JAPAN
INTES

A study about solid rivet model considering shear resistance mechanism and pretension force

PERMAS Users' Conference
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Agenda

- Background
- Purpose
- Construction Procedure
- Shear Resisting System
- Simple Rivet Models
- Assembled Parts with Rivet
- Conclusion
- Future Works

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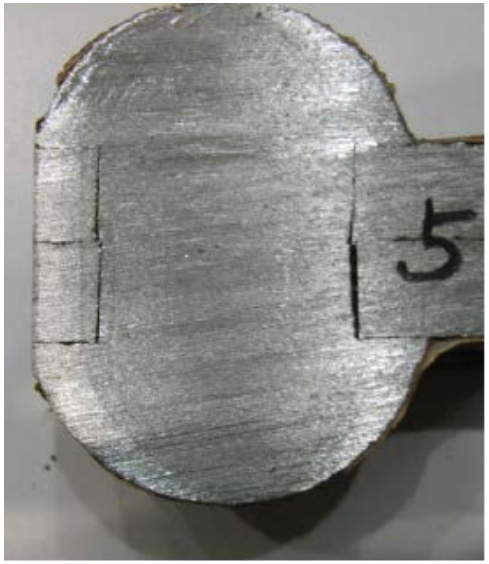
- Background -

Over 50 years ago in Japan, rivet connection was the most general connection method to assemble plural steel parts represented by steel bridge. Nowadays, it has been a serious problem about durability of steel structure owing to deterioration of materials (ex. corrosion).

To evaluate a structural efficiency for such an historical steel structure, it is essential to investigate into the structural behavior about assembled parts connected with rivet.

steel plate structure with rivet



cross section of steel rivet structure

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- Purpose -

In order to know the stress transmission mechanism of the assembled parts model connected by rivet, it is an effective study to compare the stress distribution with between bolt and rivet option. Especially , the most important point is that no shear contact definition in bolt option makes no chance to resist shear deformation.

The main purpose of this study is to suggest a possibility of new rivet connection model for large scale assembled parts model. There are several type of bolt tightening connection in PERMAS, it is a good study to evaluate **$PRETENSION** option for shear deformation, and estimate the usage limitation of these ones.

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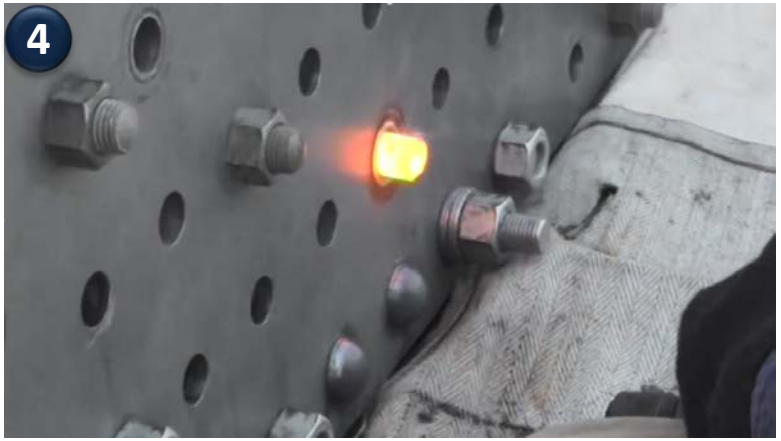
- Construction Procedure – 1 To 4

rotary cutting machine

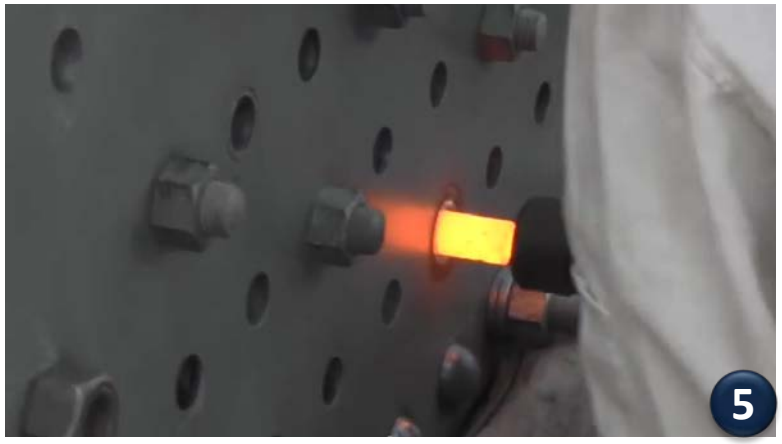
red riped rivet by 1200 deg.

rivet into hole by hammer

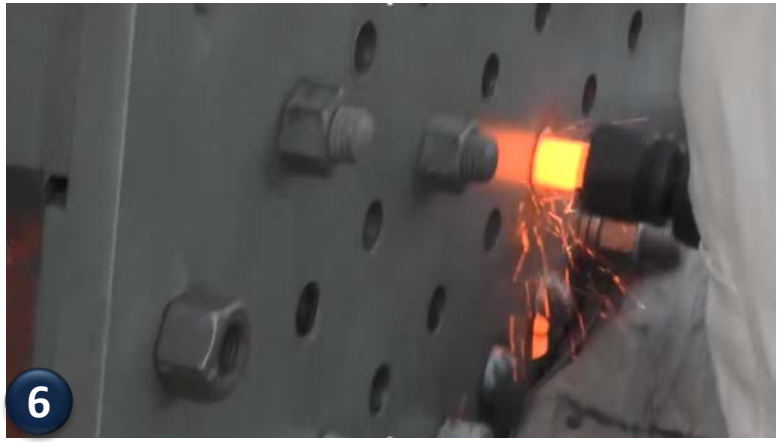


heated rivet head appeared

- Construction Procedure – 5 To 8



rivet hammer for caulking



intense single vibration

cool down during caulking

caulking almost finished

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- Shear Resisting System - Analysis Overview

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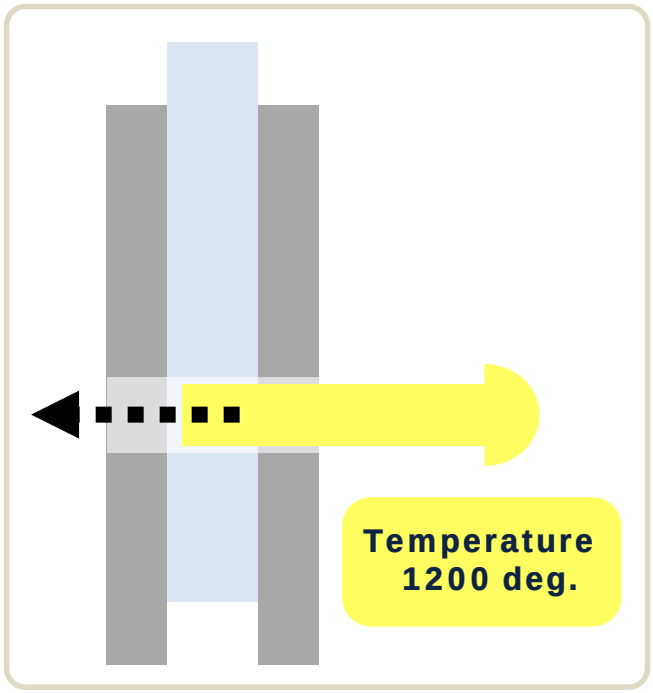
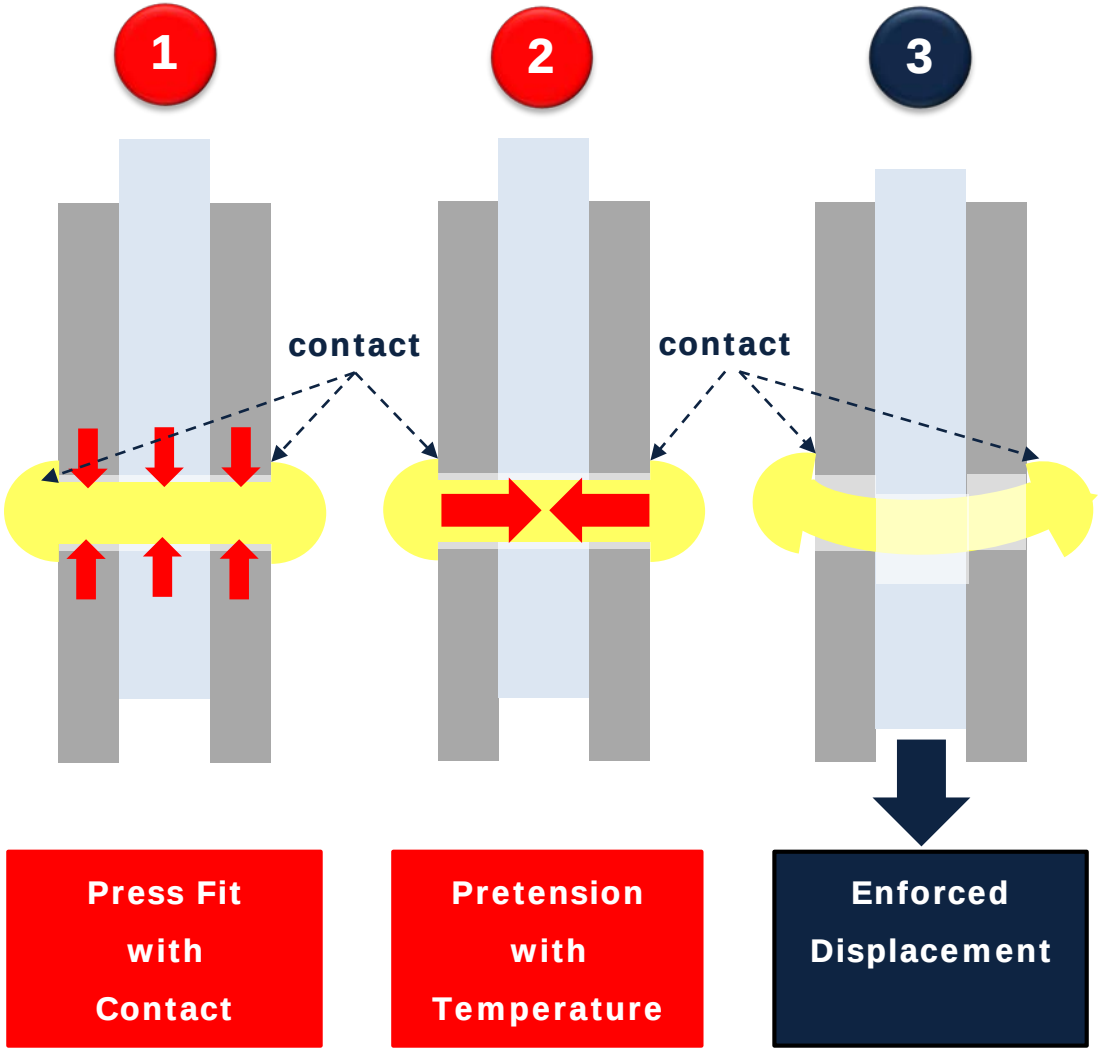
Double Shear Surfaces Model





- Shear Resisting System - Analysis Process (Thermal Strain Rivet Model)

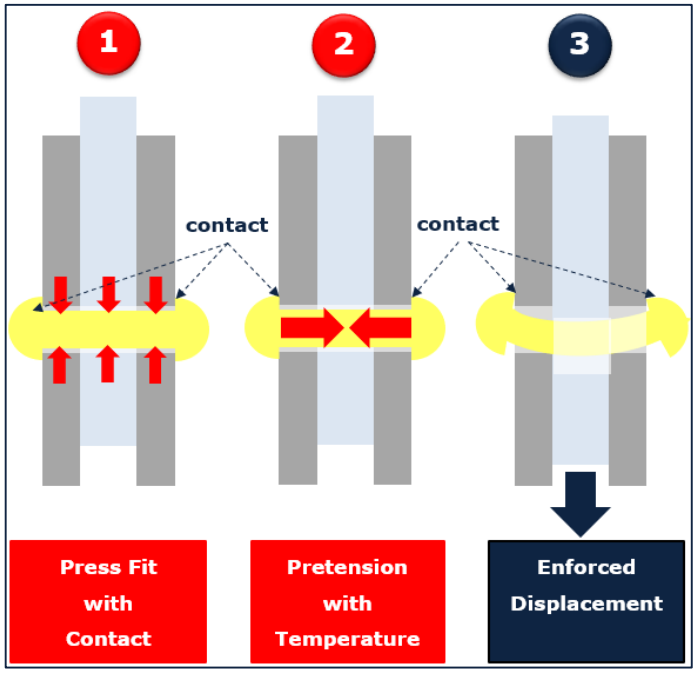
```
$LOADING  NAME = NLV
  $REFVAL TEMP              ! thermal strain reference
    PLATE_UPPER      0.0    ! plate no strain @    0.0
    PLATE_CENTER     0.0    ! plate no strain @    0.0
    PLATE_LOWER      0.0    ! plate no strain @    0.0
    RIVET         1200.0    ! revet no strain @ 1200.0
  $NLLOAD  TABLE  TIME = LIST
                  1.0  2.0  3.0
     LPAT = 100   0.0  1.0   -      ! CONTACT DETECTION / PRESSFIT
     LPAT = 201   1.0  0.0   -      ! THREMAL LOAD (START)
     LPAT = 202   0.0  1.0   -      ! THREMAL LOAD (END)
     LPAT = 300   0.0  0.0  1.0     ! ENFORCED DISP.
  $CONTACT LOAD  LPAT = 100  GAPWIDTH = ABS
     CNTS             -0.025
     PLATE_U           0.00
     PLATE_L           0.00
     PLATE_RIVET_U     0.00
     PLATE_RIVET_L     0.00
  $DISLOADN  TEMP  LPAT=201  DOFTYPE=DISP
    PLATES            0.0
    RIVETNODES     1200.0
  $DISLOADN  TEMP  LPAT=202  DOFTYPE=DISP
    PLATES            0.0
    RIVETNODES        0.0
  $PREVAL LPAT = 300
     MPC_G  2 : -2.5
$END LOADING
```

Press Fit with Contact 1

Pretension with Temperature 2

Enforced Displacement 3

```
$MATERIAL  NAME = RIVET  TYPE = ISO
  $ELASTIC   GENERAL  INPUT = TABLE   DEP = TEMP
     206000.0   0.3  :     0.0
     155000.0   0.3  :   800.0
      75000.0   0.3  :  1200.0
   $DENSITY   GENERAL  INPUT = DATA
     7.850000E-09
   $THERMEXP  GENERAL  INPUT = DATA
     1.10000E-05
$END MATERIAL
```



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Simple Rivet Models
4 Models

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A

$PRETENSION PLANE

B

$PRETENSION PLANE + CONTACT

C

$PRETENSION THREAD

D

THERMAL STRAIN

Simple Rivet Models
4 Models → 2 Models

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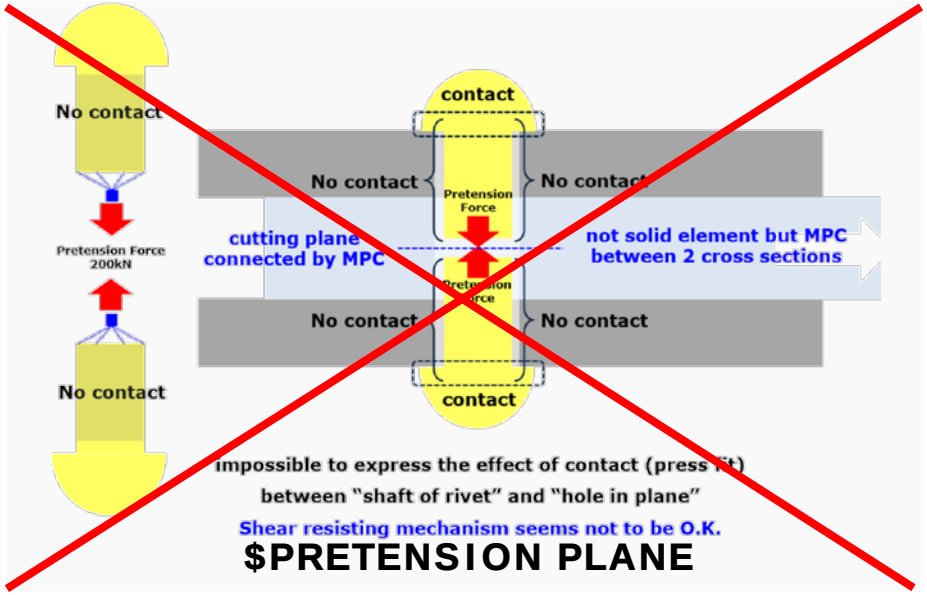
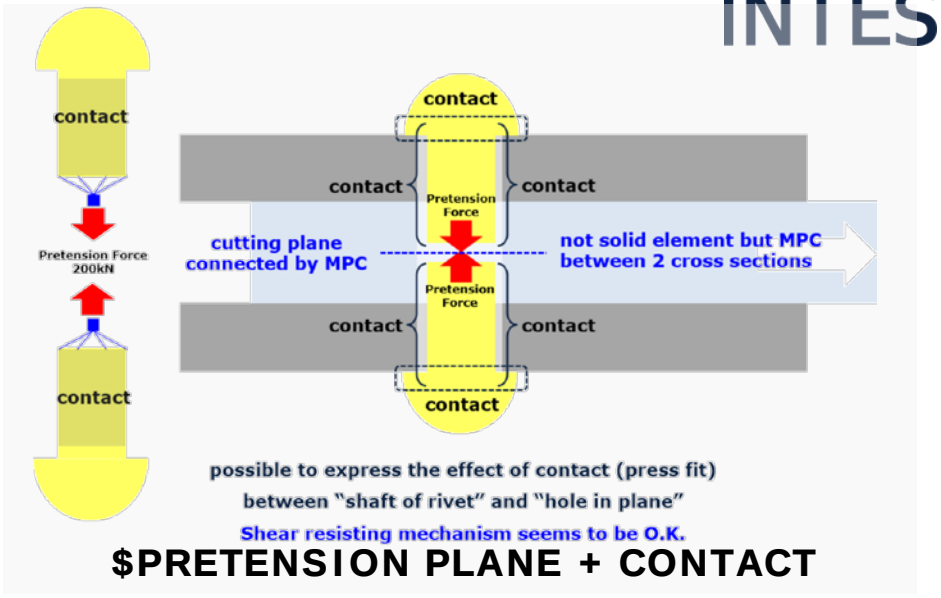
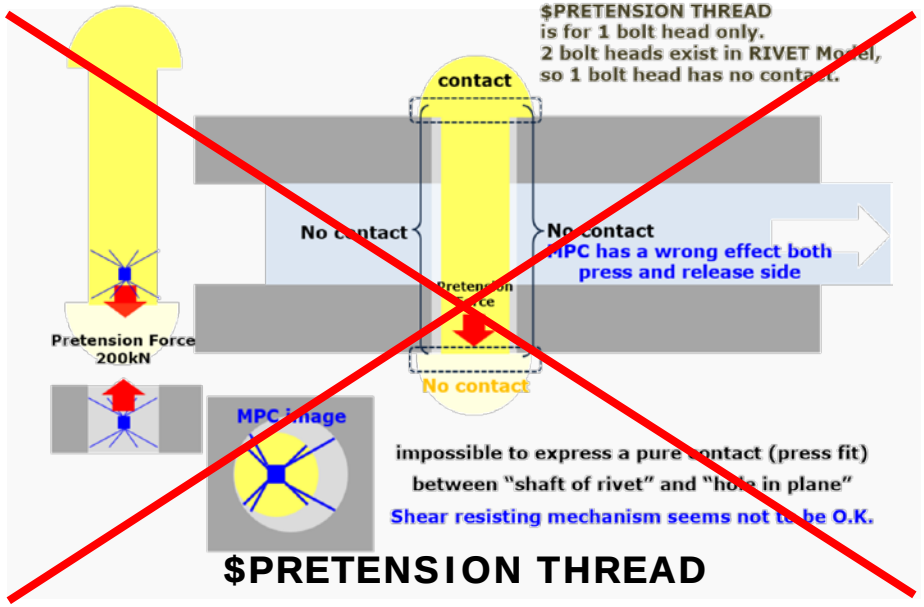


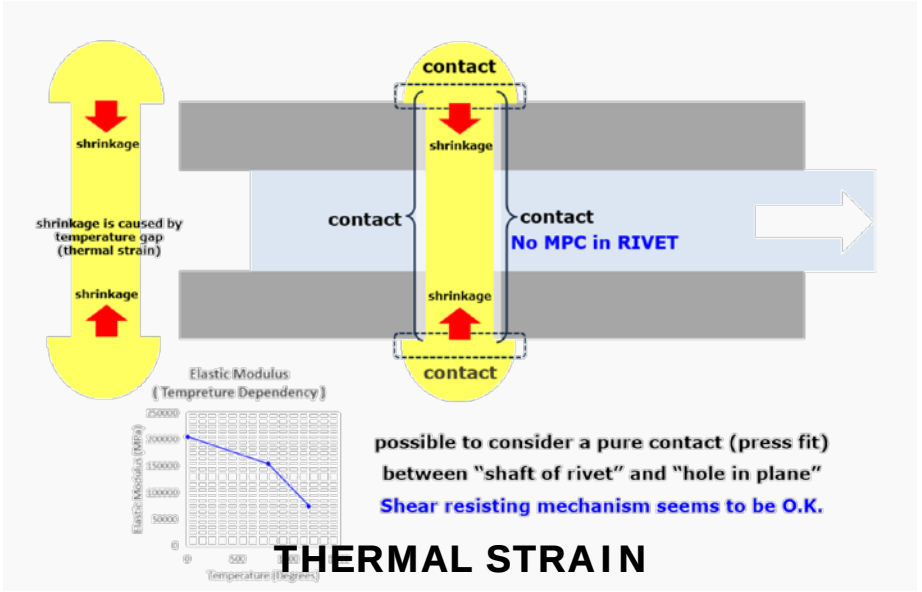
$PRETENSION PLANE



$PRETENSION PLANE + CONTACT

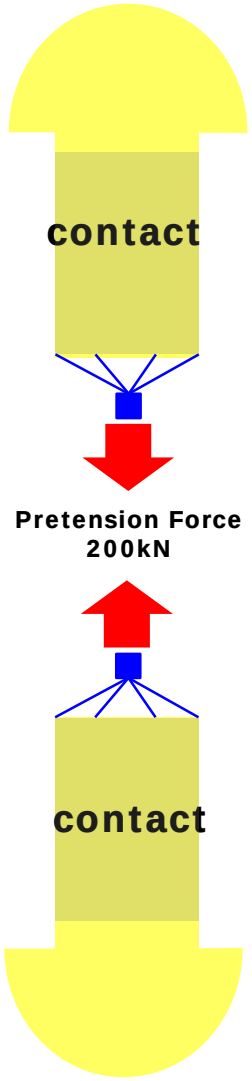


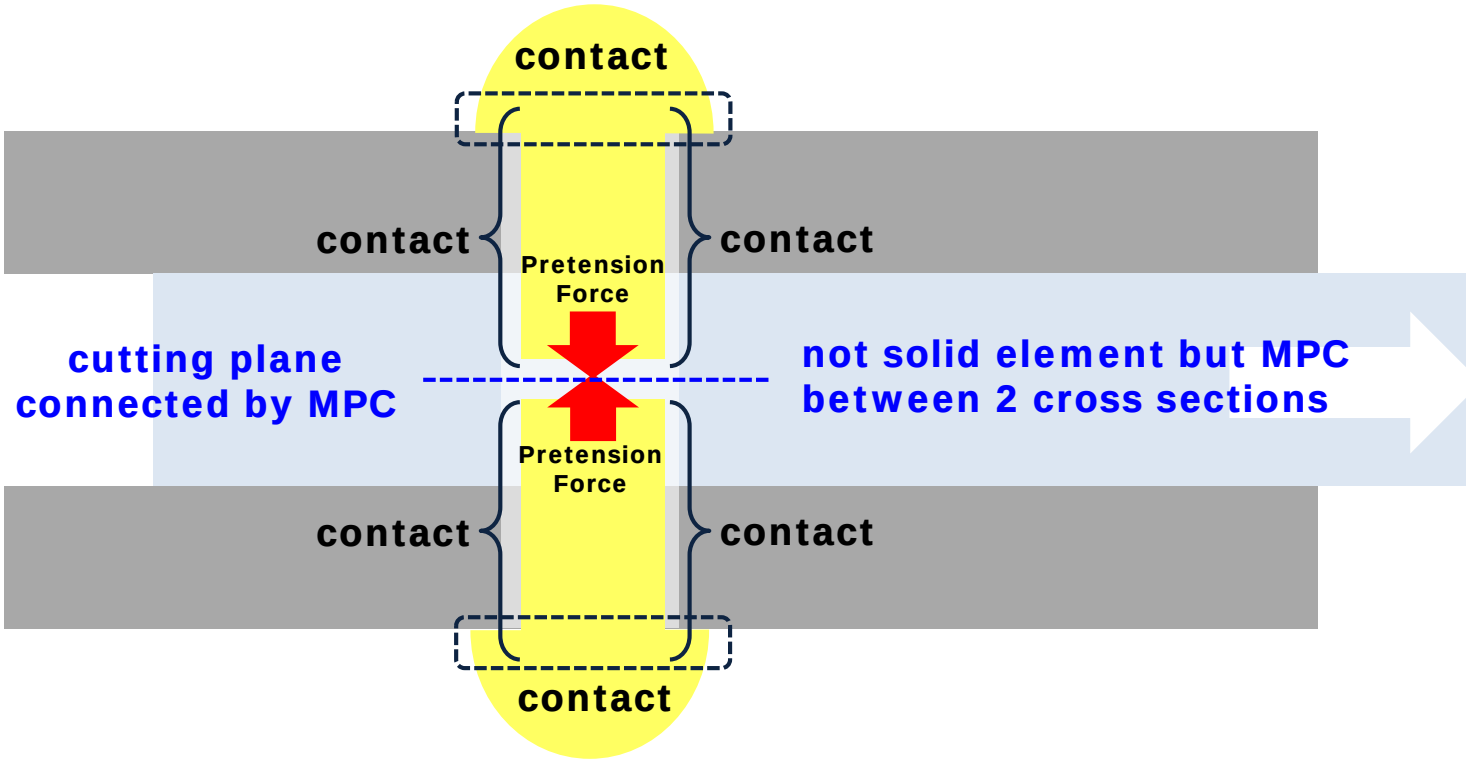
$PRETENSION THREAD



THERMAL STRAIN

Simple Rivet Models
B: $PRETENSION PLANE + CONTACT



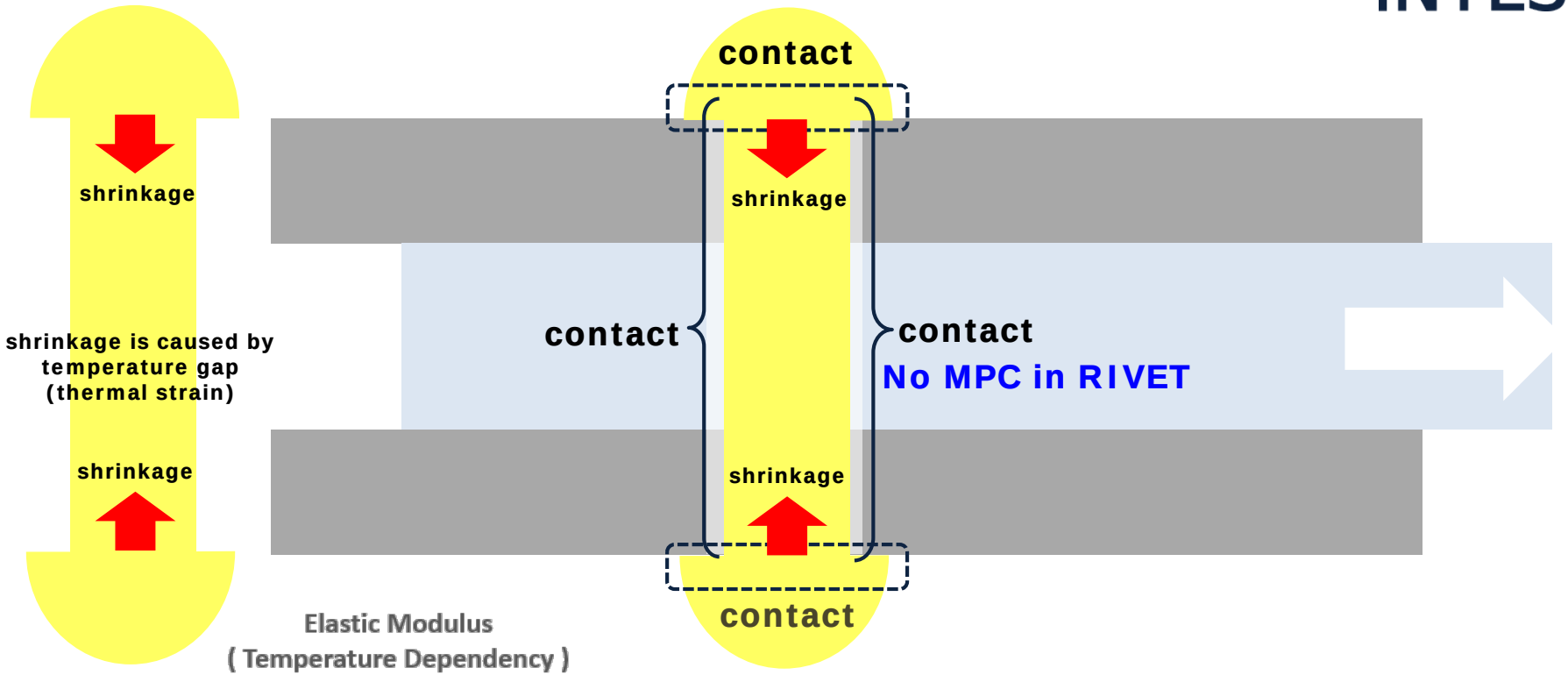


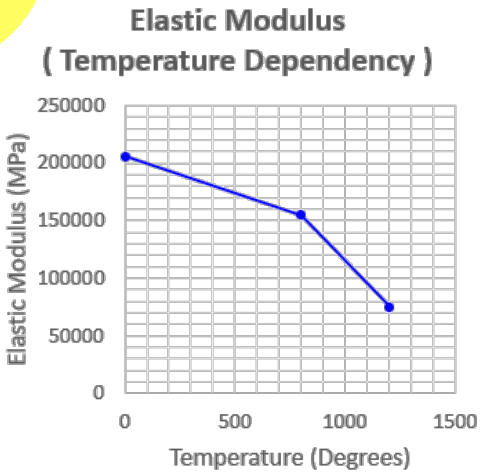
possible to express the effect of contact (press fit)

between “shaft of rivet” and “hole in plane”

Shear resisting mechanism seems to be O.K.

Simple Rivet Models
D: THERMAL STRAIN





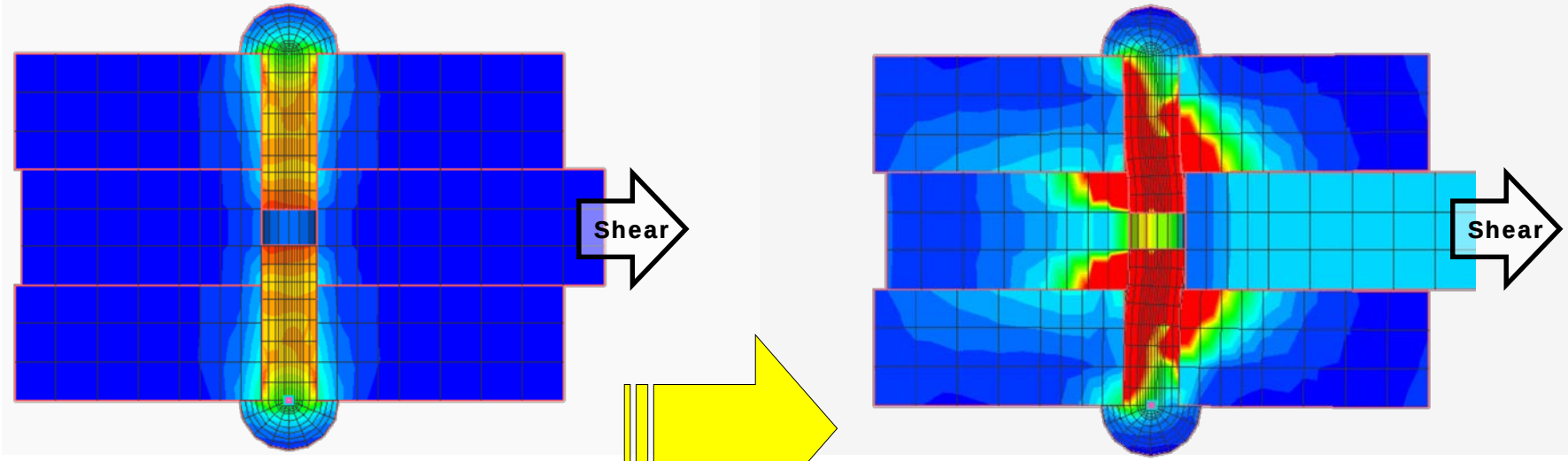
possible to consider a pure contact (press fit)

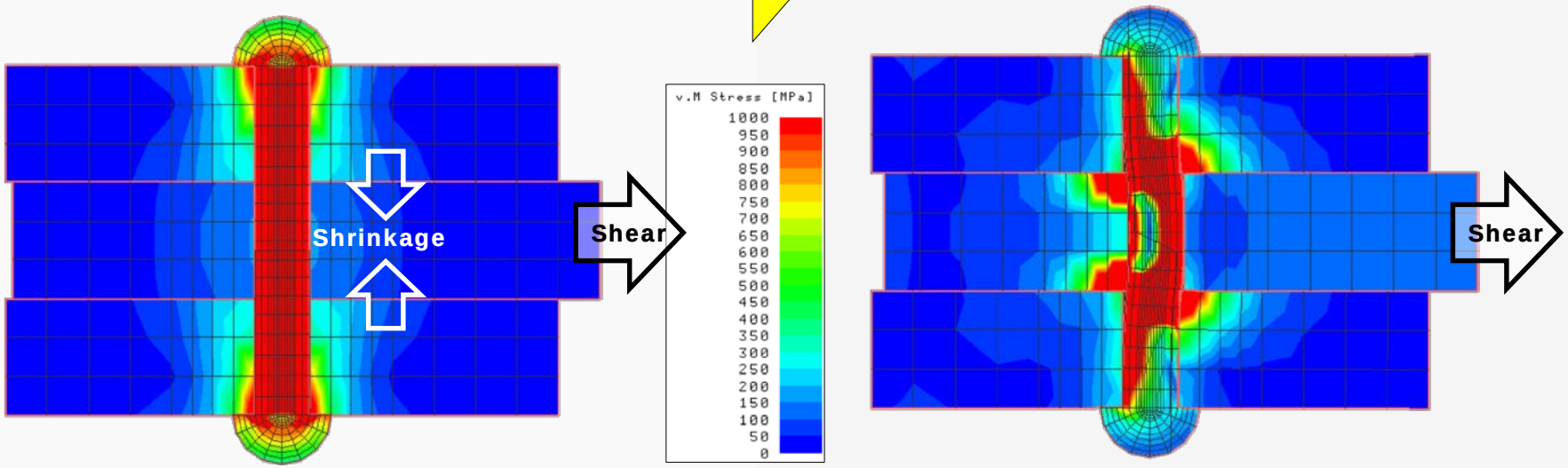
between “shaft of rivet” and “hole in plane”

Shear resisting mechanism seems to be O.K.

Simple Rivet Models
v.M. Stress Distribution (Bolt Tightening / Shear Deformation)

A: $PRETENSION PLANE + Press Fit (Bolt Tightening / Shear Deformation)



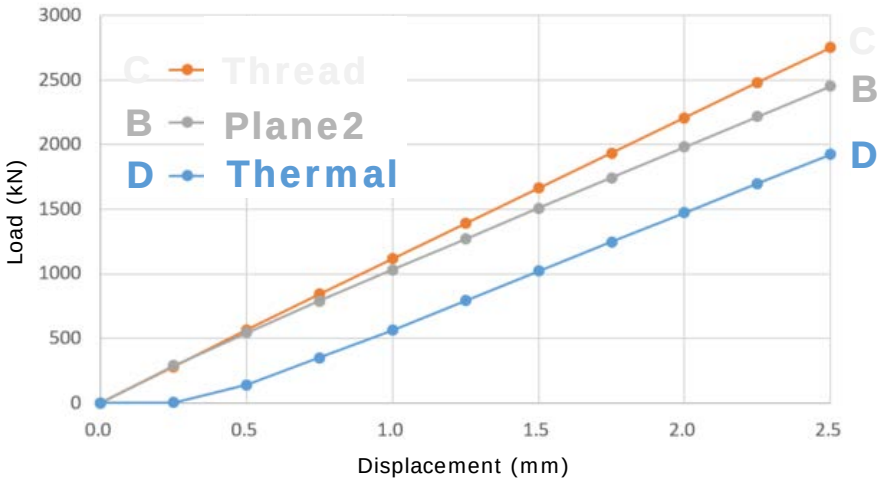


B: Thermal Strain + Press Fit (Bolt Tightening / Shear Deformation)

Simple Rivet Models
Load – Displacement Curve

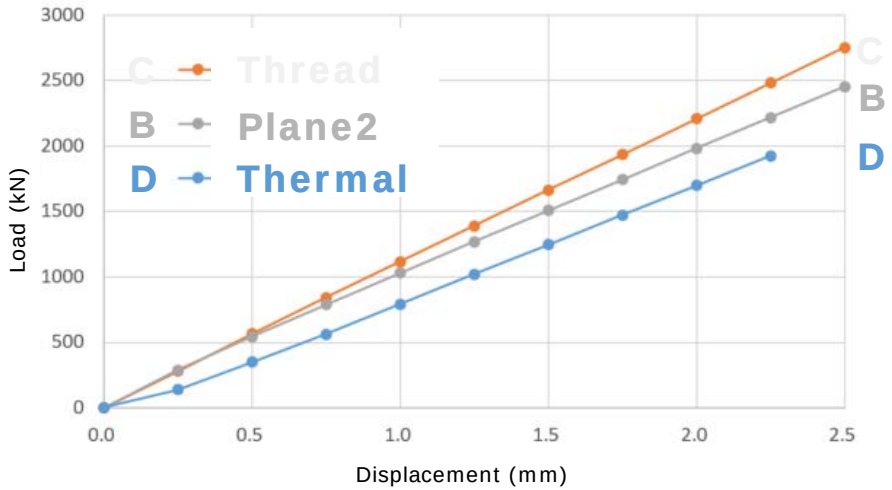
Thermal < Plane2 < Thread
D B C

Load - Displacement (original)



shift

Load - Displacement (arranged)



C “Thread” curve has the highest stiffness (load / disp.)
thread definition is not pure contact about shear deformation, but a kind of MPC

B “Plane2” curve shows gradually the less stiffness, the more disp. increases.
The separated pretension plane linked by MPC is stiffer than deformable body, but the number of contact definition decreases according to sliding process

D “Thermal” curve displays initial special low load zone during bolt pretension, shrinkage of shaft makes gaps between rivets and holes

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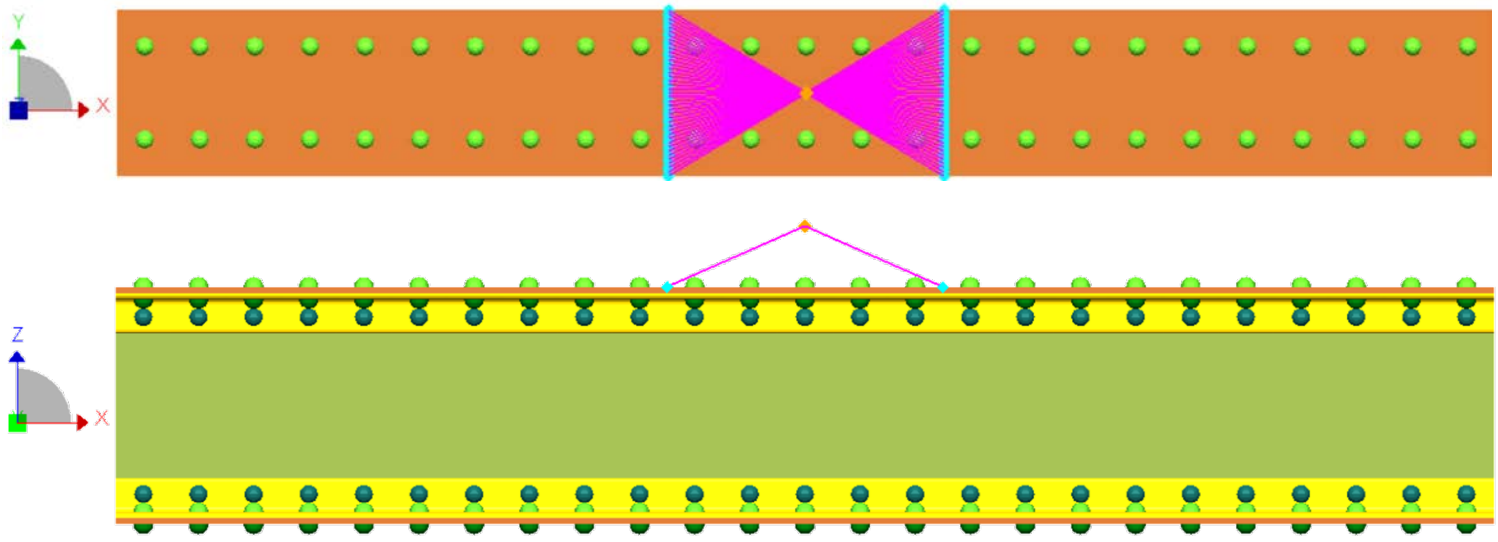
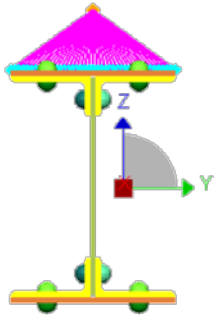
- Assembled Parts with Rivet -
Model Description (Thermal Strain)

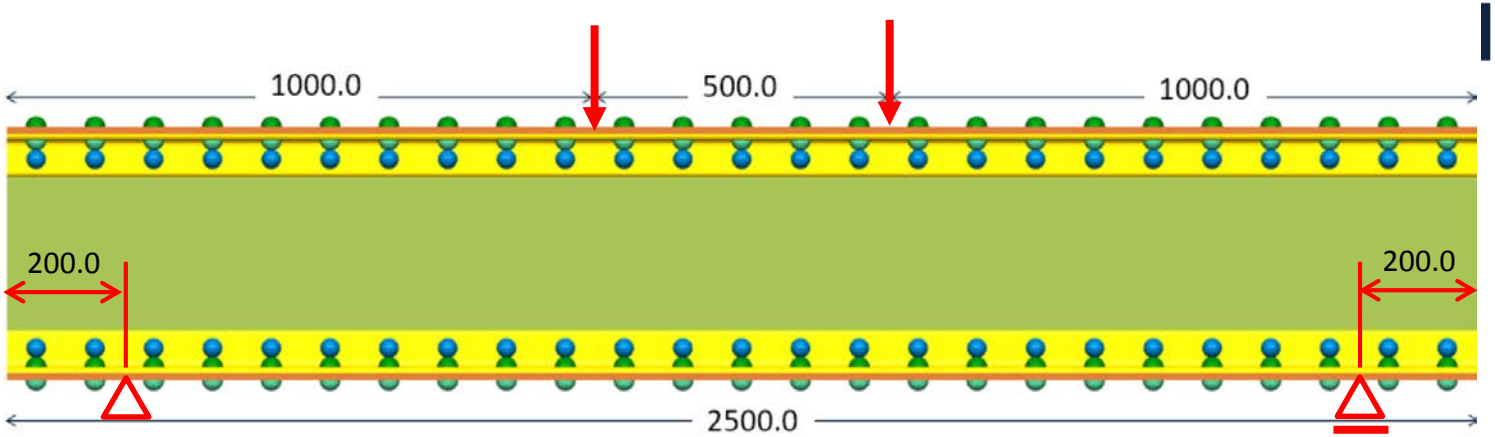


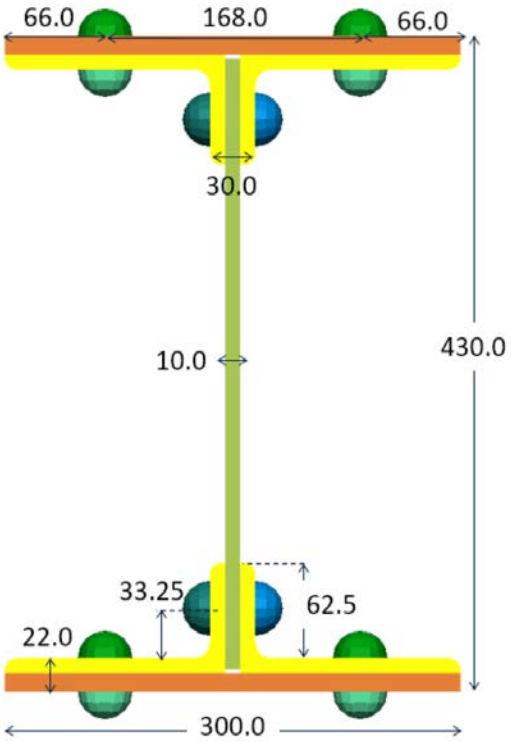


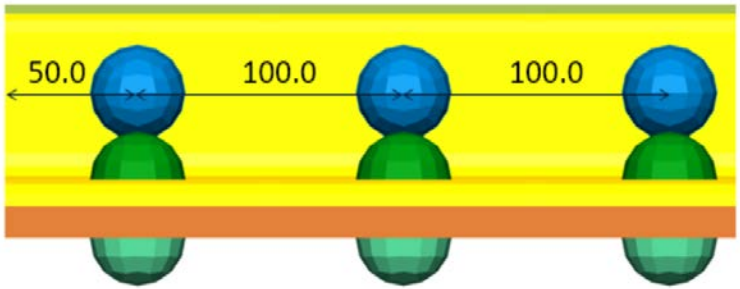
DOFtype=DISP for Component DFLT_COMP in Situation STRESS_SIT

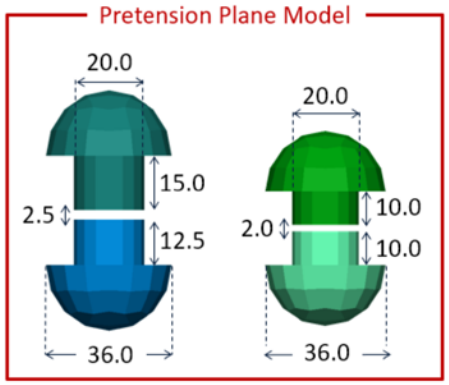
3509053 Unknowns	0 External DOFs	0 External guidings
1415253 Nodes(m6D)	1 Prescribed DOFs	1 Prescribed guidings
891593 Elements	208 Suppressed DOFs	3 Suppressed guidings
113128 MPCs	737196 Dependent DOFs	259172 Local guidings
79048 CA-DOFs	356 CA-Definitions	194873 Total CA-Guid. DOFs
78466 Normal	194420 Local CA-Guid.	453 Dependent CA-Guid.
0 Gasket CA-DOFs	582 Zero-Force CA-DOFs	194 Zero-Force Elements

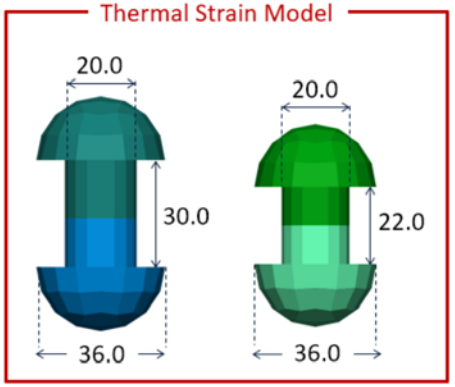
- Assembled Parts with Rivet - Model Dimensions (mm)









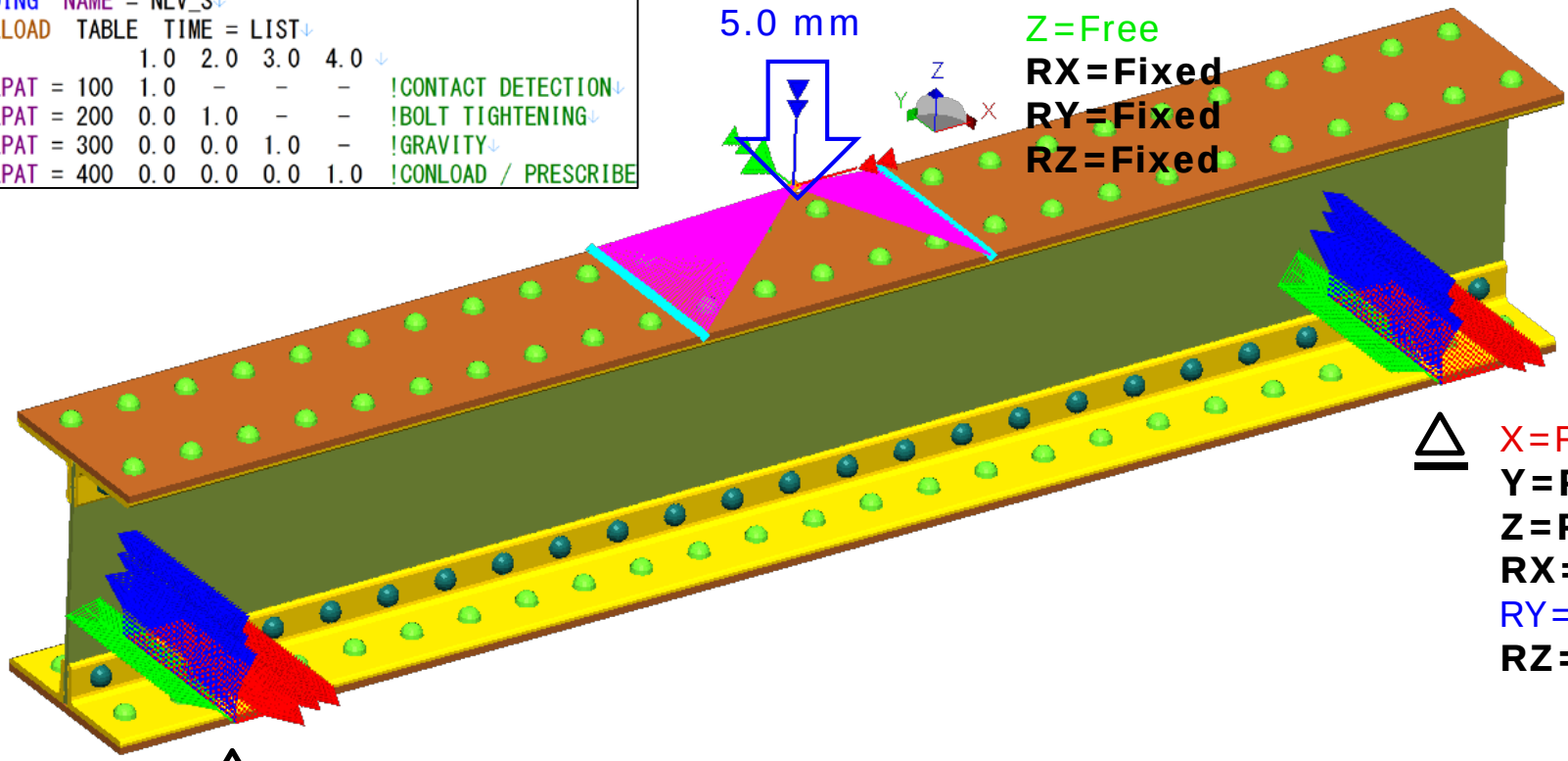


- Assembled Parts with Rivet - Boundary Conditions

$PRETENSION PLANE + $CONTACT(No Friction)

```
$LOADING  NAME = NLV_S
  $NLLOAD  TABLE  TIME = LIST
                  1.0   2.0   3.0   4.0
    LPAT = 100    1.0    -     -     -    !CONTACT DETECTION
    LPAT = 200    0.0   1.0    -     -    !BOLT TIGHTENING
    LPAT = 300    0.0   0.0   1.0    -    !GRAVITY
    LPAT = 400    0.0   0.0   0.0   1.0   !CONLOAD / PRESCRIBE
```

Enforced Disp.
5.0 mm



X=Free
Y=Fixed
Z=Free
RX=Fixed
RY=Fixed
RZ=Fixed

△
X=Free
Y=Fixed
Z=Fixed
RX=Fixed
RY=Free
RZ=Fixed

△
X=Fixed
Y=Fixed
Z=Fixed
RX=Fixed
RY=Free
RZ=Fixed

Bolt Pretension:
PRETENTION PLANE
PRETENSION FORCE = 200KN
Contact Definition:
SURFACE TO SURFACE
NO FRICTION
GAP WIDTH = 0.0

Bolt Pretension:
THERMAL STRAIN (1200 DEG.)
Contact Definition:
SURFACE TO SURFACE
NO FRICTION
GAP WIDTH = 0.0
GAP WIDTH = -0.025
(press fit only for shaft)

- Assembled Parts with Rivet - Elapsed Time

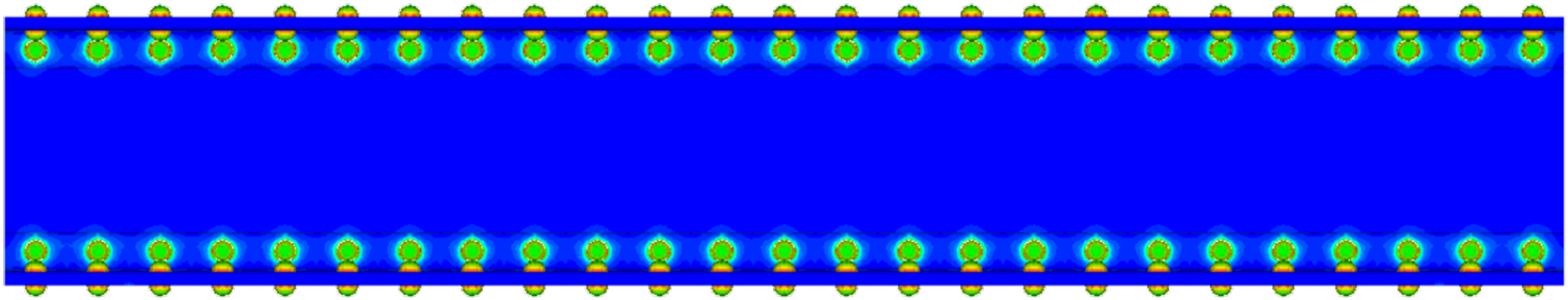
Model	Condition	Elapsed Time
A	$PRETENSION PLANE + $CONTACT(No Friction)	02:32:25
B	$THERMAL STRAIN + $CONTACT(No Friction)	14:55:25

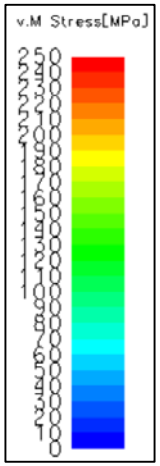
Machine Specification :
2*18 cores Intel(R) Xeon(R) CPU E5-2697 v4 @ 2.30GH / 502.92 GiByte

```
+-------------------------------------------------------------------------+
| DOFtype=DISP for Component DFLT_COMP in Situation STRESS_SIT            |
|-------------------------------------------------------------------------|
|    3509053 Unknowns           0 External DOFs          0 External guidings |
|    1415253 Nodes(m6D)         1 Prescribed DOFs        1 Prescribed guidings |
|     891593 Elements         208 Suppressed DOFs        3 Suppressed guidings |
|     113128 MPCs          737196 Dependent DOFs    259172 Local guidings     |
|      79048 CA-DOFs          356 CA-Definitions    194873 Total CA-Guid. DOFs |
|      78466 Normal        194420 Local  CA-Guid.      453 Dependent CA-Guid.  |
|          0 Gasket CA-DOFs   582 Zero-Force CA-DOFs   194 Zero-Force Elements |
+-------------------------------------------------------------------------+
```

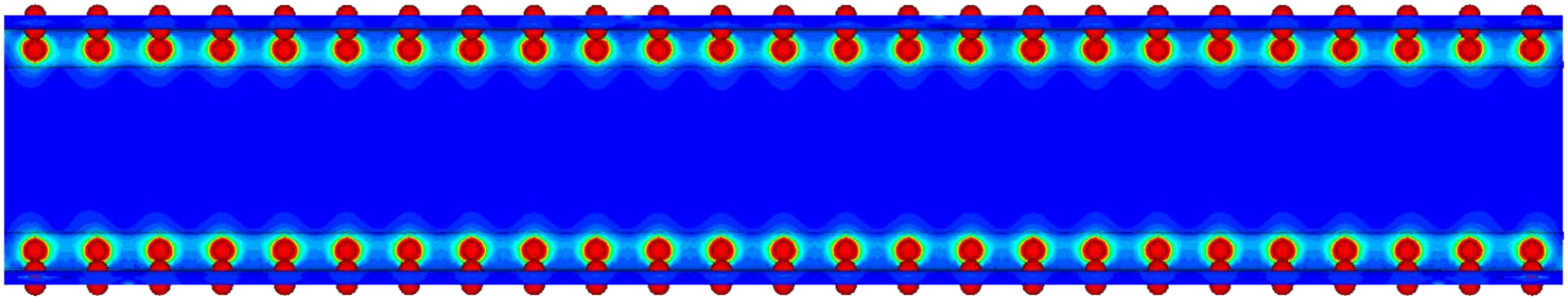
- Assembled Parts with Rivet - v.M. Stress Distribution (Bolt Tightening)

MODEL A ($PRETENSION PLANE + $CONTACT)



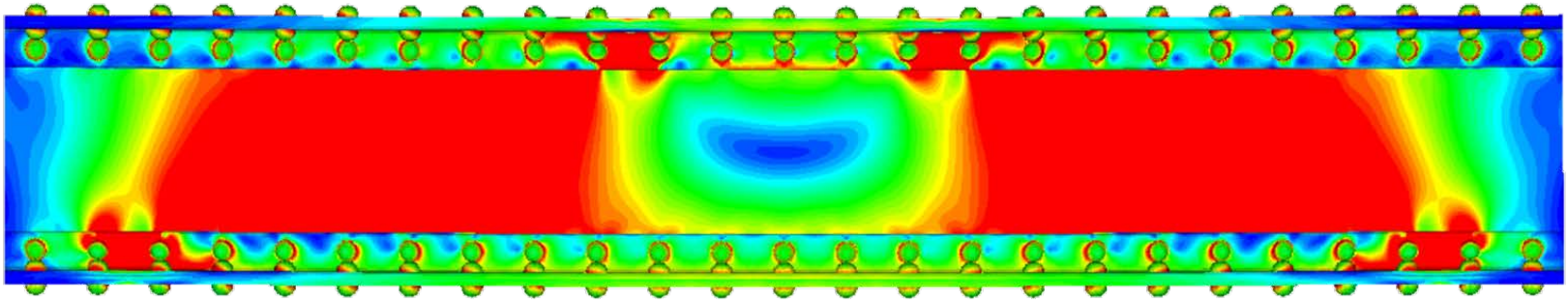


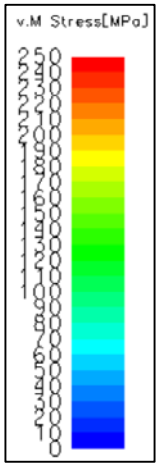
MODEL B (Thermal Strain + $CONTACT)



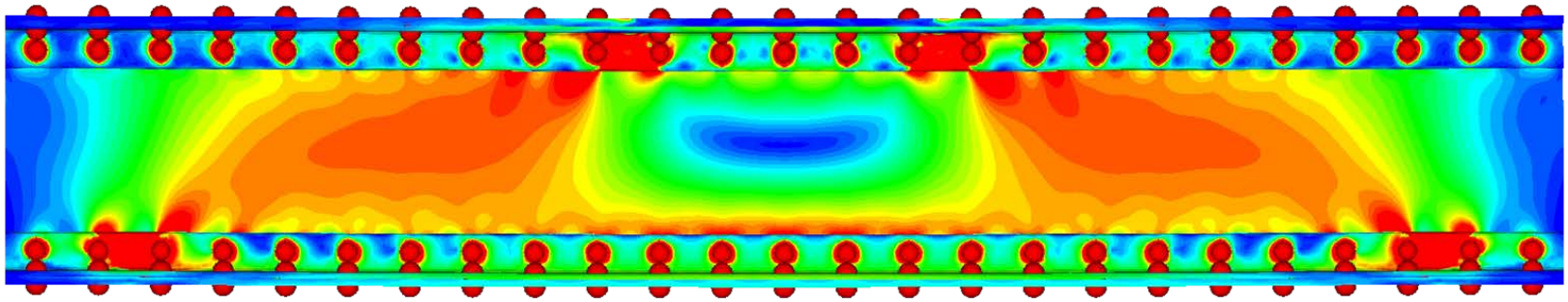
- Assembled Parts with Rivet - v.M. Stress Distribution (Shear Deformation)

MODEL A ($PRETENSION PLANE + $CONTACT)



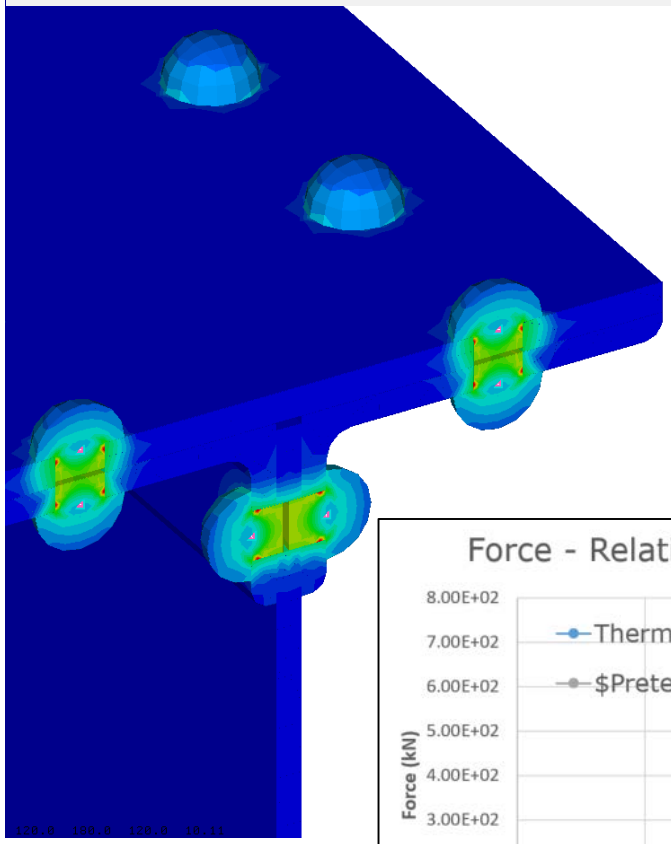


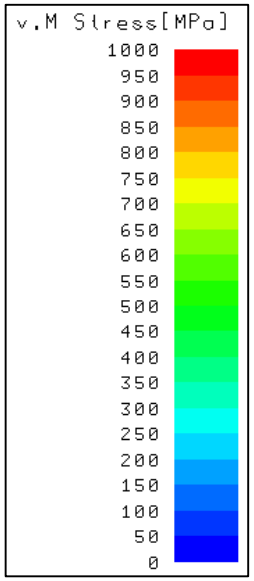
MODEL B (Thermal Strain + $CONTACT)



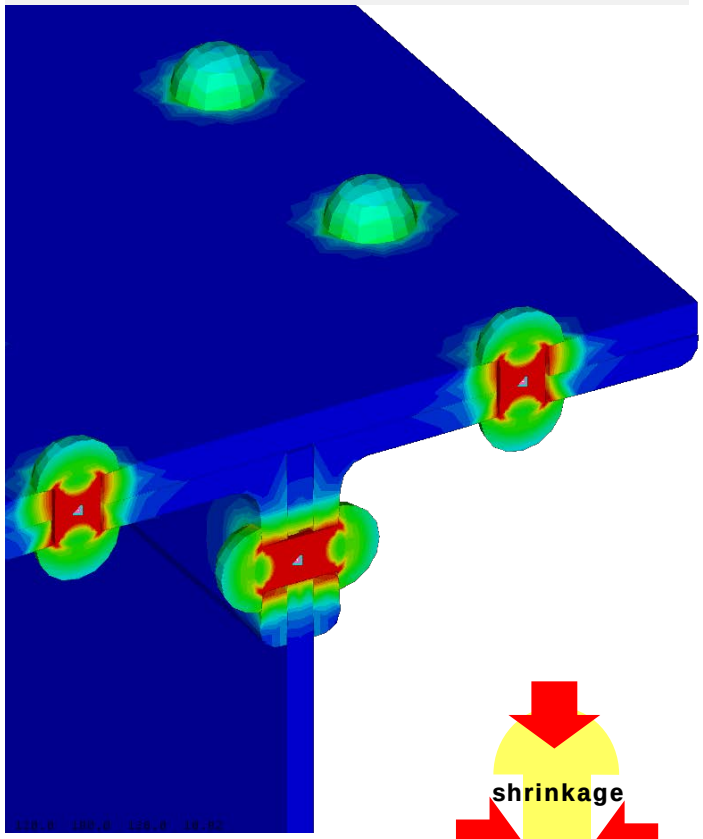
- Assembled Parts with Rivet - Relationship between Reaction Force – Disp.

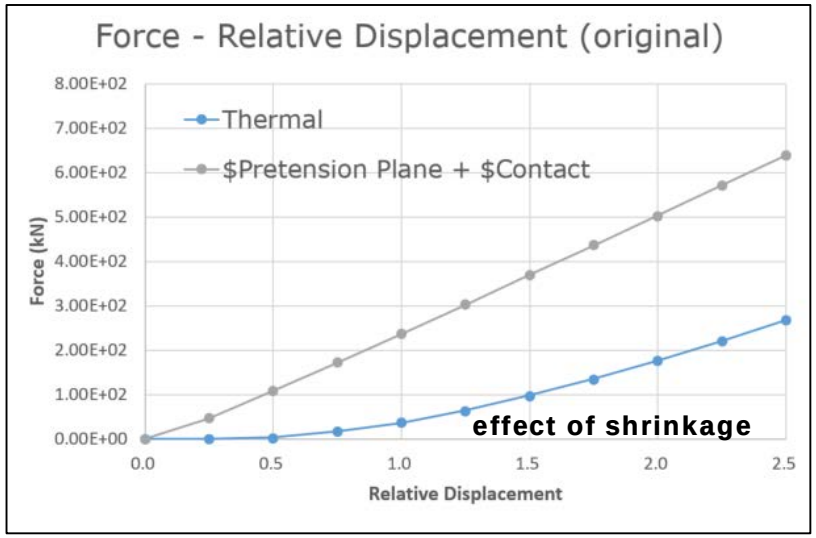
Bolt Tightening: Pretension Plane (Factor = 10.0)

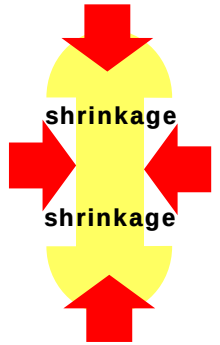




Bolt Tightening: Thermal Strain (Factor = 10.0)







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Simple Rivet Models

According to v.M. stress distributions and load-displacement curve, PERMAS bolt pretension option may be stiffer than realistic rivet behavior only about shear resistance mechanism of the rivet.

Assembled Parts with Rivet

Using new rivet model, it may be able to give a temperature load for tightening rivet, and to estimate more accurate stress distribution of steel structure to be used for long time.

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- Future Works -

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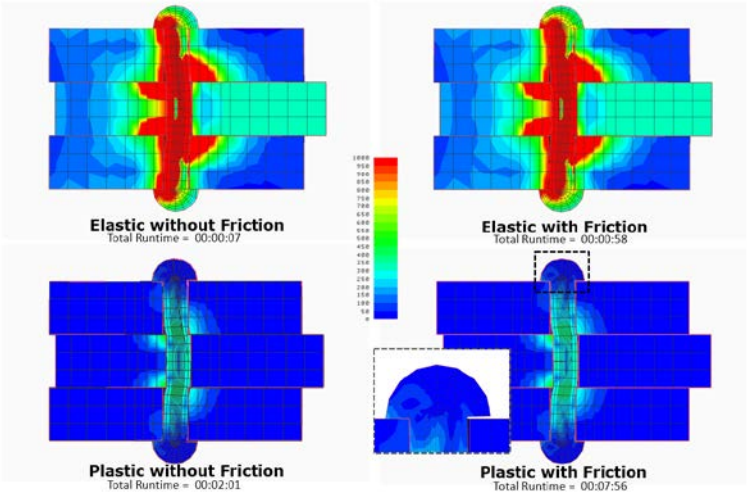
- Conclusion
- Future Works

- Future Works - Getting more realistic result !

JAPAN INTES

Frictional Contact

Frictional contact cannot be ignored about large relative sliding in case a large shear deformation occurs on the boundary surface

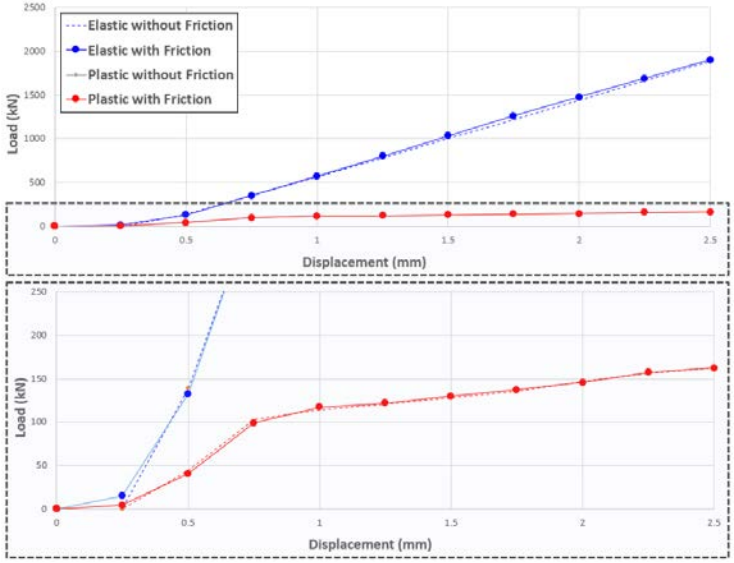


Temperature Dependency of Material

Elastic modulus, thermal expansion of material properties has a strong temperature dependency

Elasto-Plastic Nonlinear Material Behaviour

Materials of rivet and plate with hole has also nonlinear material behaviour with temperature dependency



Fatigue Life Estimation with Cyclic Loading

Assembled parts with rivet, hard to replace from old parts to new, so it is so important to consider a fatigue life of structure


Thanx for Your Attention !
Raum Hesse