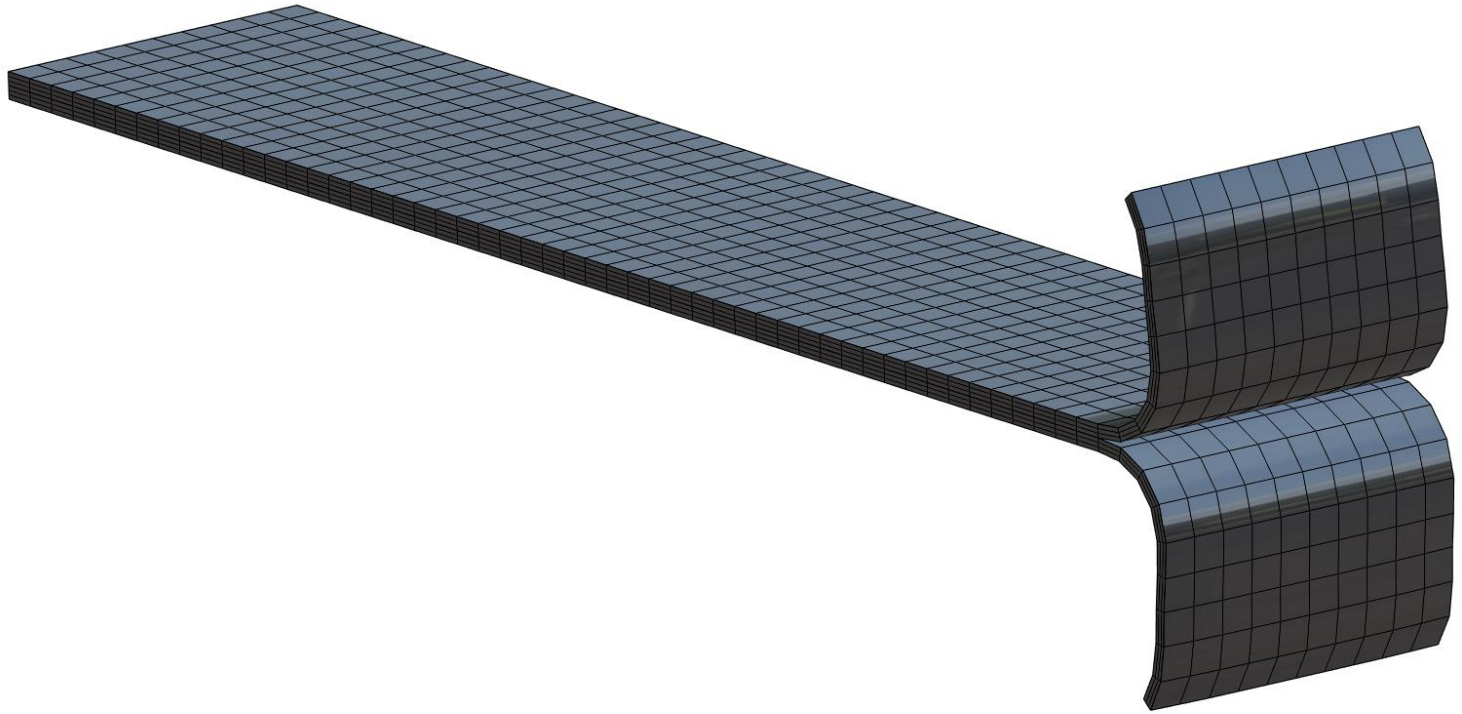
Tied and tiebreak contacts in LS-DYNA
- Explicit simulation (MPP)



Webinar 2022-03-10

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Outline

- Scope of presentation
- Penalty or constraint-based
- Offset options
- Rotational DOF
- Tying tolerance
- Tiebreak contacts
- Automatic tiebreak contacts
- D3hsp and message files
- Control and database cards
- MORTAR contacts
- Example: CONTACT_AUTOMATIC_..._TIEBREAK, OPTION 9
- Short summary

Scope of the presentation

- This presentation mainly cover tied -and tiebreak contact types for general purposes.

Tied

- CONTACT_TIED_NODES_TO_SURFACE
- CONTACT_TIED_NODES_TO_SURFACE_OFFSET
- CONTACT_TIED_NODES_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE
- CONTACT_TIED_SURFACE_TO_SURFACE_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_CONSTRAINED_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIED

Tiebreak

- CONTACT_TIEBREAK_NODES_TO_SURFACE
- CONTACT_TIEBREAK_NODES_ONLY
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE_ONLY
- CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET

The basic principle for all these contacts is that nodes are tied to contact surfaces.

Scope of the presentation

- Tied and tiebreak contact types not covered in this presentation:
  - User defined tiebreak contacts
    - CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK_USER
    - CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK_USER_MORTAR
    - CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK_USER

    See webinar ”Guideline for user-defined interfaces in LS-DYNA”
  - Weld contacts
    - CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIED_WELD
    - CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_MORTAR_TIED_WELD

    See webinar ”Welding Simulations in LS-DYNA and LS-PrePost”
  - Spotweld contacts
    - CONTACT_SPOTWELD
    - CONTACT_SPOTWELD_WITH_TORSION
    - CONTACT_SPOTWELD_WITH_TORSION_PENALTY

    Contacts intended for spotwelds, see *MAT_SPOTWELD.
  - 2D contacts
    - CONTACT_2D_AUTOMATIC_TIED
    - CONTACT_2D_AUTOMATIC_TIED_ONE_WAY

    See webinar ”2D-simulations in LS-DYNA”

Penalty or constraint-based

Constraint

- CONTACT_TIED_NODES_TO_SURFACE*#
- CONTACT_TIED_NODES_TO_SURFACE_CONSTRAINED_OFFSET#
- CONTACT_TIED_SURFACE_TO_SURFACE*#
- CONTACT_TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET#
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE*#
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_CONSTRAINED_OFFSET#
- CONTACT_TIED_SHELL_EDGE_TO_SOLID*
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_CONSTRAINED_OFFSET

Penalty

- CONTACT_TIED_NODES_TO_SURFACE_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_BEAM_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIED
- CONTACT_TIEBREAK_NODES_TO_SURFACE
- CONTACT_TIEBREAK_NODES_ONLY
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE_ONLY
- CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET

- Constraint based contacts will not work with rigid bodies.
- Penalty based contacts will work with rigid bodies.
- Contacts marked with (*) will project and move the node to the contact surface.
- For constraint-based contacts marked with (#) using IPBACK ≠ 0 on Optional Card E will automatically create a “backup” penalty contact for rigid nodes.
- The tie-condition for these contacts is generally “one-way”, with the exception for the contacts listed below that are “two-way”.

  CONTACT_AUTOMATIC_SINGLE_SURFACE_TIED
  CONTACT_AUTOMATIC_GENERAL_TIEBREAK
  CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET
  CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
  CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET

  Note: Tie will happen also within a part for the above contacts.

- From my experience a reduced penalty stiffness, e.g. SFS = SFM = 0.1, is sometimes needed for the penalty-based variants to avoid instability. The same holds for constraint-based variants that utilize IPBACK ≠ 0.

- In general, constraint-based contacts have less stability issues compared to penalty-based contacts.

OFFSET options

OPTION4

```
*CONTACT_TIED_NODES_TO_SURFACE_OFFSET_MPP_THERMAL_ID
$#     cid                                                          title
         1
$#  ignore     bcket     lcbckt    ns2trk    inititr    parmax    unused    cparm8
         0        200          0         3          2    1.0005                 0
$#    ssid      msid      sstyp     mstyp     sboxid    mboxid       spr       mpr
         0         0          0         0          0         0         0         0
$#      fs        fd        dc        vc        vdc    penchk        bt        dt
       0.0       0.0       0.0       0.0       0.0         0       0.0 1.00000E20
$#     sfs       sfm       sst       mst       sfst      sfmt       fsf       vsf
       1.0       1.0       0.0       0.0        1.0       1.0       1.0       1.0
$#      cf      frad       htc      lmin      lmax    ftoslv    bc_flg      algo
       0.0       0.0       0.0       0.0       0.0       0.5         0         0
```

Allowed options for OPTION4:

OFFSET	Switches the formulation type from constraint to penalty. Force and moment (if applicable) resultants are transferred by discrete springs. Rigid bodies are supported.
BEAM_OFFSET	Switches the formulation type from constraint to penalty. Force and moment (if applicable) resultants are transferred by beam-like springs. Rigid bodies are supported.
CONSTRAINED_OFFSET	A constraint type formulation. Force and moment (if applicable) resultants are transferred in a beam-like manner. Rigid bodies are not supported in the constraint-based definition.

***CONTACT**_OPTION1_{OPTION2}_{OPTION3}_{OPTION4}_{OPTION5}_{OPTION6}*

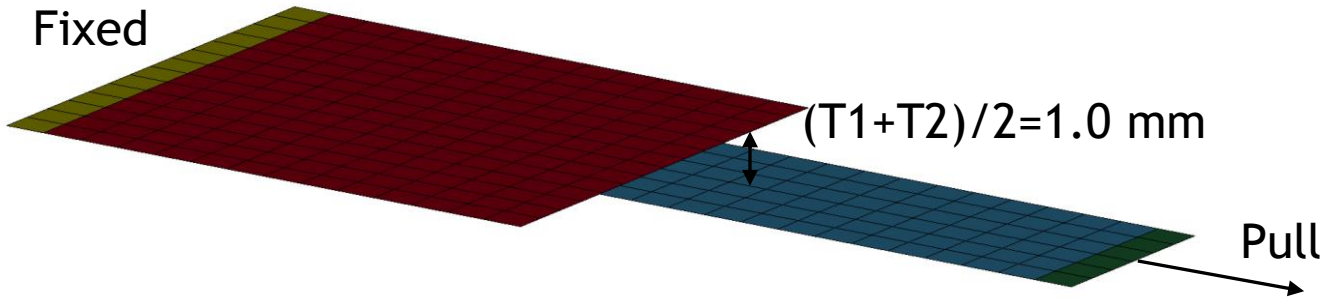
Purpose: Define a contact interface in a 3D model. For contact in 2D models, see *CONTACT_2D_*OPTION*.

OPTIONS FOR *CONTACT KEYWORD

OPTION	REQUIRED	DESCRIPTION
OPTION1	Yes	Specifies contact type
OPTION2	No	Flag for thermal
OPTION3	No	Flag indicating ID cards follow
OPTION4	No	Offset options
OPTION5	No	Flag for MPP
OPTION6	No	Flag for orthotropic friction

Note: the general recommendation is that offset distances should always be reasonable, realistic, and preferable as small as possible.

Example: Offset options



Note: CARD E, FTORQ = 2 must be set for the contacts listed below in order to transfer the moment.

CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET
CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET

Results for OPTION4 = OFFSET -> No coupling between transmitted forces and moments, equilibrium is not enforced.

Results for OPTION4 = BEAM_OFFSET -> Coupling between transmitted forces and moments.

Results for OPTION4 = CONSTRAINED_OFFSET -> Coupling between transmitted forces and moments.

Rotational DOF

Can not tie rotational DOF (A)

- CONTACT_TIED_NODES_TO_SURFACE
- CONTACT_TIED_NODES_TO_SURFACE_OFFSET
- CONTACT_TIED_NODES_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE
- CONTACT_TIED_SURFACE_TO_SURFACE_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIED
- CONTACT_TIEBREAK_NODES_TO_SURFACE
- CONTACT_TIEBREAK_NODES_ONLY
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE_ONLY
- CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET

Can tie rotational DOF (B)

- CONTACT_TIED_SHELL_EDGE_TO_SURFACE
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_CONSTRAINED_OFFSET

Can tie rotational DOF (C)

- CONTACT_TIED_SHELL_EDGE_TO_SOLID
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_CONSTRAINED_OFFSET

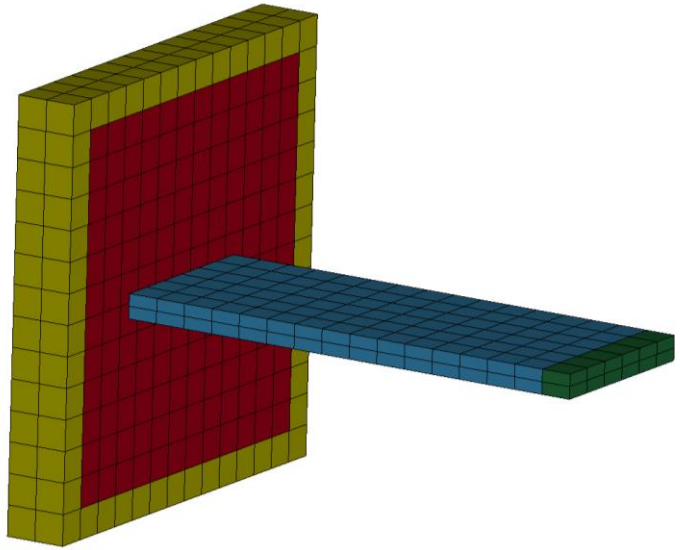
- The contacts in category A can not tie rotational DOF.
- The contacts in category B can tie rotational DOF if both sides of the contact have rotational DOF, the intended use is shells to shells and beams to shells.

Note: the drilling rotation constraint method that is used by default in implicit calculations can be activated for a part set in explicit simulations as well, see DRCPSID on *CONTROL_SHELL. By doing this also torsion can be constrained for beams tied to shells.

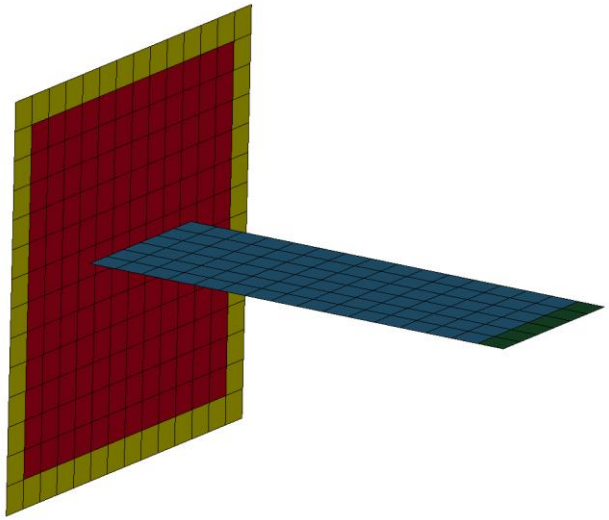
- The contacts in category C can tie rotational DOF and the intended use is shell edges to solids and beam ends to solids. The OFFSET variants does only tie rotational DOF for solid elements with rotational DOF, i.e. ELFORMs 3, 4, 20 or 22, or when the solid part is rigid.

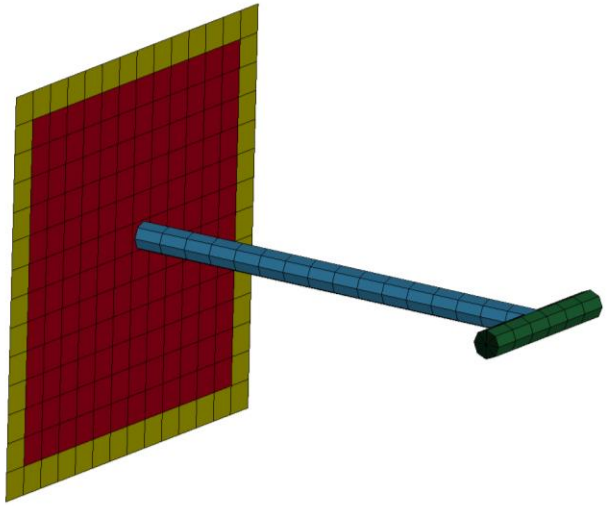
- Recommendations for tied contact types (see the manual):
  - Solids to solids
    - CONTACT_TIED_NODES_TO_SURFACE (opt. OFFSET or CONSTRAINED_OFFSET)
    - CONTACT_TIED_SURFACE_TO_SURFACE (opt. OFFSET or CONSTRAINED_OFFSET)
  - Shells to shells or beams to shells
    - CONTACT_TIED_SHELL_EDGE_TO_SURFACE (opt. OFFSET, BEAM_OFFSET, CONSTRAINED_OFFSET)
  - Shell edges to solids or beam ends to solids
    - CONTACT_TIED_SHELL_EDGE_TO_SOLID (opt. OFFSET, BEAM_OFFSET, CONSTRAINED_OFFSET)

Rotational DOF

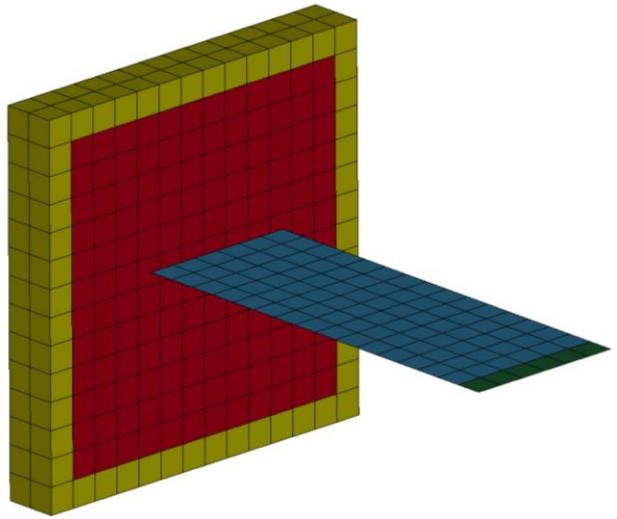


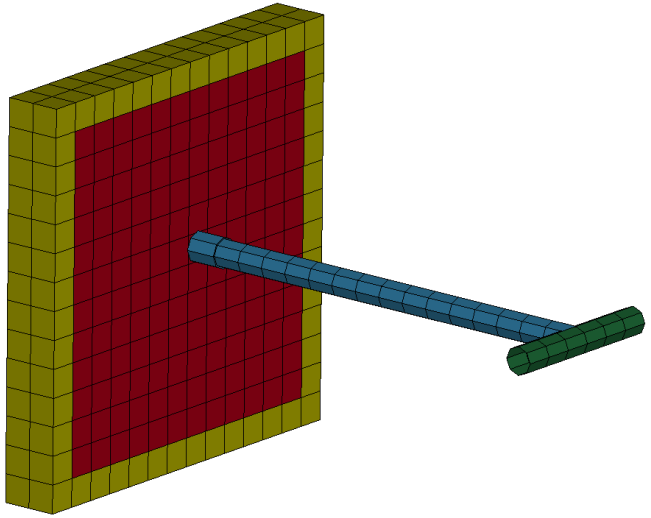
CONTACT_TIED_NODES_TO_SURFACE_(OPTION4)
CONTACT_TIED_SURFACE_TO_SURFACE_(OPTION4)





CONTACT_TIED_SHELL_EDGE_TO_SURFACE_(OPTION4)





CONTACT_TIED_SHELL_EDGE_TO_SOLID _(OPTION4)

Tying tolerance

Category A

- CONTACT_TIED_NODES_TO_SURFACE
- CONTACT_TIED_NODES_TO_SURFACE_OFFSET
- CONTACT_TIED_NODES_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE
- CONTACT_TIED_SURFACE_TO_SURFACE_OFFSET
- CONTACT_TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SURFACE_CONSTRAINED_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_BEAM_OFFSET
- CONTACT_TIED_SHELL_EDGE_TO_SOLID_CONSTRAINED_OFFSET

Category B

- CONTACT_TIEBREAK_NODES_TO_SURFACE
- CONTACT_TIEBREAK_NODES_ONLY
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE
- CONTACT_TIEBREAK_SURFACE_TO_SURFACE_ONLY

Category C

- CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET

Category D

- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIED

- Tying will only work if the surfaces are “close” to each other.
- The maximum separation distance, the tolerance, to tie a node is set by criteria.
- The tie distance might be affected by the circumstances at hand.
- So, check so that the addressed nodes are correctly tied.

To my understanding the tolerances are typically evaluated as follows:

- Category A

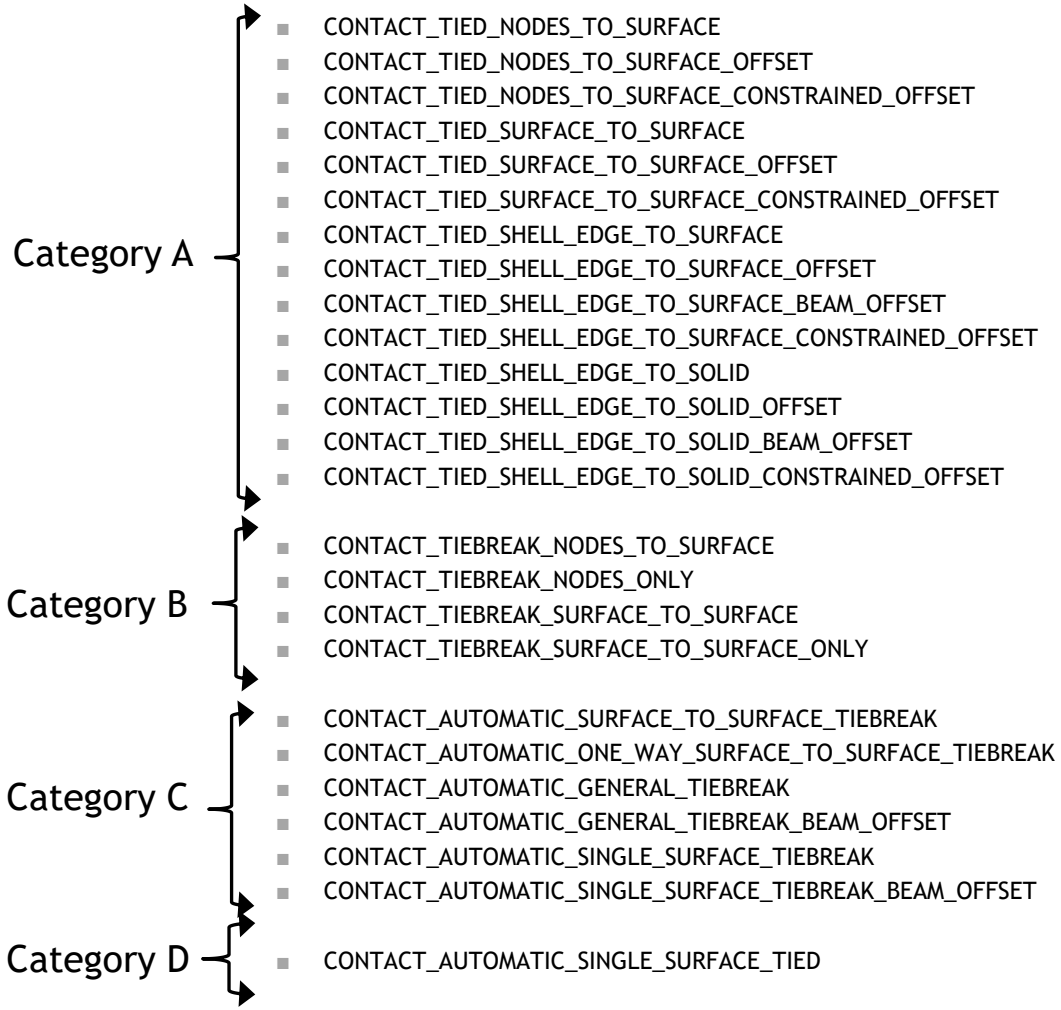
  δ_1 = 0.60 * (thickness of tracked node + thickness of reference segment)
  δ_2 = 0.05 * min (reference segment diagonals)
  δ = max (δ_1,δ_2)

  Example: shell thickness T1=T2=1.0 mm, 5 mm mesh -> diagonal = 7.07107 mm
  δ_1 = 0.6 * (1.0 + 1.0) = 1.2 mm, δ_2 = 0.05 * (7.07107) = 0.35 mm -> δ = 1.2 mm

  The thicknesses in the above formula can be set by using negative values on SST and MST, which will simplify the tolerance: δ = abs (δ_1)

  Example: SST=MST=-2.0 mm -> δ_1 = 0.6 * (2.0 + 2.0) = 2.4 mm

Tying tolerance



- Category B

  d = minimum of the lengths of the reference segment diagonals.
  tol = max (node thickness + segment thickness, d/2)

  For solid elements, the node thickness is zero and the segment thickness is the element volume divided by the segment area; otherwise, the same procedure is used.

- Category C

  Tying occurs if the tracked node is within a small tolerance of the reference surface after taking into account contact thicknesses.

  For MPP, tol = $0.01*(2 * \text{reference segment area})^{0.5}$

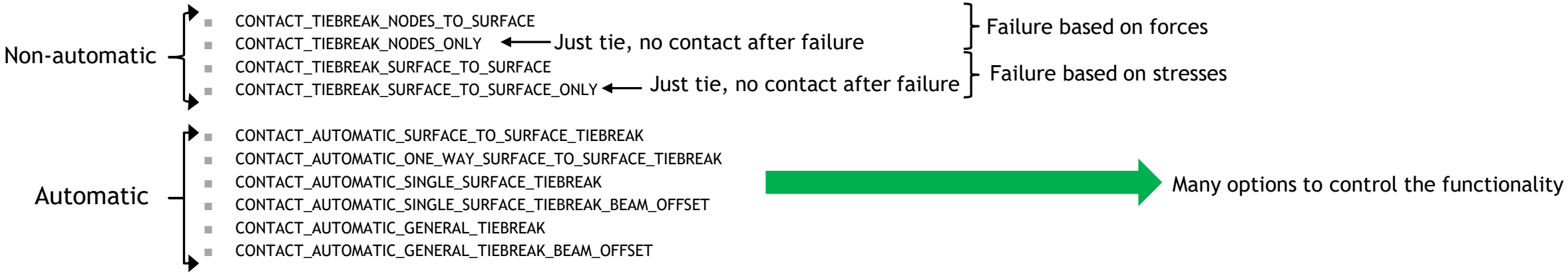
  Example (MPP): 5 mm mesh -> $0.01*(2*25)^{0.5} = 0.0707$ mm

- Category D

  The tolerance is set by contact parameter CLOSE, which is after taking into account contact thicknesses.

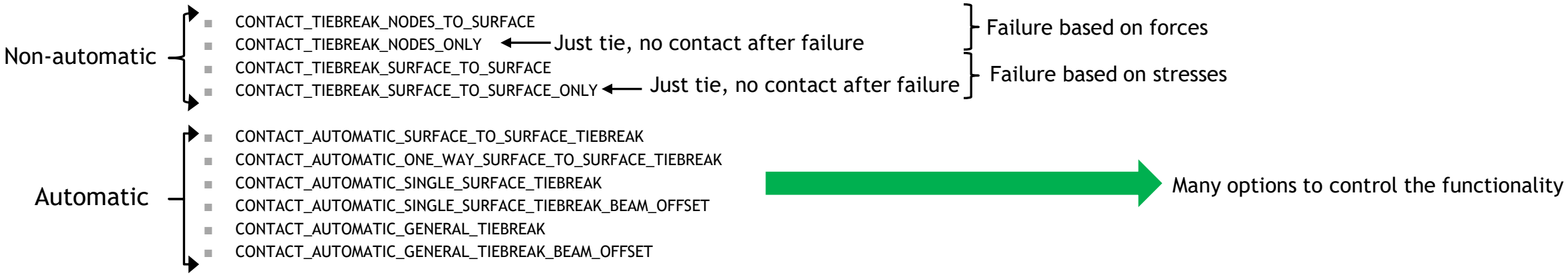
  The default value of CLOSE is $0.0106*(\text{reference segment area})^{0.5}$.

Tiebreak contacts



- After failure the tiebreak contact will turn into the corresponding sliding contact. Therefore, appropriate settings such as for instance SOFT (Note: SOFT=2 is not supported for tiebreak), contact damping VDC, contact friction FS/FD and IGNORE may be set.
- For tiebreak contacts it is recommended to use segment sets rather than part/part sets (see the manual). This approach gives better control of what segments are included in the contact and better control of the contact segment normal vectors.
- Segment normal vectors should point toward the opposing contact surface so that tension is properly distinguished from compression (see manual).

Tiebreak contacts



- The old style non-automatic tiebreak contacts were not developed with offsets in mind. These contact should therefor only be used when the nodes are positioned on the contact surface or near to avoid instability.
  Note that after failure the contact will behave as an old style non-automatic NODES_TO_SURFACE or SURFACE_TO_SURFACE contact, which means thickness offsets will not be considered.
- For the automatic contacts thickness offsets are considered after failure.
- Verify so that the contact does what you want.

Automatic tiebreak contacts

Automatic
- CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET

- There are many options available to control failure and damage, as well as when to tie and how to tie.
- For options 6 to 11 with CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK "contact gap" in the intfor file indicates the condition of the tiebreak, which is ranging from 0 (tied, no damage) to 1 (released, full damage).

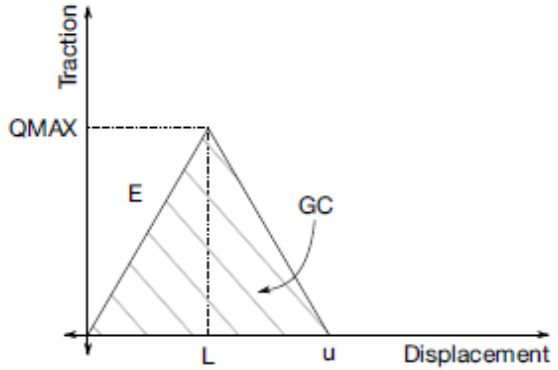
OPTION	Response:
EQ.-11:	See 11. NFLS/SFLS/ERATEN/ERATES are functions of temperature. MORTAR option *only*.
EQ.-9:	See 9. NFLS/SFLS/ERATEN/ERATES are functions of temperature. MORTAR option only.
EQ.-3:	See 3. Moments are transferred. SMP only.
EQ.-2:	See 2. Moments are transferred. SMP only.
EQ.-1:	See 1. Moments are transferred. SMP only.
EQ.1:	Slave nodes in contact and which come into contact will permanently stick. Tangential motion is inhibited.
EQ.2:	Tiebreak is active for nodes which are initially in contact. Until failure, tangential motion is inhibited. If PARAM is set to unity (1.0), shell thickness offsets are ignored, and the orientation of the shell surfaces is required such that the outward normals point to the opposing contact surface.
EQ.3:	Same as 1 above but with failure after sticking.
EQ.4:	Tiebreak is active for nodes which are initially in contact but tangential motion with frictional sliding is permitted.
EQ.5:	Tiebreak is active for nodes which are initially in contact. Stress is limited by the yield condition described in Remark 5 below. Damage behavior is modeled by a curve which defines normal stress as a function of gap (crack opening). This option can be used to represent deformable glue bonds.
EQ.6:	This option is for use with solids and thick shells only. Tiebreak is active for nodes which are initially in contact. Failure stress must be defined for tiebreak to occur. After the failure stress tiebreak criterion is met, damage is a linear function of the distance between points initially in contact. When the distance is equal to PARAM, damage is fully developed, and interface failure occurs. After failure, this option behaves as a surface-to-surface contact.
EQ.7:	Dycoss Discrete Crack Model. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option. See Remark 3.
EQ.8:	Similar to OPTION = 6, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.
EQ.9:	Discrete Crack Model with power law and B-K damage models. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option. See Remark 3.
EQ.10:	Similar to OPTION = 7, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.
EQ.11:	Similar to OPTION = 9, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.
EQ.13:	Elastoplastic, rate-dependent damage model based on *MAT_240. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option. See Remark 7.
EQ.14:	Similar to OPTION = 13, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.

Automatic tiebreak contacts

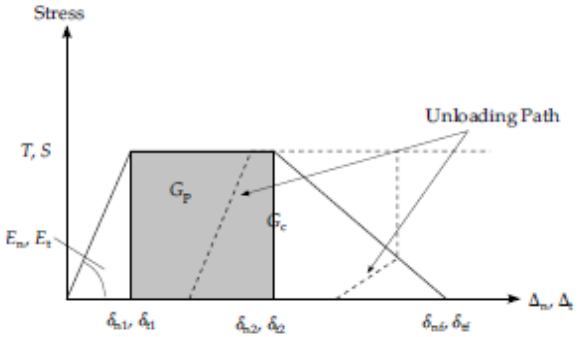
Automatic
- CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK
- CONTACT_AUTOMATIC_SINGLE_SURFACE_TIEBREAK_BEAM_OFFSET
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK
- CONTACT_AUTOMATIC_GENERAL_TIEBREAK_BEAM_OFFSET

- Options 9 and 11:
  - Based on the fracture model in the cohesive material model *MAT_COHESIVE_MIXED_MODE (MAT_138).
  - Failure stresses/peak tractions can be defined as functions of characteristic element length (square root of reference segment area) using load curves.
  - With these options, nearly the same global responses (for instance load-displacement curve) can be obtained with coarse meshes compared to fine meshes.
  - For the MORTAR variant also temperature dependency can be considered (-9, -11).

- Options 13 and 14:
  - Based on the fracture model in the cohesive material model *MAT_COHESIVE_MIXED_MODE_ELASTOPLASTIC_RATE (MAT_240).



*MAT_138: Bilinear traction separation law

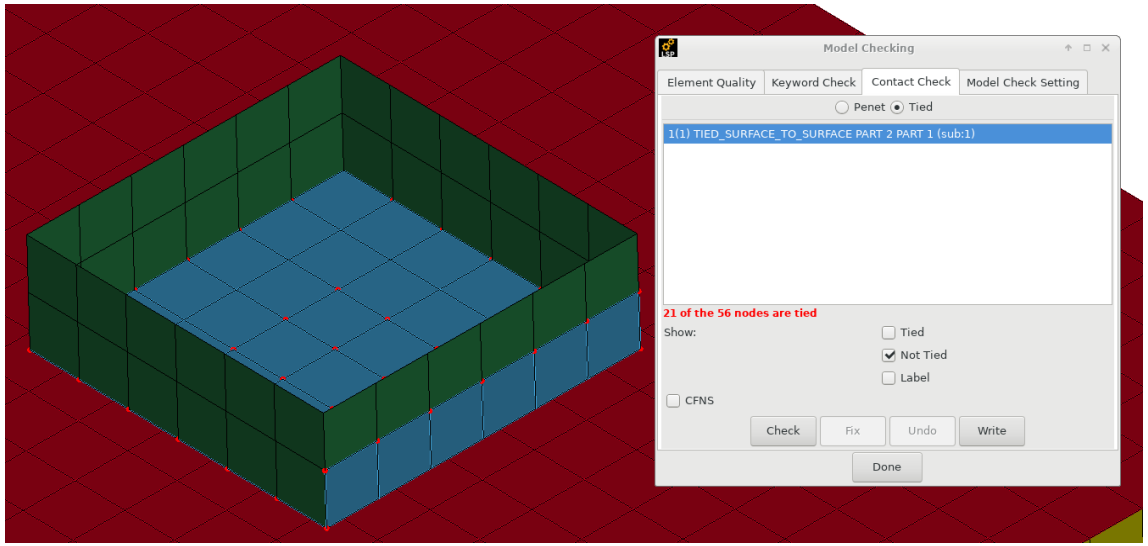


*MAT_240: Trilinear traction separation law

D3hsp and message files

- Warning messages can be found in d3hsp and message files.
- The DYNAmore tool ”check-c” can be used to get a quick summary for tied contacts.
- Postprocessors such as LS-PrePost can be used to check some tied and tiebreak contacts.

Example: CONTACT_TIED_SURFACE_TO_SURFACE




```
check-c.lnx -sel tied mes*

==================================
Interface ID:        1         max:
 separations:       29     1.00000
     too far:        7     6.00000
   not found:        1
rigid master:        8
 rigid slave:       19
==================================
```

29 nodes were projected/moved to contact segments.
7 nodes too far from segment to tie.
1 node not tied since it could not find a segment.
8 nodes not tied since segment contains rigid body nodes.
19 nodes are rigid body and therefore not tied.

In this case 56-7-1-8-19 = 21 nodes were properly tied.

D3hsp and message files

- For tiebreak contacts nodes that are ”not tied” are listed in the message files in a *SET_NODE format.

```
*** Warning 41253 (SOL+1253)
     Summary of untied nodes
       interface ID = 1
       number of untied nodes = 8
  untied *set_node_list below

*SET_NODE_LIST

      626       651       667       668       673       677       681       685
```

- Information about failed nodes in tiebreak contacts can be found in the message files.

```
Contact surface          1: failure at node        644
Timestep no.:    20093   Time:   0.16676E+02
Normal force:   0.93170E-01   Shear force:   0.36532E-01
```

non-automatic tiebreak

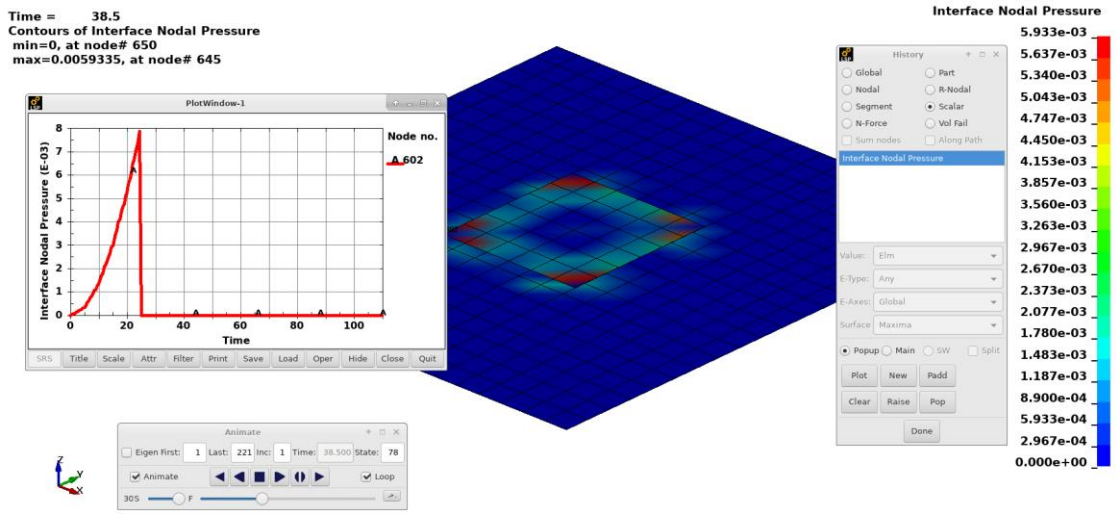
```
Node      644 failed on automatic tiebreak interface       1 at time  0.1175E+02
   Normal force= 0.50243473E-01 Normal stress= 0.80389558E-02
    Shear force= 0.00000000E+00  Shear stress= 0.00000000E+00
```

automatic tiebreak

Control and database cards

- DATABASE_BINARY_INTFOR
  - Fringe plot contact forces, pressure and, when applicable, tiebreak state, from the intfor file.
  - Set SPR=MPR=1 on *CONTACT, S=intfor on the command line.

- CONTROL_ACCURACY, IACC = 2 (dev LS-DYNA)
  - Activates ”implicit” tied contacts.
  - Useful when switching between explict/implicit, e.g. for *CASE.
  - Strong objectivity in tied contacts meaning that large rotations will not induce stresses, see manual for details.
  - Available for the following contacts:
    - TIED_NODES_TO_SURFACE_CONSTRAINED_OFFSET
    - TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET
    - TIED_NODES_TO_SURFACE_OFFSET
    - TIED_SURFACE_TO_SURFACE_OFFSET
    - TIED_SHELL_EDGE_TO_SURFACE_CONSTRAINED_OFFSET
    - TIED_SHELL_EDGE_TO_SURFACE_BEAM_OFFSET
    - CONTACT_TIED_NODES_TO_SURFACE
    - CONTACT_TIED_SURFACE_TO_SURFACE
    - CONTACT_TIED_SHELL_EDGE_TO_SURFACE
    - CONTACT_TIED_SHELL_EDGE_TO_SOLID



Fringe plot of interface nodal pressure from the intfor file.

Control and database cards

- *CONTACT, Optional card D, TIEDID = 1
  - Flag for incremental displacement update for tied contacts.
  - Reduce numerical round-off errors in stationary parts.
  - Single precision in particular.
  - Using this feature will activate the GROUPABLE option.
    (see GRPABLE = 1 on MPP card 2)

- *CONTACT, Optional card E, IPBACK ≠ 0
  - Automatically create a “backup” penalty contact for rigid nodes that fail to tie.
  - Note that since an OFFSET or BEAM_OFFSET is created for the rigid nodes, they will not be projected and moved to the contact surface.
  - Using this feature, it is reasonable to set options such as TIEDID or penalty stiffness that, other wise, would not be applicable to constraint-based contacts.

- *CONSTRAINED_EXTRA_NODE_OPTION
  - It may sometimes be advantageous to use the CONSTRAINED_EXTRA_NODE instead for tying deformable nodes to rigid bodies since the nodes can be an arbitrary distance away from the rigid body.

Contacts that support TIEDID
- TIED_NODES_TO_SURFACE_OFFSET
- TIED_SURFACE_TO_SURFACE_OFFSET
- TIED_SHELL_EDGE_TO_SURFACE_OFFSET
- AUTOMATIC_..._TIEBREAK
- AUTOMATIC_SINGLE_SURFACE_TIED

Contacts that support IPBACK
- TIED_NODES_TO_SURFACE
- TIED_NODES_TO_SURFACE_CONSTRAINED_OFFSET
- TIED_SURFACE_TO_SURFACE
- TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET
- TIED_SHELL_EDGE_TO_SURFACE
- TIED_SHELL_EDGE_TO_SURFACE_CONSTRAINED_OFFSET

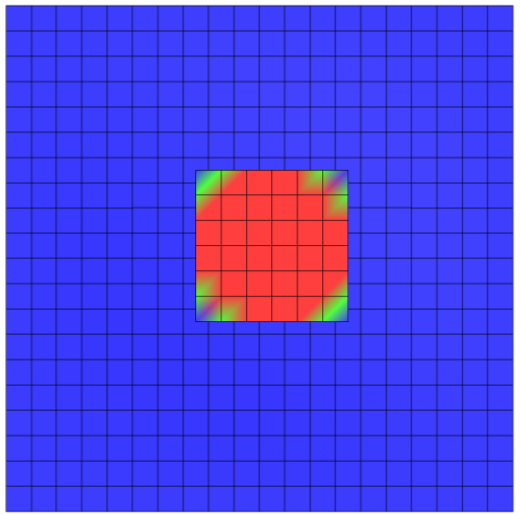
MORTAR contacts

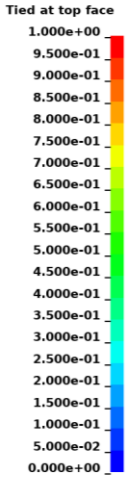
- MORTAR contacts
  - CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_MORTAR_TIED
  - CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK_MORTAR
- Target is implicit, but explicit is also supported.
- Segment-to-segment tie instead of node-to-segment tie.
- High accuracy, but at a higher cost.
- For the TIED option:
  - The tie tolerance is by default 0.05 * T, where T is the element thickness for shells and the characteristic size for solids.
  - PENMAX can be used to set the tolerance, meaning that when PENMAX is positive then segments are tied if the distance is less than PENMAX.
- For OPTION = -11, -9, 2, 4, 6, 7, 8, 9 and 11 of CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK, the MORTAR contact treatment may be activated.

OPTION	Response:
→	EQ.-11: See 11. NFLS/SFLS/ERATEN/ERATES are functions of temperature. MORTAR option *only*.
→	EQ.-9: See 9. NFLS/SFLS/ERATEN/ERATES are functions of temperature. MORTAR option only.
	EQ.-3: See 3. Moments are transferred. SMP only.
	EQ.-2: See 2. Moments are transferred. SMP only.
	EQ.-1: See 1. Moments are transferred. SMP only.
	EQ.1: Slave nodes in contact and which come into contact will permanently stick. Tangential motion is inhibited.
→	EQ.2: Tiebreak is active for nodes which are initially in contact. Until failure, tangential motion is inhibited. If PARAM is set to unity (1.0), shell thickness offsets are ignored, and the orientation of the shell surfaces is required such that the outward normals point to the opposing contact surface.
	EQ.3: Same as 1 above but with failure after sticking.
→	EQ.4: Tiebreak is active for nodes which are initially in contact but tangential motion with frictional sliding is permitted.
	EQ.5: Tiebreak is active for nodes which are initially in contact. Stress is limited by the yield condition described in Remark 5 below. Damage behavior is modeled by a curve which defines normal stress as a function of gap (crack opening). This option can be used to represent deformable glue bonds.
→	EQ.6: This option is for use with solids and thick shells only. Tiebreak is active for nodes which are initially in contact. Failure stress must be defined for tiebreak to occur. After the failure stress tiebreak criterion is met, damage is a linear function of the distance between points initially in contact. When the distance is equal to PARAM, damage is fully developed, and interface failure occurs. After failure, this option behaves as a surface-to-surface contact.
→	EQ.7: Dycoss Discrete Crack Model. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option. See Remark 3.
→	EQ.8: Similar to OPTION = 6, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.
→	EQ.9: Discrete Crack Model with power law and B-K damage models. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option. See Remark 3.
	EQ.10: Similar to OPTION = 7, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.
→	EQ.11: Similar to OPTION = 9, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.
	EQ.13: Elastoplastic, rate-dependent damage model based on *MAT_240. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option. See Remark 7.
	EQ.14: Similar to OPTION = 13, but it works with offset shell elements. "..._ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK" definition is recommended for this option.

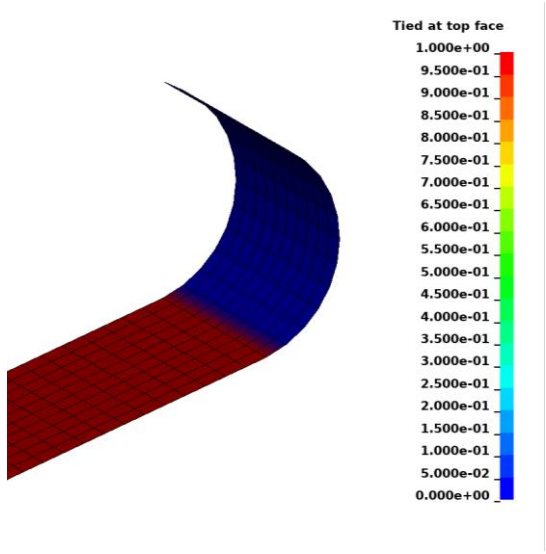
MORTAR contacts

- DATABASE_EXTENT_INTFOR, NTIED = 1 to visualize if a segment is tied (=1) or not (=0) using the intfor file (for TIED).
- DATABASE_EXTENT_INTFOR, NTIED = 1 to visualize relative adhesive strength, that is 1-D where D is damage. Fully damaged segments will show 0 and undamaged segments will show 1 (for TIEBREAK).



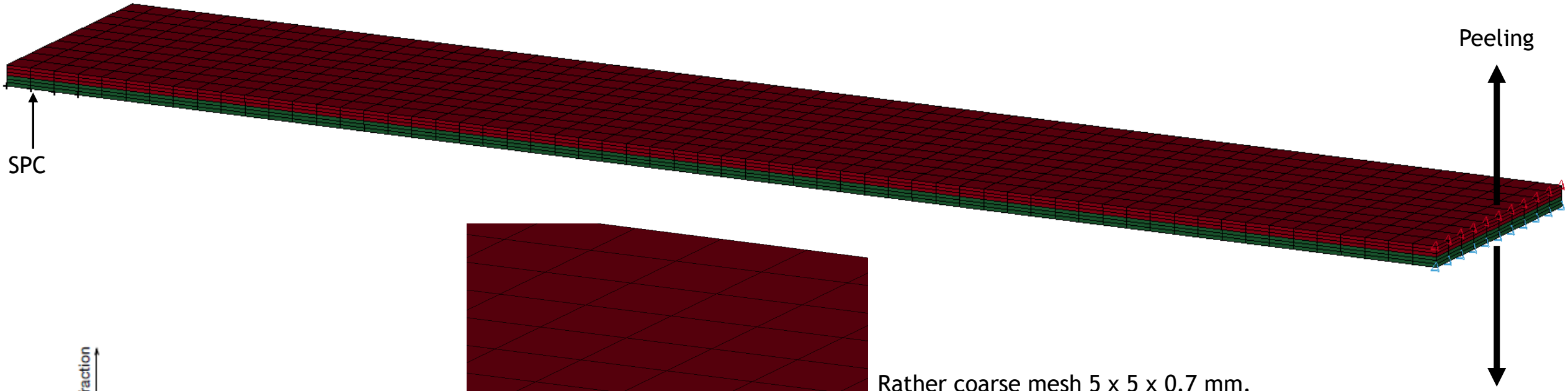


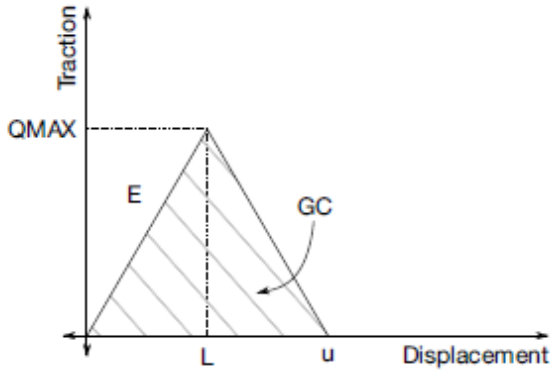
NTIED = 1, TIED contact

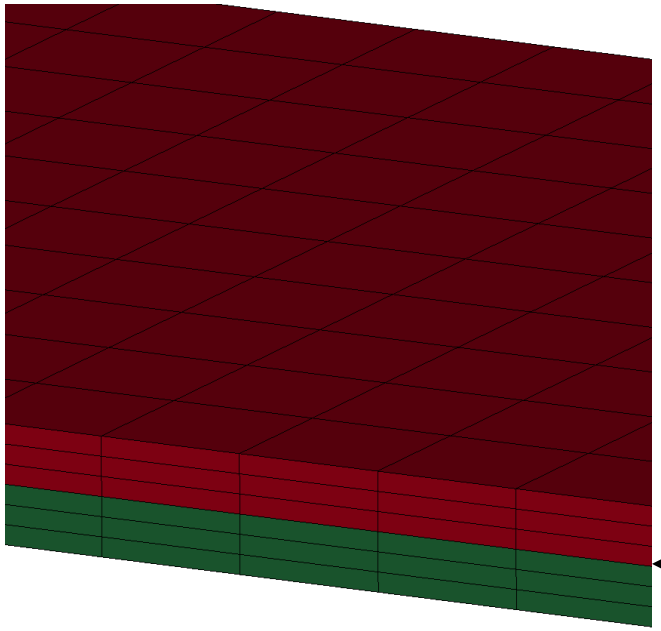


NTIED = 1, TIEBREAK contact

Example: CONTACT_AUTOMATIC_..._TIEBREAK, OPTION 9







Rather coarse mesh 5 x 5 x 0.7 mm.

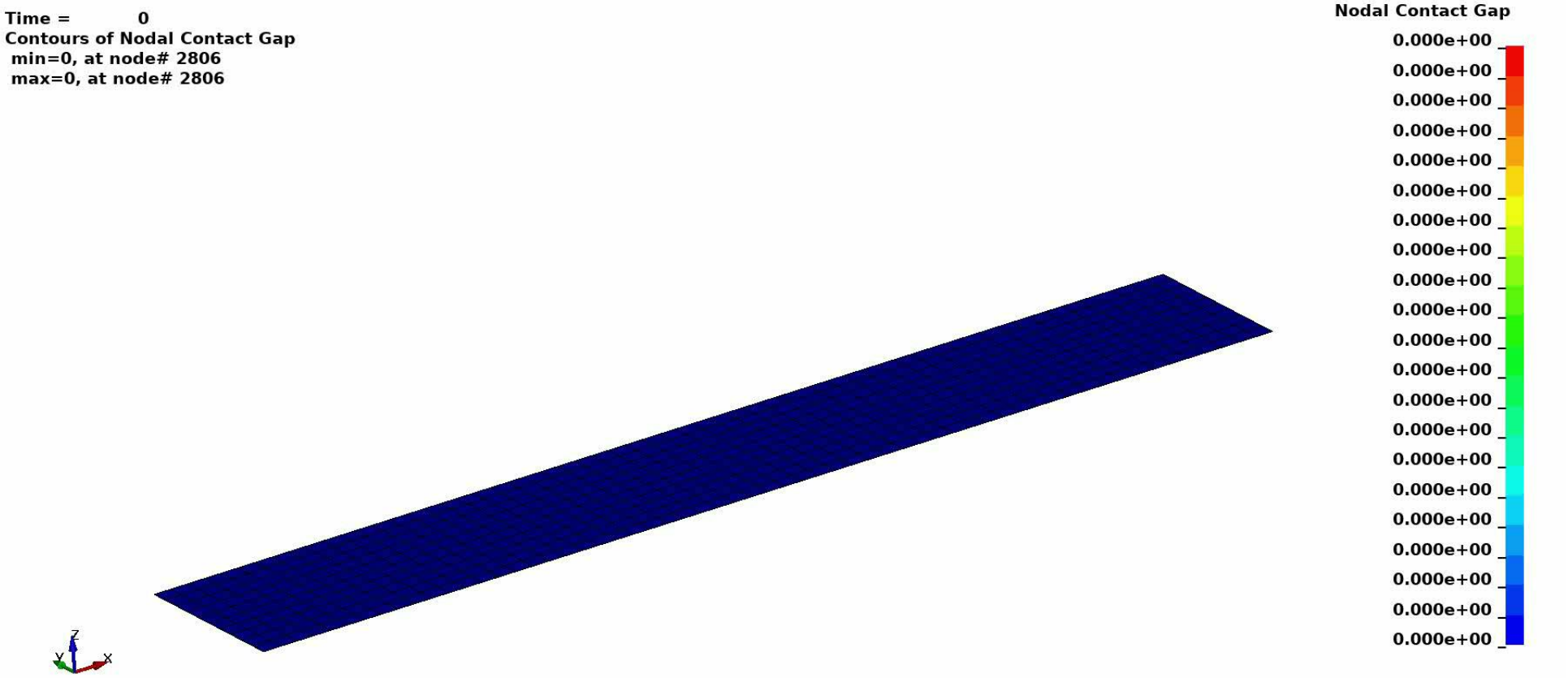
Interfaces bonding through
MAT_COHESIVE_MIXED_MODE (elform 19), or
CONTACT_AUTOMATIC_..._TIEBREAK (option 9).

Example: CONTACT_AUTOMATIC_..._TIEBREAK, OPTION 9

MAT_COHESIVE_MIXED_MODE

CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK (option 9)

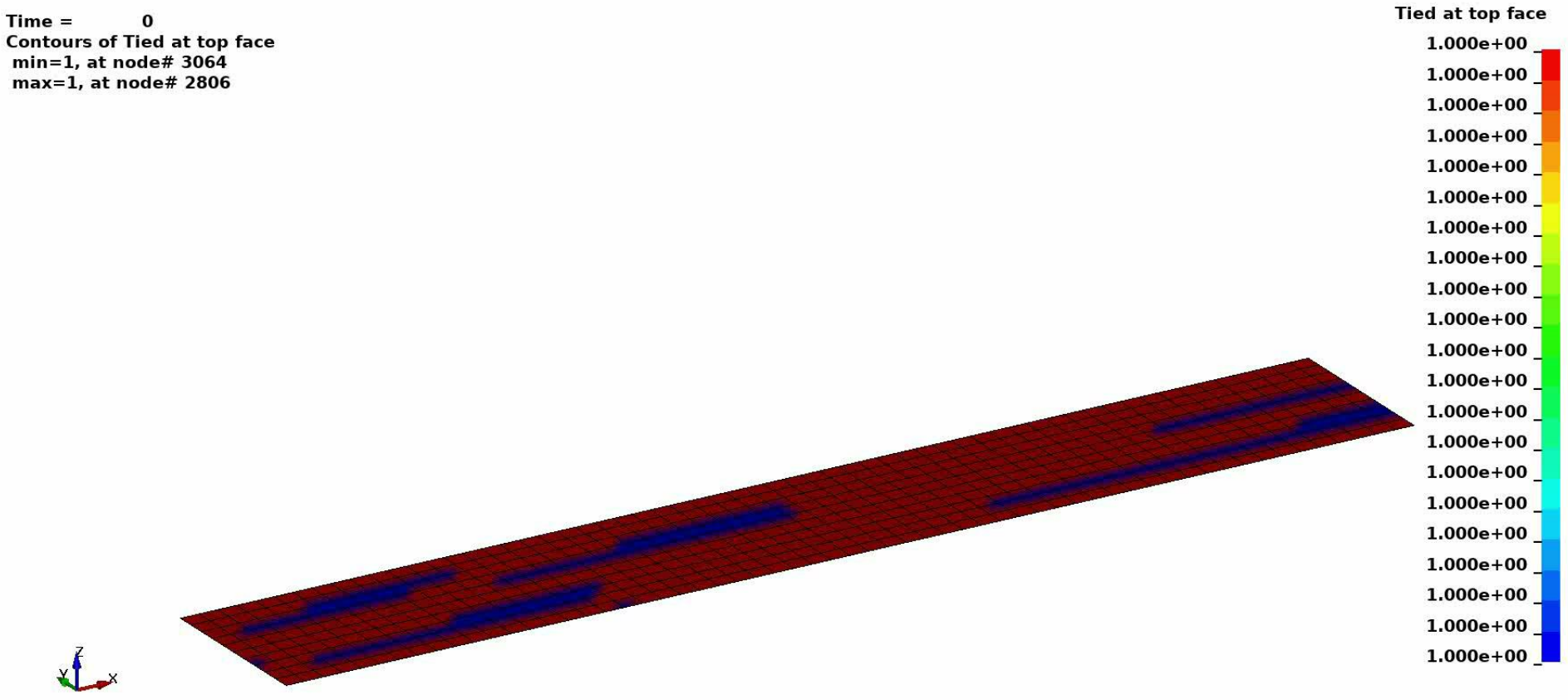
Example: CONTACT_AUTOMATIC_..._TIEBREAK, OPTION 9



Intfor file ”Contact Gap”
1 -> Released, full damage

CONTACT_AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK (option 9)

Example: CONTACT_AUTOMATIC_..._TIEBREAK, OPTION 9



Intfor file ”Tied at top face”
0 -> Released, zero strength

CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK_MORTAR (option 9)

Short summary

- Penalty based contacts will work with rigid bodies. TIEDID = 1 may be beneficial, note though that it will turn on the GROUPABLE option. If stability issues arise, a decrease of penalty factors might be needed.

- Constraint-based contacts will not work with rigid bodies. IPBACK ≠ 0 can be used to create a backup penalty-based contact for rigid nodes that can not tie. In general, less stability issues compared to penalty-based contacts.

- Use reasonable and realistic offsets distances in offset contacts. Preferrable as small as possible.

- Tied contacts:
  a. For solids to solids: TIED_NODES_TO_SURFACE_(OPTION4) or TIED_SURFACE_TO_SURFACE_(OPTION4)
  b. For shells to shells or beams to shells: TIED_SHELL_EDGE_TO_SURFACE_(OPTION4)
  c. For shell edges to solids or beam ends to solids: TIED_SHELL_EDGE_TO_SOLID_(OPTION)

- For old style tiebreak contacts (non-automatic) the nodes should be positioned on (or near) the surface.

- Automatic tiebreak contacts offer many possibilities to control the functionality and is generally preferred. Thickness offsets are considered after failure

- For tiebreak contacts it is recommended to use segment sets rather than parts/part sets.

Thank you!

DYNA MORE

Your LS-DYNA distributor and more