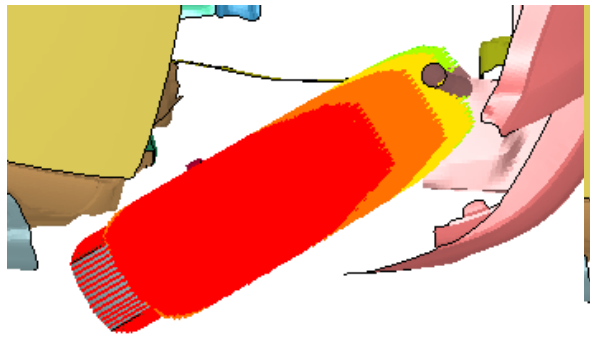
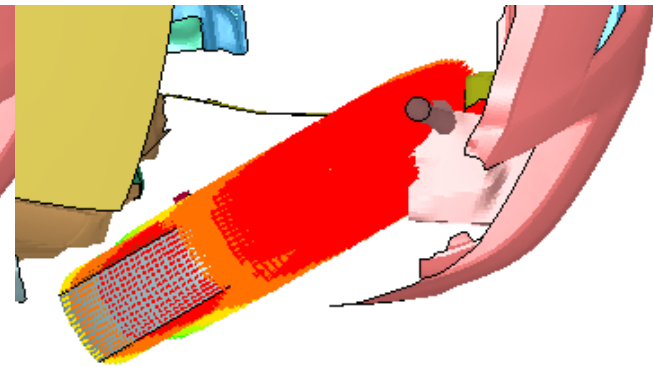
- Nodes NOT connected to any real element/part (through a node set).
- Ordinary nodes (through a part set).



Turned wheels simulation

- Where is the velocity defined?
  - Master keywordfile → need local information from includefile.
    - Nodes defining vector (nx=-999)
    - ICID – local coordinate system.
  - Includefile → could use ‘coordinate system’ of that includefile.

Main(ny=1) main(nx=-999) main(icid, ny=1) main(icid,nx=-999)

*INITIAL_VELOCITY_GENERATION

- Changes/fixes in functionality when omega>0 and icid>0
  - Nx=-999 the directional cosine defined by Ny and Nz is the final one.
  - Nx !=-999 (xc,yc,zc) not rotated along icid
  - When included with INCLUDE_TRANSFORM (xc,yc,zc) are also transformed.
- Fix for incorrect initial velocity when ICID .ne. 0 and omega!=0 and *PART_INERTIA is also present.

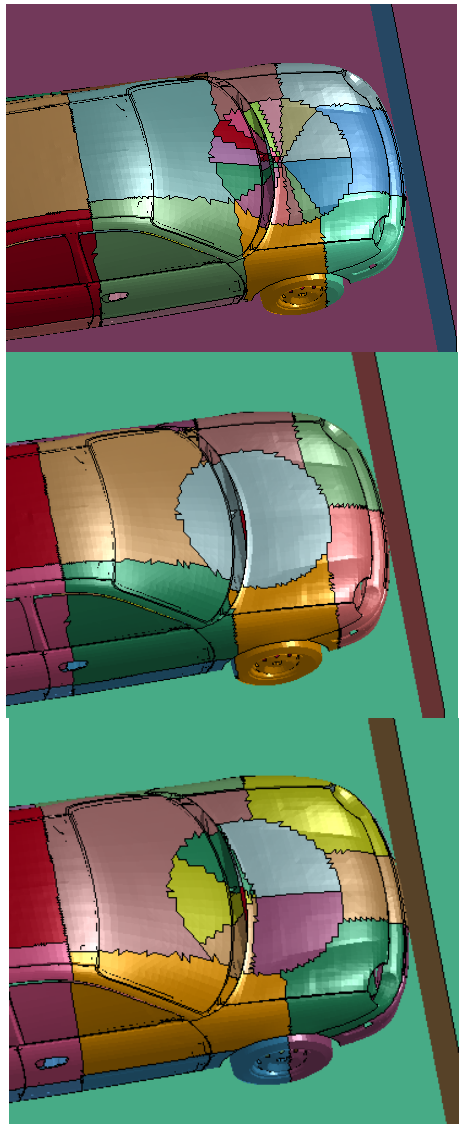
MPP - Decomposition

- *CONTROL_MPP_PFILE

```
decomp { numproc 20 show
region { cylinder 3700 0 0 0 0 1 500 0
         c2r 3700 0 0 0 0 1 1 0 0 sy 1000 distribute }
}
```

  - Distribute → Lump

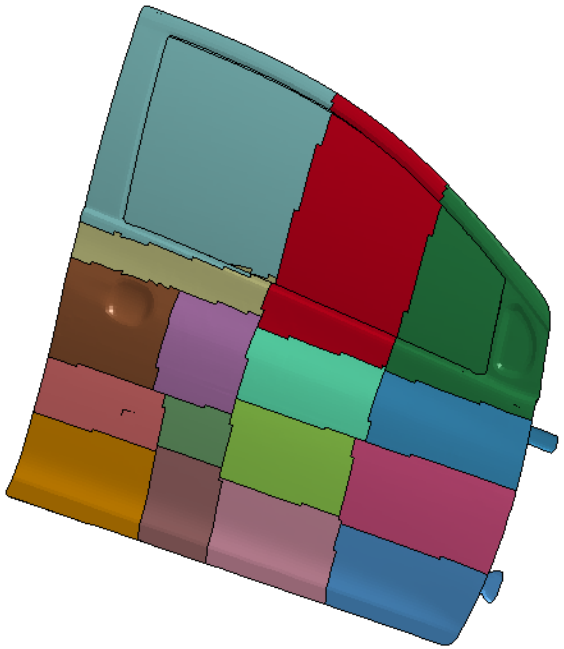
  - Lump → %nproc 25
    Make use of 25 % of the cores and distribute the region to these cores.



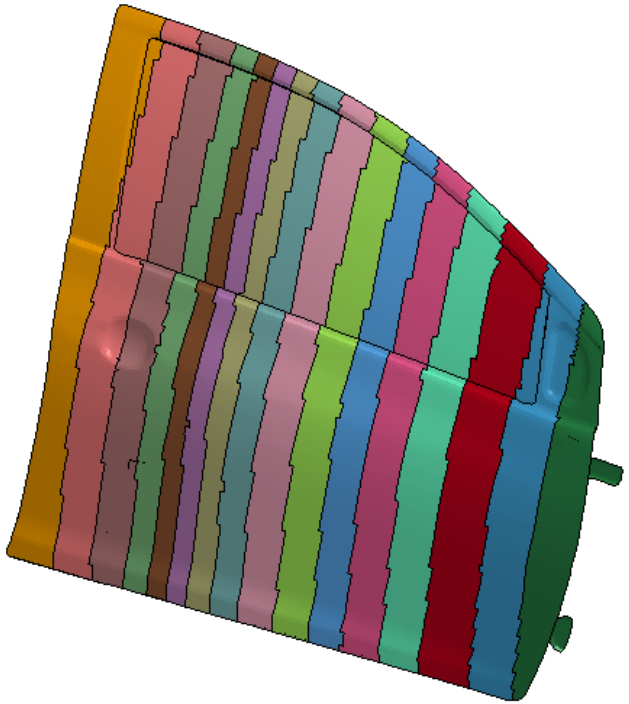
Decomposition in local system of includefile

- Submodels validated using another/local submodel

Default

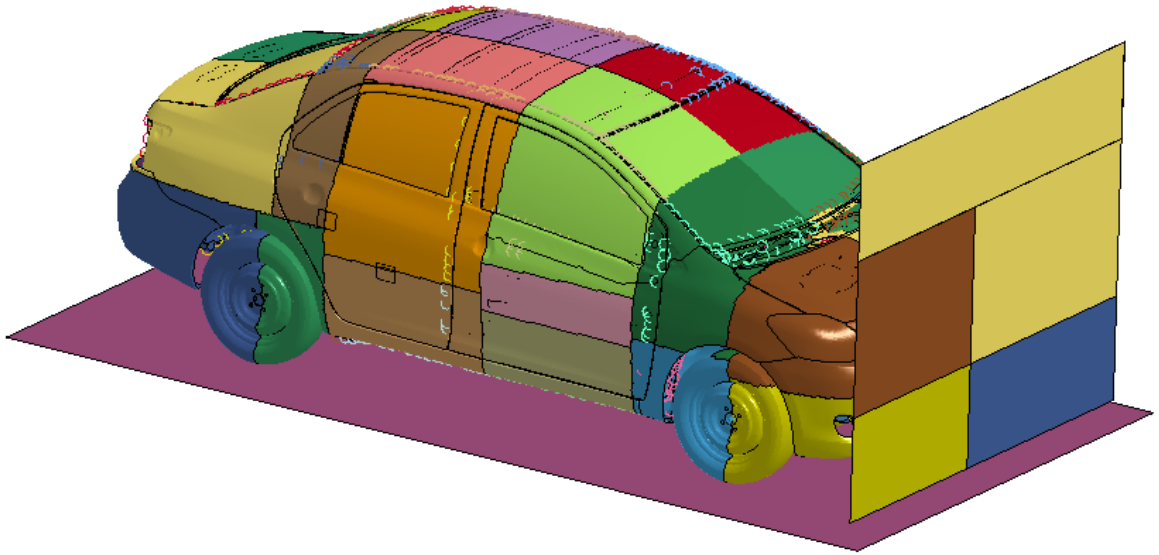


*CONTROL_MPP DECOMPOSITION AUTOMATIC

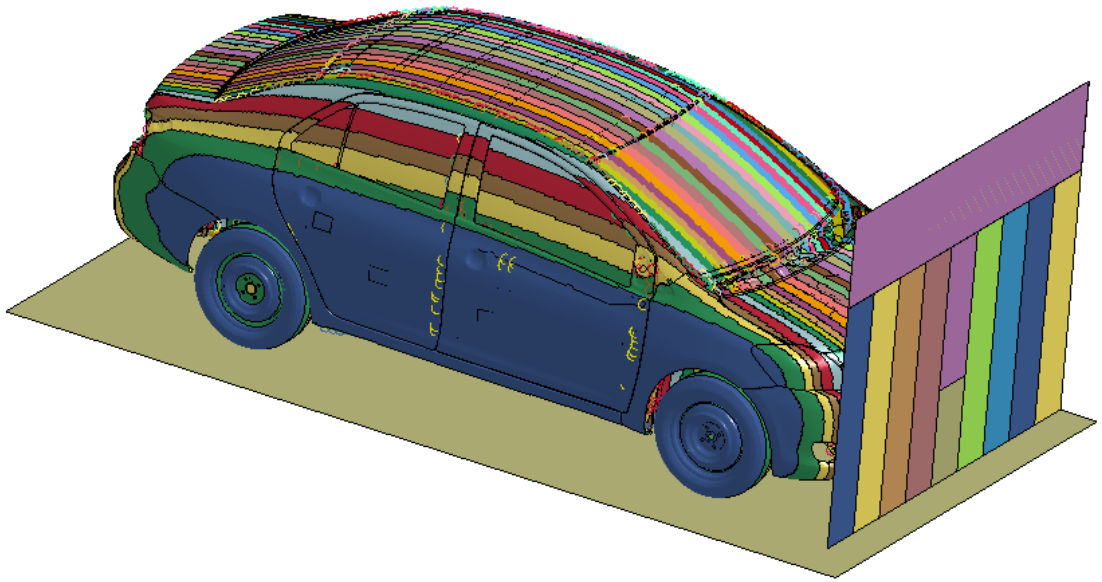


Door decomposition in local model vs default global model

Default

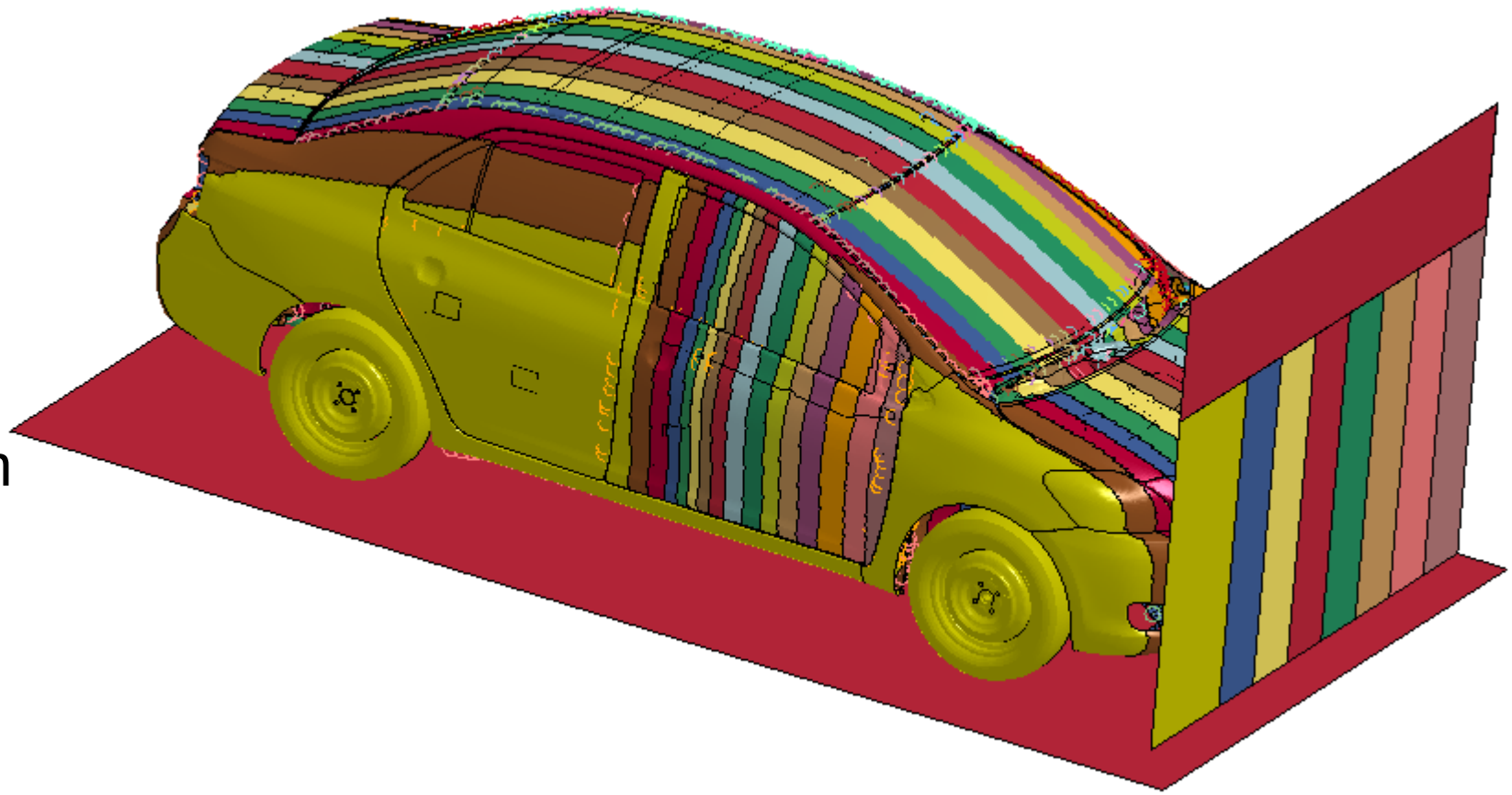


*CONTROL_MPP_DECOMPOSITION_AUTOMATIC



Door decomposition in global model using local system of include

- *CONTROL_MPP_PFILE
  decomp { numproc 16
    region { partsets 1
     local sy 0 sz 0
  } }
- In included file
- If INCLUDE_TRANSFORM local activates that the region is decomposed in that coordinate system.



One other option with limitations

***CONTROL_MPP_DECOMPOSITION_ARRANGE_PARTS**

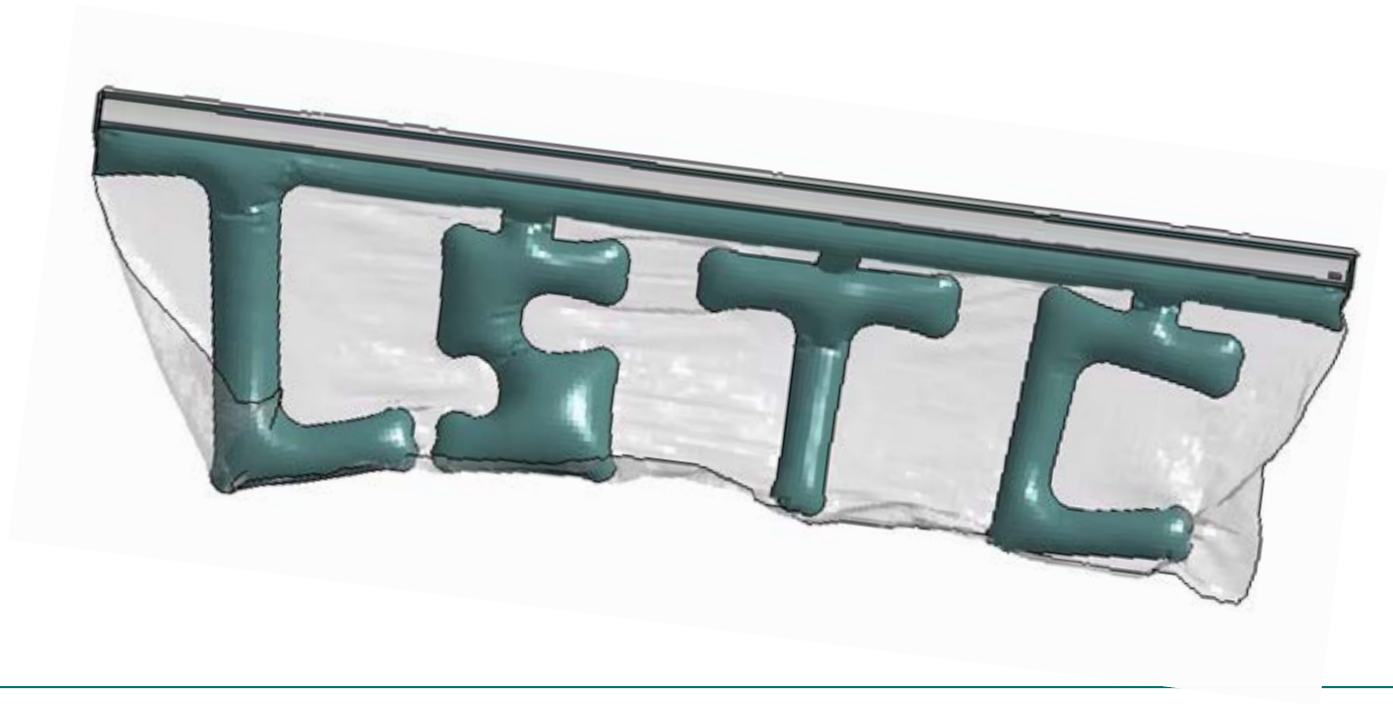
Card 1 1 2 3 4 5 6 7 8

Variable	Part/Partset	TYPE	NPROC	FRSTP				
Type	I	I	I	I				
Setting	-	-	-	-				

- With this you can easily distribute a bunch of elements on a specific number of cores.

Airbags - CV

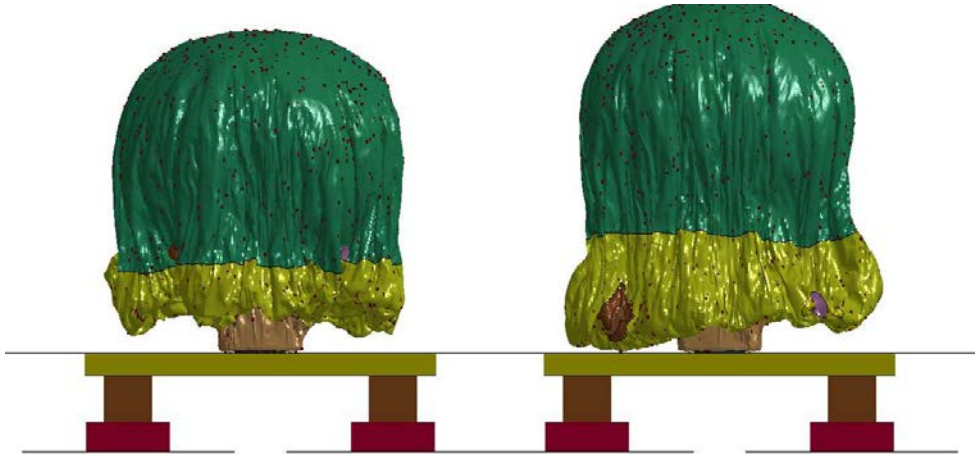
- Possible to use *MAT_ADD_EROSION to affect the VENT for *AIRBAG_HYBRID using parameter ventopt=2.
- *AIRBAG_HYBRID/SIMPLE_AIRBAG_MODEL
  - LCIDM/LCIDT defined by *DEFINE_CURVE FUNCTION.
- *AIRBAG_INTERACTION
  - Negative PID consider blockage of partitions area due to contact.
- _ID option for
  - *AIRBAG_SHELL_REFERENCE
  - *AIRBAG_REFERENCE_GEOMETRY

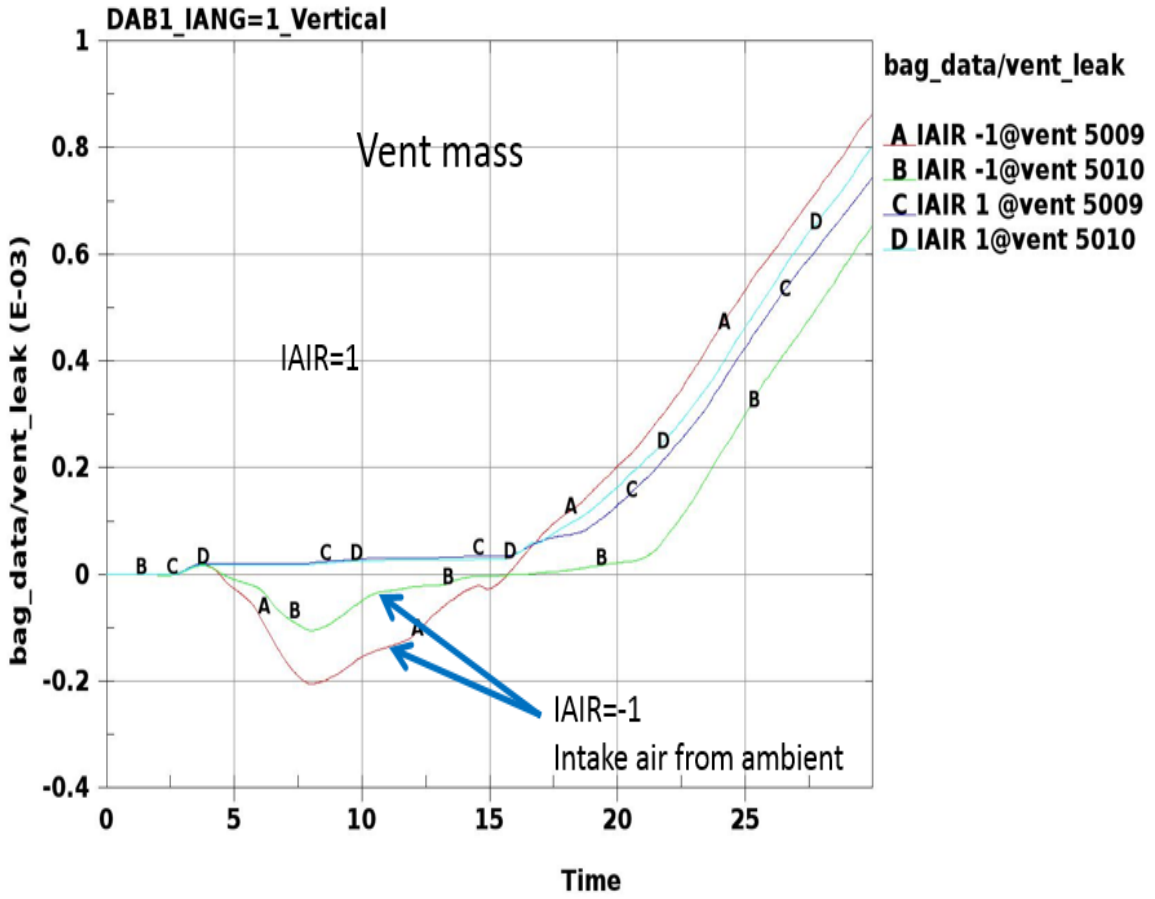


Airbag CPM – IAIR=-1

- Allow for outside air to flow into CPM bag due to pressure difference.
- Vents and fabric leakage.

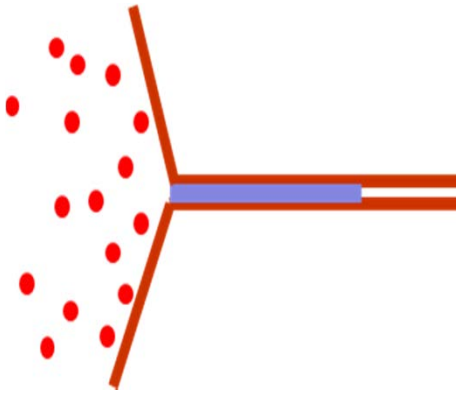
- Available in UP mode of CPM bag.

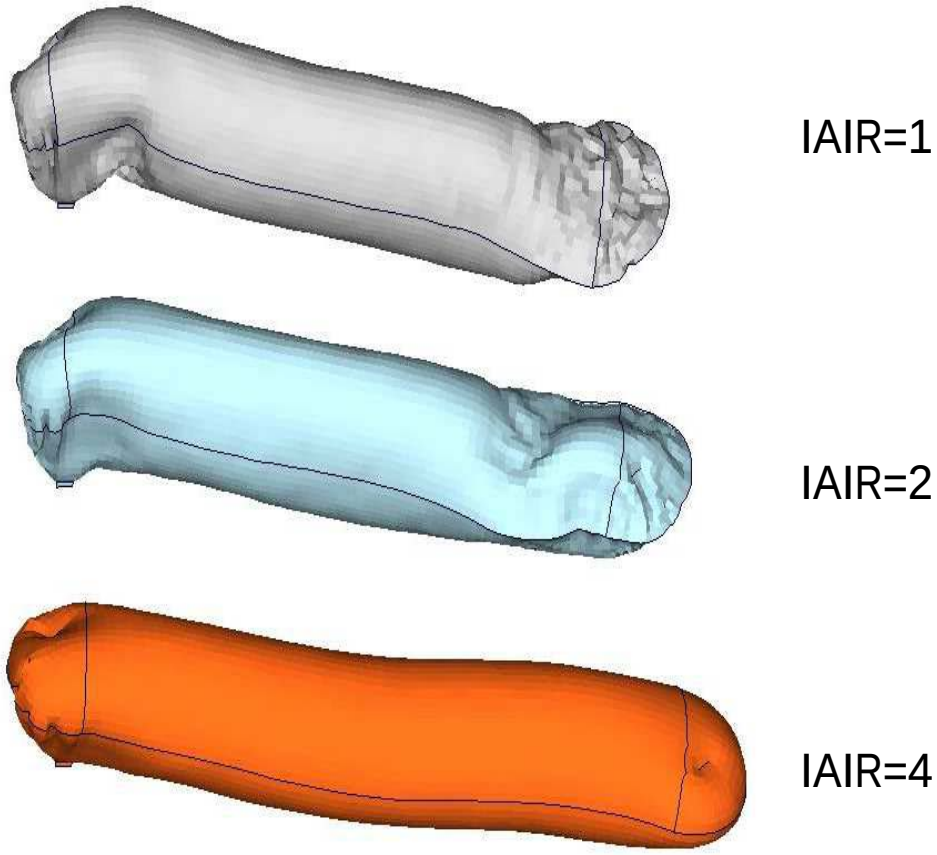




Airbag CPM IAIR=4

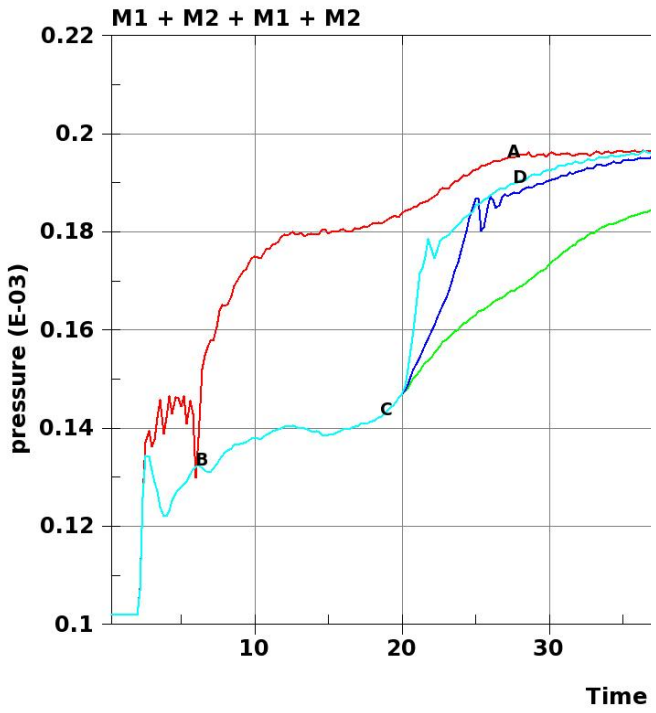
- Turns on gas front tracking algorithm.
- Add pressure based on ratio of initial air particles and gas particles to keep fabric seperated until gas particles gets to that volume.
- Improves performance of tightly rolled airbags.

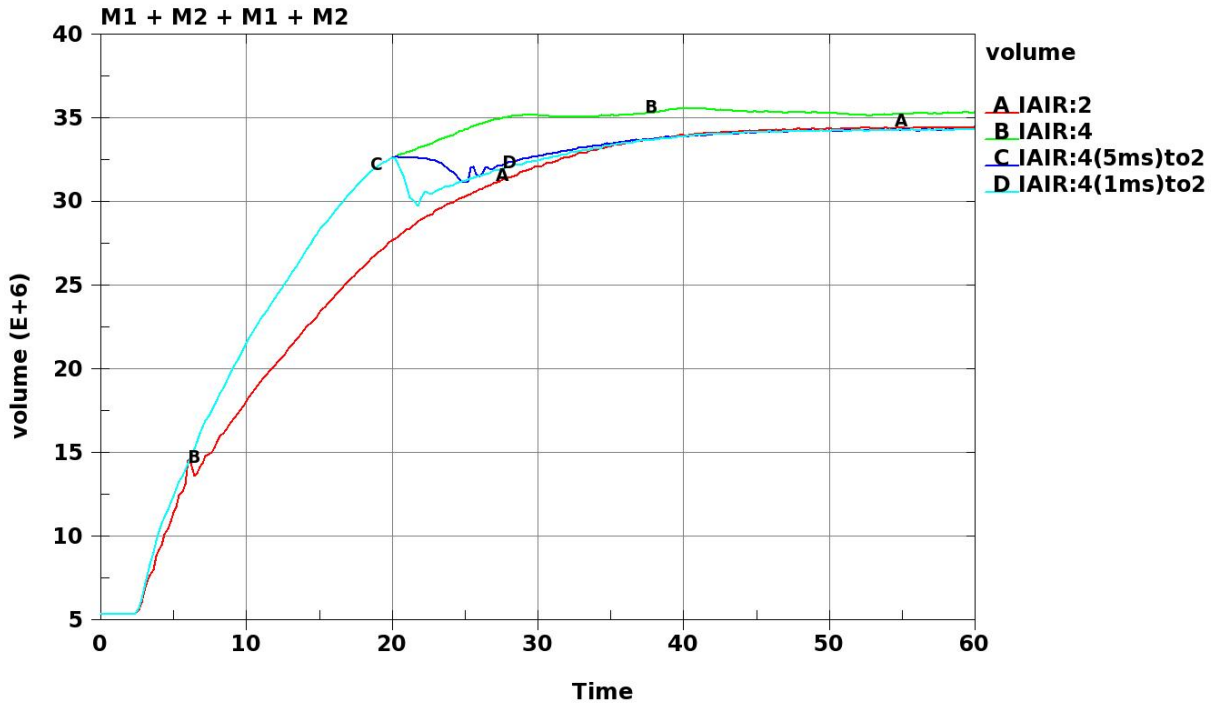




Airbag CPM IAIR=4 switch to IAIR=2

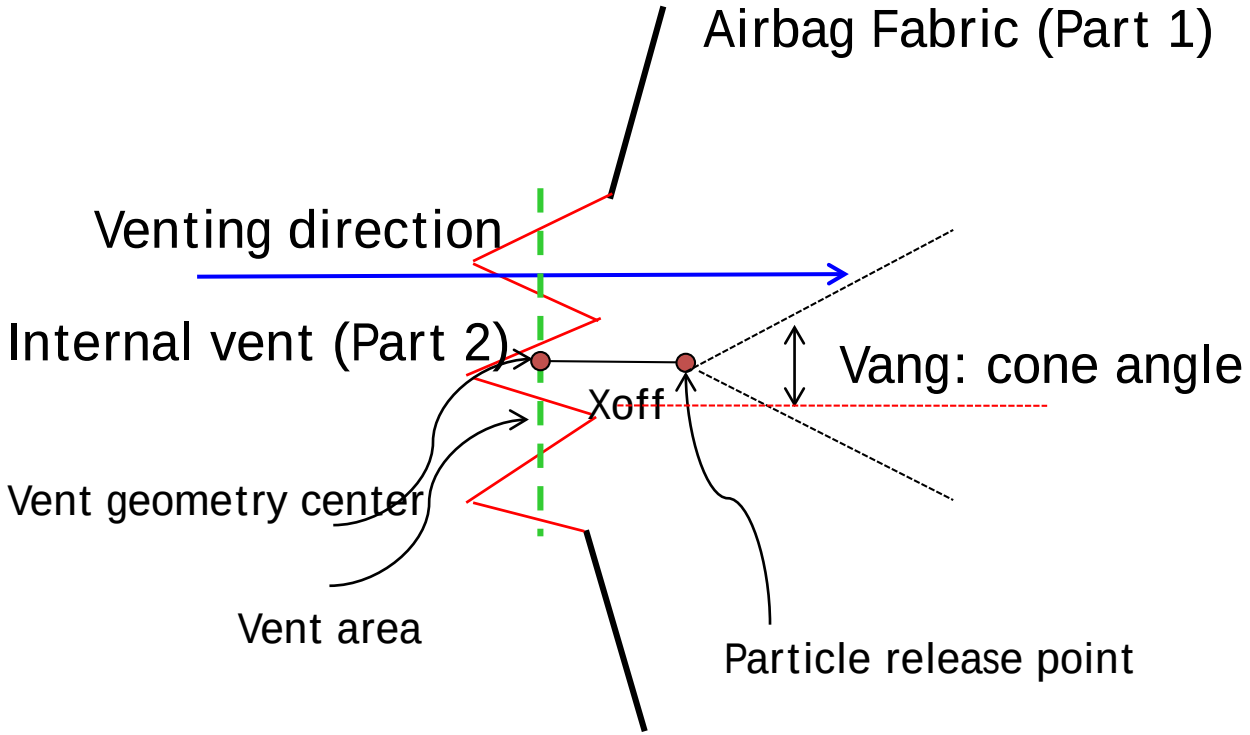
- TSTOP: Time to stop gasfront tracking algorithm.
- TSMTH: Period of time for smooth transition from IAIR=4 to IAIR=2 (def 1ms).

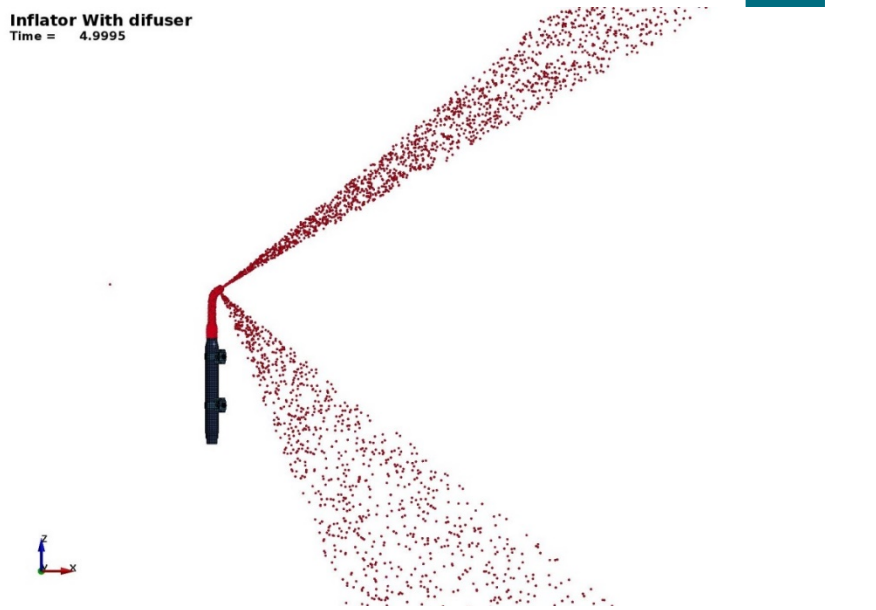


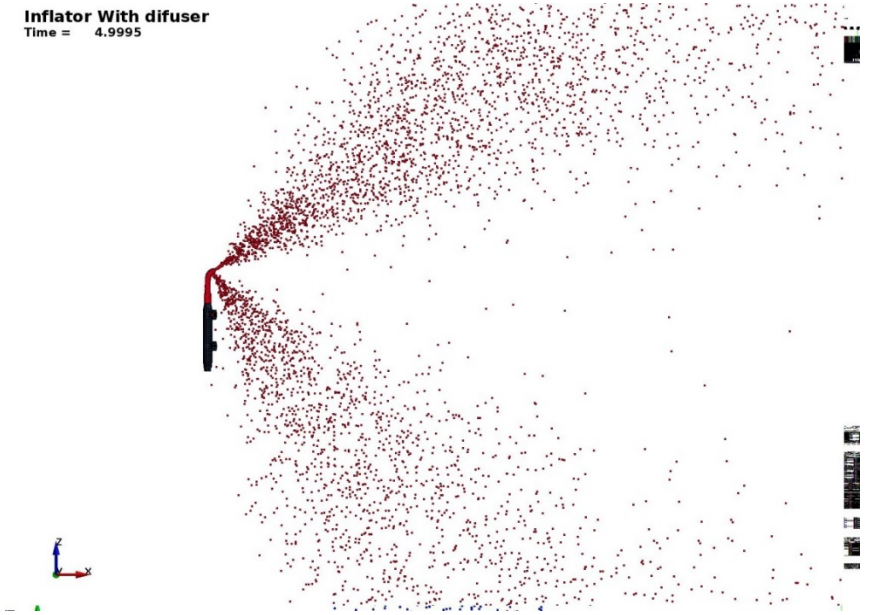


Airbag CPM – Internal vent with uni-direction/cone an

- DEFINE_CPM_VENT
  - VANG: The 7th field of the 2nd card
  - Only valid for internal vent







Airbag CPM – deactivate particles differently

- Push-out vent

IOPT

Directional venting:

EQ.1: In shell normal

EQ.2: Against shell normal

One-way venting:

EQ.10: In shell normal

EQ.20: Against shell normal

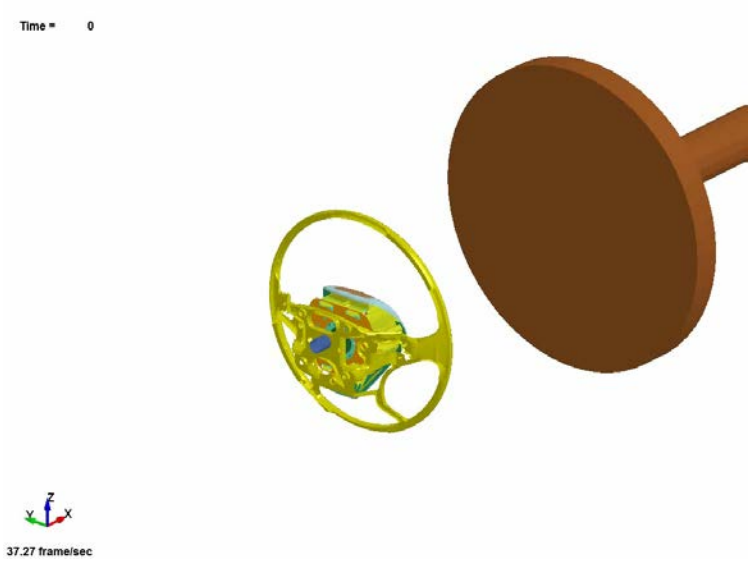
Special vent option::

EQ.100: Enable compression seal vent. Vent area is adjusted according to the formula below. See Remark 1.

$$A_{vent} = \max(A_{current} - A_0, 0)$$

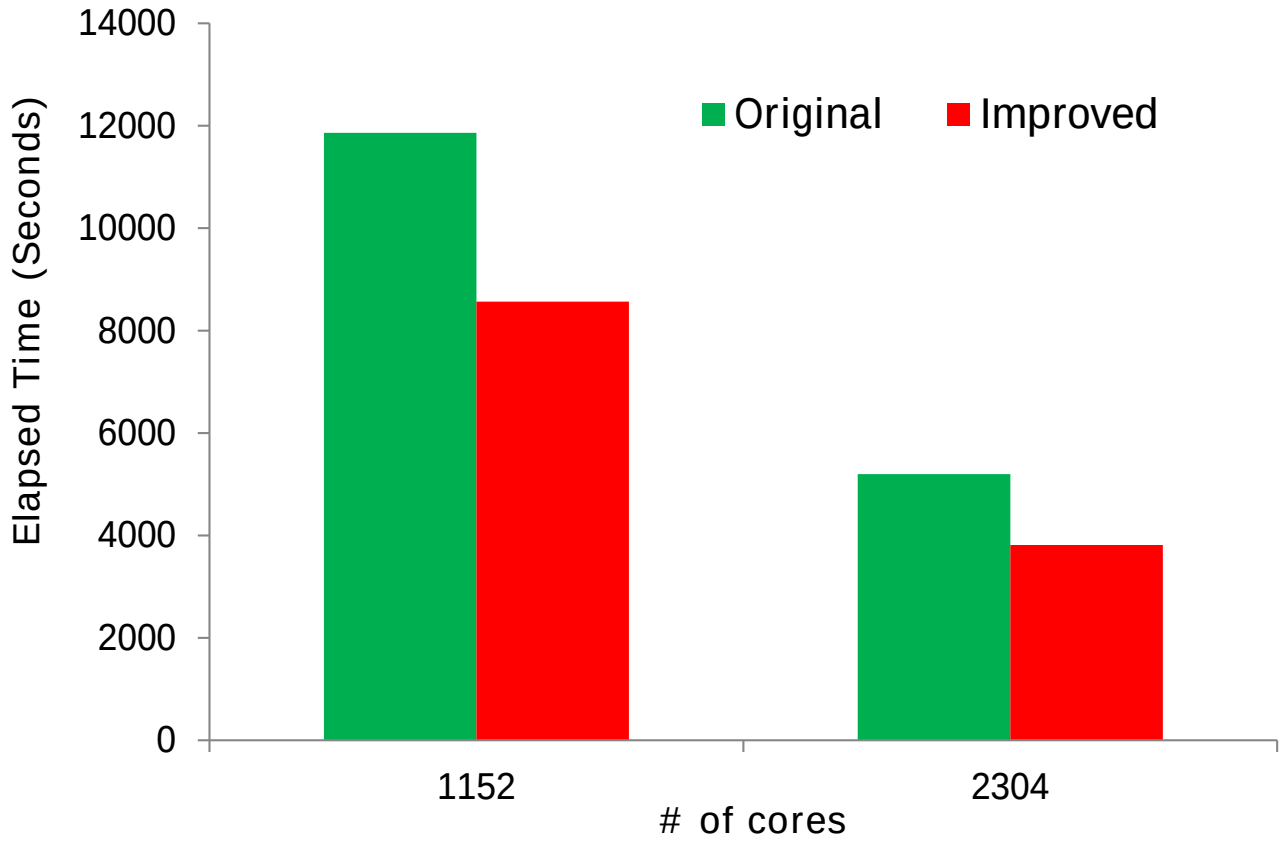
EQ.200: Enable push-out vent. Particle remains active while going through this external vent within the range of 2 times of its characteristic length, l_{vent}.

$$l_{vent} = \sqrt{A_{vent}}$$



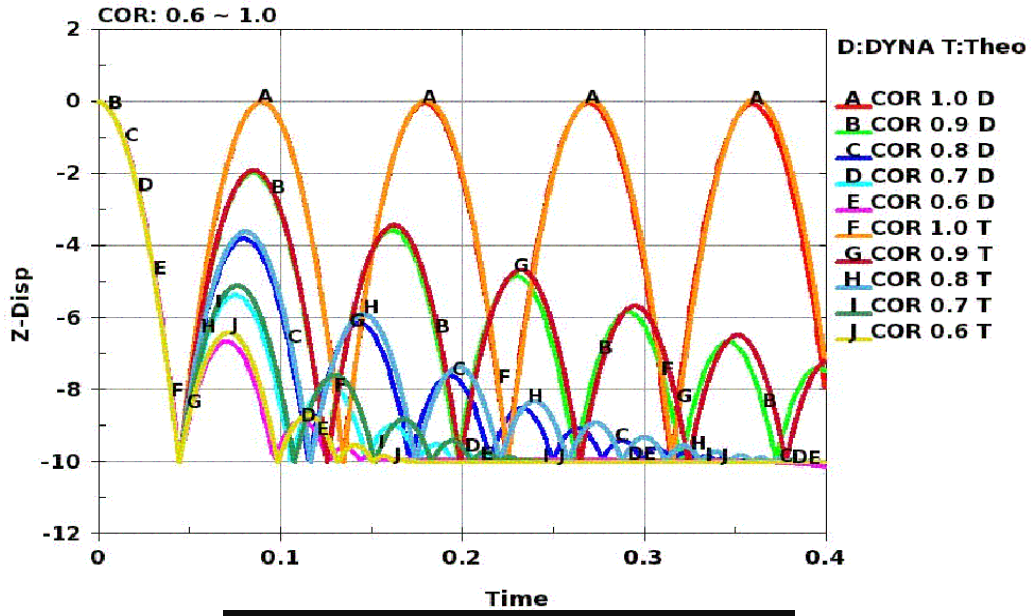
Contact

- *CONTACT_ERODING_xxx
  - Major re-write of MPP contact algorithms.
  - Major area is contact surface determination.
  - SIGNIFICANT improvment!
  - Example from Fan Blade Out simulation.



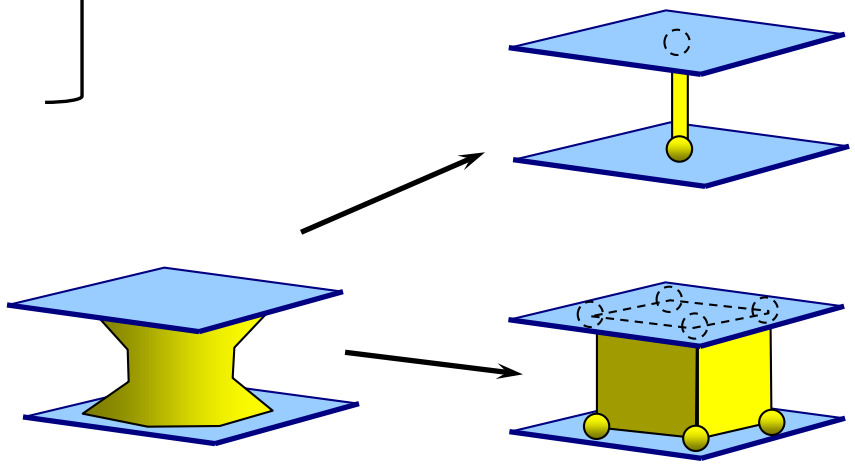
Contact ICOR

- If ICOR≠0 on Optional Card E, the viscous damping coefficient, VDC, is the coefficient of restitution expressed as percentage of damping.
- Coefficient of restitution of two colliding objects represents the ratio of speeds after and before an impact, taken along the line of the impact.
- 0.0 (plastic collision) ≤ VDC (COR) ≤ 100.0 (elastic collision).



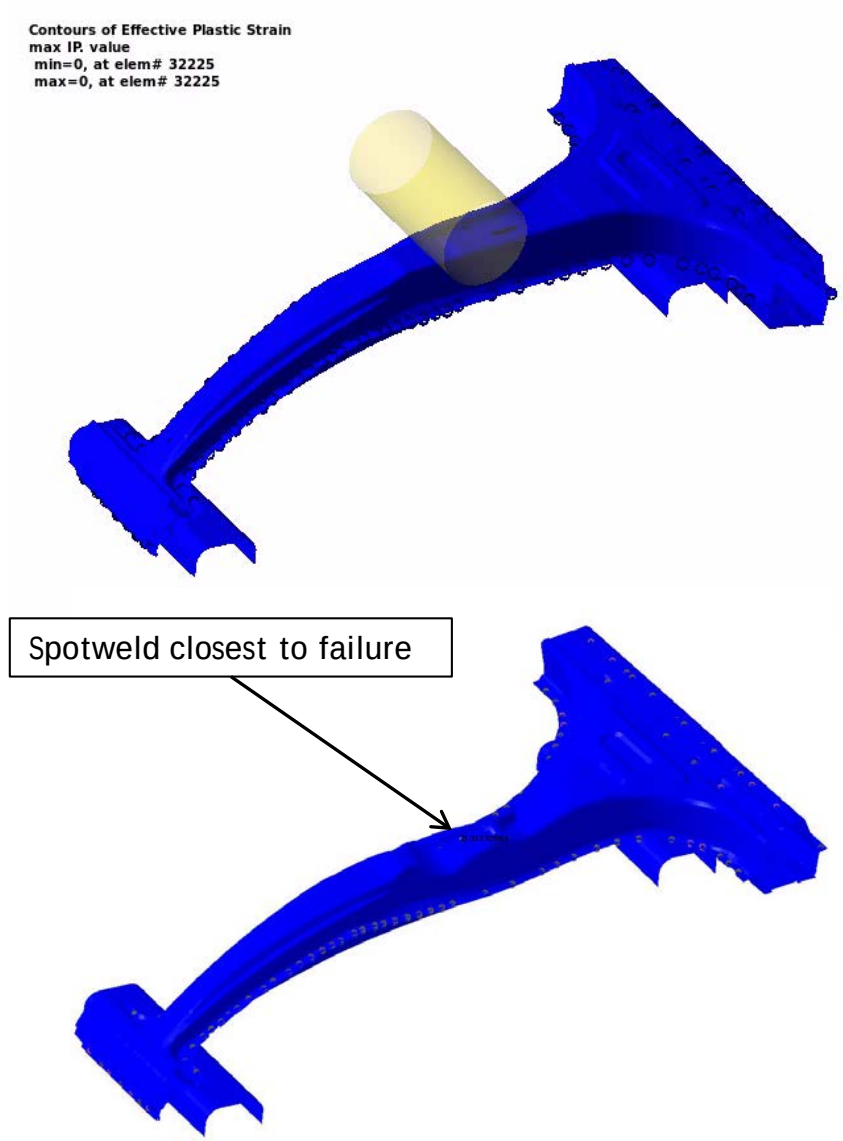
*MAT_SPOTWELD

- MAT_SPOTWELD
  - *MAT_100_DA with output of "failure function" on hisvar 18.
  - Add possibility to use yield curve or table in *MAT_100 (*MAT_SPOTWELD) for solid elements if SIGY.lt.0 is used.
  - Add a solid spot weld material option to treat the stress state as uniaxial. This option is available for solid assemblies also. The uniaxial option is used by setting the elastic modulus to a negative number on *MAT_SPOTWELD where the absolute value of E is the elastic modulus.
  - Enabled OPT=-1 for solids.
  - Fixed TRUE_T option MAT_100(_DA) more robust behavior with bricks and brick assemblies
  - Possible to use DEFINE_FUNCTION for _DAMAGE_FAILURE, OPT=-1/0
    - Fail_func(N_rr, N_rs, N_rt, M_rr, M_ss, M_tt)



History Management

- Purpose, to facilitate and organize the post-processing of history variables in the d3plot database
- *DEFINE_MATERIAL_HISTORIES
  - Allows to customize the history variable output
    - Instability
    - Damage
    - Plastic strain rate
    - Select a certain historyvariable in a given part and material
- A given history variable # will correspond to the specific quantity listed in the keyword
  - No contamination by combination of materials
  - Effective plastic strain *is* effective plastic strain



Thank you!

DYNA MORE

Your LS-DYNA distributor and more