LSDYNA Seat Belt Modeling Guideline

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1. *ELEMENT_SEATBELT
   - 1D is recommended. 2D seatbelt element is used only when needed to model these seatbelt segments which are or potentially might be in contact with dummy. An example is the seatbelt around the slipring connecting shoulder belt and shoulder belt, Fig. 1. When using 2D seatbelt element, turn off the compression for these elements around slipring and retractor by setting COMP in *MAT_SEATBELT, the 6th column, to 0, Fig. 2. The rest of seatbelt, especially these central parts in direct contact with dummy, should carry compression, with COMP=1, so that they will not be badly squeezed.
   - Limit the variation of initial length of belt elements.

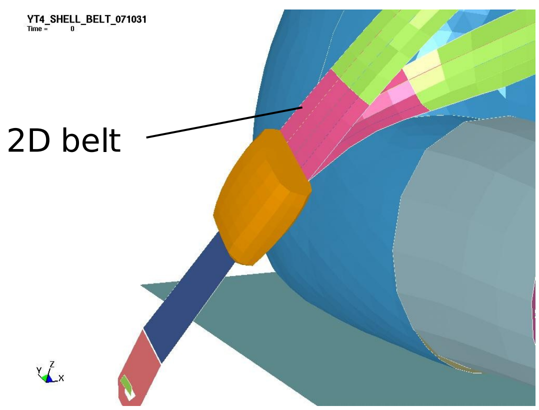


Fig. 1

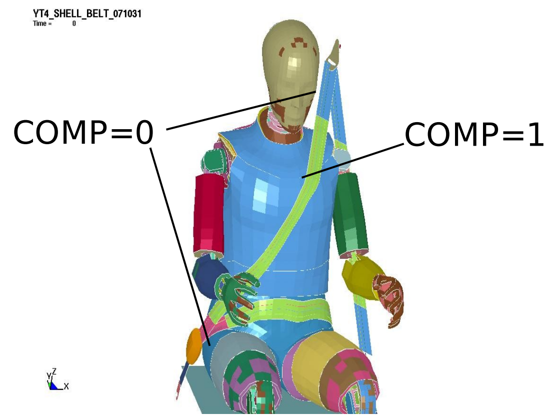


Fig. 2

2. Some remarks on 2D belt
   - As mentioned in (1), this 2D belt is not developed to replace 1D belt. The advantage of 2D belt over 1D lies in the better contact with neighboring parts or dummies. However, 1D has still has the upper hand on robustness and stability.
   - A part representing a 2D belt should have a *MAT_SEATBELT and *SECTION_SHELL.
   - The *MAT_SEATBELT is same as that for 1D, except the new input of COMP for 2D belt. As mentioned in the previous section, COMP=1 turns on the compression in the shell element and therefore avoids the possibility of badly squeezed elements. COMP=0 will increase the robustness and is recommended in the area around retractors and sliprings.
   - *SECTION_SHELL for 2D belt needs the definition of the edge-node set, 8th column of the 2nd card. The edge-node set contains the nodes on one of the edge of a belt, Fig. 3. If there exists a retractor, it can be the set of nodes coincident with retractor's SBRNID. If a belt consists of more than one part, only the section of one of the parts has to be given

the edge-node set. The space for edge-node-set of the sections of other parts should contain the negative value of the section carrying the edge-node set. Taking the following part definition as an example, which actually represents the model in Fig. 3, section-2111120 of the green part carry the edge-node set, 2003292, and section 2111121 of the blue and pink parts has “-2111120” in the space for edge-node set. This tells lsdyna that all parts of section 2111121, the blue and pink parts, are actually in the same belt system.

```
*PART
Green Part
    20036  2111120    20036        0        0        0        0        0
*PART
Blue Part
    20037  2111121    20037        0        0        1        0        0
*PART
Pink Part
    20038  2111121    20037        0        0        1        0        0
*SECTION_SHELL_TITLE
Section for the green part
 2111120            9       0.0        3      0.0      0.0        0
$                                                              edge_node
        1.2         1.2       1.2      1.2      0.0      0.0        0  2003292
*SECTION_SHELL_TITLE
Section for the blue and pink part
 2111121            9       0.0        3      0.0       0.0        0
$                                                              edge_node
        1.2        1.2        1.2      1.2      0.0        0        0 -2111120
*MAT_SEATBELT_TITLE
MAT_SEATBELT w. Compression for green part
$                                                         COMP
    20036 5.9700E-08    849003    849013      1.5        1
*MAT_SEATBELT_TITLE
MAT_SEATBELT w/o Compression for blue and pink parts
    20037 5.9700E-08    849003    849013      1.5        0
```

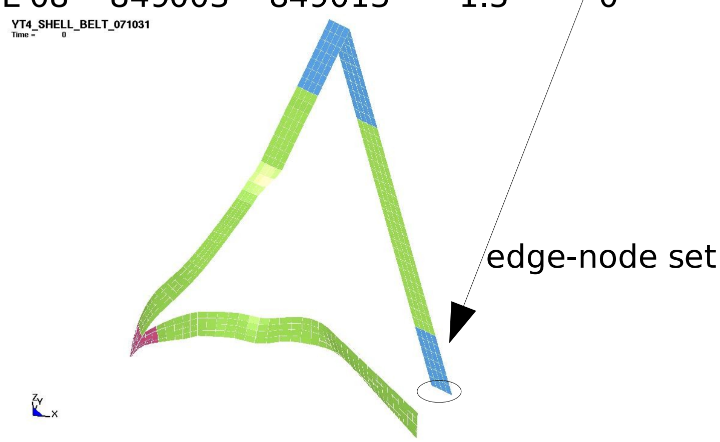


Fig. 3

- To define a 2D belt retractor, SBRNID, the 2nd column of the 1st card, has to be the negative value of the node set containing the set of retractor nodes. The nodes in both edge-set node and -SBRNID has to be input in the same sequence, Fig. 4. Also, SBID now contains set of 2D belt elements connected to “-SBRNID”.

```
*ELEMENT_SEATBELT_RETRACTOR
$#   SBRID    SBRNID       SBID        SID1      SID2      SID3      SID4
  2000001 -2000001   2000100   2000001         0         0         0
$#    tdel      pull        LC       ULC      lfed
       0         0   2002000   2002001        20
*SET_SHELL_LIST
  2000100
  2003037   2003074   2003111   2003148
*SET_NODE_LIST
  2000001
  2013292   2013293   2013291   2013294   2013295
*SET_NODE_LIST
  2003292
  2003292   2003293   2003291   2003294   2003295
```

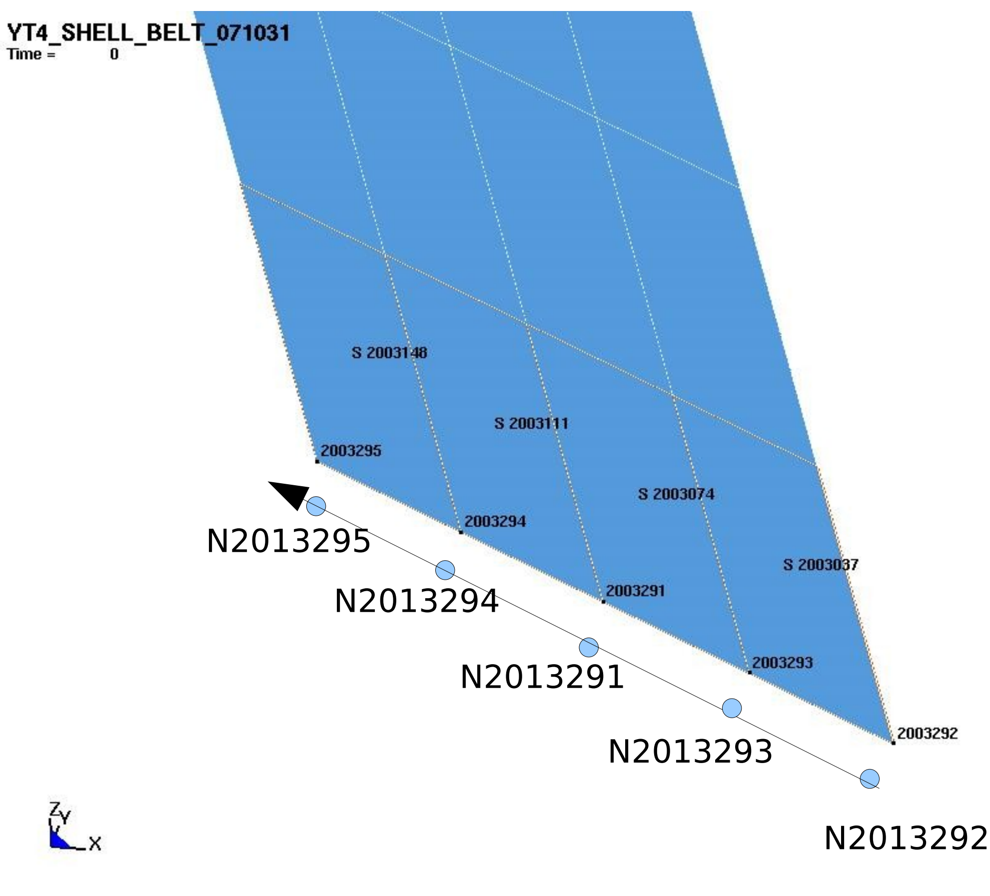


Fig. 4 Edge-node set and retractor node set, -SBRNID

- 2D belt elements are defined by *ELEMENT_SEATBELT with column 8 and column 9 containing N3 and N4. 2D belt elements have to be as uniform, in both shape and size, as possible.
- Slipring for 2D belt can be defined through a negative SBSNID, the 5th column of the 1st card. "-SBSNID" is the set of slipring node. Again, it has to be input in the same sequence as "_SBRNID" and "edge-node set".

3. *ELEMENT_SEATBELT_RETRACTOR
   - Some retractor spoolout curves, if derived directly from test result, might involve abrupt slope change. Even LSDYNA is able to handle most "realistic" retractor curve. However, such quick slope change, especially the change between positive and negative, could possibly cause instability. Approximating test curves by a series of straight line, Fig. 5, can get around such abrupt change and increase analysis stability.
   - A too large "minimum tension", the y-coordinate of the 1st point in LLCID, might cause unexpected pull-in in the early stage of analysis.
   - LFED is a parameter used by DYNA to determine when to pullout an absorbed element. The average belt element length, mostly 10mm~20mm, should be a good fit for LFED.
   - LMIN in *MAT_SEATBELT can be set to be about 10% of LFED, or the average seatbelt element length.
   - The newly added "S1way", the 8th column of the 1st card of *ELEMENT_SEATBELT_RETRACTOR, enables users to turn off pull-in once SEATBELT_SENSOR S1way is on, since then only pull-out is allowed.
   - The unloading curve, ULCID, has to be input. A curve containing two points, (0,0) and (10mm, 1000KN) seems to work fine.

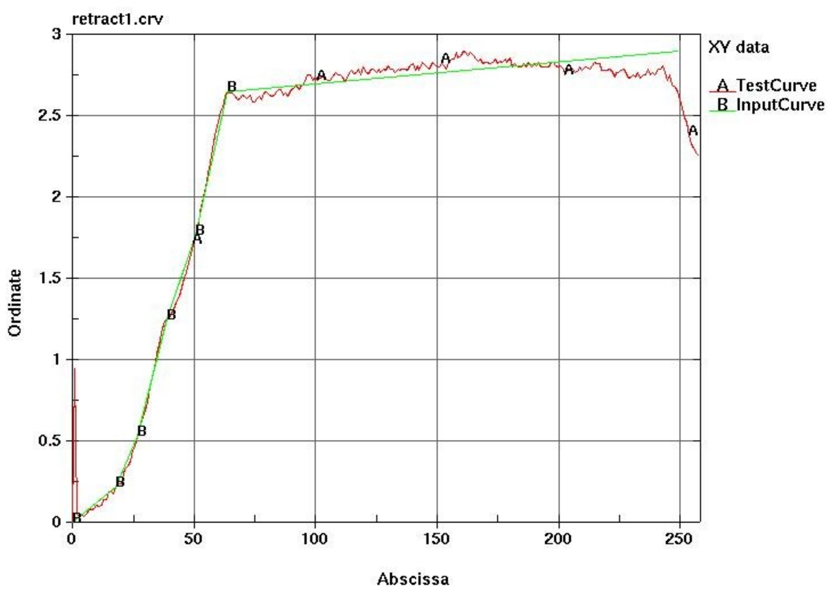


Fig. 5 Approximating a test curve by a series of straight line

4. *ELEMENT_SEATBELT_PRETENSIONER
   - TYPE 5 is recommended when the pretensioning effect is modeled as a

pull-in-time curve. TYPE 5 draws the seatbelt into retractor exactly as specified by PTLCID, if the retractor force is always smaller than the force limit, LMTFRC. A too small LMTFRC will generate a premature switch of the control from pretensioner to retractor and therefore the pretensioning effect specified in PTLCID will be ignored after the switch is initiated. "0" is recommended for LMTFRC, i.e., the force limit is ignored so that the pretensioning effect, which is mostly from test result, will be 100% reflected in the simulation. When running into stability, instead of giving a non-zero LMTFRC or scaling down the displacement values in PTLCID, scaling up the time values in LMTFRC is recommended.

- For TYPE5, retractor will be automatically locked and take over the control from pretensioner once the simulation time is larger than the max time in PTLCID.
- TYPE 7 is recommended when the pretensioning effect is modeled as a force-time curve. PTLCID for TYPE7 has to end with a force value of "0". For example, a curve containing the following three points (0,0), (10,50), (20,0) represents a pretension starting with (0,0), peaking at time=10 with a peak force of 50, and then cedes to 0 when time=20.
- TYPE1 will balance the pretension load with belt load, therefore the pretension effect specified in PTLCID will be compromised. It is more stable, however, it is not recommended since PTLCID, mostly from test result, is expected be 100% reflected in the simulation. Also, to activate the TYPE1 pretensioning effect, its corresponding retractor has to be fired no later than pretensioner.

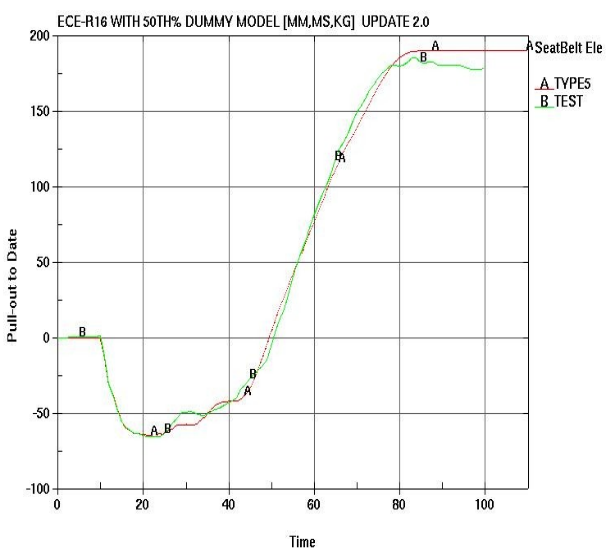
An example of TYPE5 pretensioner

```
$ a retractor with TYPE5 pretensioner
$ pretensioner effects ranges from 0 to 23 msec, then retractor is locked.
$ pullin will be turned off after 23 msec, when pretension cedes.
*ELEMENT_SEATBELT_RETRACTOR
$#   sbrid    sbrnid      sbid      sid1      sid2      sid3      sid4     s1way
    99001   5002165  10024916         2                                         6
$#    tdel      pull     llcid     ulcid      lfed
    0.000     0.000      5002      2007    20.000
*ELEMENT_SEATBELT_PRETENSIONER
$#  sbprid    sbprty    sbsid1    sbsid2    sbsid3    sbsid4
    99001         5         3
$#   sbrid      time    ptlcid    lmtfrc
    99001     0.000      2005
*ELEMENT_SEATBELT_SENSOR
$#   sbsid    sbstyp               sbsfl
         2         3
$#    time
       23.
$#   sbsid    sbstyp               sbsfl
         3         3
$#    time
```

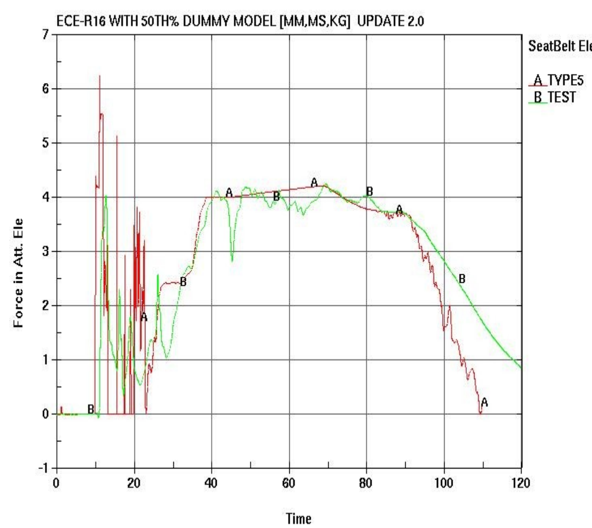
```
          0.
$#   sbsid    sbstyp           sbsfl
           6         3
$#     time
        23.0
*DEFINE_CURVE
$pull-in vs time
$#     lcid       sidr       sfa       sfo       offa       offo    dattyp
     2005          0   1.000 1.0000
                 0.0                0.0
                10.0                0.0
                11.0               12.0
                12.0               30.0
                13.0               37.0
                14.0               46.0
                15.0               55.0
                16.0               59.0
                23.0               61.0
               18.0               63.0
               19.0               63.0
               23.0               65.0
*DEFINE_CURVE
$#     lcid       sidr       sfa       sfo       offa       offo    dattyp
     5002          0  1.0000  1.000
                0.0                0.0
                5.0               2.33
               15.0               2.70
               23.0               4.00
              200.0               4.22
```

Correlation result of a retractor w. TYPE5 pretensioner

Retractor pay-out



Retractor load



An example of TYPE7 pretensioner

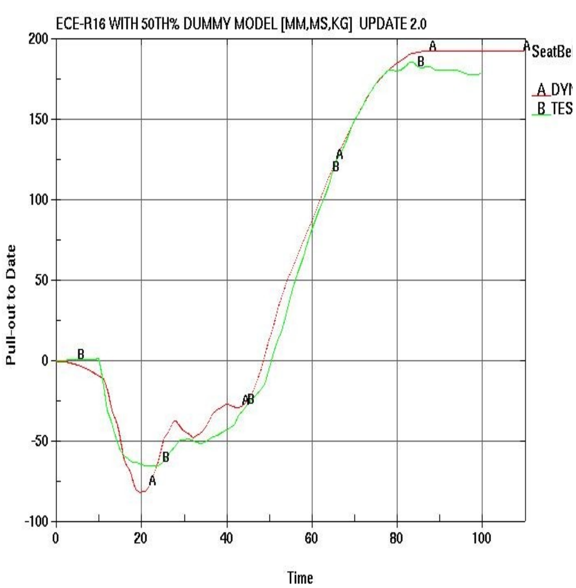
```
$ represents the above preteneioner as a TYPE7

*ELEMENT_SEATBELT_RETRACTOR
$#   sbrid    sbrnid     sbid      sid1      sid2      sid3      sid4    s1way
    99001   5002165  10024916            2                                  6
$#    tdel        pull      llcid      ulcid      lfed
    0.000        0.10      5002      2007  20.000
*ELEMENT_SEATBELT_PRETENSIONER
$#  sbprid    sbprty    sbsid1    sbsid2    sbsid3    sbsid4
    99001           7           3
$#   sbrid      time     ptlcid    lmtfrc
    99001     0.000    2006

*DEFINE_CURVE
$$$$$  pyro       time               Force
$#    lcid      sidr       sfa       sfo      offa      offo    dattyp
     2006         0  1.000        1.0
$#             a1                 o1
                0              0.00
           11.05              0.03
           11.80              3.34
           12.20              3.37
           12.70              4.01
           13.80              1.35
           15.50              0.82
           16.75              1.25
            23.00              0.00 <- has to end with  "0" or a very small value
```

Correlation result of a retractor w. TYPE7 pretensioner

Retractor pay-out



Retractor load