Applying Bolt Pre-Loads in LS-DYNA

The Arup Campus, Blythe Gate, Blythe Valley Park, Solihull, West Midlands, B90 8AE

tel: +44 (0) 121 213 3399

email: dyna.support@arup.com

January 2019

Bolt Pre-Load Methods

There are a number of ways of applying a pre-load to a bolt in LS-DYNA; the following methods are covered in these notes:

Bolts modelled using solid elements:

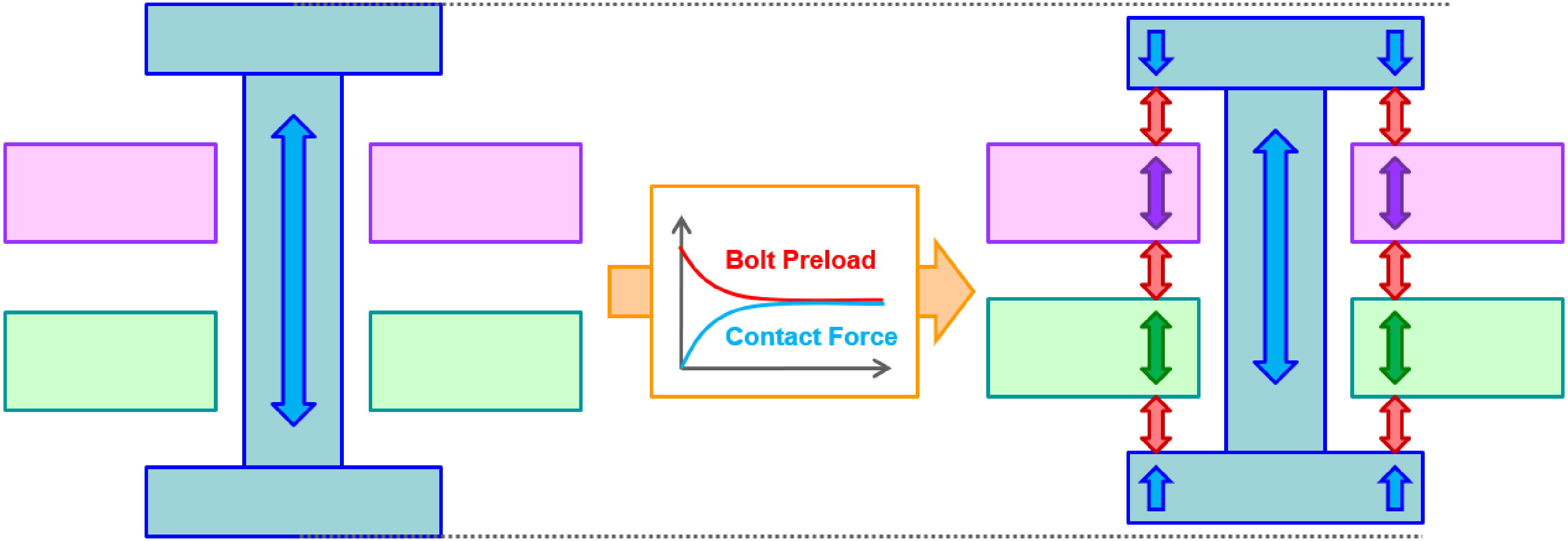
- *INITIAL_STRESS_SECTION method
- Nut translation method

Bolts modelled using beam elements:

- *INITIAL_AXIAL_FORCE_BEAM method (LS971 R4)

Problem with using standard *INITIAL_STRESS

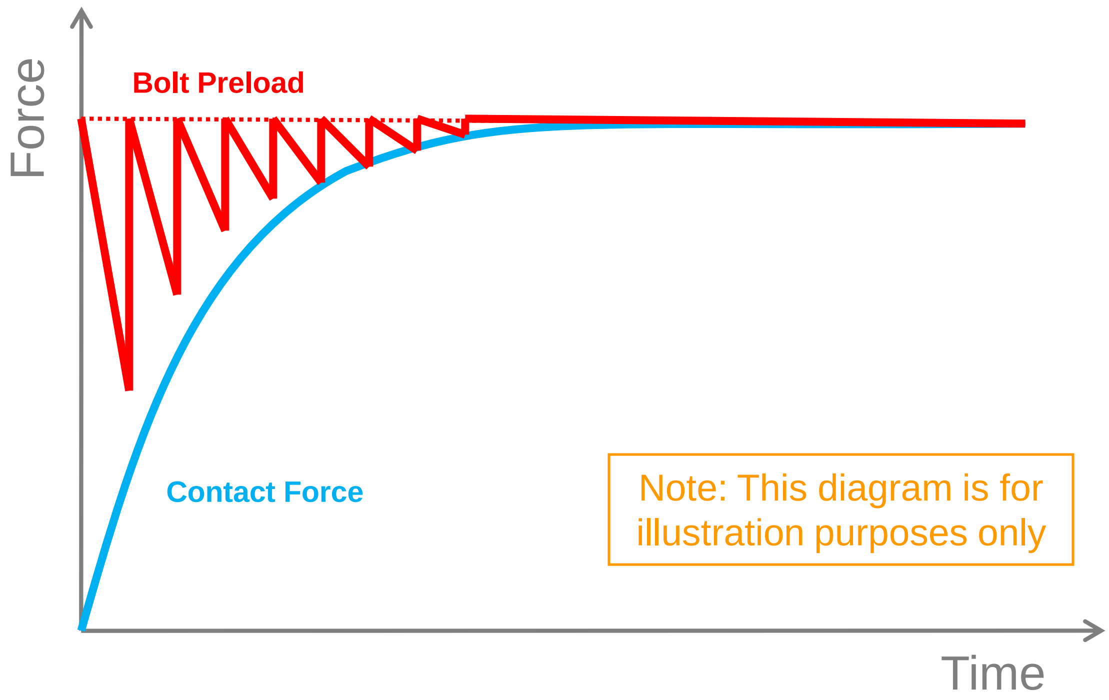
If the standard *INITIAL_STRESS_SOLID/BEAM is used to generate the preload in a bolt then some of the load in the bolt will be lost during the start of the analysis as the contact force and stresses in the plates increase to balance out the clamping load in the bolt.



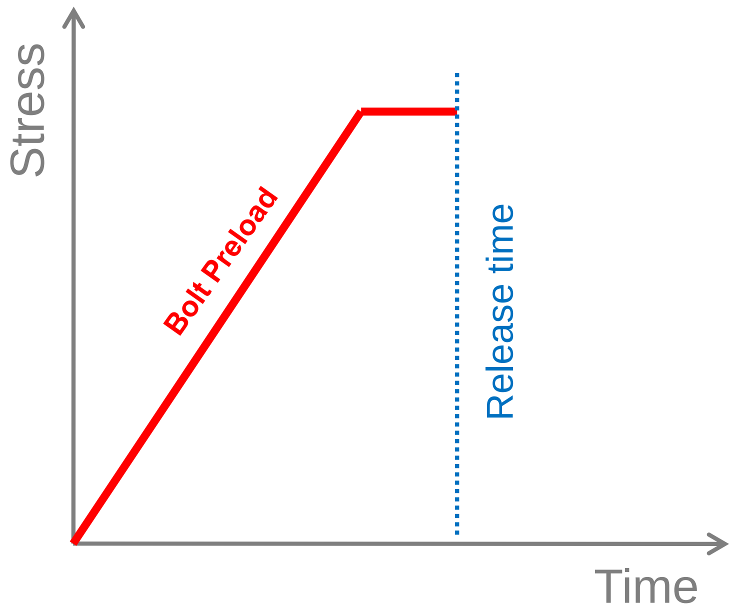
Initial state with the forces out of balance
(time = 0)

After the pre-load, contact force and stress in the plates has equalized
(After a few timesteps)

In this method the stress to be applied to the bolt elements is defined using a load curve (stress vs time). During the analysis at the start of each timestep, the stress in the solid elements is reset to this value, and when the load curve ends, the stress in the elements stops being reset. This allows the stress in the bolt to be held at a set value until the pre-load, contact force and stress in the plates have all equalized.



Typically, the stress is ramped up from zero then held constant for a short period time at the start of analysis.



The stress required for a given pre-load can be calculated using;

Stress = Force / Bolt Area

Note: The bolt cross sectional area is not the area of the real bolt but the area of the elements representing the bolt.

The slower the load can be applied the more accurate the final preload at release will be and the less noise will be generated.

Solid Elements - *INITIAL_STRESS_SECTION

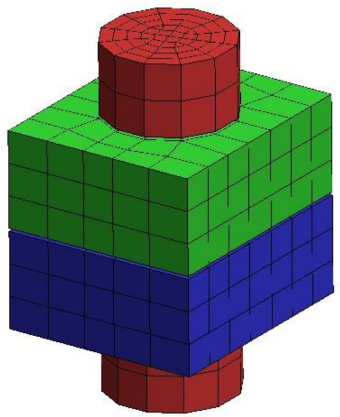
The *INITIAL_STRESS_SECTION card references the:

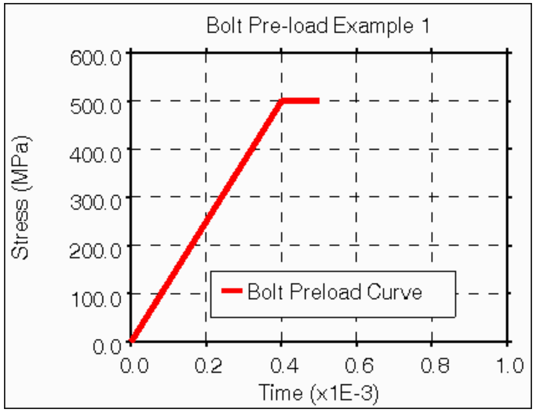
- *DATABASE_CROSS_SECTION – that cuts through the elements to be loaded
- *DEFINE_CURVE – used to define the pre-load
- *SET_PART – used to define the parts to apply the pre-load to

```
*INITIAL_STRESS_SECTION
         1         1         1         1         0
```

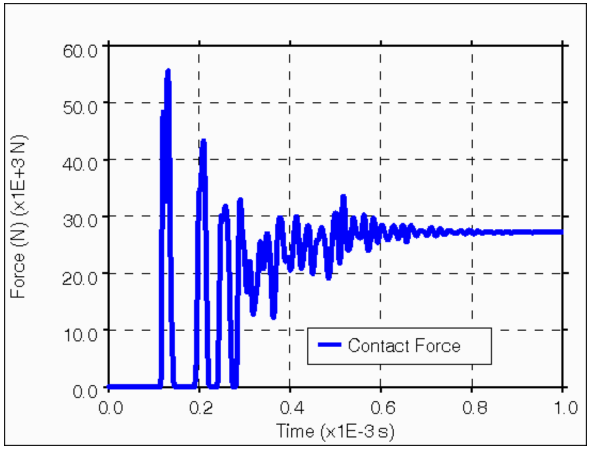
Example 01 - *INITIAL_STRESS_SECTION

In this example, a pre-loaded bolt is used to clamp two plates together using *INITIAL_STRESS_SECTION. The preload ramps up from zero to 500MPa and is released at 0.5msec.

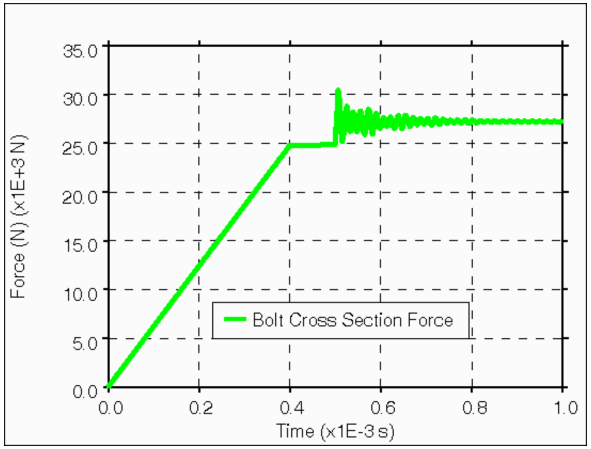




Resulting Contact Force between the plates

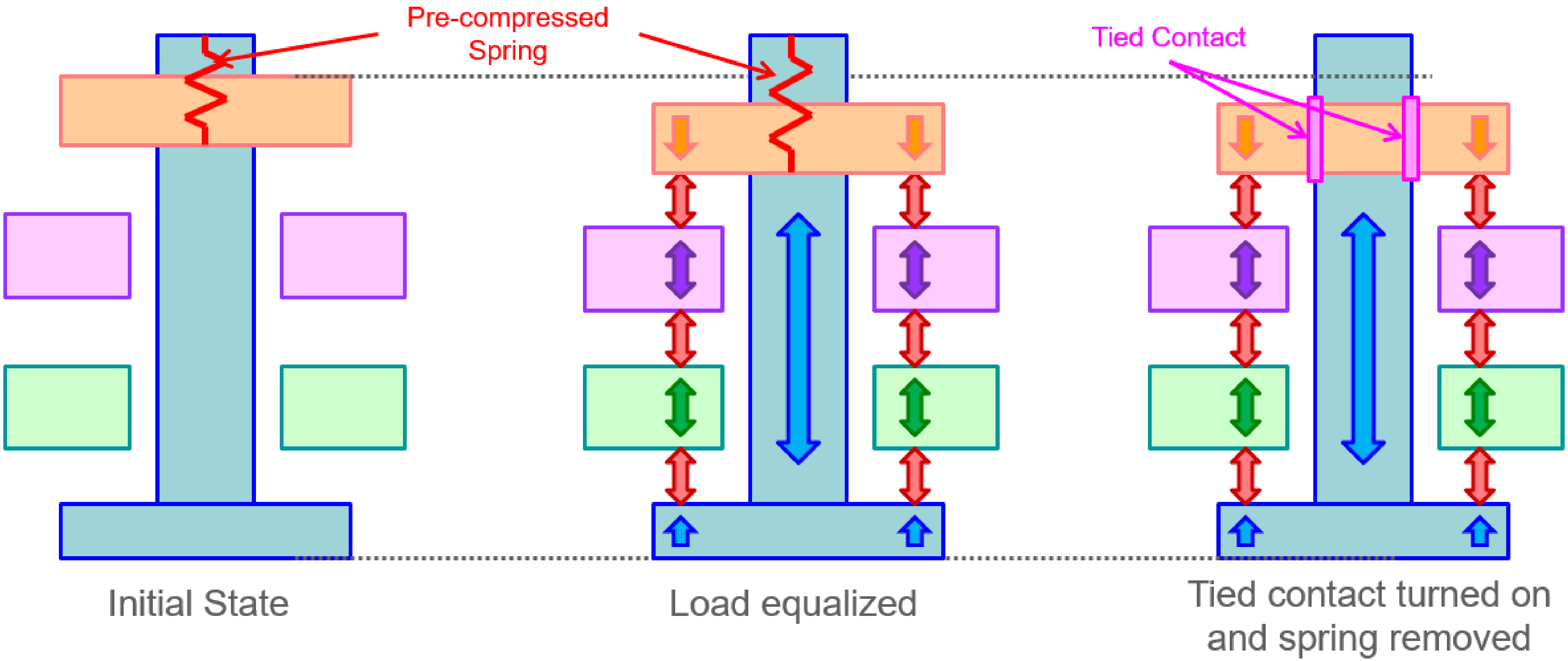


Resulting Cross-sectional Force in the bolt



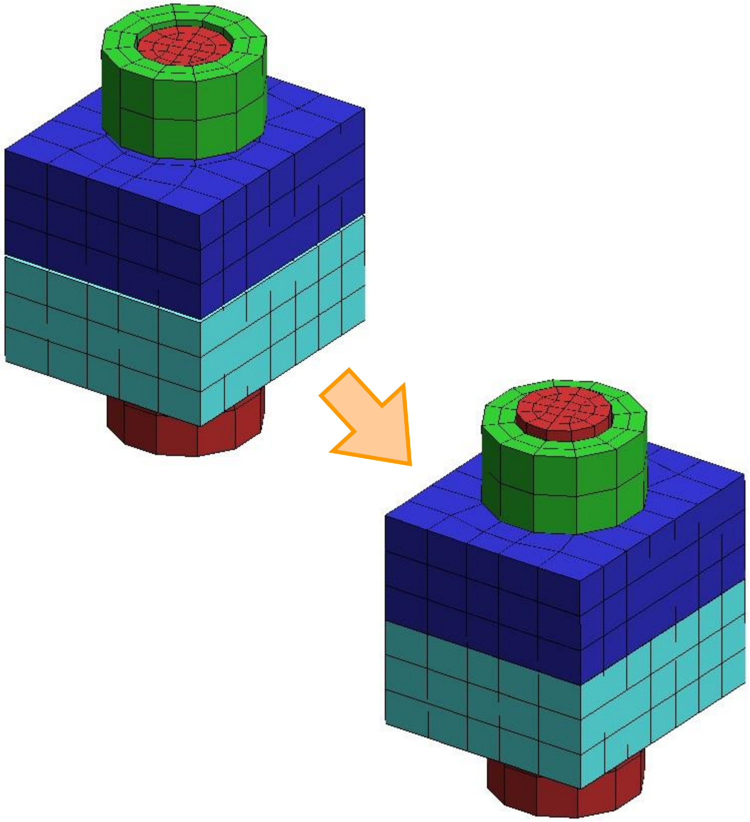
Nut Translation Method

In this method the nut and bolt are modelled separately and at the start of the analysis the plates are clamped together by moving the nut down the shaft of the bolt. The nut is moved using a pre-compressed spring connected between the bolt and the nut. Once the required load is achieved the nut and bolt are fixed together using a tied contact with a particular birth time and then the spring is removed.

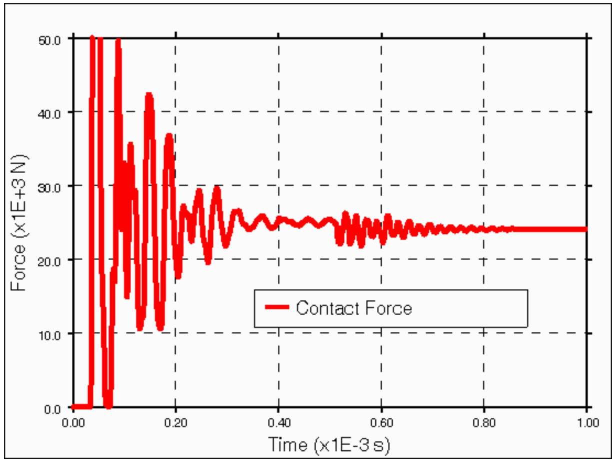


Example 02 - Nut Translation Method

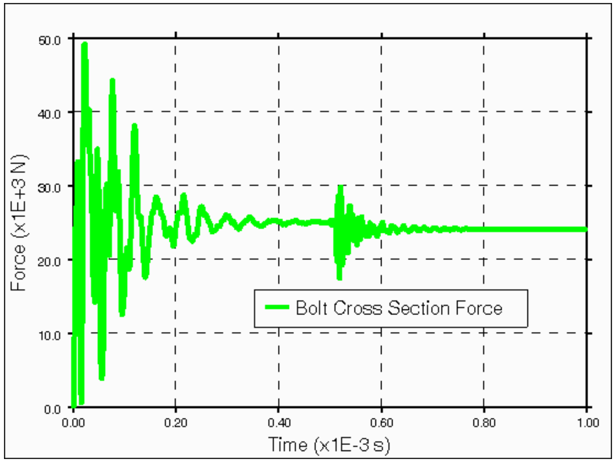
In this example, a pre-loaded bolt is used to clamp two plates together by moving the nut down the bolt shaft. The bolt and nut are locked together using a tied contact at 0.5msec.



Resulting Contact Force between the plates



Resulting Cross-sectional Force in the bolt



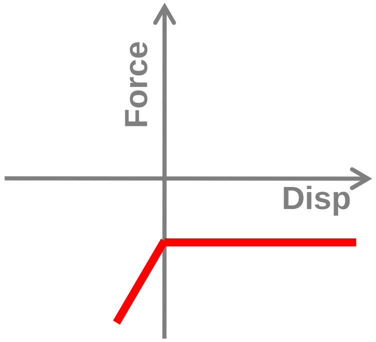
The pre-compressed spring is modelled as a discrete beam (Type 6) using *MAT_NONLINEAR_ELASTIC_DISCRETE _BEAM to reference a force vs displacement curve

```
*SECTION_BEAM
         6         6       0.0       0.0       0.0       2.0       0.0
      10.0       0.0         0       0.0       0.0       0.0       0.0       0.0
```

```
*MAT_NONLINEAR_ELASTIC_DISCRETE_BEAM_TITLE
Pre-load spring
         4   7.85E-9         1         0         0         0         0         0
         0         0         0         0         0         0
       0.0       0.0       0.0       0.0       0.0       0.0
```

The pre-compression in the spring is modelled by giving it a negative force at zero deflection.

```
*DEFINE_CURVE_TITLE
Spring Load
1         0       0.0       0.0       0.0       0.0         0
          -10.000000          -26000.000
                 0.0          -25000.000
           100.00000          -25000.000
```



Example 02 - Nut Translation Method

The nut and bolt are locked together using a Tied Contact with a Birth Time (0.5msec).

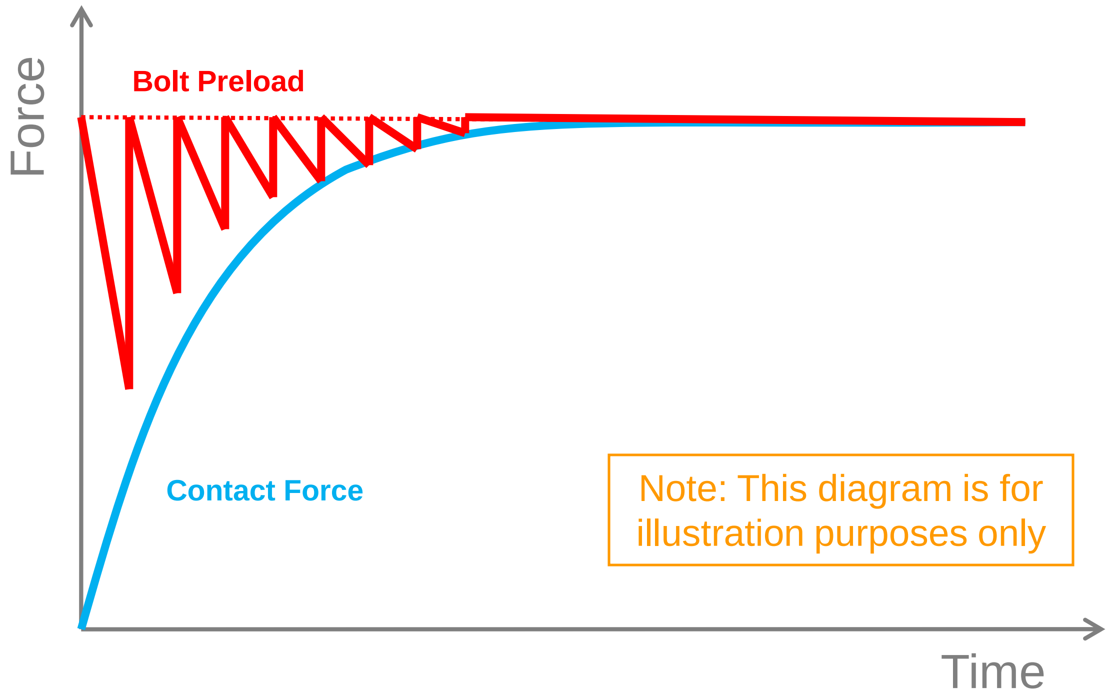
```
*CONTACT_TIED_SURFACE_TO_SURFACE_ID_OFFSET
         6Nut to Bolt Fixing
         2         1         3         3         0         0         1         1
       0.0       0.0       0.0       0.0       0.0         0    5.0E-4       0.0
       0.0       0.0       0.5       0.5       0.0       0.0       0.0        0.
```

The discrete beam (part 6) is removed at time = 0.51msec using the *LOAD_REMOVE_PART card (available for beams in 971 R4.2.1).

```
*LOAD_REMOVE_PART
         6    5.0E-4    5.1E-4         0
```

Beam Elements - *INITIAL_AXIAL_FORCE_BEAM

In this method, the pre-load to be applied to the bolt elements is defined using a load curve (axial load vs time). During the analysis, at the start of each timestep, the load in the beam elements is reset to this value, and when the load curve ends, the load in the elements stop being reset. This allows the load in the bolt to be held at a set value until the pre-load, contact force and stress in the plates have all equalized (similar to the *INITIAL_STRESS_SECTION card).



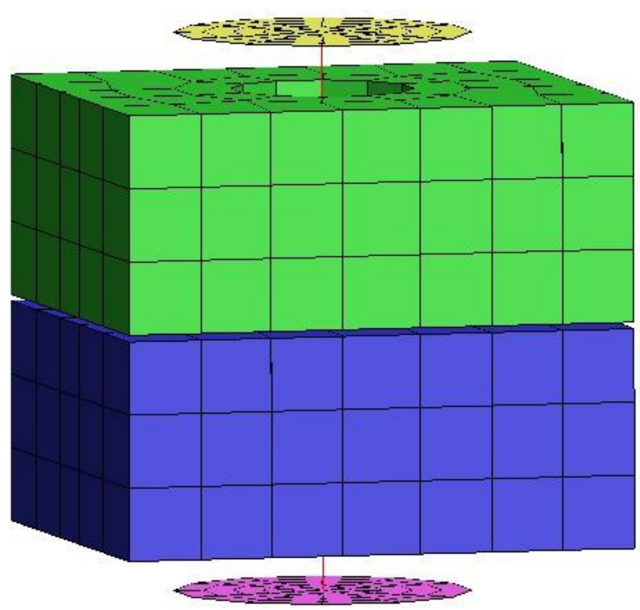
Solid Elements - *INITIAL_AXIAL_FORCE_BEAM

The *INITIAL_AXIAL_FORCE_BEAM card works with beam element using element type 9 (Spotweld) and *MAT_SPOTWELD (MAT_100). It references the;

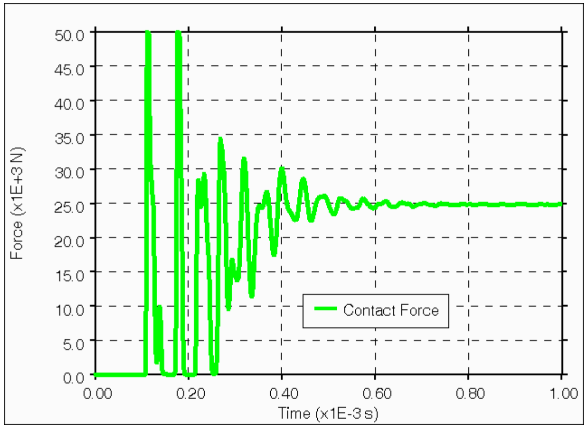
- *SET_BEAM – that contains the elements to be loaded
- *DEFINE_CURVE – used to define the pre-load

```
*INITIAL_AXIAL_FORCE_BEAM
         1         1
```

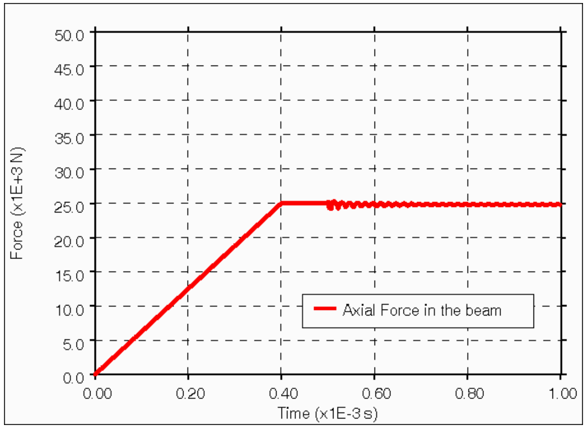
In this example, a pre-loaded bolt is used to clamp two plates together using *INITIAL_AXIAL_FORCE_BEAM. The preload ramps up from zero to 25kN and is released at 0.5msec. The heads of the bolt are modelled using rigid elements.



Resulting Contact Force between the plates

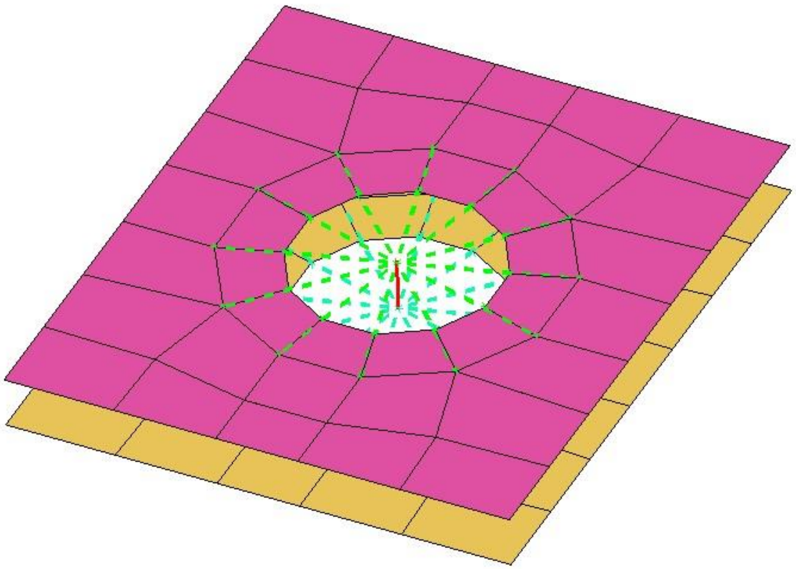


Resulting Axial Force in the bolt

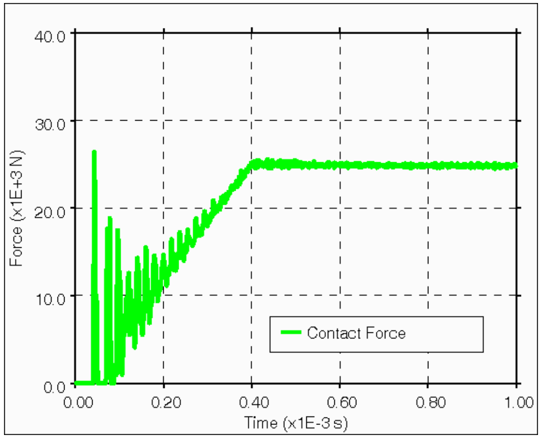


Example 04 - * INITIAL_AXIAL_FORCE_BEAM

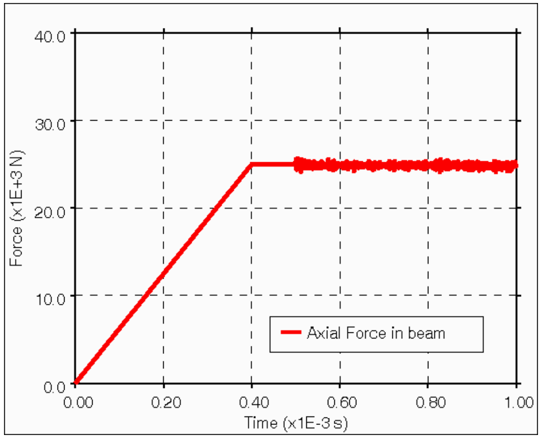
In this example, a pre-loaded bolt is used to clamp two shell element plates together using *INITIAL_AXIAL_FORCE_BEAM. The preload ramps up from zero to 25kN and is released at 0.5msec. The ends of the bolt are connected to the plates using *CONSTRAINED_NODAL_RIGID_BODIES.



Resulting Contact Force between the plates



Resulting Axial Force in the bolt



General Advice

- A small amount of clearance between the parts is recommended, however keeping this to a minimum will reduce the amount of noise.
- A few trial model may need to be run to find the optimum ramp up time for the pre-load (shorter runtime, more noise vs longer runtime, less noise).

ARUP

www.arup.com/dyna

For more information please contact the following:

UK:

Arup
The Arup Campus
Blythe Valley Park
Solihull, West Midlands
B90 8AE
UK
T +44 (0)121 213 3399
F +44 (0)121 213 3302
dyna.support@arup.com

China:

Arup
39/F-41/F Huai Hai Plaza
Huai Hai Road (M)
Shanghai
China 200031

T +86 21 6126 2875
F +86 21 6126 2882
china.support@arup.com

India:

Arup India Pvt Ltd
Plot No. 39, Ananth Info Park
Hi-Tec City Madhapur Phase 2
Hyderabad - 500081
India

T +91 (0) 40 44369797 / 8

india.support@arup.com