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

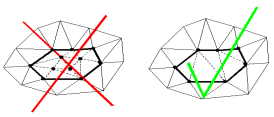
- Uniform Pressure –UP– is typically used with scaled airbags and IMM2 (In-Position load cases)
- Gas Flow –GF– is typically used with folded airbags and IMM1 (Out of Position / detailed analysis)

CONTROL_ANALYSIS.TIME

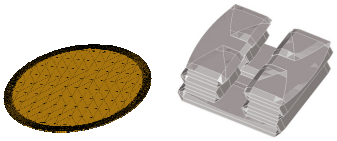
- Use INT_MTH=EULER
- Use TIME_STEP in range [1.10^{-6} … 5.10^{-6}]
- Avoid sub-cycling between MB and FE
  ⚠The initial element time step is determined from the reference mesh and also from the IMM time step when IMM2 is used with IMM_DAMP_MTH=1 or 2. Check the required FE time step in the Reprint file.
- The FE time step used is: $\Delta t_{used} = \min(\Delta t_{FE(element)}, \Delta t_{GF})$

MESHING AND FOLDING

- Recommended element size: max 10 mm for correct deployment and well-handled contact
- Element type: MEM3
- Use a closed mesh: Preferably 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.



- 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

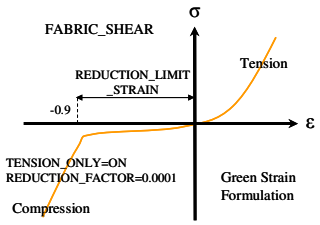


Scaled *Folded*

- AUTO_VOLUME=ON (normals of elements will point outwards for correct calculation of the initial bag volume)
- When reference elements are used (reference panels) set OUTWARD_NORMAL_STATE=INITIAL

ELEMENT AND MATERIAL FORMULATION

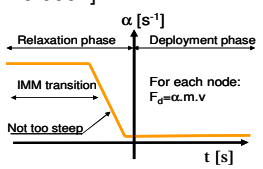
- Use MATERIAL.FABRIC_SHEAR (direction-dependent material with separate shear stiffness, input data: parameters or curves), alternatives are ISOLIN or ORTHOLIN.
- In PROPERTY.MEM3, use STRAIN_FORM=GREEN
- Model wrinkling of the elements (low material compression stiffness) by using TENSION_ONLY=ON and REDUCTION_FACTOR in range [0.0001 …0.1] for coarse to very fine meshes. Below REDUCTION_LIMIT_STRAIN, compression stiffness equals again tension stiffness ⚠ For material FABRIC* expressed in engineering strain, for other materials: same strain formulation as in the property definition.



- MATERIAL.HOLE properties for meshed holes:
  - Set STIF≤1E-2. 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
- Model straps with MATERIAL.STRAP and DAMP~0.7 instead of STRAP
- Model heat loss through material by using Kappa~50

RELAXATION AND CONTROL OF THE AIRBAG

- Relaxation when initial and reference meshes are present
  - Scaled bags: add CONTROL_IMM.METHOD2 (spring damper based method)
    ⚠ *The criterion for taking elements out of IMM has been updated in V7.4 which may influence the deployment*
    In PROPERTY.MEM3, preferably set IMM_DAMP_MTH=0, IMM_DAMP=[0.05 … 0.2], IMM_STIF_REDUC=[0 … 0.0001]
    alternative is IMM_DAMP_MTH=2, IMM_DAMP=[0.00001 … 0.0001], IMM_STIF_REDUC=[0 … 0.0001]
  - 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



- 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
- 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

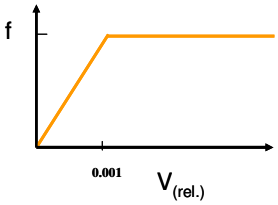
- INFLATOR_MTH=SONIC_CELL
- ANTI_THROUGH_FLOW=ON

TIP Potential CPU improvements when using GF
1. in CONTROL_AIRBAG use time delay GAS_FLOW_TRIGGER
2. in CONTROL_AIRBAG switch from GF to UP with ISOBARIC_SWITCH.TIME when bag is fully inflated
3. 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

- 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



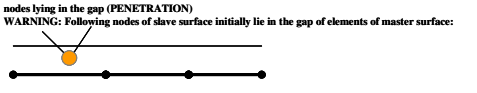
- Self contact, only MASTER_SURFACE to be defined, no slave surface required.
  - Can be neglected in UP with scaled bags if deployment allows this. Generally only inflated end state is relevant.
  - For self contact with GF (==contact between FE surfaces) use the contact settings described above.
- **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
- STATE.FE_MODEL and STATE.CONTACT related e.g. to the inflator SWITCH can improve the CPU performance.
- **TIP** See also the MADYMO Facet Modelling Guidelines

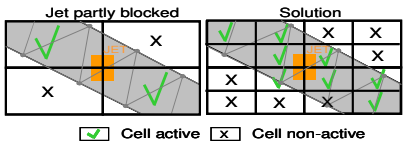
OUTPUT

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

Reprint file

- Pay attention to all warnings
  - Avoid contact warnings about intersections; penetrations are less harmful
  - Check extrapolation warnings (be careful with pressure dependent outflow)
- Check the different required time steps (MB, FE, GF)
- Check initial element stretches
  - Scaled bags with CONTROL_IMM.METHOD2: keep max stretches < 1
  - Folded bags with CONTROL_IMM.METHOD1:
    - Keep initial IMM ratio A_0/A_{ref} ideally between 90%–110%
    - Keep max local stretches < 1.25
- 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





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 (e.g. friction, permeability, hole and material properties)
- Time history files: Use EXTENDED_SAMPLING in relevant output to avoid aliasing effects.
- Elements in "IMM2" have "zero stress". Check ani file with e.g. Von Mises stress with "2 ranges (0, 1E-5) ABS" to see if elements are "out of IMM2".

TIP See released application examples e.g.:
- a_driver_airbag.xml, a_immrefpasbag.xml, a_thorax_airbag_up.xml, a_frontal(el/fc)_scaled_dab.xml
- a_passenger_airbag.xml, a_thorax_airbag_gf.xml