July 05

The Analysis of Ultrahigh Vacuum CF Flange Joints Applied in Accelerator and Space Technology

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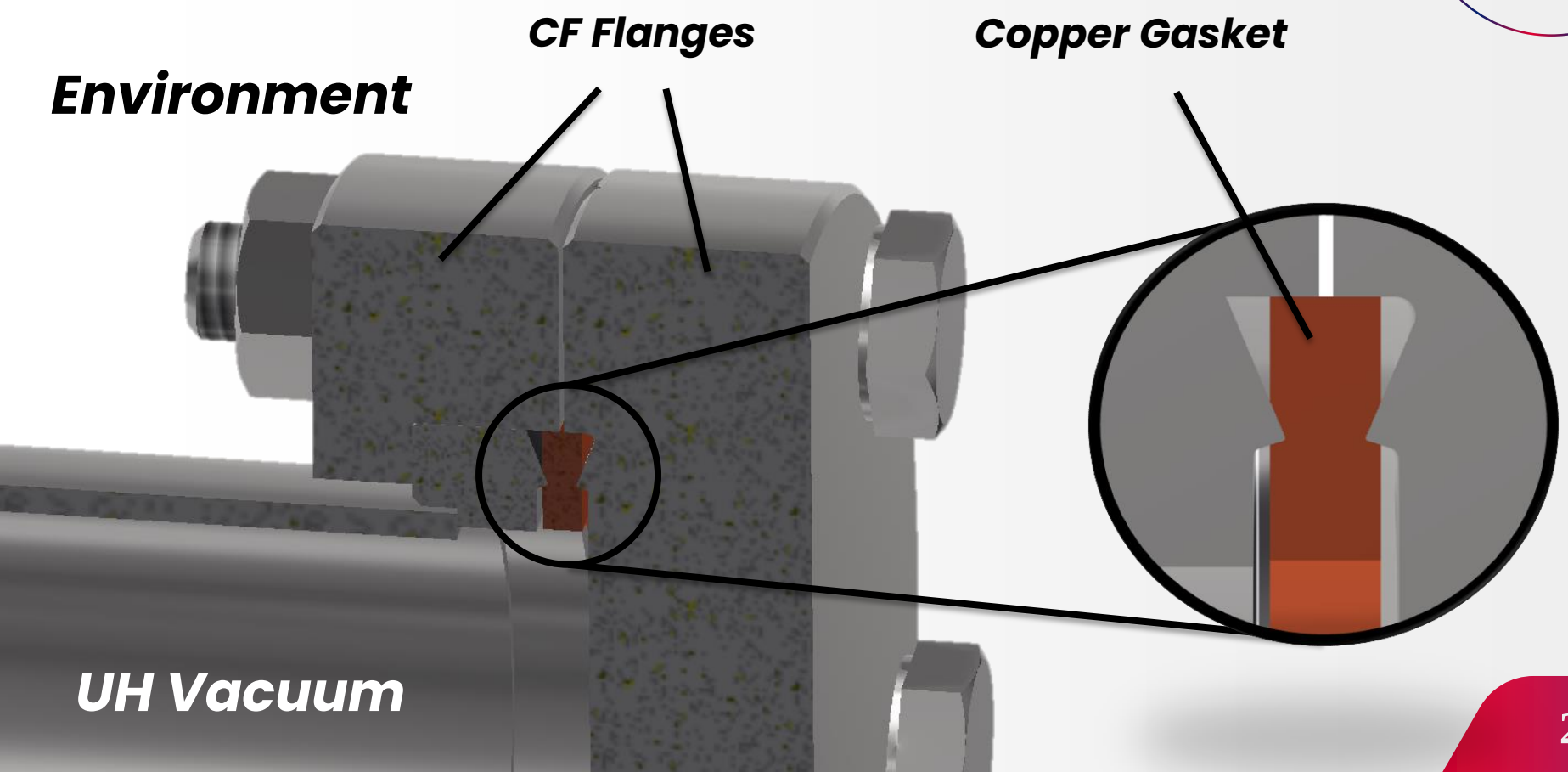
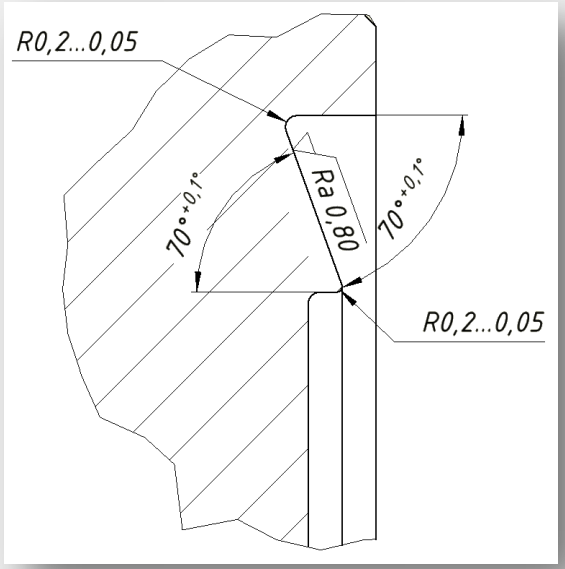
CANDLE Synchrotron Research Institute
“Vacuum Technologies” Laboratory

About UHV Systems Joints

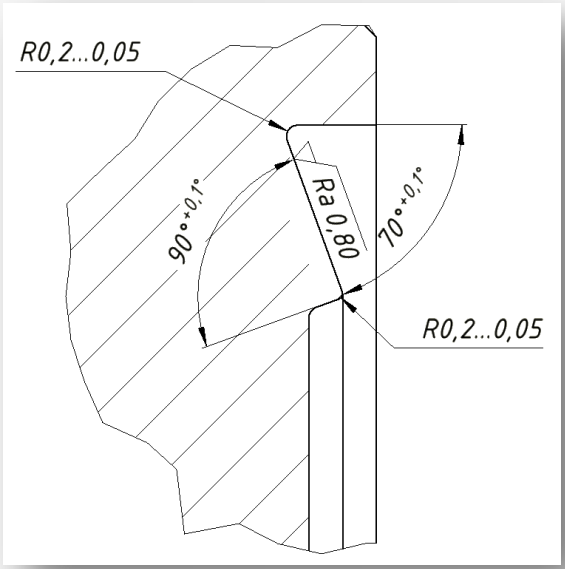


General Types of Knife Edges of CF Flanges



Before

Knife-edge with 70° between the shelves (After Wheeler)



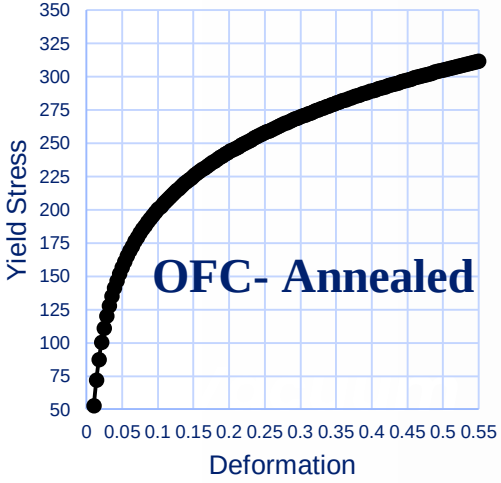
Now

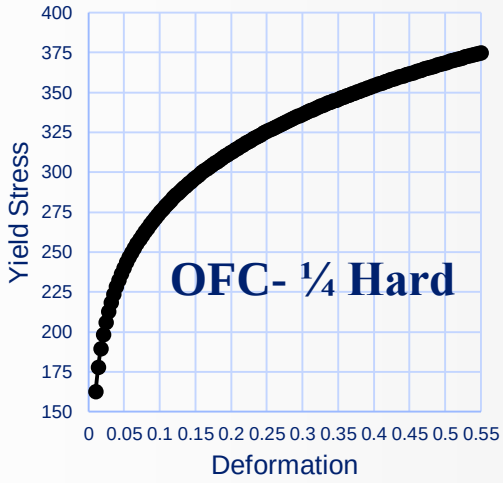
Knife-edge with 90° between the shelves (CERN design)

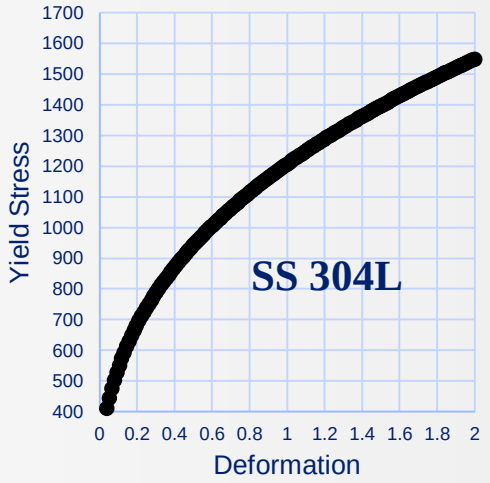
Conditions

Type of analysis – Finite element analysis (FEA)
Initial conditions:
- Soft and hard (1/4 hard copper) gaskets
- Flanges material – stainless steel (304L)
- Gaskets and flanges are deformable
- Initial temperature 24°C

Mechanical Properties of Materials





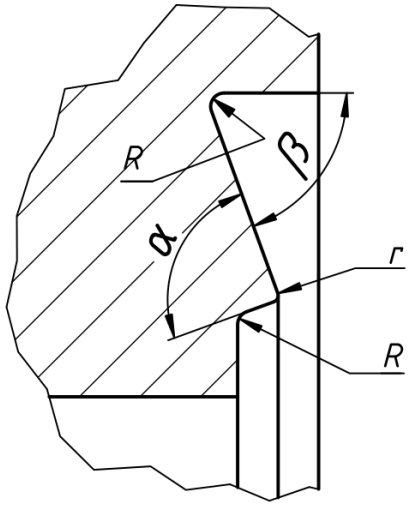


Analysis Variable Parameters

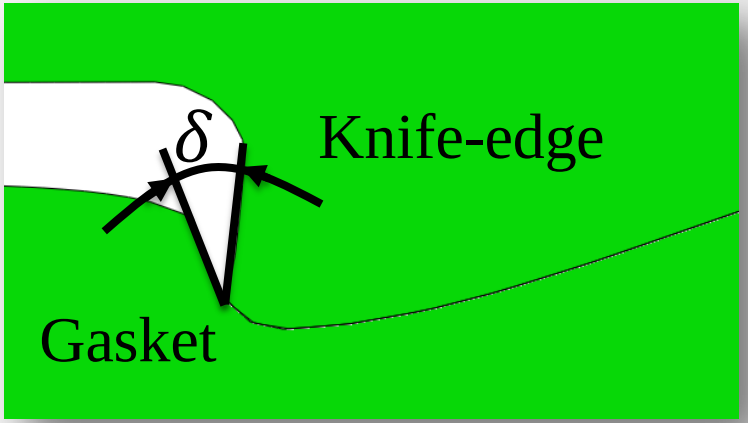
- Radius of rounding at the top of the knife-edge - r
- Angle between the shelves forming the knife-edge - α
- Material properties of the copper ring - annealed & ¼ hard

As result:

- Gap between the sealing ring and the flange - δ



$$R = 0{,}2 = const$$
$$\beta = 70° = const$$
$$\alpha = 70°;\ 90°$$
$$r = 0{,}05;\ 0{,}1;\ 0{,}2$$



Simulation Assignments

$\beta\alpha(10r)(10R)\_[Gasket\ state]$

7090052_Soft

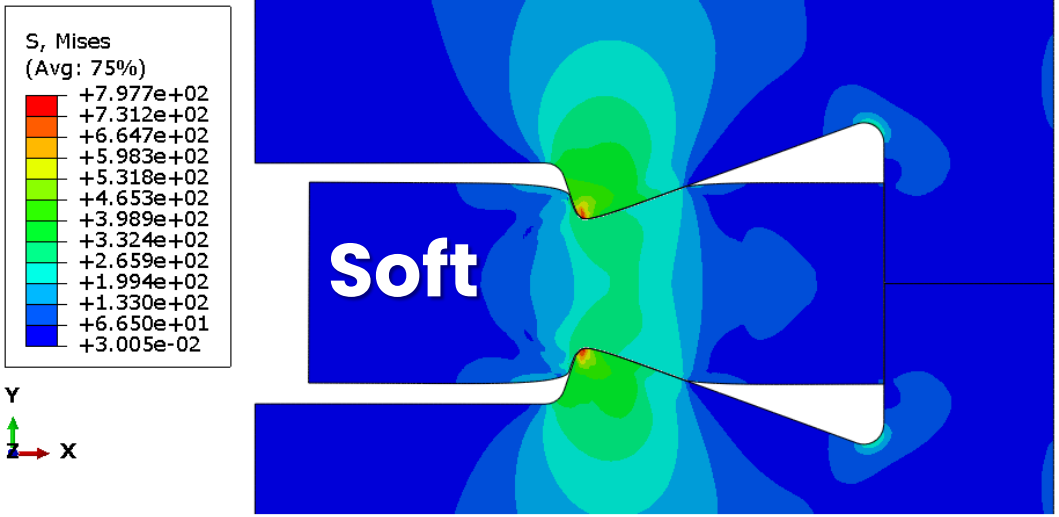
709012_Hard

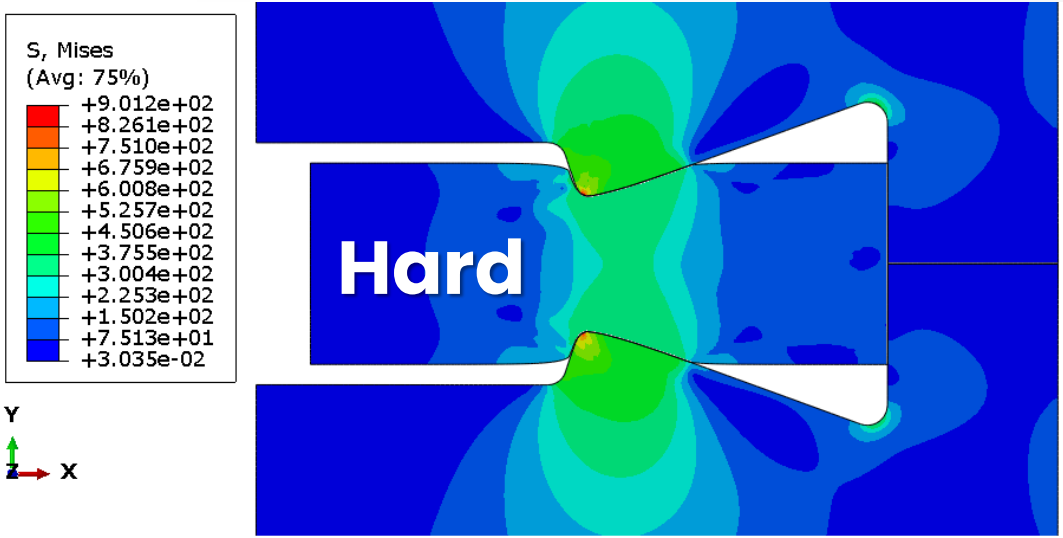
707022_Soft

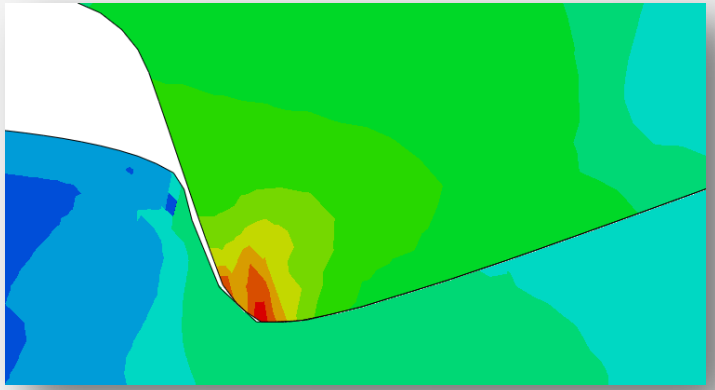
7070052_Hard

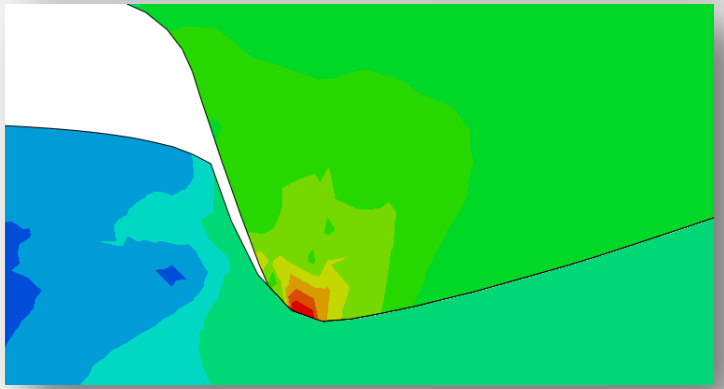
...

7090052

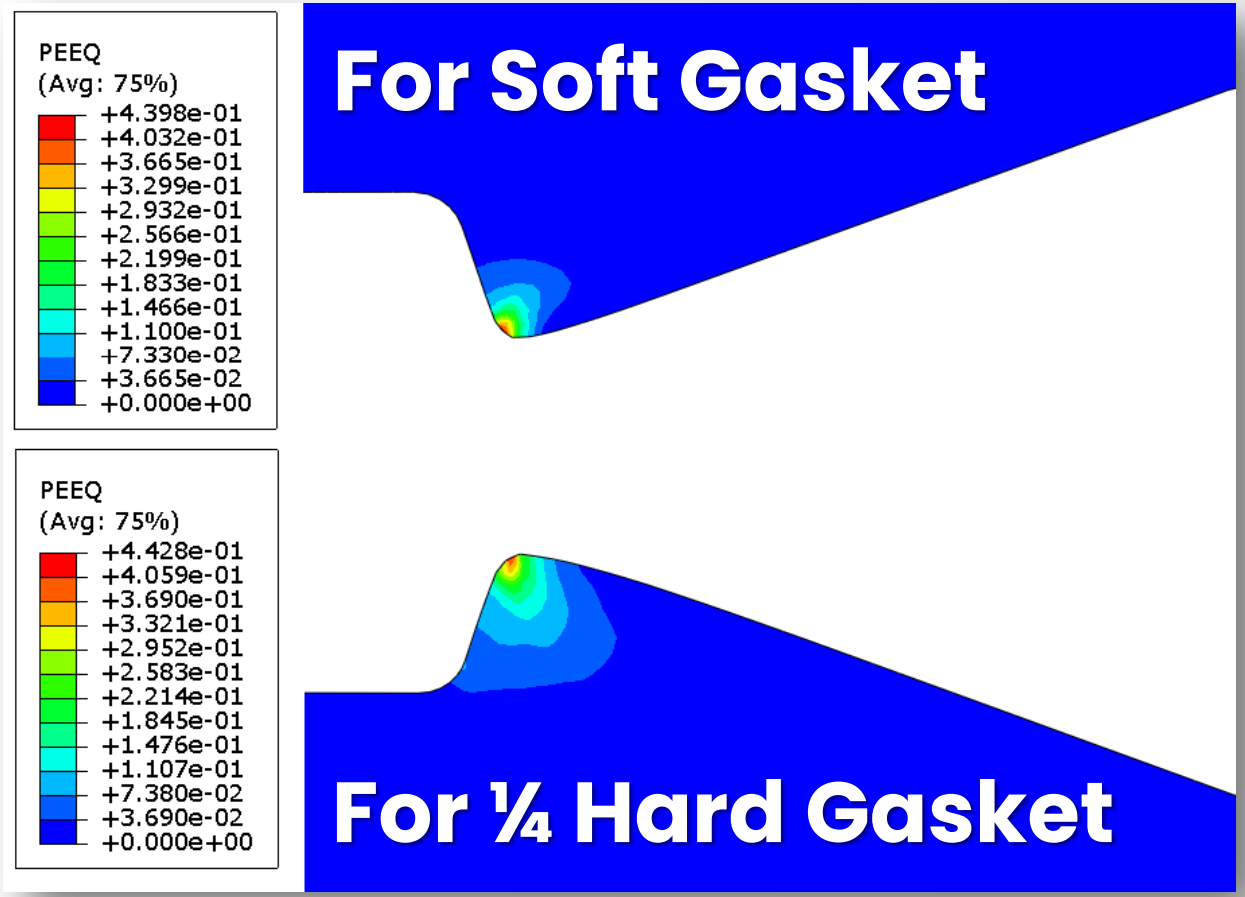

S, Mises
(Avg: 75%)
+7.977e+02
+7.312e+02
+6.647e+02
+5.983e+02
+5.318e+02
+4.653e+02
+3.989e+02
+3.324e+02
+2.659e+02
+1.994e+02
+1.330e+02
+6.650e+01
+3.005e-02
Soft
Y
X


S, Mises
(Avg: 75%)
+9.012e+02
+8.261e+02
+7.510e+02
+6.759e+02
+6.008e+02
+5.257e+02
+4.506e+02
+3.755e+02
+3.004e+02
+2.253e+02
+1.502e+02
+7.513e+01
+3.035e-02
Hard
Y
X





7090052



$$\sigma_i^{max} = 797,7\ \boldsymbol{MPa}$$

$$\varepsilon_i^{max} = 0,4398$$

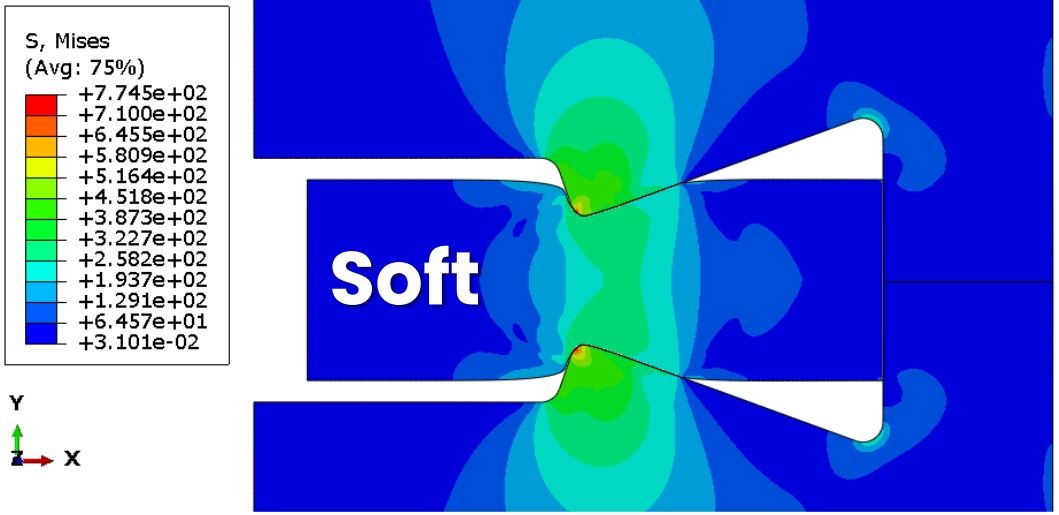
$$\delta = 4,15°$$

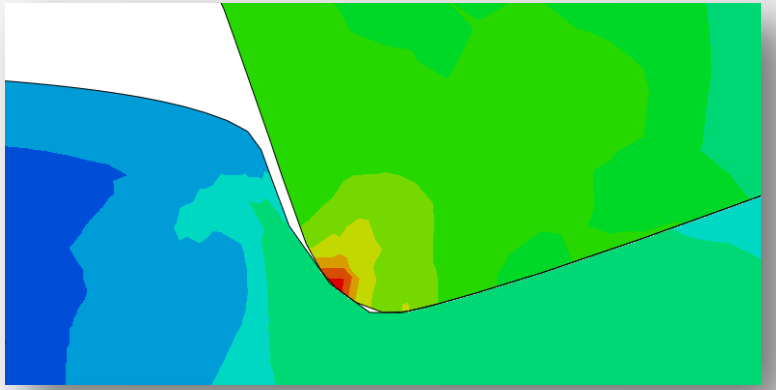
$$\sigma_i^{max} = 901,2\ \boldsymbol{MPa}$$

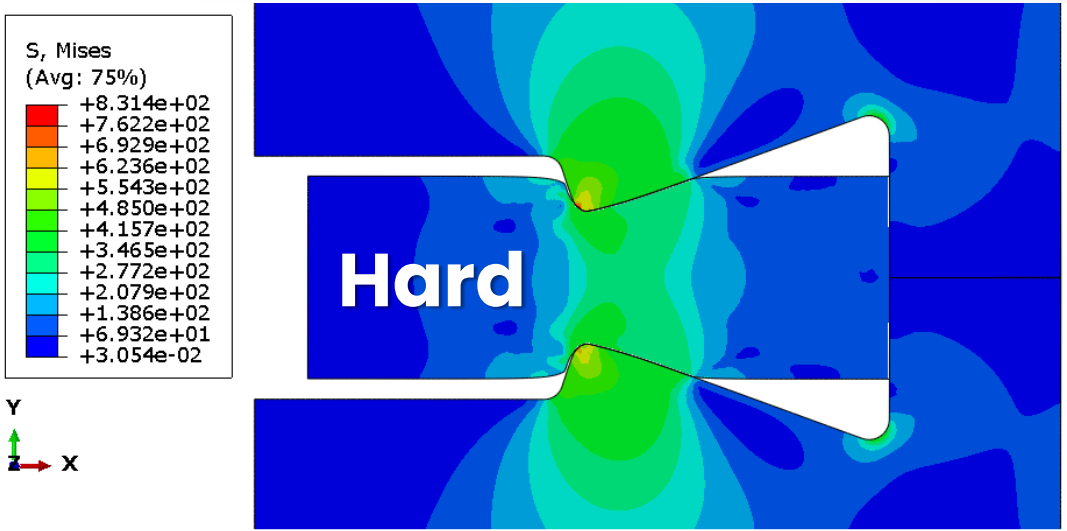
$$\varepsilon_i^{max} = 0,4428$$

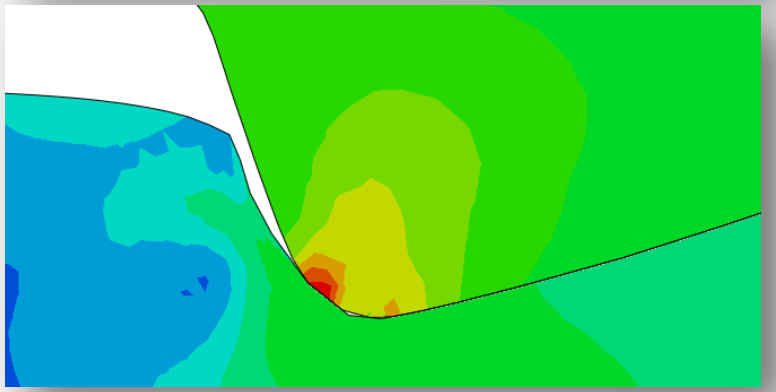
$$\delta = 4,74°$$

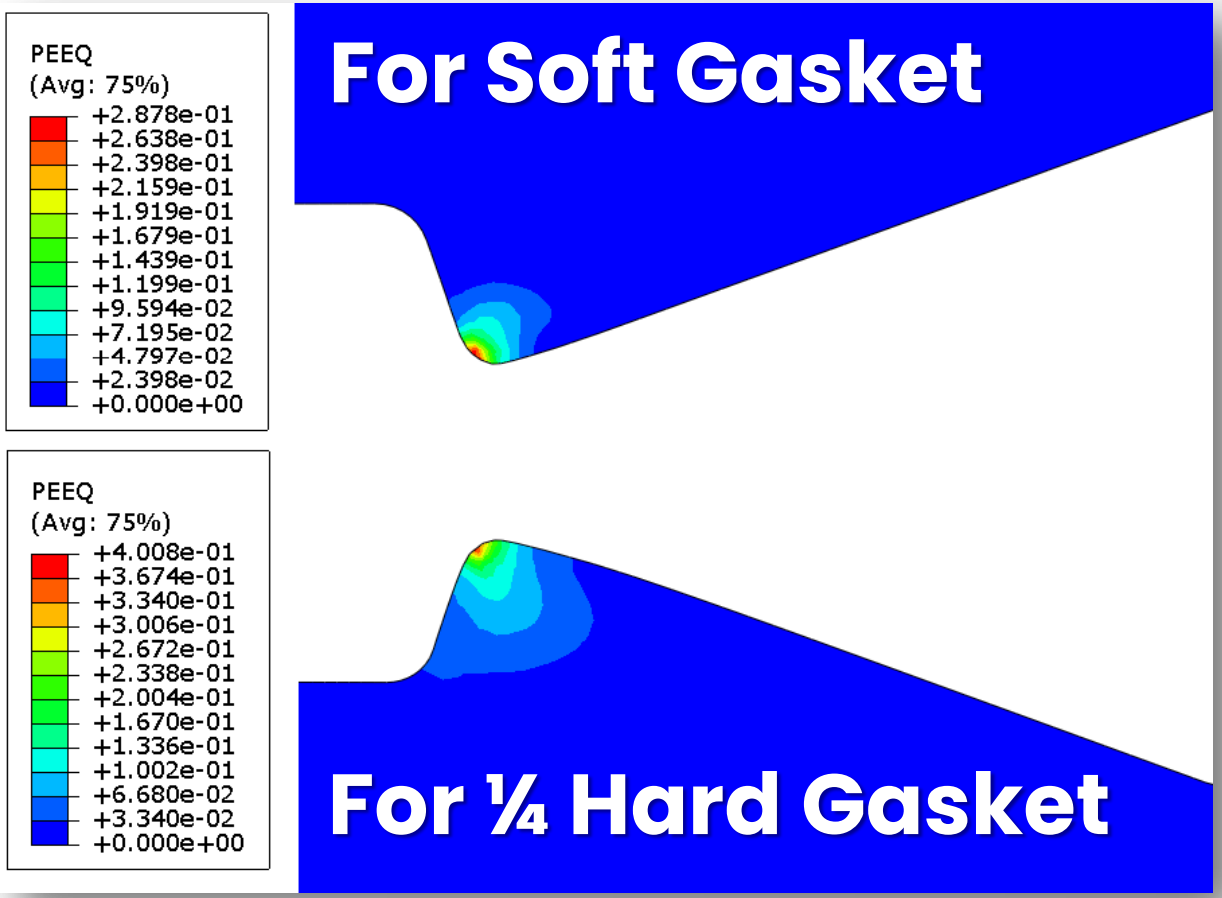
709012


S, Mises
(Avg: 75%)
+7.745e+02
+7.100e+02
+6.455e+02
+5.809e+02
+5.164e+02
+4.518e+02
+3.873e+02
+3.227e+02
+2.582e+02
+1.937e+02
+1.291e+02
+6.457e+01
+3.101e-02
Y
Z
X
Soft




S, Mises
(Avg: 75%)
+8.314e+02
+7.622e+02
+6.929e+02
+6.236e+02
+5.543e+02
+4.850e+02
+4.157e+02
+3.465e+02
+2.772e+02
+2.079e+02
+1.386e+02
+6.932e+01
+3.054e-02
Y
Z
X
Hard





$$\sigma_i^{max} = 774,5\ \boldsymbol{MPa}$$

$$\varepsilon_i^{max} = 0,2878$$

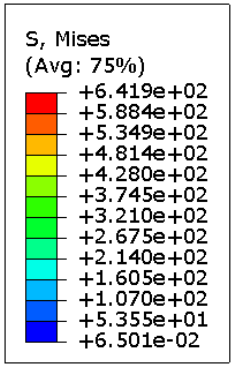
$$\delta = 4,94°$$

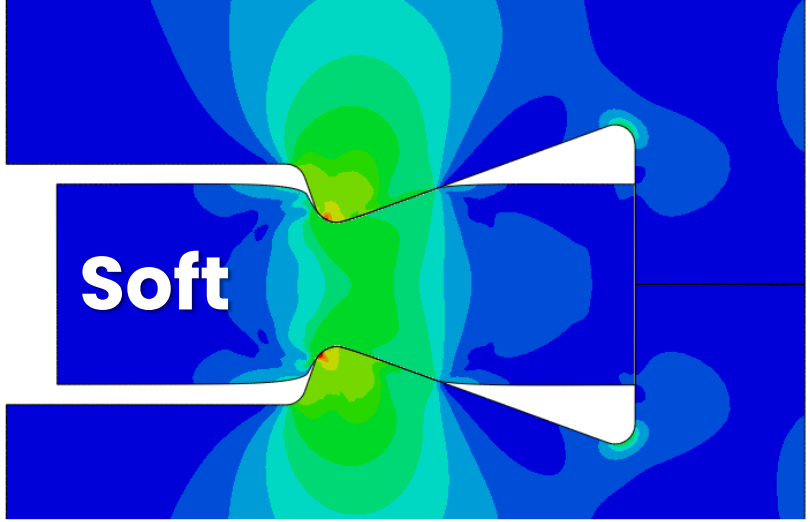
$$\sigma_i^{max} = 831,4\ \boldsymbol{MPa}$$

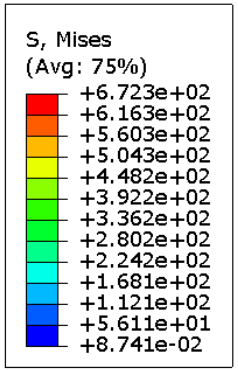
$$\varepsilon_i^{max} = 0,4008$$

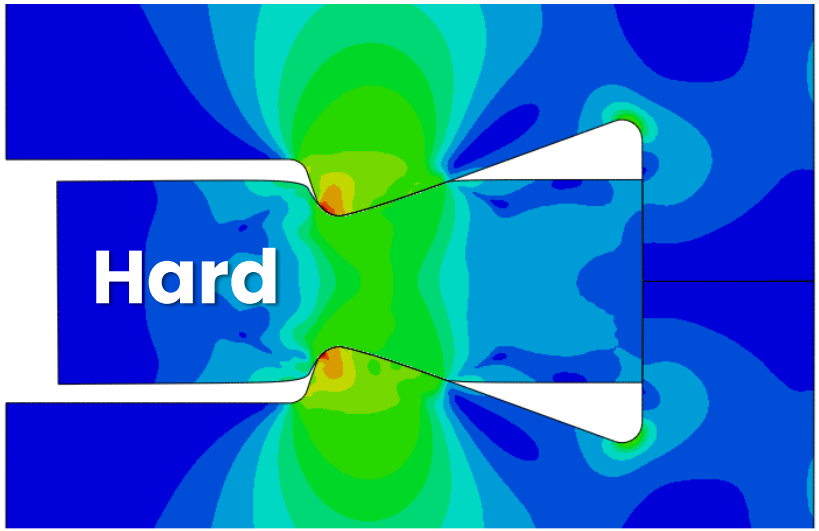
$$\delta = 5,4°$$

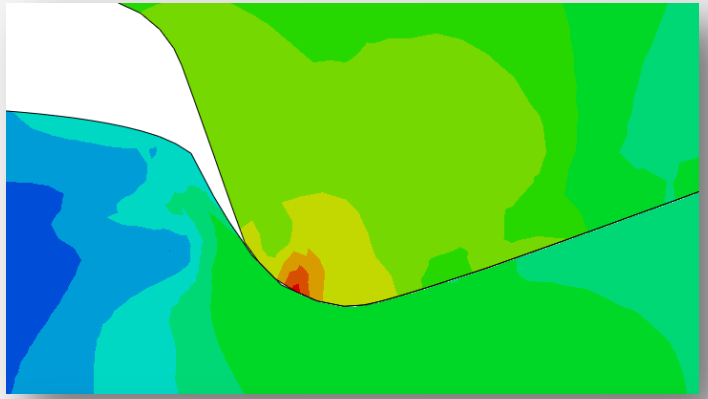
709022

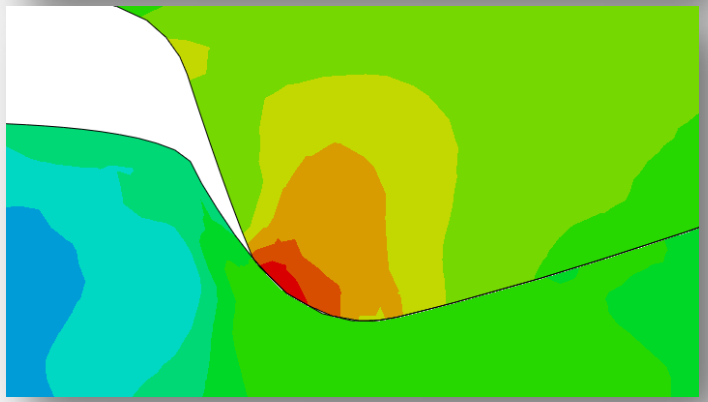

S, Mises
(Avg: 75%)
+6.419e+02
+5.884e+02
+5.349e+02
+4.814e+02
+4.280e+02
+3.745e+02
+3.210e+02
+2.675e+02
+2.140e+02
+1.605e+02
+1.070e+02
+5.355e+01
+6.501e-02
Y
X


Soft

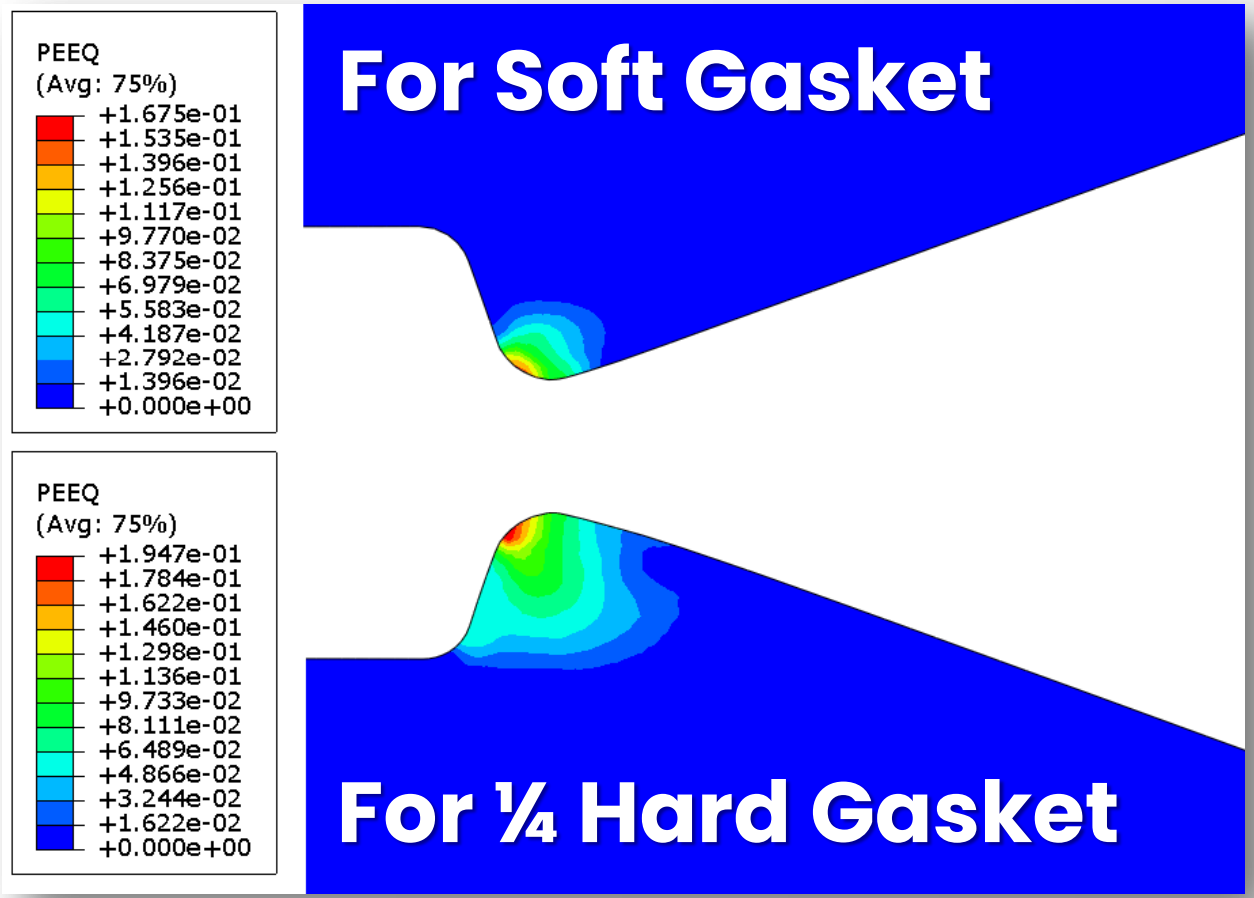

S, Mises
(Avg: 75%)
+6.723e+02
+6.163e+02
+5.603e+02
+5.043e+02
+4.482e+02
+3.922e+02
+3.362e+02
+2.802e+02
+2.242e+02
+1.681e+02
+1.121e+02
+5.611e+01
+8.741e-02
Y
X


Hard





709022



$$\sigma_i^{max} = 641,9\ \boldsymbol{MPa}$$

$$\varepsilon_i^{max} = 0,1675$$

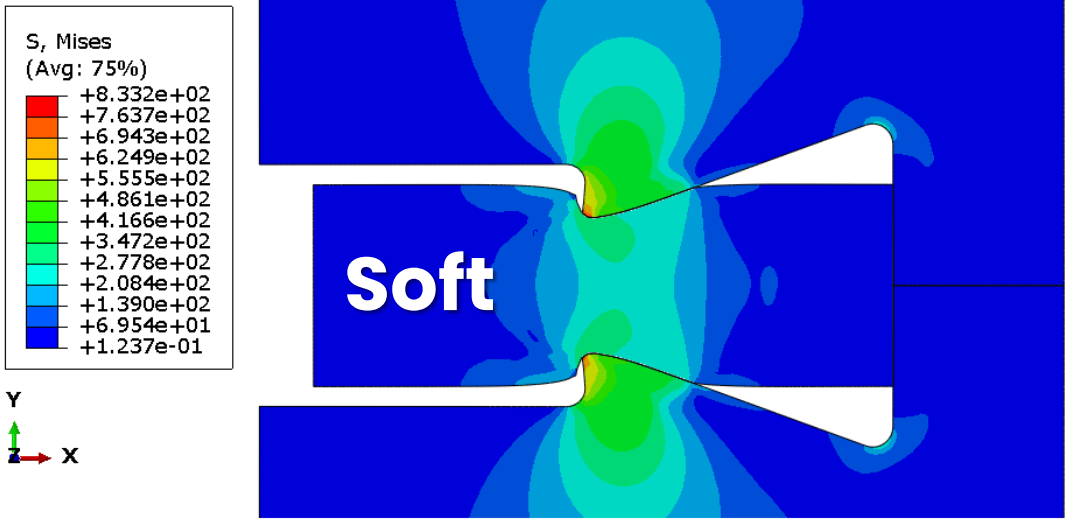
$$\delta = 11,39°$$

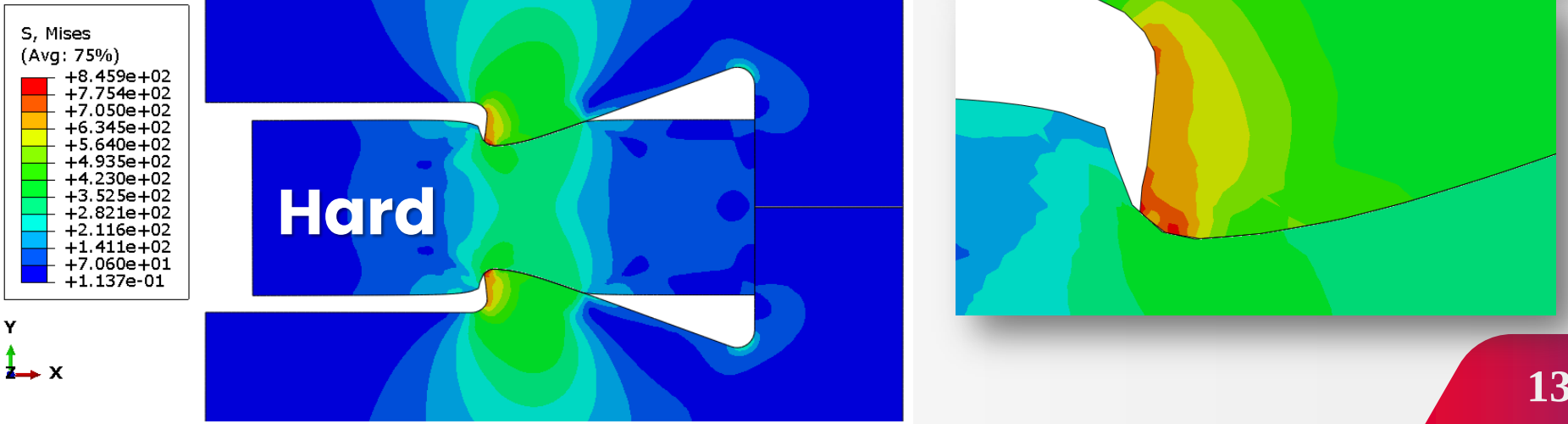
$$\sigma_i^{max} = 672,3\ \boldsymbol{MPa}$$

$$\varepsilon_i^{max} = 0,1947$$

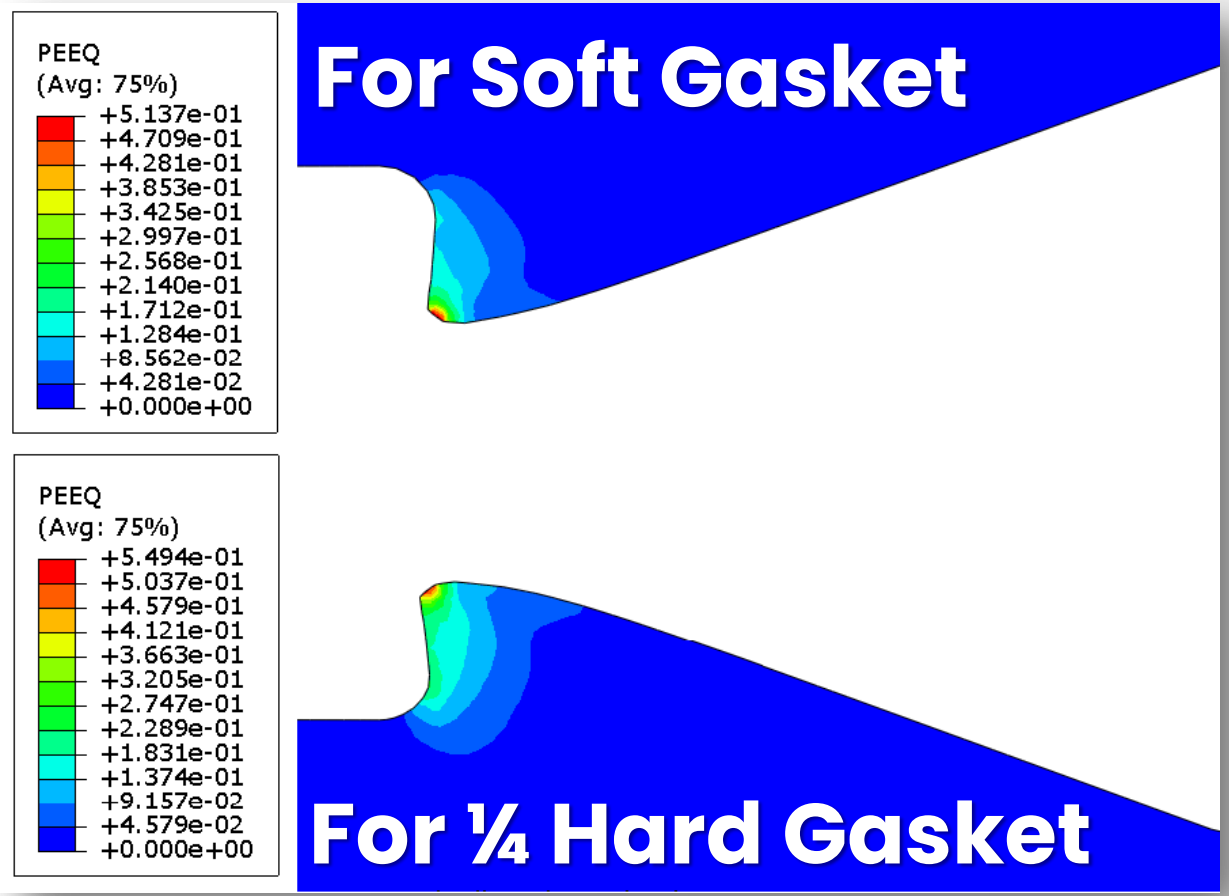
$$\delta = 12,49°$$

7070052


S, Mises
(Avg: 75%)
+8.332e+02
+7.637e+02
+6.943e+02
+6.249e+02
+5.555e+02
+4.861e+02
+4.166e+02
+3.472e+02
+2.778e+02
+2.084e+02
+1.390e+02
+6.954e+01
+1.237e-01
Soft
Y
Z
X


S, Mises
(Avg: 75%)
+8.459e+02
+7.754e+02
+7.050e+02
+6.345e+02
+5.640e+02
+4.935e+02
+4.230e+02
+3.525e+02
+2.821e+02
+2.116e+02
+1.411e+02
+7.060e+01
+1.137e-01
Hard
Y
Z
X

7070052



$$\sigma_i^{max} = 833,2\ MPa$$

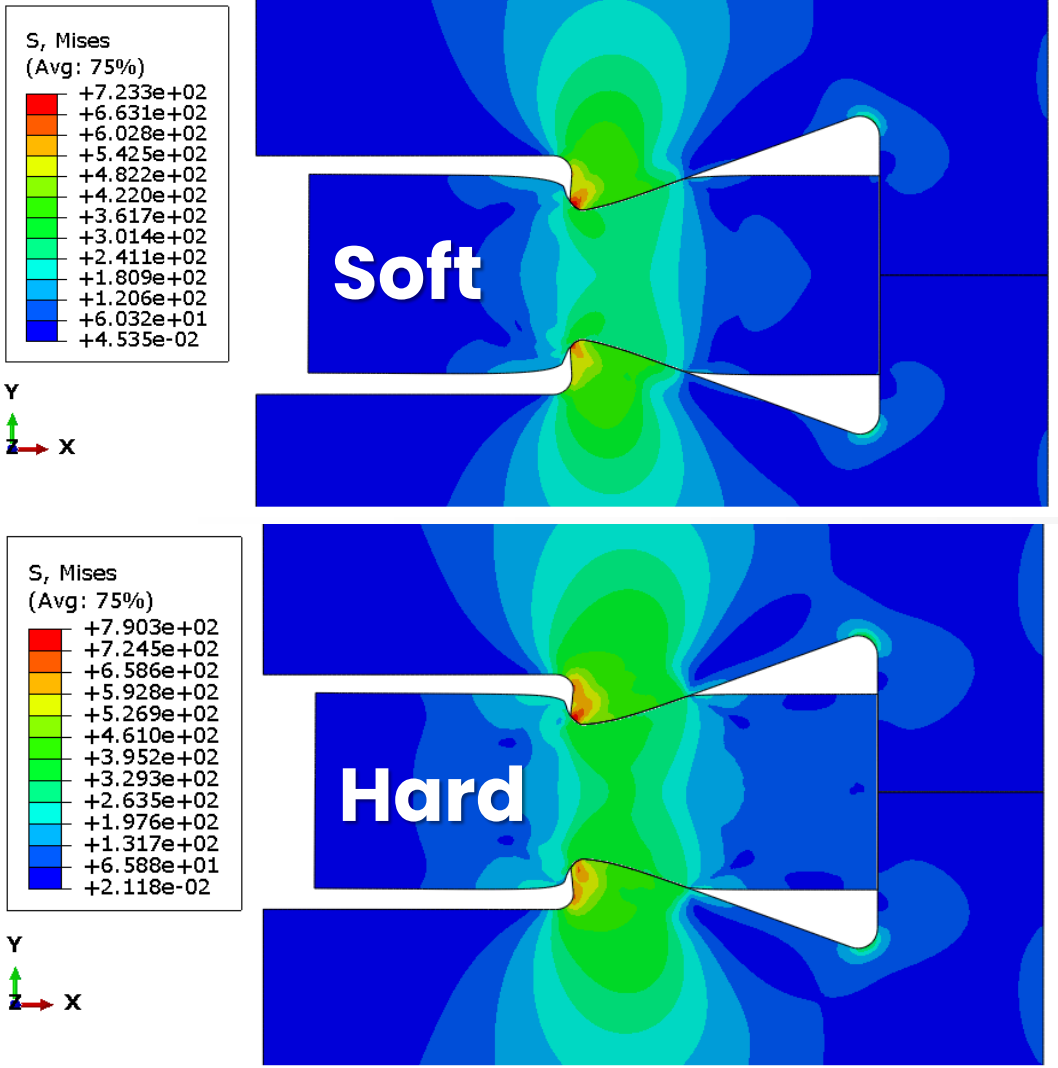
$$\varepsilon_i^{max} = 0,5137$$

$$\delta = 27,04°$$

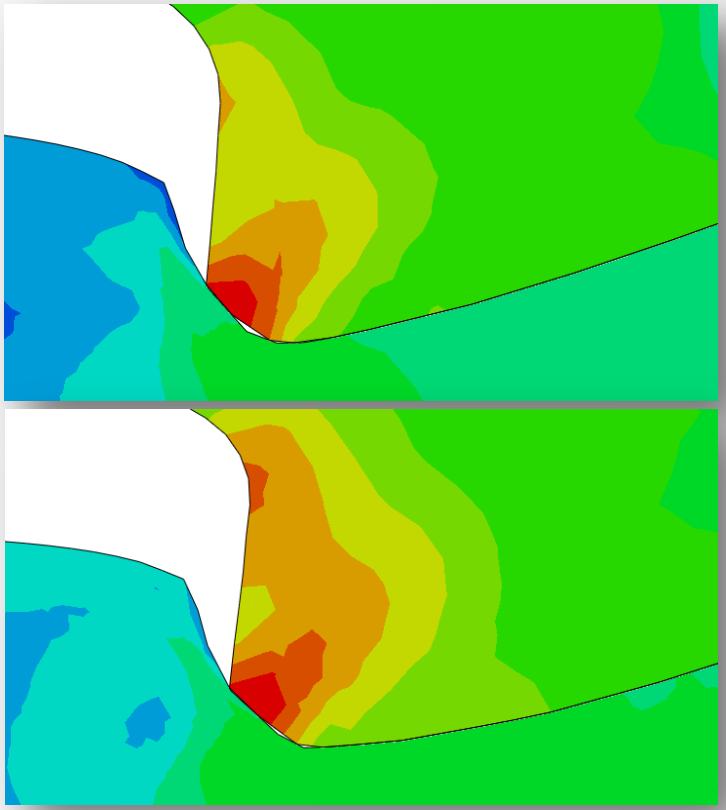
$$\sigma_i^{max} = 845,9\ MPa$$

$$\varepsilon_i^{max} = 0,5494$$

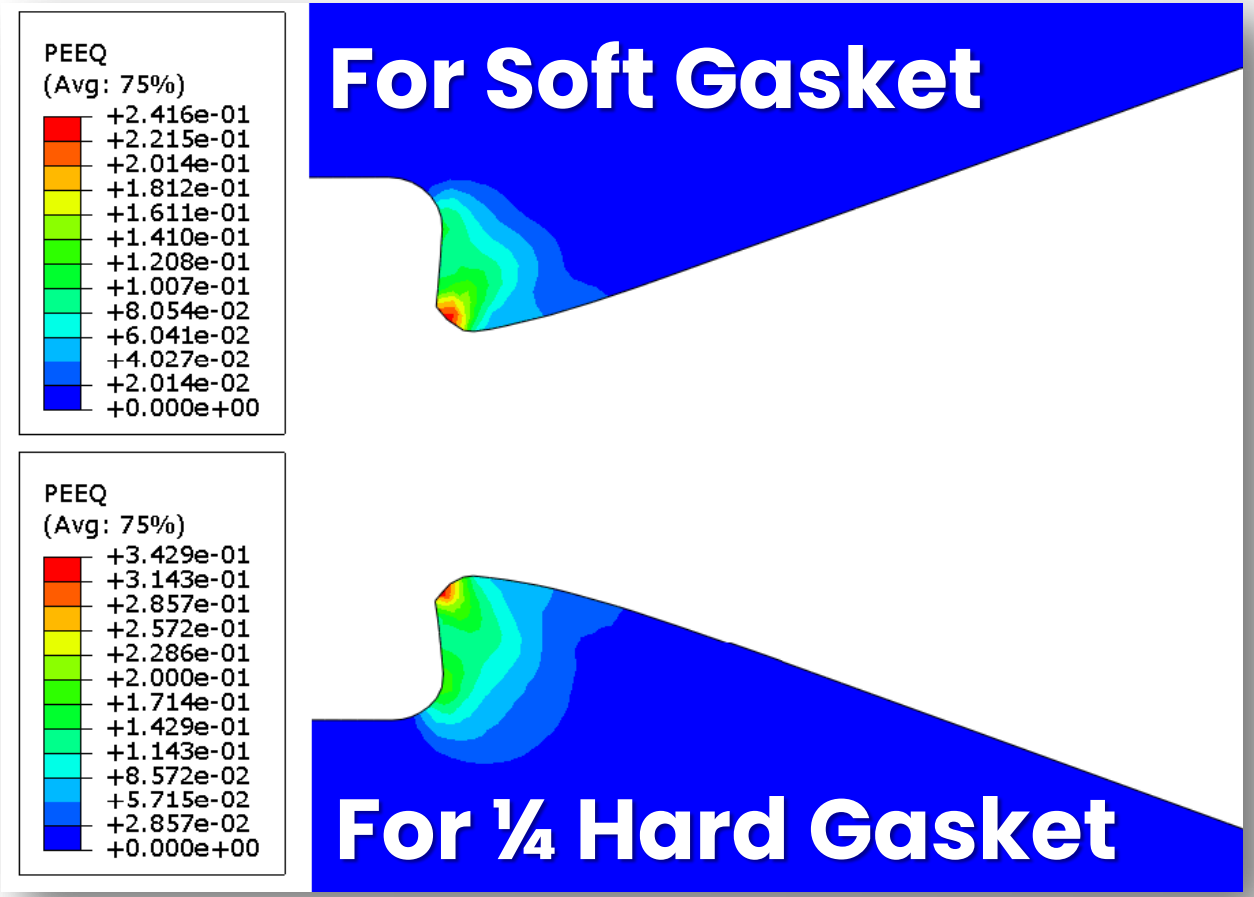
$$\delta = 30,03°$$


S, Mises
(Avg: 75%)
+7.233e+02
+6.631e+02
+6.028e+02
+5.425e+02
+4.822e+02
+4.220e+02
+3.617e+02
+3.014e+02
+2.411e+02
+1.809e+02
+1.206e+02
+6.032e+01
+4.535e-02
Y
X
Soft
S, Mises
(Avg: 75%)
+7.903e+02
+7.245e+02
+6.586e+02
+5.928e+02
+5.269e+02
+4.610e+02
+3.952e+02
+3.293e+02
+2.635e+02
+1.976e+02
+1.317e+02
+6.588e+01
+2.118e-02
Y
X
Hard

707012



707012



$$\sigma_i^{max} = 723,3\ MPa$$

$$\varepsilon_i^{max} = 0,2416$$

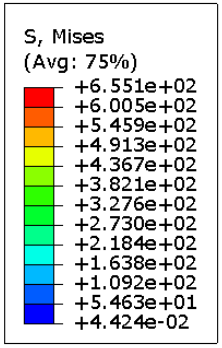
$$\delta = 27,29°$$

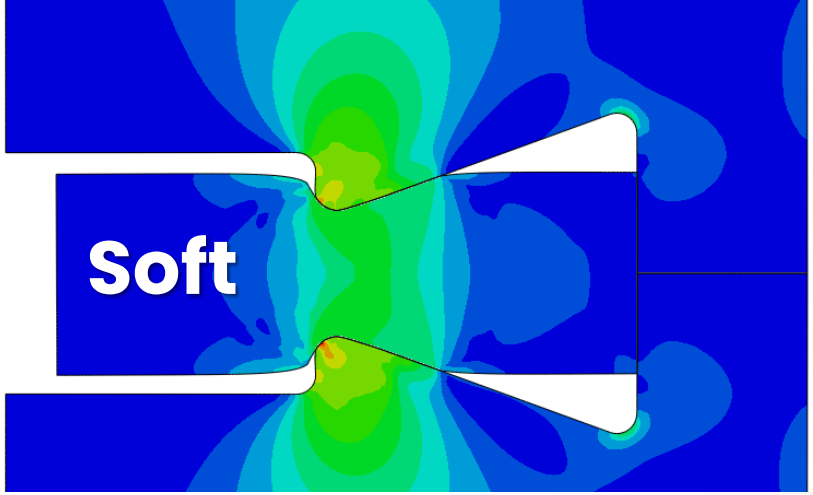
$$\sigma_i^{max} = 790,3\ MPa$$

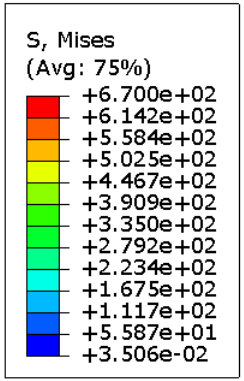
$$\varepsilon_i^{max} = 0,3429$$

$$\delta = 29,27°$$

707022


S, Mises
(Avg: 75%)
+6.551e+02
+6.005e+02
+5.459e+02
+4.913e+02
+4.367e+02
+3.821e+02
+3.276e+02
+2.730e+02
+2.184e+02
+1.638e+02
+1.092e+02
+5.463e+01
+4.424e-02


Soft


S, Mises
(Avg: 75%)
+6.700e+02
+6.142e+02
+5.584e+02
+5.025e+02
+4.467e+02
+3.909e+02
+3.350e+02
+2.792e+02
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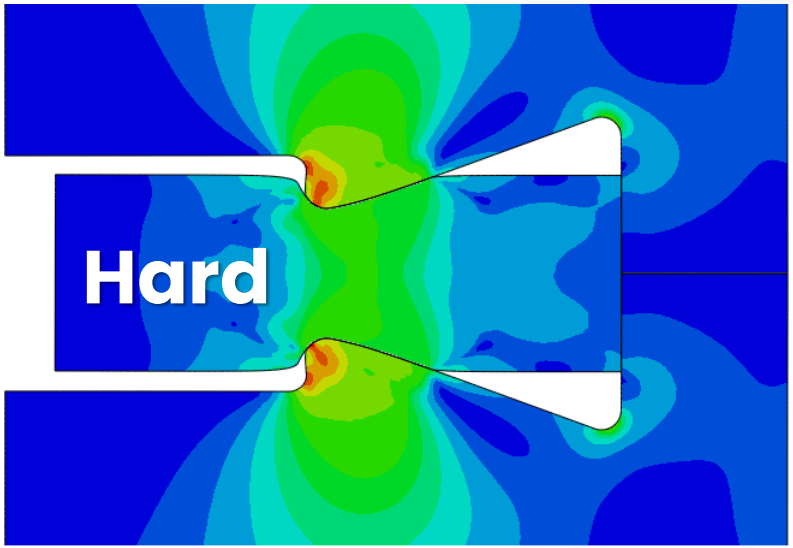
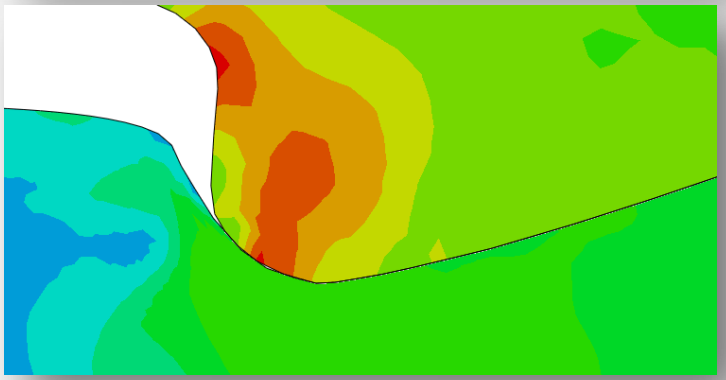
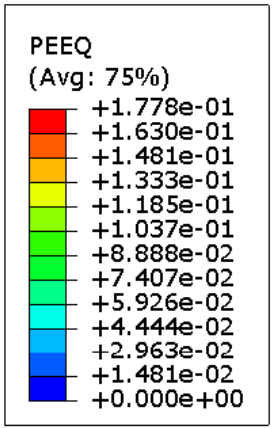
+1.117e+02
+5.587e+01
+3.506e-02


Hard



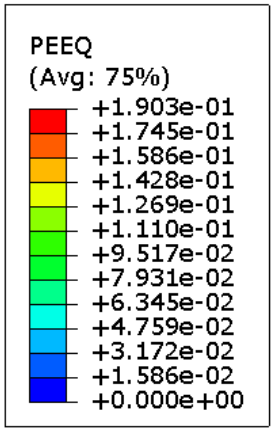
707022



$$\sigma_i^{max} = 655,1\ MPa$$

$$\varepsilon_i^{max} = 0,1778$$

$$\delta = 32,28°$$

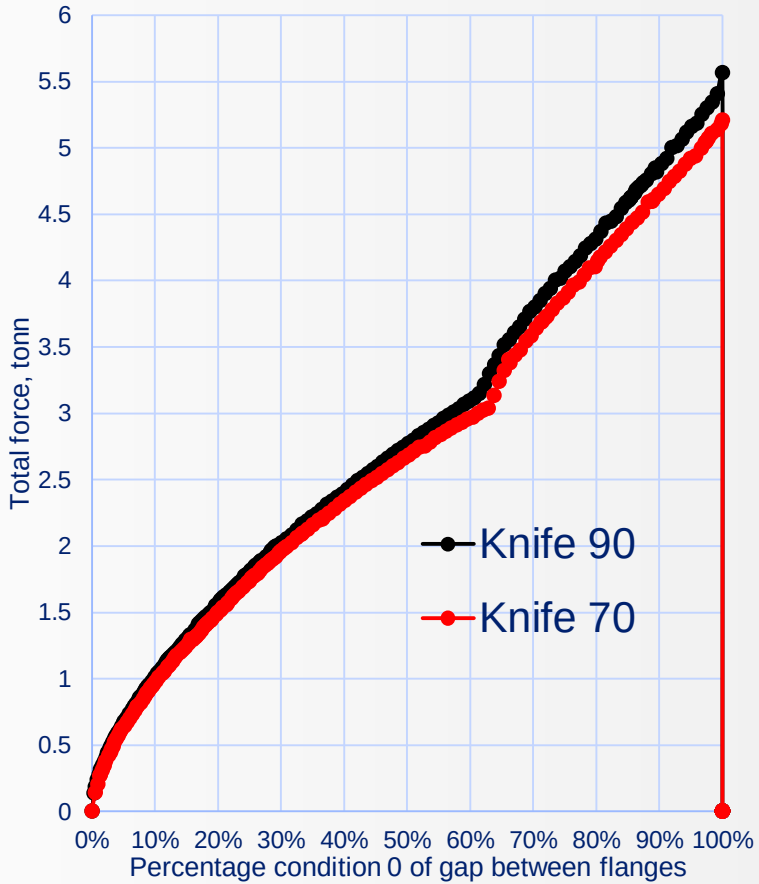


$$\sigma_i^{max} = 670\ MPa$$

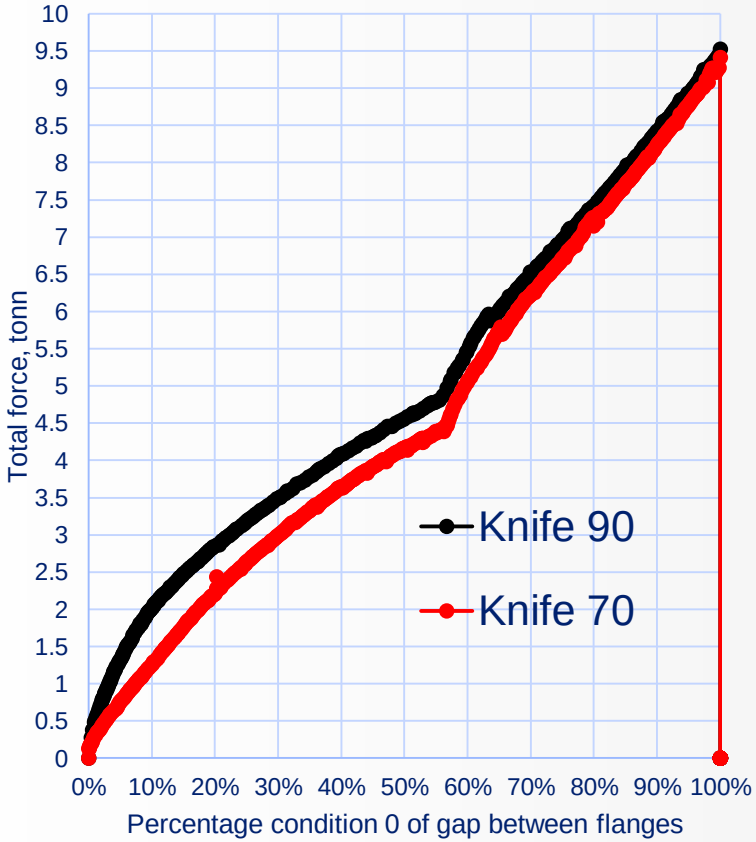
$$\varepsilon_i^{max} = 0,1903$$

$$\delta = 32,46°$$

Analysis for Soft Gaskets



Analysis for Hard Gaskets



Bolts Minor Diameter Calculation

$$F \leq i\frac{\pi d_1^2}{4}[\sigma]$$

$$F \leq i\frac{\pi d_1^2}{4}\sigma_{Yield}$$

$$d_{1_{min}} = \sqrt{\frac{4F}{i\pi\sigma_{Yield}}};\ i = 6$$

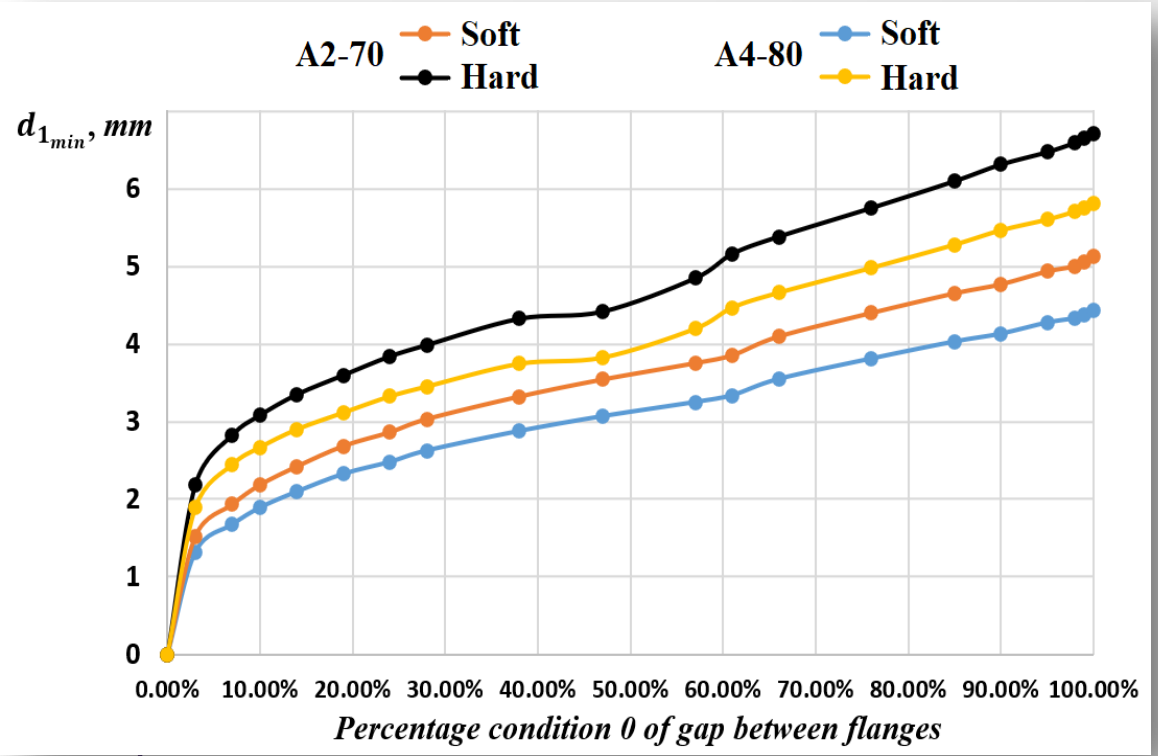
$$A2 - 70\ grade\ -\ \sigma_{Yield} = 450[N/mm^2]$$

$$A4 - 80\ grade\ -\ \sigma_{Yield} = 600[N/mm^2]$$

Bolts Minor Diameter Calculation for Knife 90

Bolts should satisfy this condition

$$d_1 \geq d_{1_{min}}$$



$A2-70\ grade$

d_1^{M6} $d_{1_{min}}$

$4{,}773[mm] \not\geq 5{,}123[mm]$

$4{,}773[mm] \not\geq 6{,}704[mm]$

$A4-80\ grade$

d_1^{M6} $d_{1_{min}}$

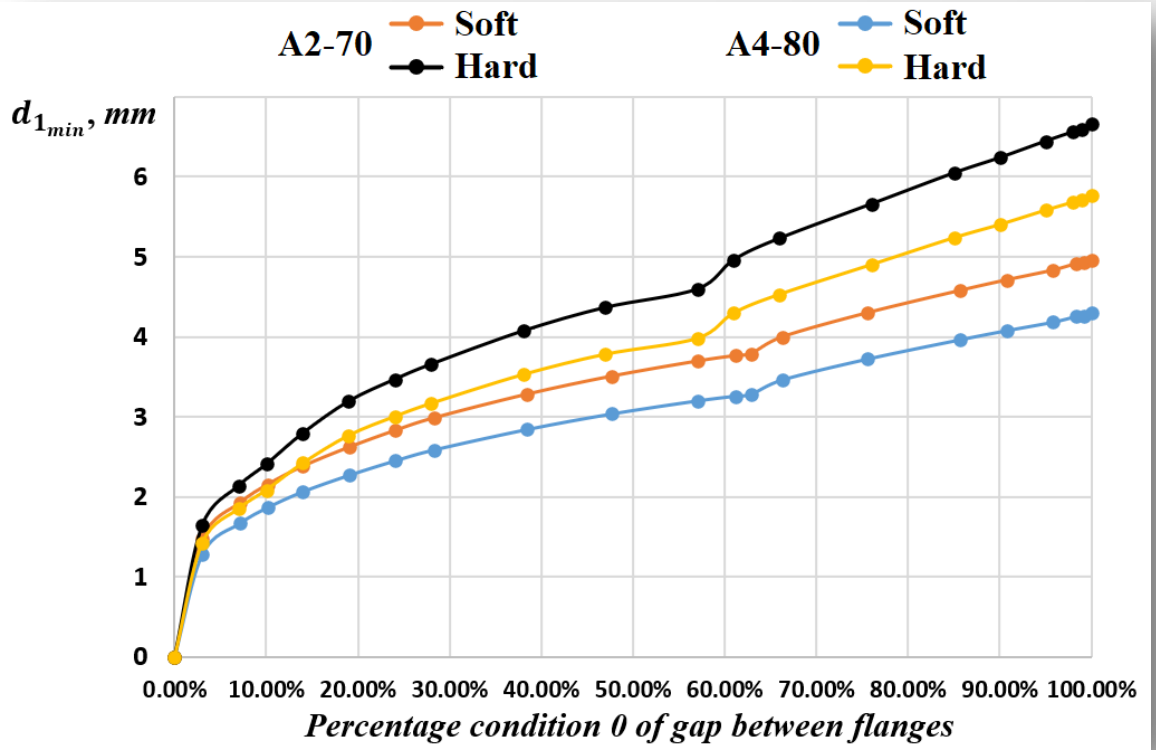
$4{,}773[mm] \geq 4{,}437[mm]$

$4{,}773[mm] \not\geq 5{,}806[mm]$

Bolts Minor Diameter Calculation for Knife 70

Bolts should satisfy this condition

$$d_1 \geq d_{1_{min}}$$



$$A2 - 70\ grade$$

d_1^{M6} $d_{1_{min}}$

$$4{,}773[mm] \not\geq 4{,}958[mm]$$

$$4{,}773[mm] \not\geq 6{,}664[mm]$$

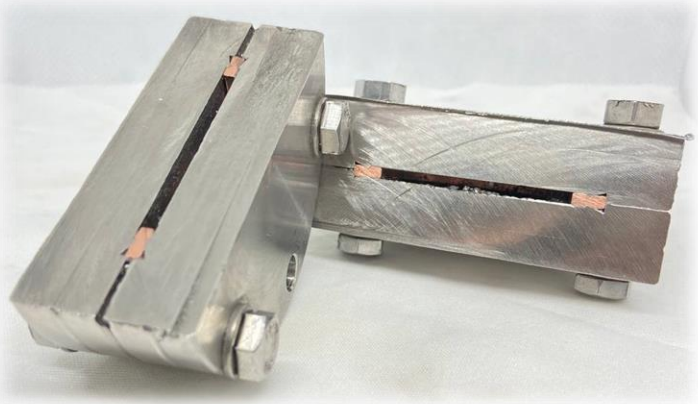
$$A4 - 80\ grade$$

d_1^{M6} $d_{1_{min}}$

$$4{,}773[mm] \geq 4{,}293[mm]$$

$$4{,}773[mm] \not\geq 5{,}771[mm]$$

Future Activities




THANK YOU!