MADYMO 7.0

AIRBAG MODELLING CHECKLIST

UNIFORM PRESSURE & GASFLOW

This document gives general recommendations regarding airbag modelling, some specific recommendations are highlighted in blue or green depending on the inflation method:

Uniform Pressure –UP– is typically used with scaled airbags and IMM2 (In-Position load cases)

Gas Flow –GF– is typically used with folded airbags and IMM1 (Out of Position / detailed analysis)

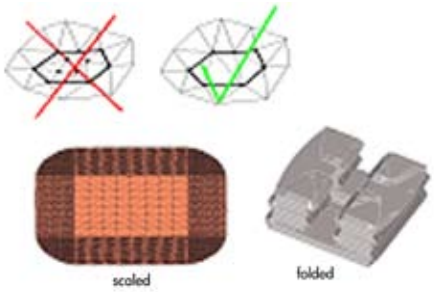
Control_analysis.Time

- Use INT_MTH=EULER
- Use TIME_STEP in range [1.10-6 … 5.10-6]
- Avoid sub-cycling between MB and FE

The initial element time step is determined from the reference mesh and also from the IMM time step when IMM2 is used with IMM_DAMP_MTH=1 or 2. Check the required FE time step in the Reprint file.

The FE time step used is: $\Delta t_{used} = \min(\Delta t_{FE(element)}, \Delta t_{GF})$

Meshing and folding



1. Recommended element size: max 10 mm for correct deployment and well-handled contact
2. Element type: MEM3
3. Use a closed mesh: mesh vent holes as well (don't leave nodes inside the hole area). If not closed by hand, mesh will be automatically closed by adding HOLE.MODEL* inside AIRBAG_CHAMBER.
4. Initial mesh
   - Scaled mesh created by scaling down the reference mesh (using SCALING or any pre-processor, don't apply projections)

   Avoid max stretches higher than 1 and elements shrunk to zero

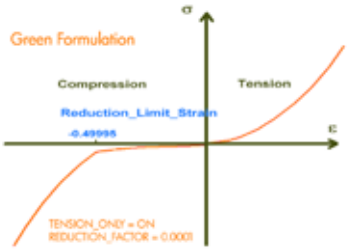
   - Folded mesh created with Folder and/or simulations

   Avoid intersected elements and minimise heavily distorted elements

5. AUTO_VOLUME=ON (normals of elements will point outwards for correct calculation of theinitial bag volume)
6. When reference elements are used (reference panels) set OUTWARD_NORMAL_STATE=INITIAL

Element and material formulation

1. Use MATERIAL.FABRIC_SHEAR (direction-dependent material with separate shear stiffness), alternatives are ISOLIN or ORTHOLIN
2. In PROPERTY.MEM3, use STRAIN_FORM=GREEN
3. Model wrinkling of the elements (low material compression stiffness) by using TENSION_ONLY=ON and REDUCTION_FACTOR in range [0.0001 …0.1] for coarse to very fine meshes
4. Below REDUCTION_LIMIT_STRAIN, compression stiffness equals again tension stiffness. Express REDUCTION_LIMIT_STRAIN in same STRAIN_FORM scale as in the property definition (==GREEN)
5. MATERIAL.HOLE properties for meshed holes:
   - Set STIF=1E-1. Only valid for holes generated by hand (automatically generated holes have no stiffness)
   - HOLE.MODEL*:



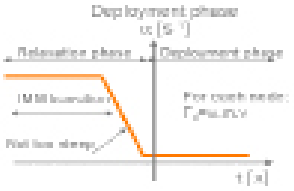
UP uses HOLE.MODEL1 for flow from chamber to ambient and for flow between chambers

GF uses HOLE.MODEL1 for flow from chamber to ambient and HOLE.MODEL3 for flow between chambers. Use a CDEX close to 1

6. Model straps with MATERIAL.STRAP and DAMP~0.7 instead of STRAP
7. Model heat loss through material by using Kappa~50

Relaxation and control of the airbag

1. Relaxation when initial and reference meshes are present
   - Scaled bags: add CONTROL_IMM. METHOD2 (spring damper based method) In PROPERTY.MEM3, preferably set IMM_DAMP_MTH=0, IMM_DAMP=[0.1 … 0.2], IMM_STIF_REDUC=0, alternative is IMM_DAMP_MTH=2, IMM_DAMP=[0.00001 … 0.0001], IMM_STIF_REDUC=0



2. Folded bags: add CONTROL_IMM.METHOD1 (strain based method)
   - Relax airbag before inflation
   - TIME_WINDOW ~3ms
   - During relaxation define alpha damping ~1.10E+4 in CONTROL_AIRBAG
3. During deployment, use alpha damping [0…10]. Higher values damp out low airbag frequencies

Airbag inflation/inflow/outflow

INFLATOR.* element only is sufficient for UP, jet can be added for jet effect. Locate jet inside chamber

- Number of Euler cells to start with: DAB [40000…75000], PAB [40000…100000], CAB ~100000
  Check convergence of results w.r.t. number of cells to optimise runtime/accuracy ratio
- ⚠ Avoid multiple jets in different directions in one GF cell
- Grid orientation ideally aligned with airbag FE mesh
- Rule of Thumb: cell is active when ~50% or more of its volume is inside airbag volume
- INFLATOR_MTH=SONIC_CELL
- ANTI_THROUGH_FLOW=ON

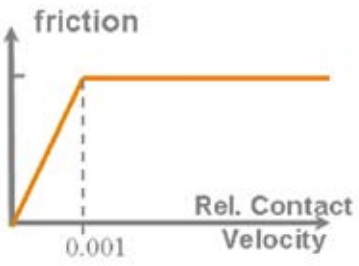
TIP Potential CPU improvements when using GF

- In CONTROL_AIRBAG use time delay GAS_FLOW_TRIGGER
- In CONTROL_AIRBAG switch from GF to UP with ISOBARIC_SWITCH.TIME when bag is fully inflated
- In GAS_FLOW_GRID use MIN_SIZE to prevent small cells initially

- ⚠ Check accuracy of inflator data (e.g. by modelling a tank test) crucial for the results
- In CONTROL_AIRBAG, use BLOCK_FLOW=1 to stop outflow through fabric elements making contact

Contact

1. Contact with environment
   - CONTACT_METHOD.NODE_TO_SURFACE_CHAR with facet surfaces
     airbag == slave
   - CONTACT_METHOD.SURFACE_TO_SURFACE with FE surfaces
     INITIAL_PEN_TRACK=ON
     CONTACT_FORCE.ADAPTIVE
       TIME_STEP 5 to 10% larger than FE time step
       DAMP_COEF in range [0.05…0.1]
       FRIC_FUNC starting at (0,0), use engineering values
       (friction coef vs. contact velocity)
     GAP_TYPE.FUNC with gap thickness constant in time
     CONTACT_EDGE
     INITIAL_TYPE.CHECK



2. Self contact

Can be neglected in UP with scaled bags, only inflated end state is relevant

For self contact with GF (==contact between FE surfaces) use the settings described above

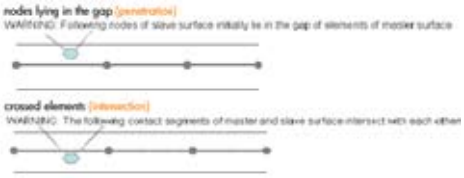
- *TIP* If contacts are lost (can be detected from animation by making cross-sections)
  - Increase gap thickness
  - Reduce the FE time step and the contact TIME_STEP
  - Define VAR_TIME_STEP in combination with contact TIME_STEP
  - Self-contact: when having very tight folds, perform a separate relaxation with low FE/contact time step and gap thickness growing in time. Set WRITE_FEMESH=ON and use this new initial mesh
- *TIP* See also the MADYMO Facet Modelling Guidelines

Output

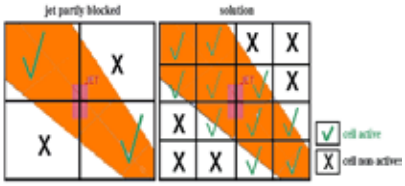
REQUEST SUFFICIENT OUTPUT to avoid having to run the model again if some results are missing

Reprint file

1. Pay attention to all warnings
   - Avoid contact warnings about intersections; penetrations are less harmful
   - Check extrapolation warnings (be careful with pressure dependent outflow)



2. Check the different required time steps (MB, FE, GF)
3. Check initial element stretches
   - Scaled bags with CONTROL_IMM.METHOD2: keep max stretches < 1
   - Folded bags with CONTROL_IMM.METHOD1:
   - Keep initial IMM ratio A0/Aref ideally between 90%–110%
   - Keep max local stretches < 1.25
4. Check working of jet
   - ⚠ "Jet partly blocked" during a long period of the run might give wrong flow
   - refine Euler grid to avoid this
   - ⚠ "Jet fully blocked" means that the jet is outside active cells
   - refine Euler grid or free space (e.g. create a thick gap) around inflator



5. Other output files
   - Study all output carefully (*.rep, *.kn3/*.h5, *.fhs, *_gf.h5, *_ani.h5, *.cntfrc, etc...)
   - Analyse the sensitivity of the model to less well-known parameters (contact friction, permeability, hole properties, material stiffness, etc…)

TIP See released application examples

- a_driver_airbag.xml, a_immpasbag.xml, a_immrefpasbag.xml, a_thorax_airbag_up.xml, a_frontalfc_Q_scaled_dab.xml
- a_passenger_airbag.xml, a_thorax_airbag_gf.xml