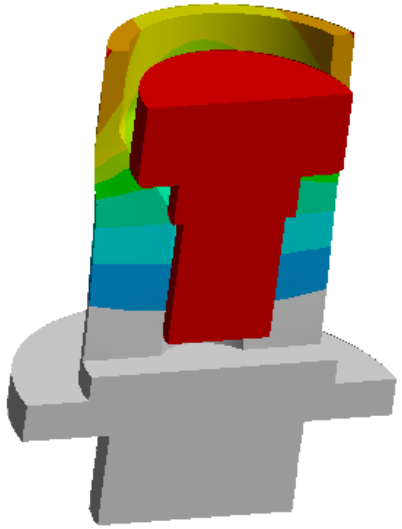
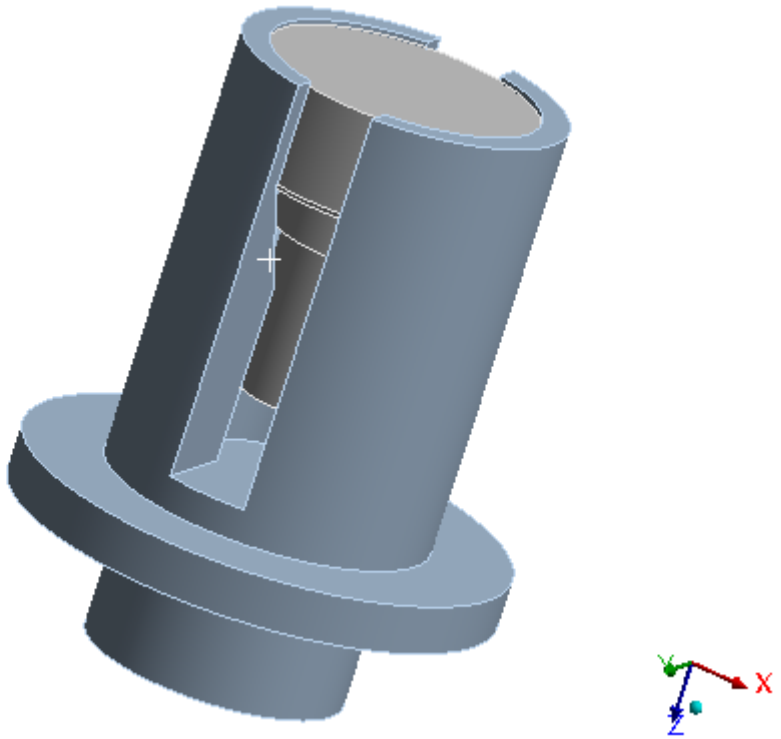


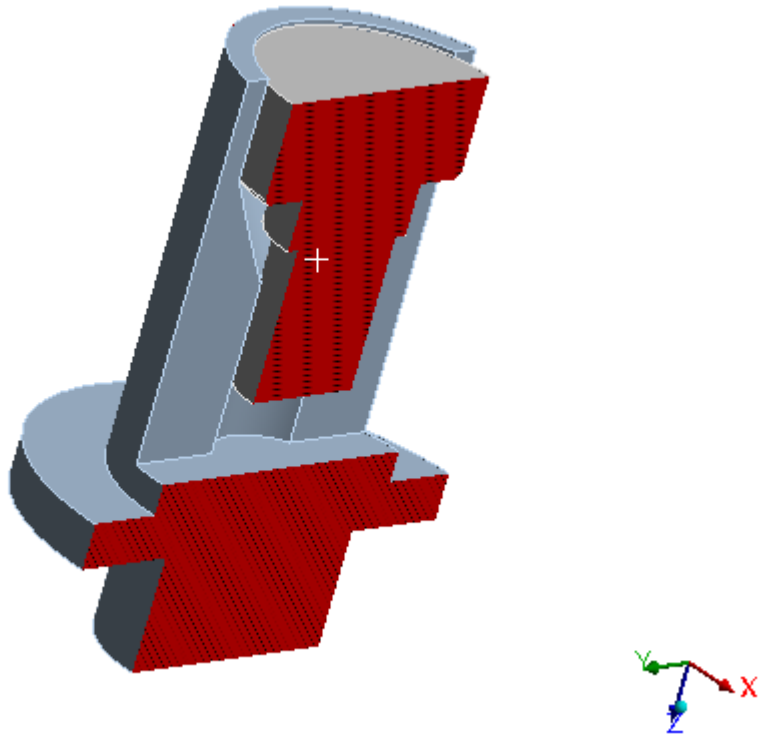
Ansys Workbench 大型塑性变形及螺栓预紧力施加 CAE

开口销：在螺栓预紧力作用下膨胀

Geometry

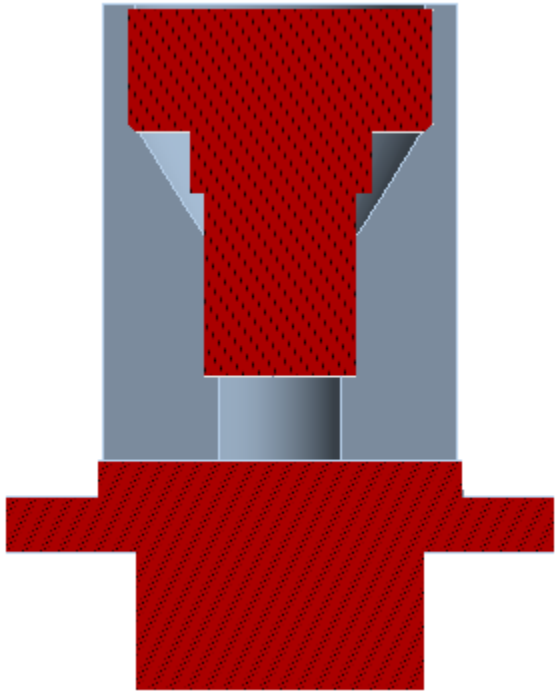


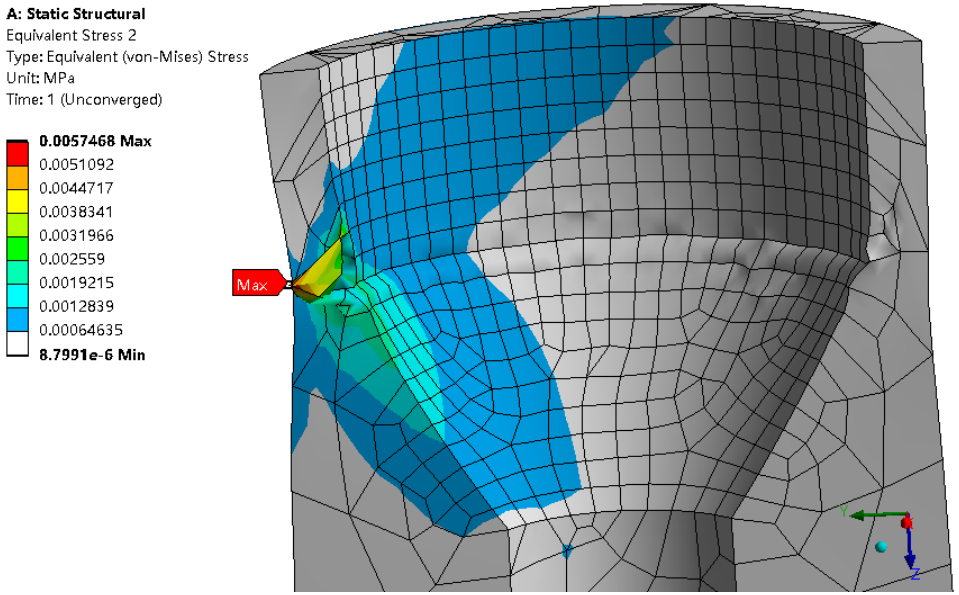
Geometry



大型塑性变形CAE分析的难点

- 材料塑性变形太大，导致网格扭矩，出现错误，从而计算终止
- 网格重划分，会遇到各种问题
- 施加螺栓预紧力载荷，导致接触脱离

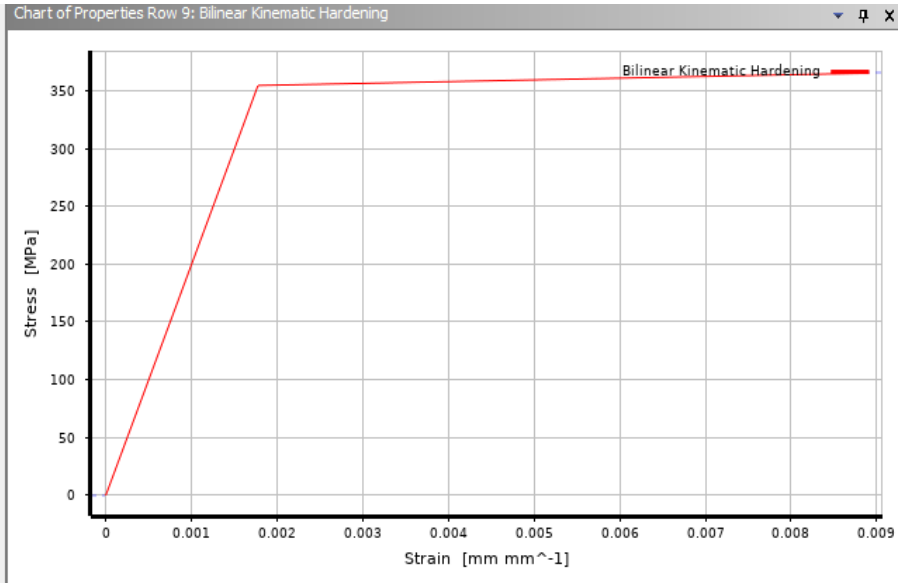




材料：双线性 vs. 多线性

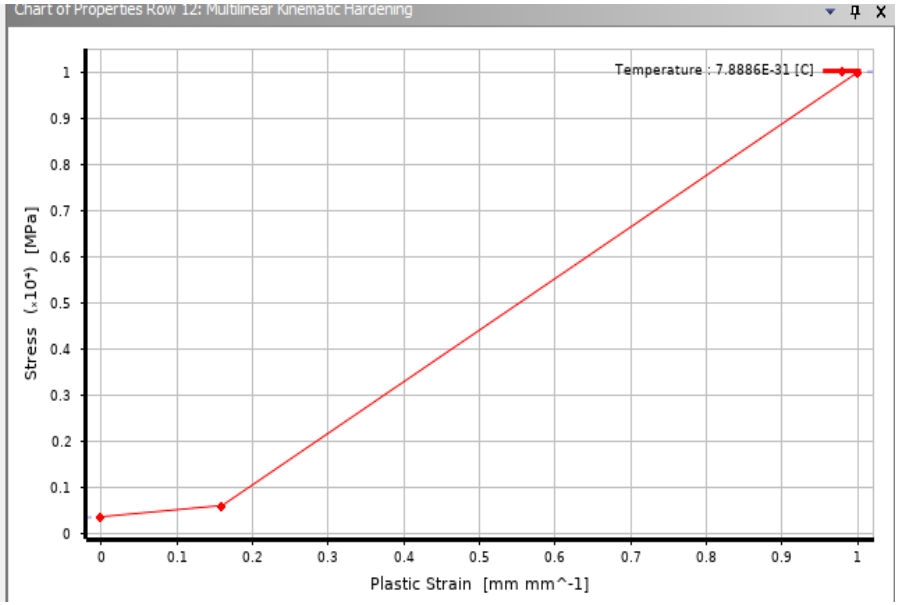
Properties of Outline Row 3: 45

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Isotropic Elasticity				
4	Derive from	Young's Modulus and Poisson...			
5	Young's Modulus	2E+05	MPa		
6	Poisson's Ratio	0.3			
7	Bulk Modulus	1.6667E+05	MPa		
8	Shear Modulus	76923	MPa		
9	~~Bilinear Kinematic Hardening~~				
10	Yield Strength	355	MPa		
11	Tangent Modulus	1500	MPa		
12	Multilinear Kinematic Hardening	Tabular			



Properties of Outline Row 3: 45

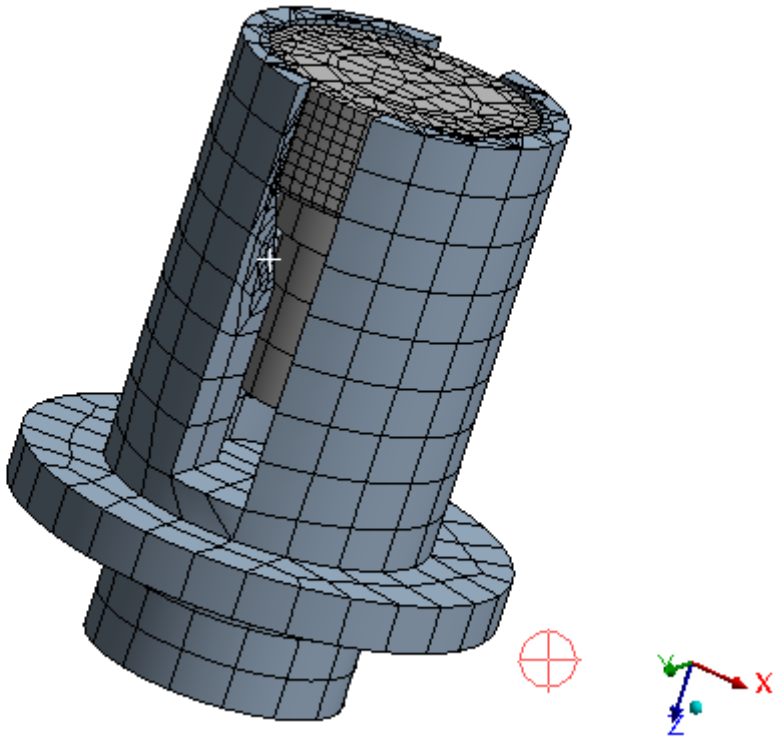
	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Isotropic Elasticity				
4	Derive from	Young's Modulus and Poisson...			
5	Young's Modulus	2E+05	MPa		
6	Poisson's Ratio	0.3			
7	Bulk Modulus	1.6667E+05	MPa		
8	Shear Modulus	76923	MPa		
9	~~Bilinear Kinematic Hardening~~				
10	Yield Strength	355	MPa		
11	Tangent Modulus	1500	MPa		
12	Multilinear Kinematic Hardening	Tabular			
13	Scale	1			
14	Offset	0	MPa		

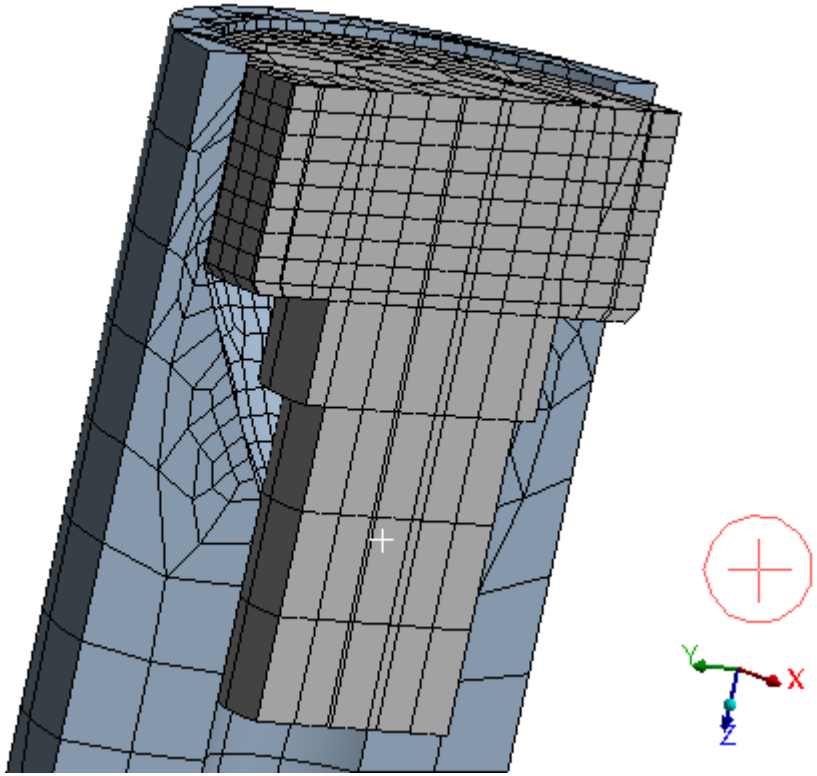


材料：45#
屈服强度：355 MPa
抗拉强度：600 MPa
断裂伸长率：0.16

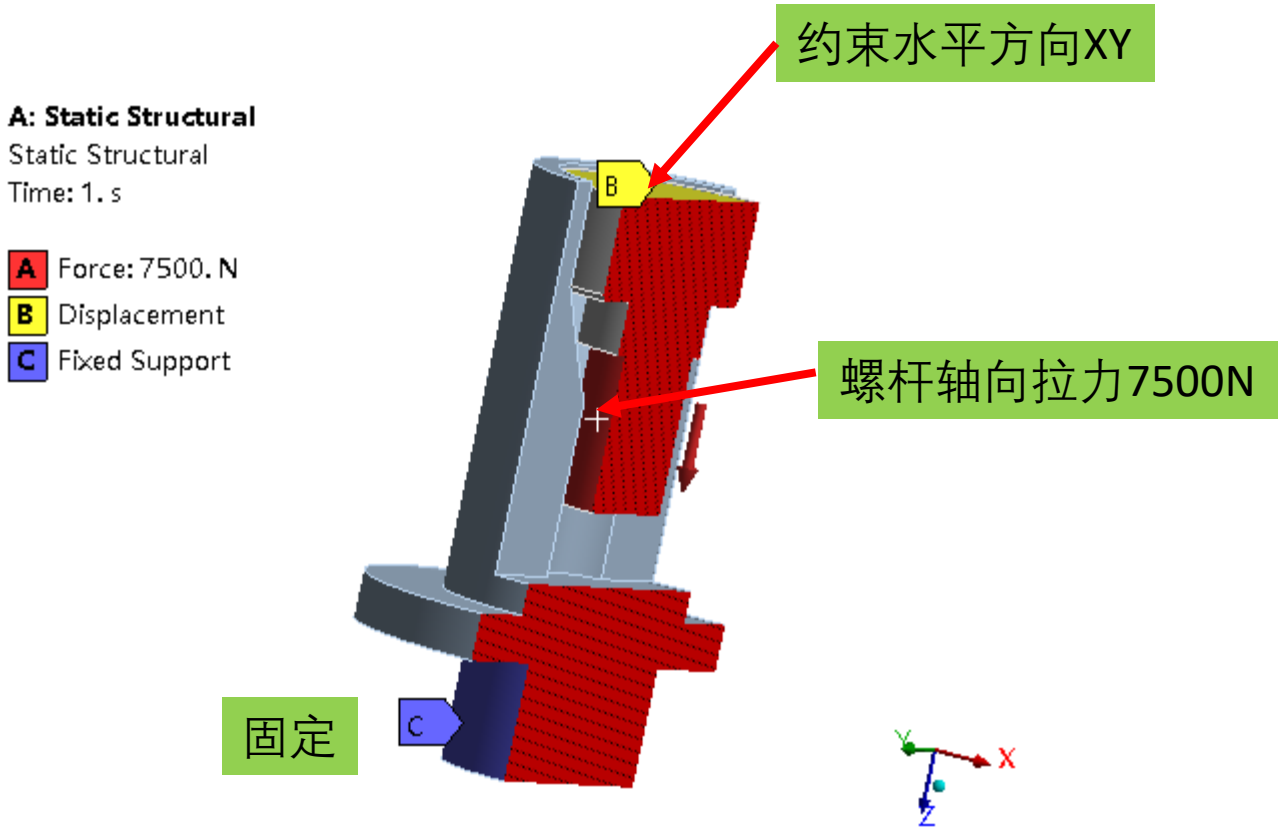
Plastic Strain (mm mm^-1)	Stress (MPa)
0	355
0.16	600
1	10000

网格



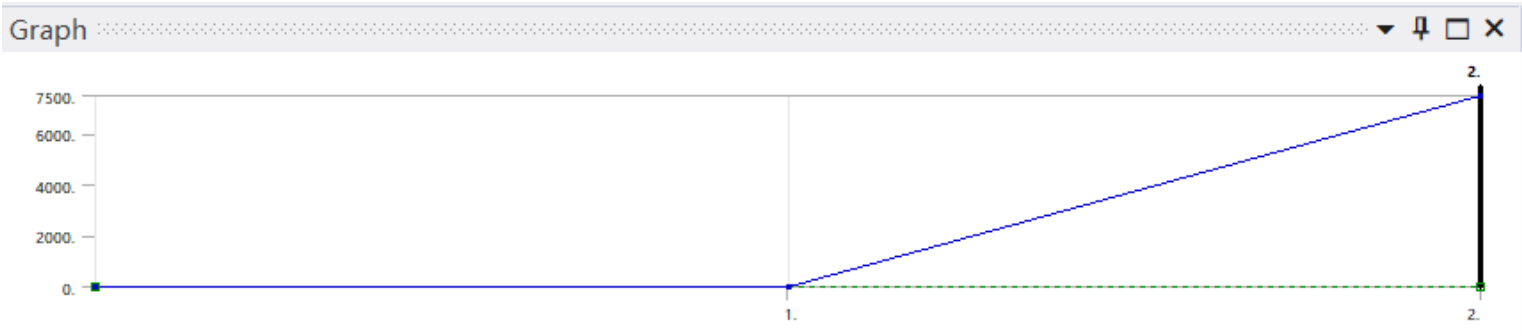


边界条件


A: Static Structural
Static Structural
Time: 1. s
A Force: 7500. N
B Displacement
C Fixed Support
约束水平方向XY
螺杆轴向拉力7500N
固定
B
C
Y
X
Z

载荷为力的非线性接触，收敛困难及对策

- 软弹簧：0.1 N/mm
- 多载荷子步： nsub,1000,1500,50
- 两个载荷步：
  - 第一步加到10N， nsub,100,1000,20
  - 第二步加到7500N， nsub,50,1000,50

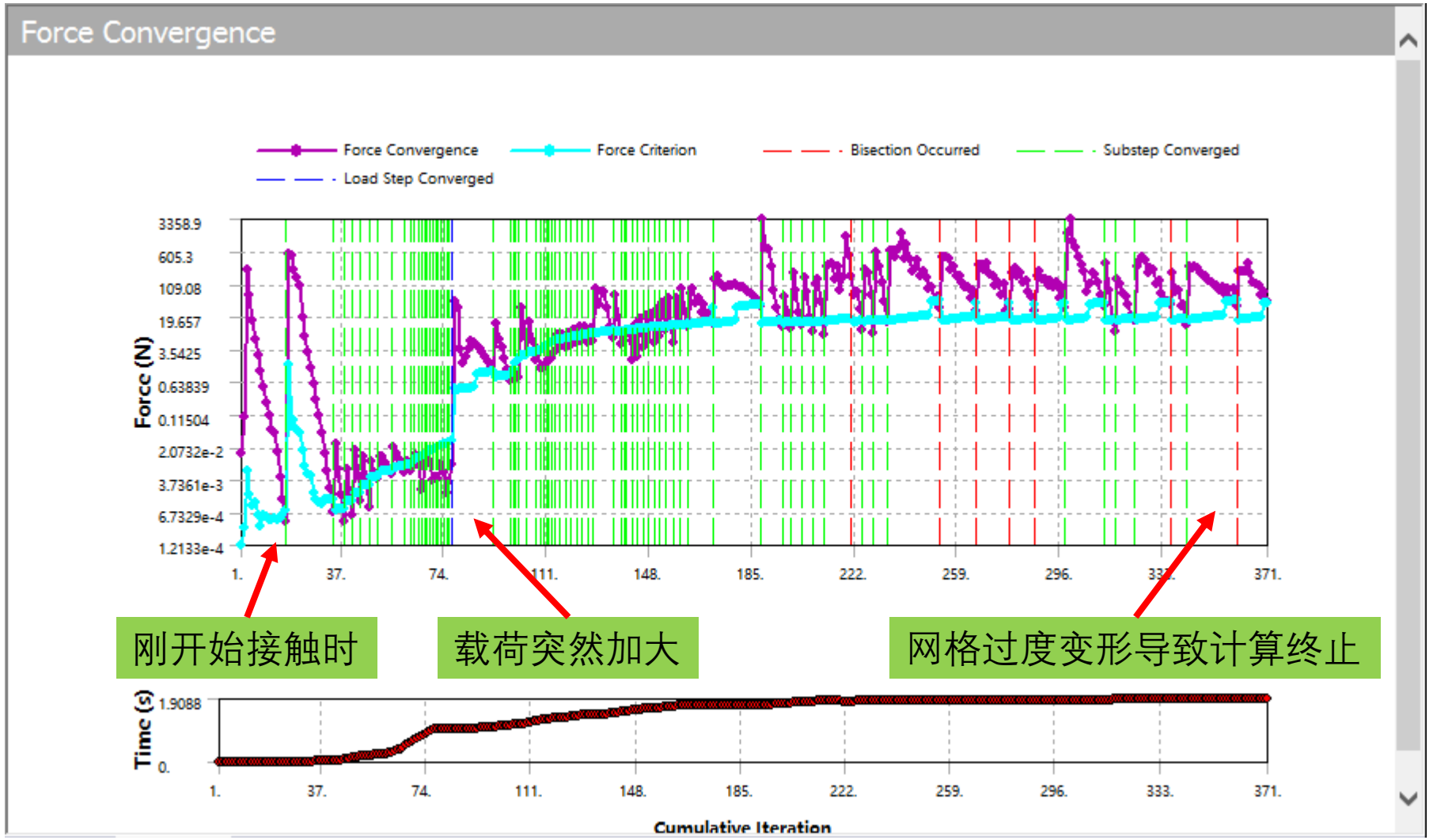


Tabular Data

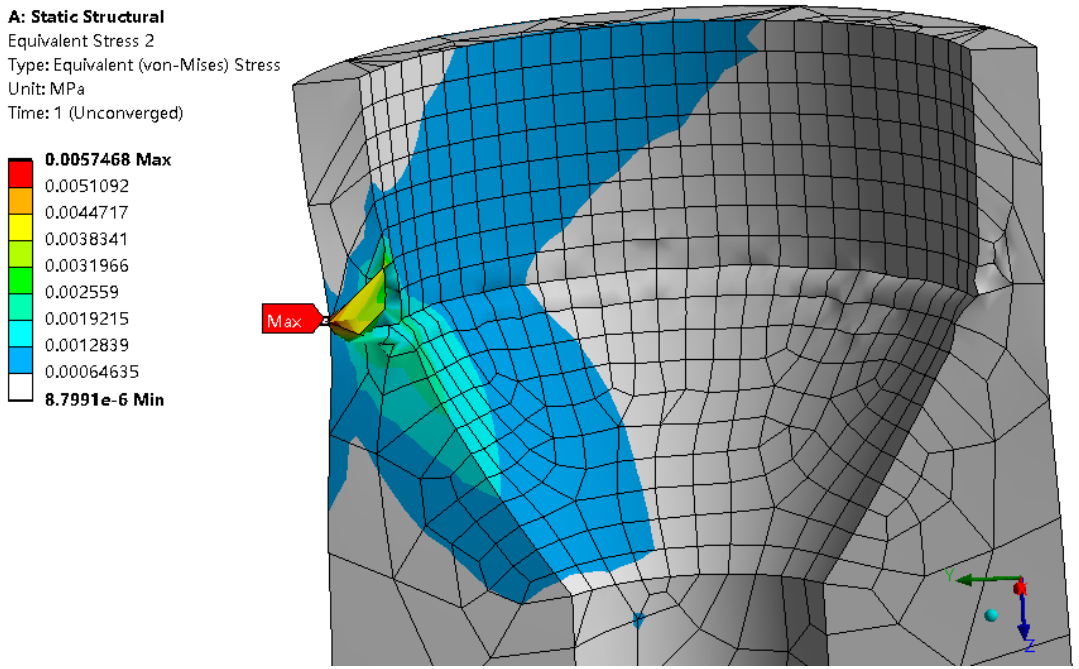
	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	= 0.	= 0.	0.
2	1	1.	0.	0.	10.
3	2	2.	= 0.	= 0.	7500.
*					

- 更改非线性求解设置：牛顿-拉普森选项, Line search, 更改收敛准则
- 查看牛顿-拉普森残差

收敛曲线


Force Convergence
Force Convergence
Force Criterion
Bisection Occurred
Substep Converged
Load Step Converged
Force (N)
3358.9
605.3
109.08
19.657
3.5425
0.63839
0.11504
2.0732e-2
3.7361e-3
6.7329e-4
1.2133e-4
1.
37.
74.
111.
148.
185.
222.
259.
296.
333.
371.
刚开始接触时
载荷突然加大
网格过度变形导致计算终止
Time (s)
1.9088
0.
Cumulative Iteration

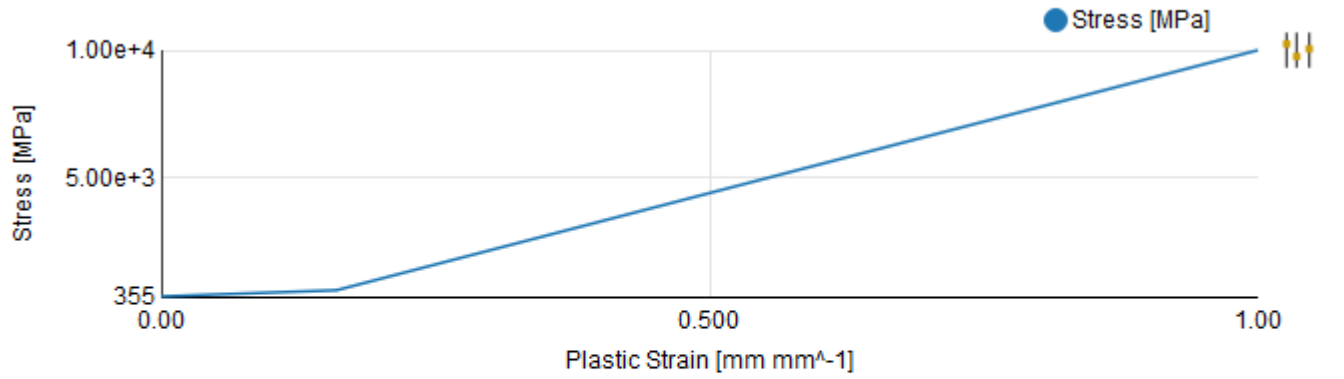
网格过度变形



- *** ERROR *** CP = 14216.734 TIME= 02:23:40
  Element 33788 (type = 4, SOLID186) (and maybe other elements) has
  become highly distorted. Excessive distortion of elements is usually a symptom indicating the need for corrective action elsewhere. Try
  incrementing the load more slowly (increase the number of substeps or
  decrease the time step size). You may need to improve your mesh to
  obtain elements with better aspect ratios. Also consider the behavior
  of materials, contact pairs, and/or constraint equations. Please rule out other root causes of this failure before attempting rezoning or nonlinear adaptive solutions. If this message appears in the first iteration of first substep, be sure to perform element shape checking.

改为多线性材料特性

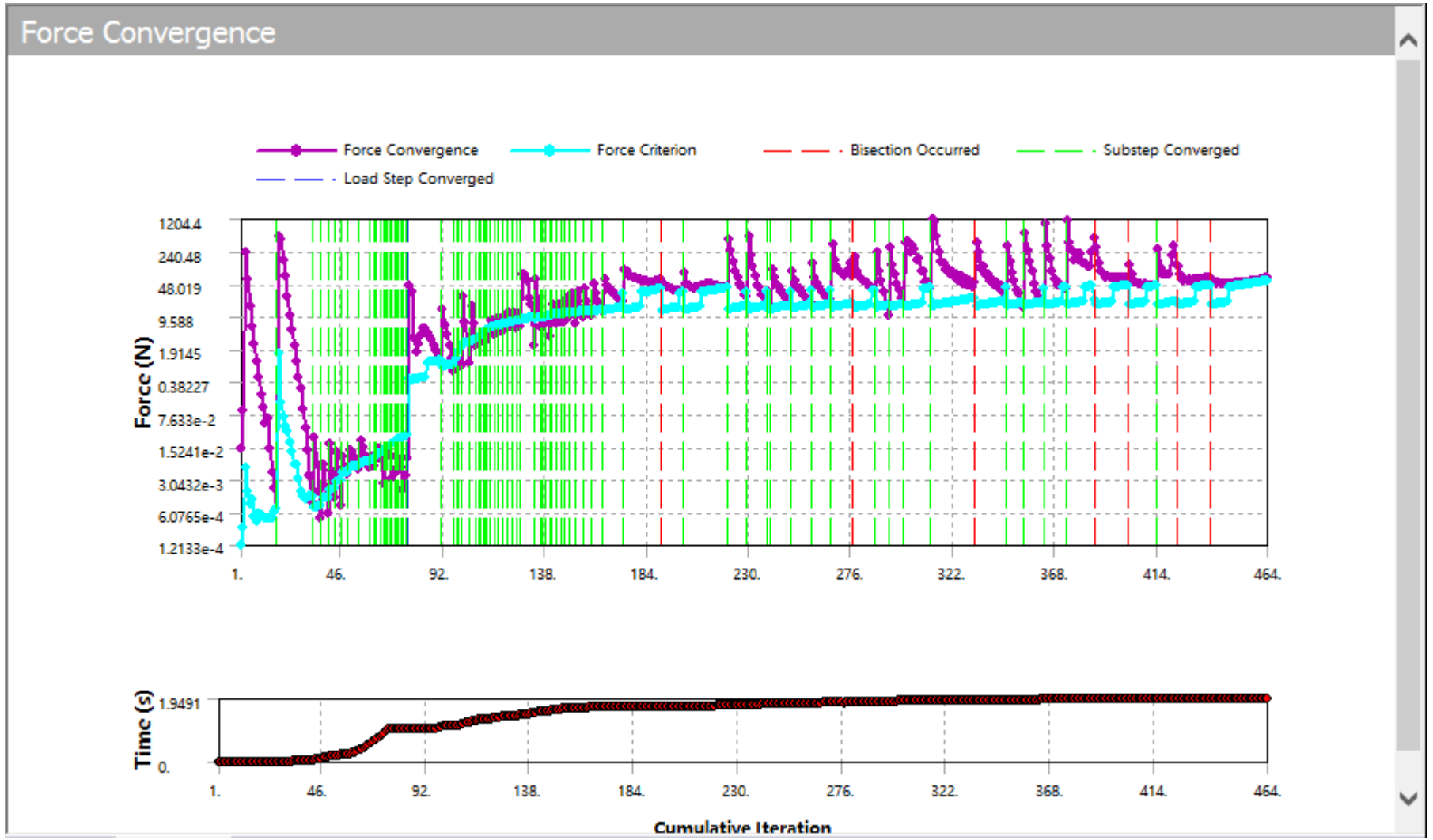
45: Kinematic Hardening



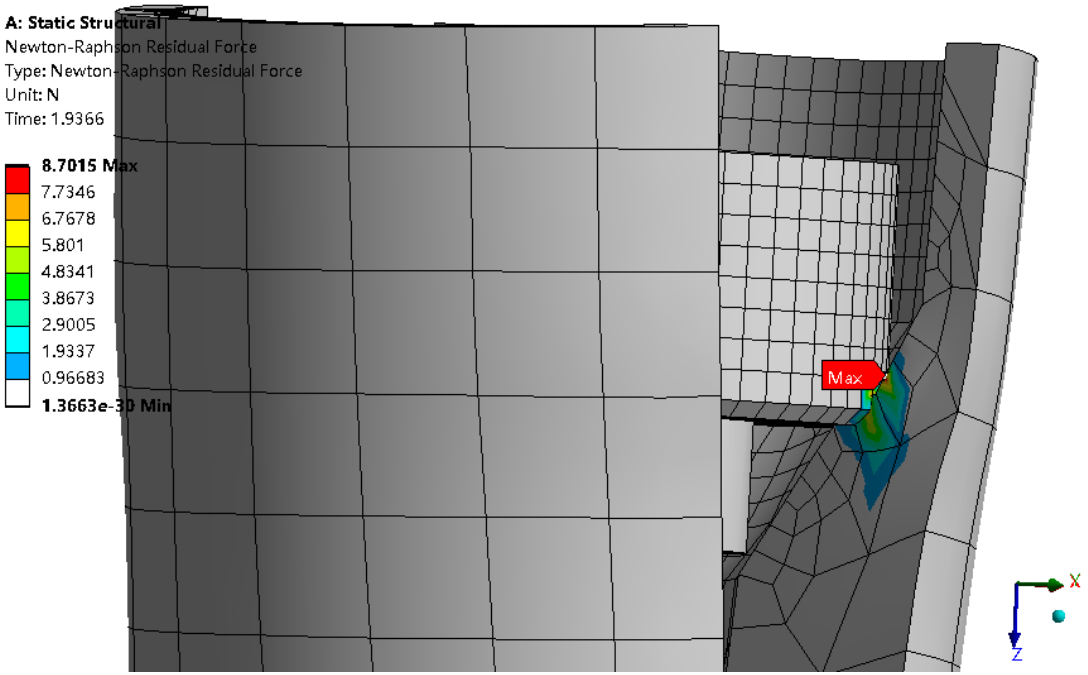
Temperature [°C]	Plastic Strain [Mm/M..]	Stress [M Pa]
0	0	355
	0.16	600
	1	10000

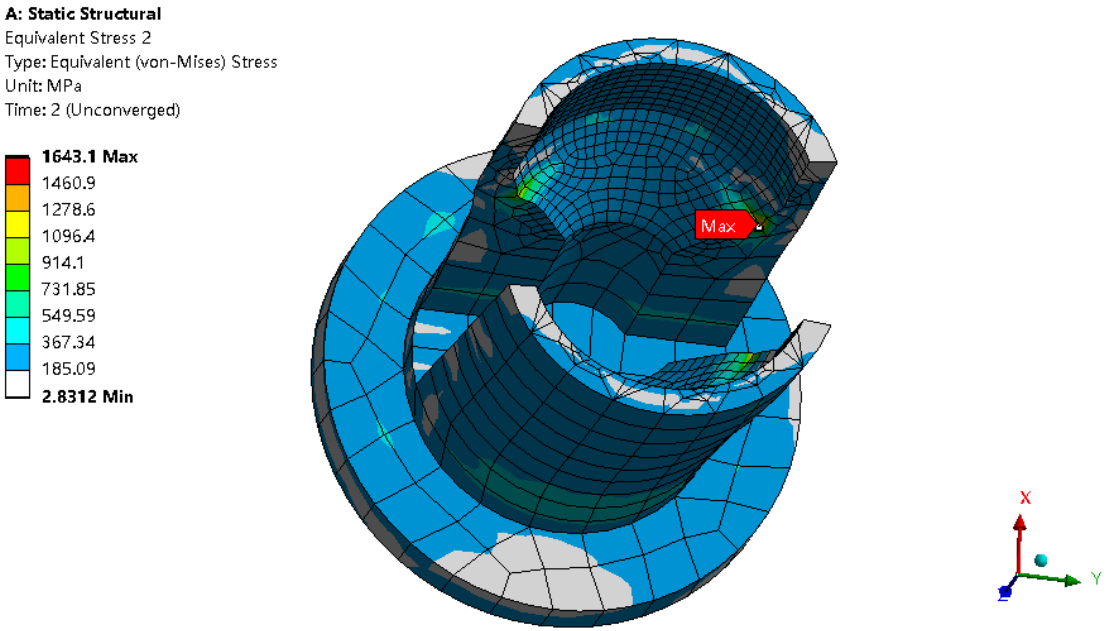
材料硬化：过了抗拉强度以后，进行硬化，减小变形导致网格扭曲

更改材料后


Force Convergence
Force Convergence
Force Criterion
Bisection Occurred
Substep Converged
Load Step Converged
Force (N)
1204.4
240.48
48.019
9.588
1.9145
0.38227
7.633e-2
1.5241e-2
3.0432e-3
6.0765e-4
1.2133e-4
1.
46.
92.
138.
184.
230.
276.
322.
368.
414.
464.
Time (s)
1.9491
0.
Cumulative Iteration

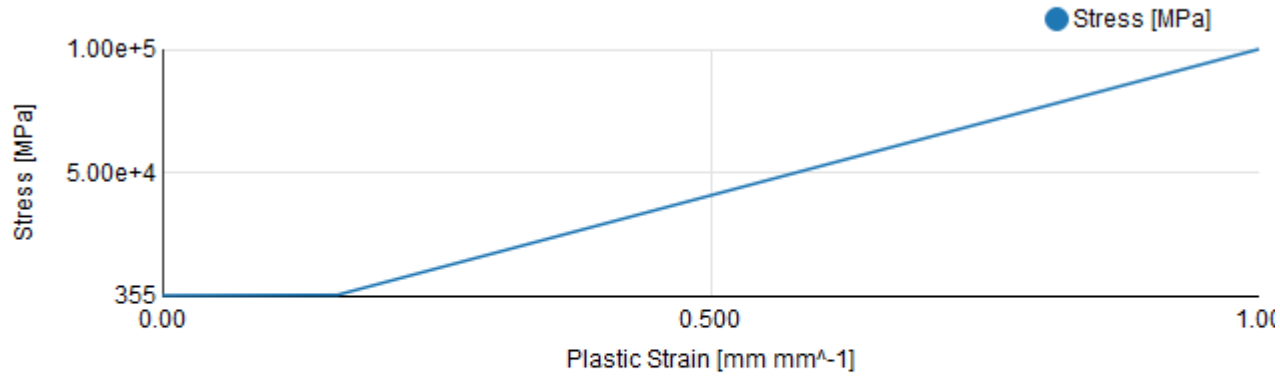
残差及应力


A: Static Structural
Newton-Raphson Residual Force
Type: Newton-Raphson Residual Force
Unit: N
Time: 1.9366
8.7015 Max
7.7346
6.7678
5.801
4.8341
3.8673
2.9005
1.9337
0.96683
1.3663e-30 Min
Max
X
Z


A: Static Structural
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 2 (Unconverged)
1643.1 Max
1460.9
1278.6
1096.4
914.1
731.85
549.59
367.34
185.09
2.8312 Min
Max
X
Y
Z

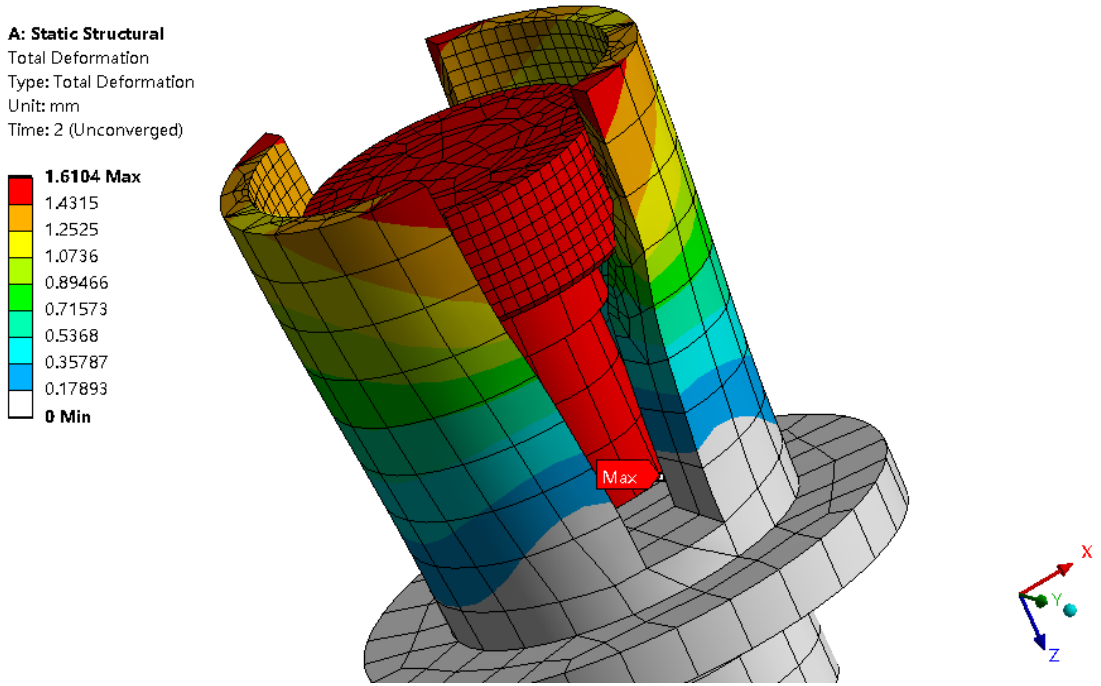
进一步硬化

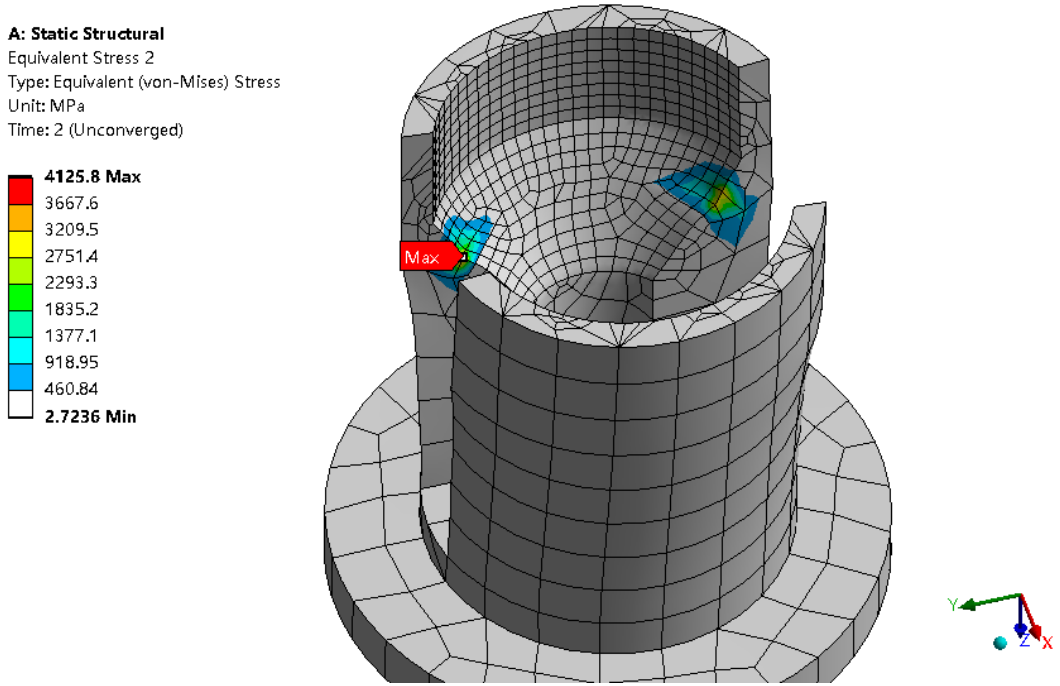
45: Kinematic Hardening



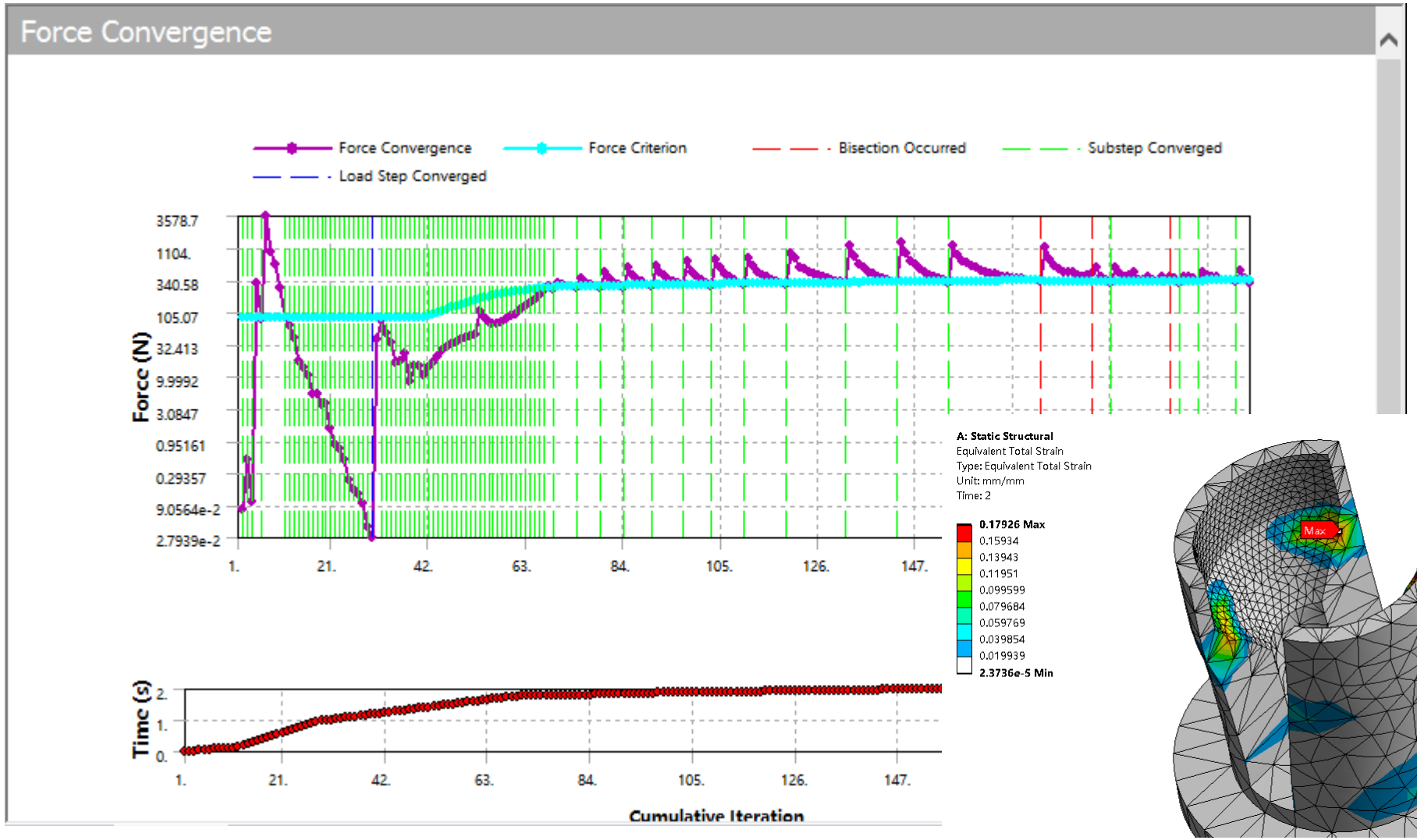
Temperature [°C]	Plastic Strain [Mm/M..]	Stress [M Pa]
0	0	355
	0.16	600
	1	1e+05

变形与应力

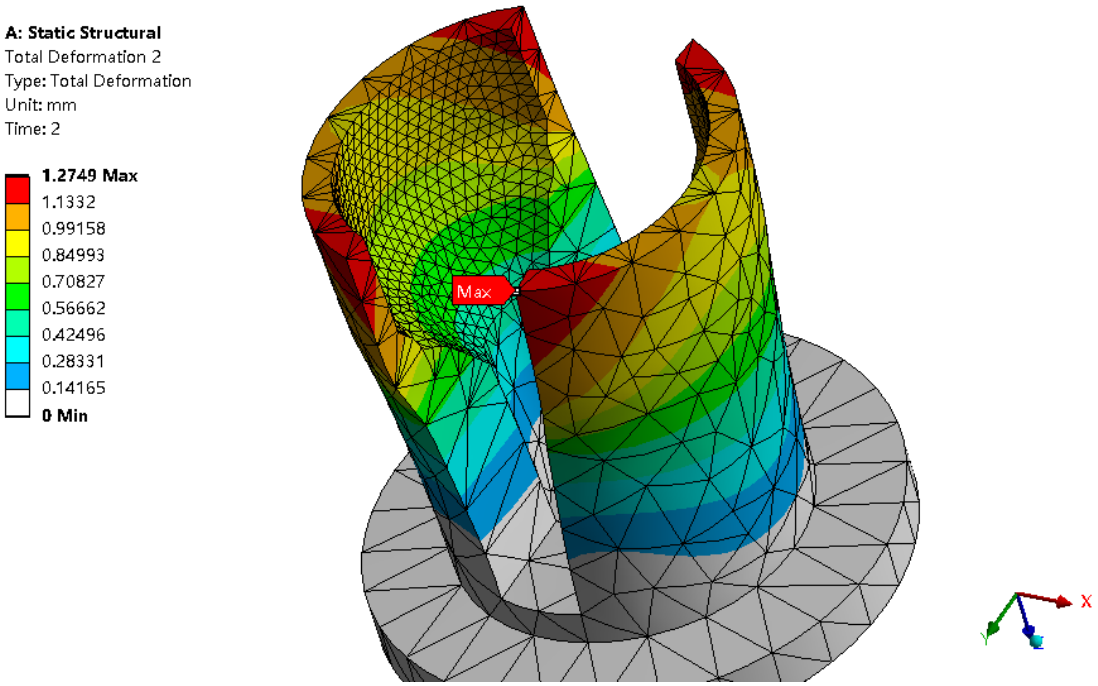

A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 2 (Unconverged)
1.6104 Max
1.4315
1.2525
1.0736
0.89466
0.71573
0.5368
0.35787
0.17893
0 Min
Max
X
Y
Z

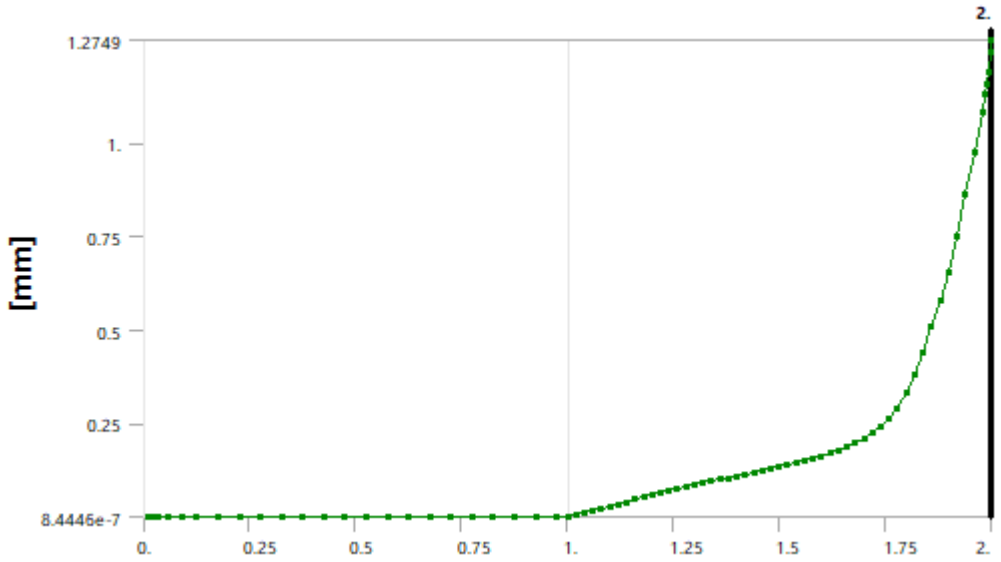

A: Static Structural
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 2 (Unconverged)
4125.8 Max
3667.6
3209.5
2751.4
2293.3
1835.2
1377.1
918.95
460.84
2.7236 Min
Max
Y
Z
X

调整网格后的收敛曲线


Force Convergence
Force Convergence
Force Criterion
Bisection Occurred
Substep Converged
Load Step Converged
Force (N)
3578.7
1104.
340.58
105.07
32.413
9.9992
3.0847
0.95161
0.29357
9.0564e-2
2.7939e-2
1.
21.
42.
63.
84.
105.
126.
147.
Time (s)
2.
1.
0.
Cumulative Iteration
A: Static Structural
Equivalent Total Strain
Type: Equivalent Total Strain
Unit: mm/mm
Time: 2
0.17926 Max
0.15934
0.13943
0.11951
0.099599
0.079684
0.059769
0.039854
0.019939
2.3736e-5 Min
Max
Y
X
Z

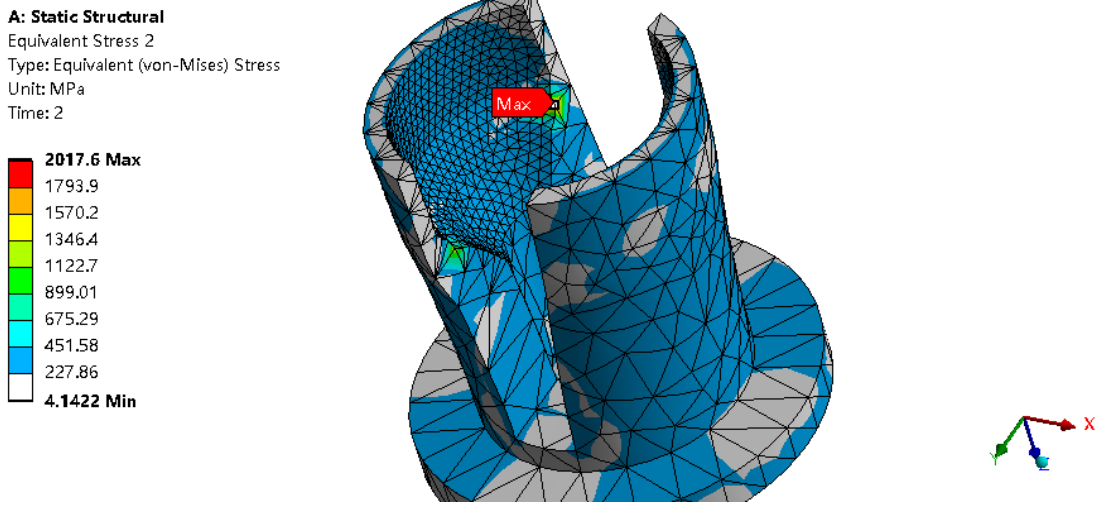
变形与变形曲线

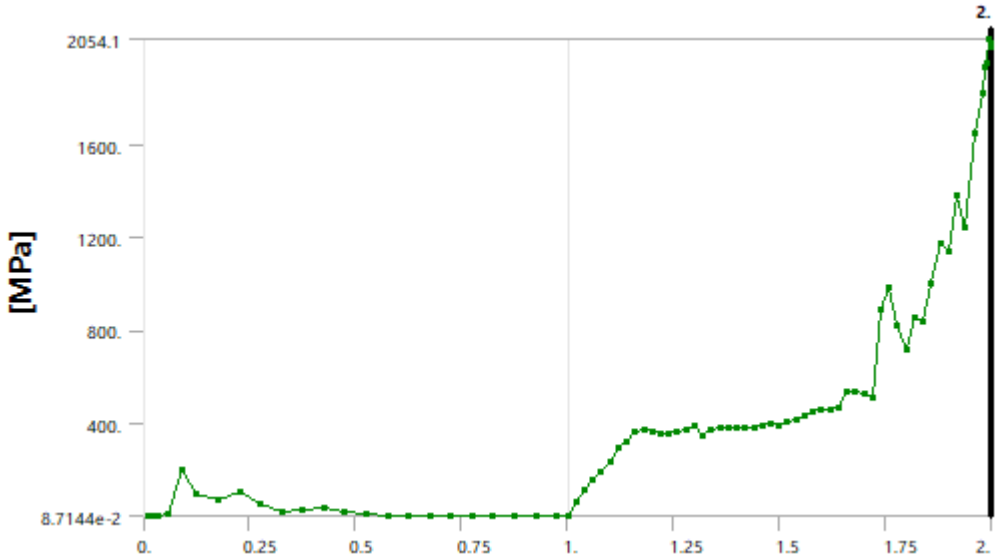




结构有失稳趋势

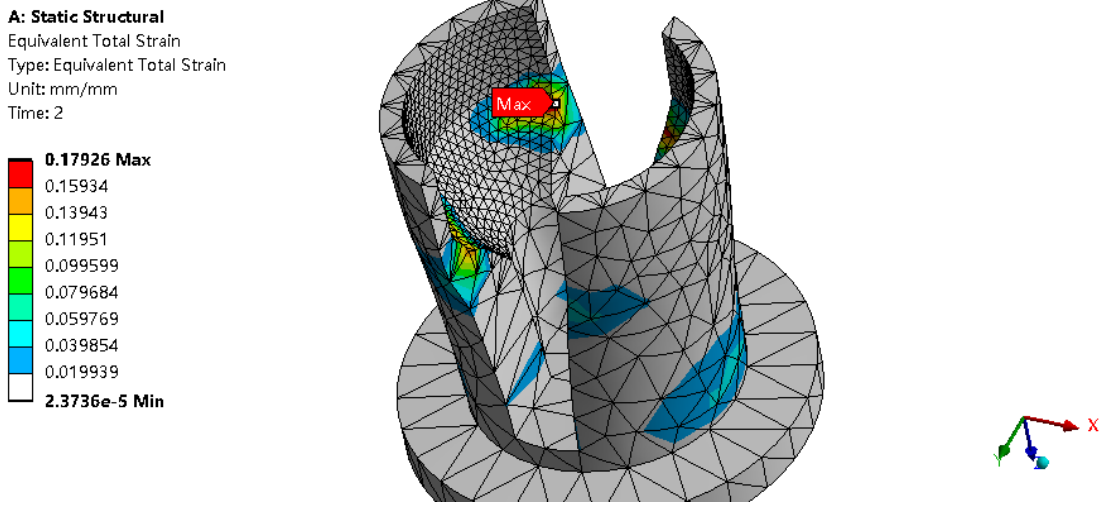
应力与应力曲线

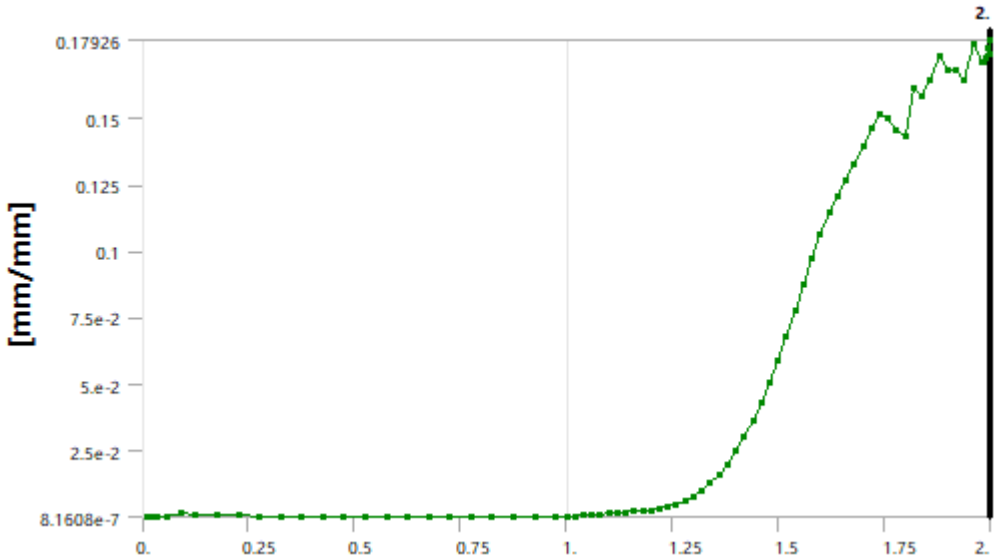

A: Static Structural
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 2
2017.6 Max
1793.9
1570.2
1346.4
1122.7
899.01
675.29
451.58
227.86
4.1422 Min
Max
X


2.
2054.1
1600.
1200.
800.
400.
8.7144e-2
[MPa]
0.
0.25
0.5
0.75
1.
1.25
1.5
1.75
2.

硬化

应变与应变曲线


A: Static Structural
Equivalent Total Strain
Type: Equivalent Total Strain
Unit: mm/mm
Time: 2
0.17926 Max
0.15934
0.13943
0.11951
0.099599
0.079684
0.059769
0.039854
0.019939
2.3736e-5 Min
Max
X


2.
0.17926
0.15
0.125
0.1
7.5e-2
5.e-2
2.5e-2
8.1608e-7
[mm/mm]
0.
0.25
0.5
0.75
1.
1.25
1.5
1.75
2.

总结

- 应用 Ansys Workbench 进行金属大型塑性变形分析 large plastic deformation，讲述了螺栓预紧力的施加 bolt preload，多载荷步。如何解决单元过度扭曲。非线性接触设置，多线性塑性材料特性的设置等。可应用于金属冲压成型，橡胶塑料材料的大型应变分析。

- 基于作者的经验以及认知水平，仅供参考。如果与您产品的CAE分析方法有所不同，请以试验为准！

- 培训或项目开发需要请与我司联系。