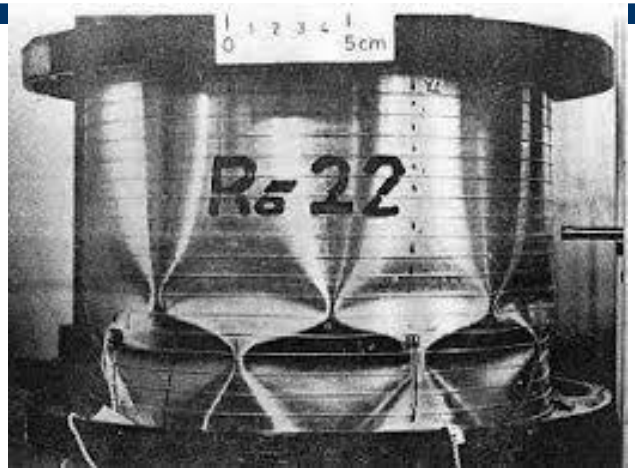
POLITECNICO DI MILANO

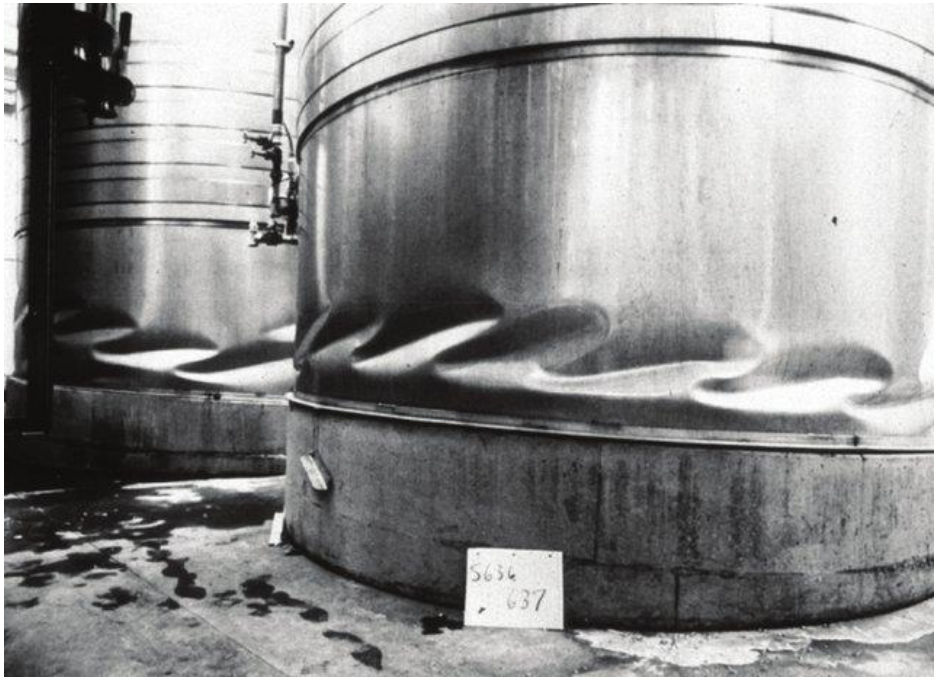
Finite Element Simulation For Mechanical Design

Buckling of thin cylindrical shells

Prof. A. Bernasconi, Dr. L. M. Martulli

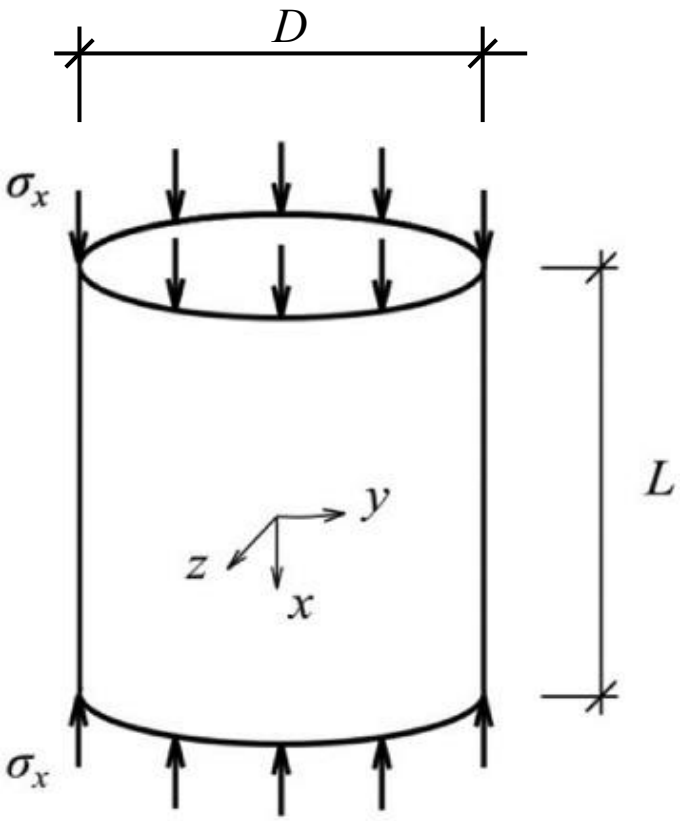
Introduction





This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

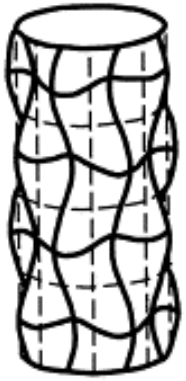
Introduction



Complex phenomenon involving:

- Bifurcation of equilibrium

Global instability

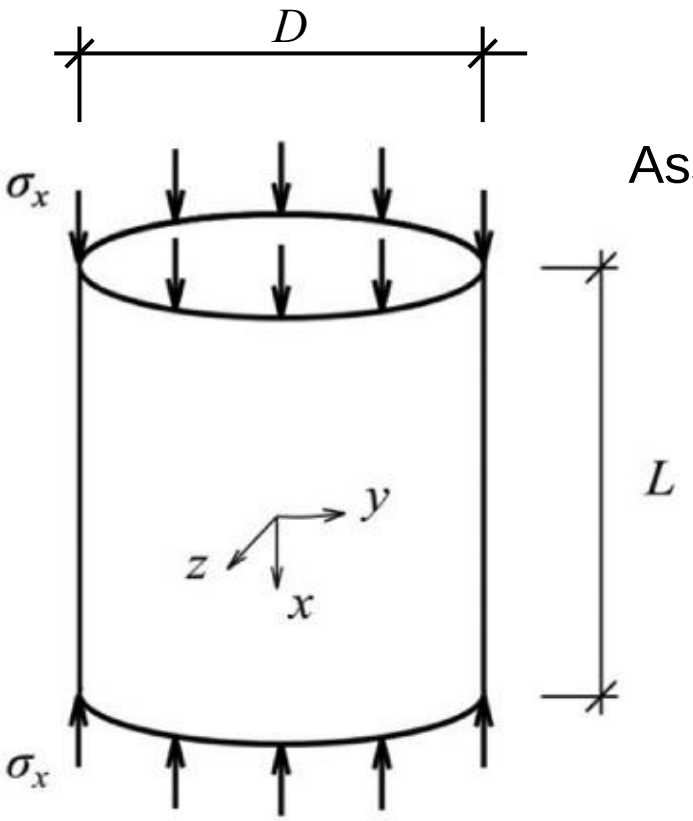


Local instability

- Plasticity (for metals)

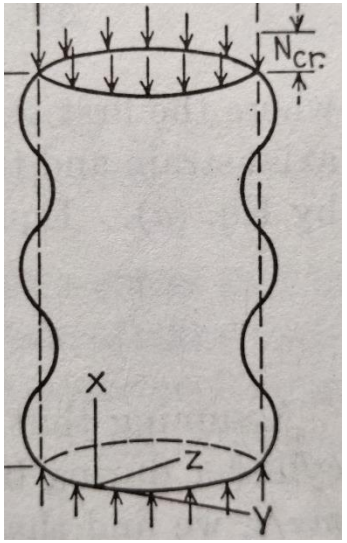
This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Introduction



Assumption: $w = -A \sin\left(\frac{m\pi x}{L}\right)$

(axis-symmetric deformation)



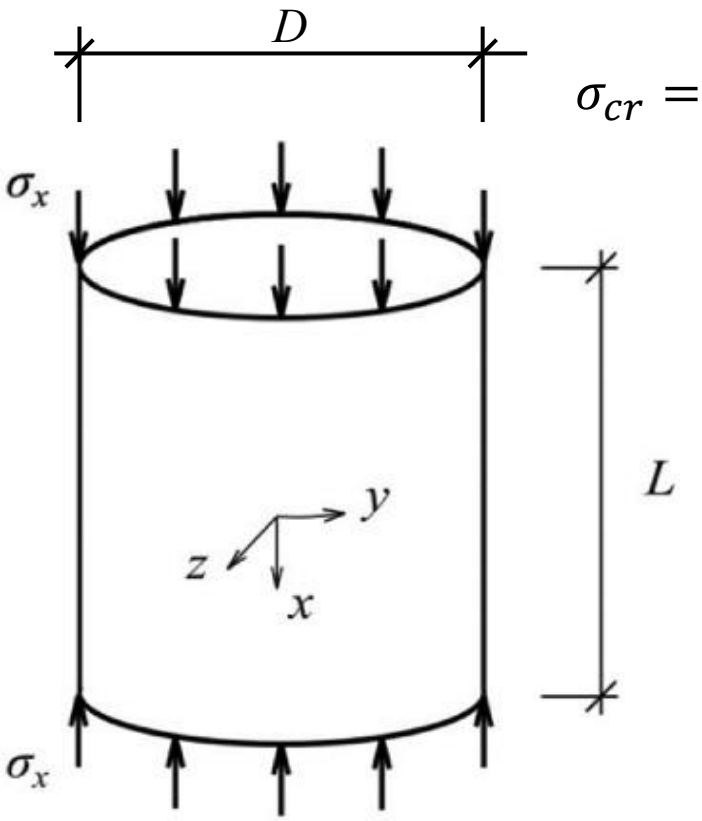
$$\sigma_{cr} = \frac{Et}{r\sqrt{3(1-\nu^2)}}$$

Occurring at:

$$\frac{L}{m} = \pi \sqrt[4]{\frac{r^2 t^2}{12(1-\nu^2)}}$$

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Introduction



$$\sigma_{cr} = \frac{Et}{r\sqrt{3(1-\nu^2)}}$$

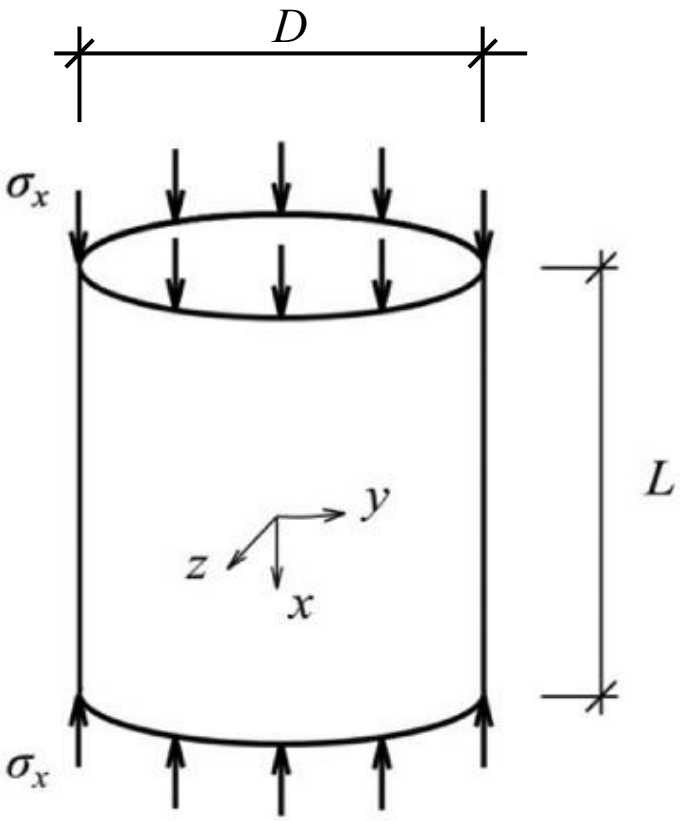
Occurring at:

$$\frac{L}{m} = \pi \sqrt[4]{\frac{r^2 t^2}{12(1-\nu^2)}}$$

	A	B	C	D	E
1	r	250	mm		
2	t	2	mm		
3	E	72000	MPa		
4	nu	0.35			
5	L	500	mm		
6					
7	s_cr	355.0081	MPa		
8					
9	A	3141.593	mm^2	L/m	38.99669
10	**P_cr**	**1115.29**	**kN**	**m**	**12.8216**

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Common settings



D = 500 mm (mid-diameter)

L = 500 mm

t = 2 mm

E = 73100 Mpa (Alu)

ν = 0.35

Plastic

Hardening: Isotropic

☐ Use strain-rate-dependent data

☐ Use temperature-dependent data

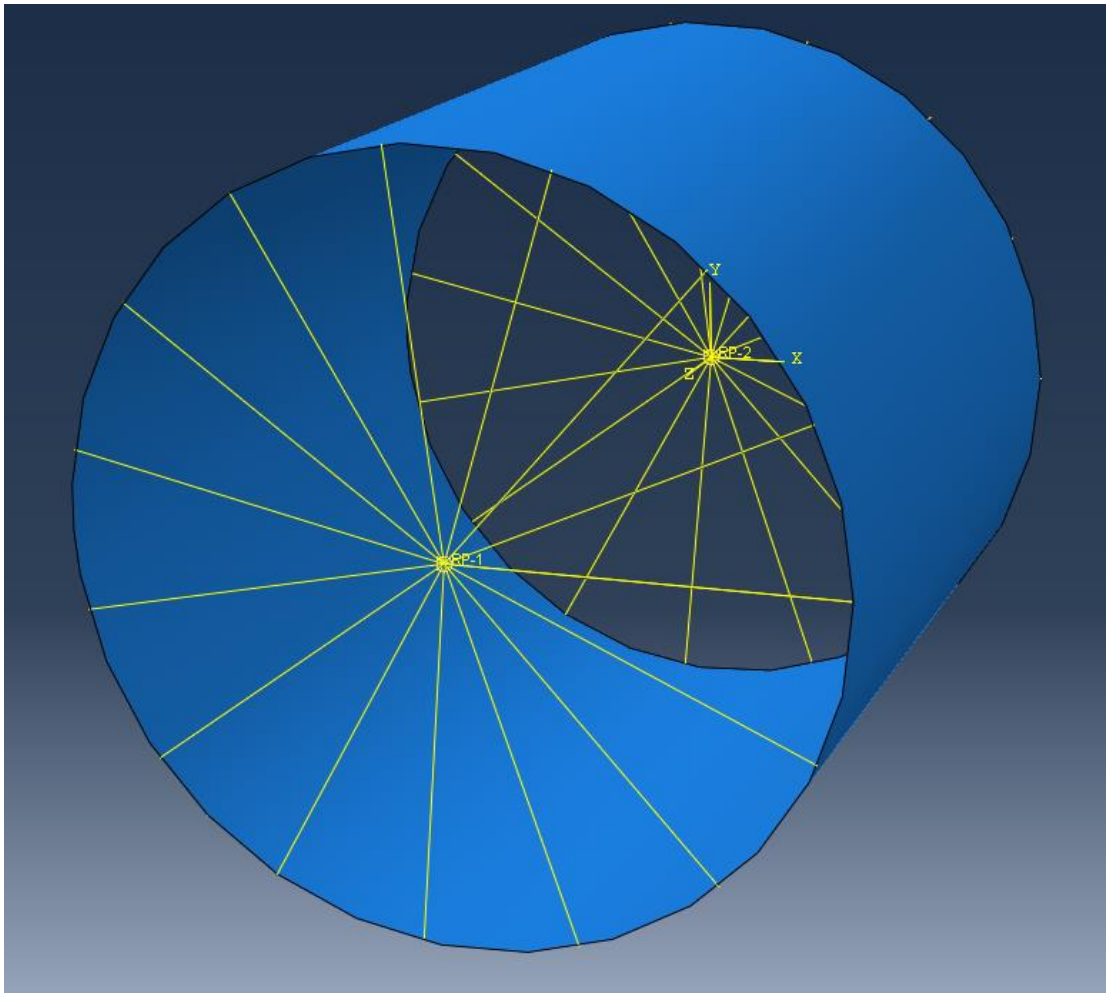
Number of field variables: 0

Data

	Yield Stress	Plastic Strain
1	160	0
2	340	0.3

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Common settings



Coupling edges with RPs

Encastre one of the two RPs

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

LINEAR BUCKLING SIMULATIONS

Sim 1: Buckle simulation (coarse mesh)

Name: Step-1

Type: Buckle

Basic | Other

Description:

NIgeom: Off

Eigensolver: ○ Lanczos ◉ Subspace

Number of eigenvalues requested: 3

☐ Maximum eigenvalue of interest:

Vectors used per iteration: 6

Maximum number of iterations: 6500

Global Seeds

Sizing Controls

Approximate global size: 10

☑ Curvature control

Maximum deviation factor (0.0 < h/L < 1.0): 0.1

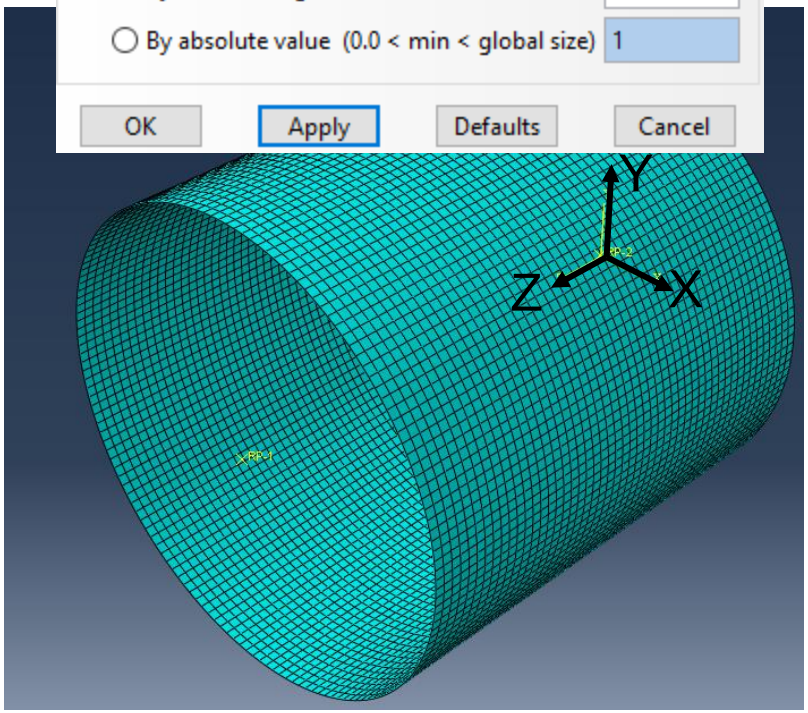
(Approximate number of elements per circle: 8)

Minimum size control

◉ By fraction of global size (0.0 < min < 1.0) 0.1

○ By absolute value (0.0 < min < global size) 1

OK | Apply | Defaults | Cancel



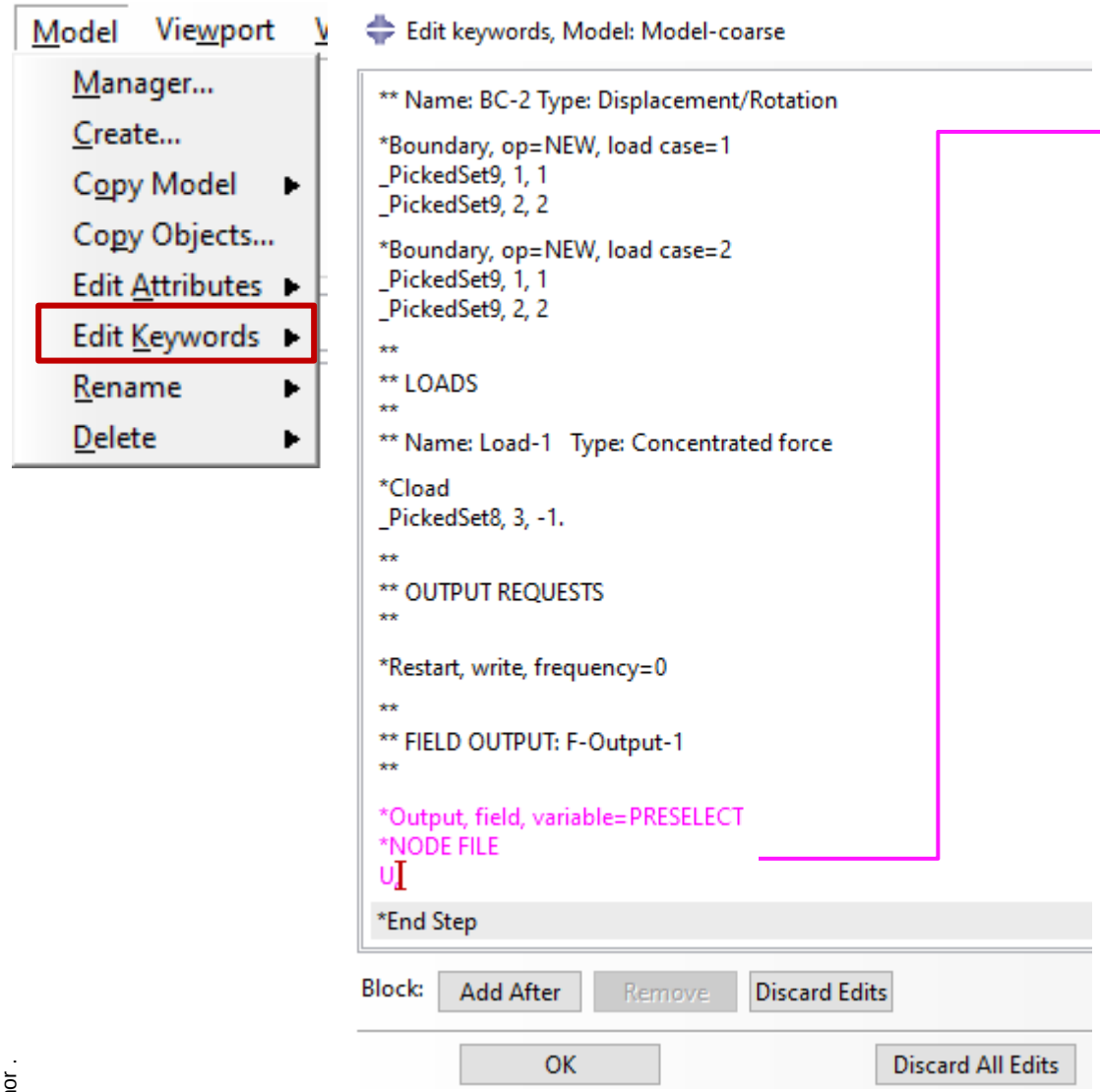
On the free RP:

$U_Y = U_Y = UR_X = UR_Y = UR_Z = 0$

$P_z = -1$

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Sim 1: Buckle simulation (coarse mesh)

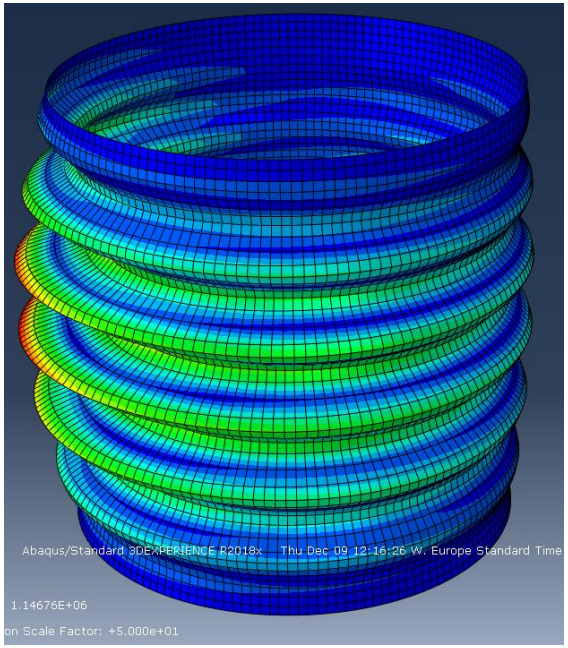


Abaqus will create a file (.fil) in which the nodal displacements will be stored.

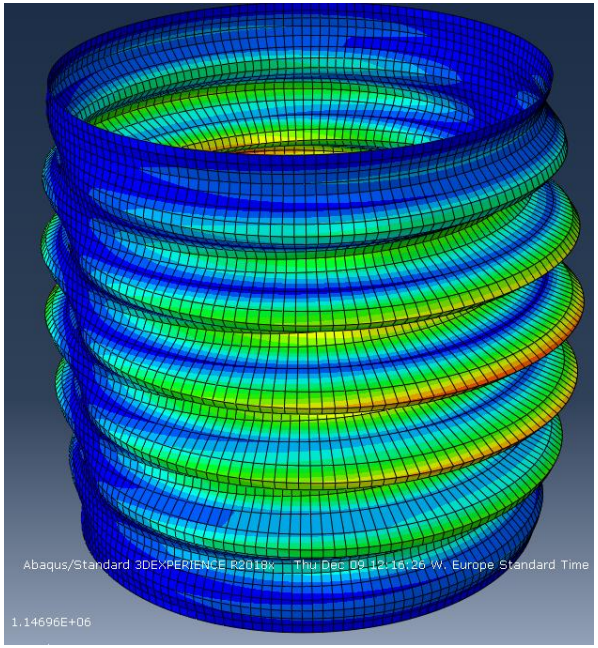
Note: files with .fil extension are not editable with text editors

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

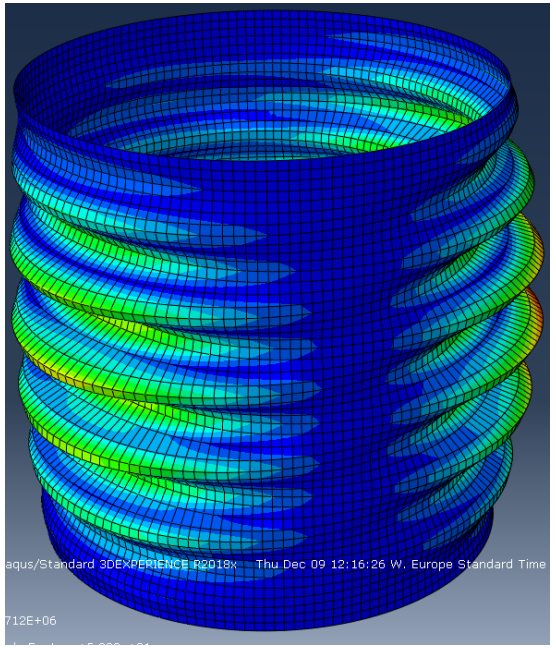
Sim 1: Buckle simulation (coarse mesh)



Step: Step-1
Mode 1: EigenValue = 1.14676E+06



Step: Step-1
Mode 2: EigenValue = 1.14696E+06



Step: Step-1
Mode 3: EigenValue = 1.14712E+06

Lin_buckle.com	09/12/2021 12:04	MS-DOS Applicati...	3 KB
Lin_buckle.dat	09/12/2021 12:13	DAT File	9,016 KB
Lin_buckle.fil	09/12/2021 12:13	FIL File	11,679 KB
Lin_buckle.inp	09/12/2021 12:03	INP File	2,594 KB
Lin_buckle.ipm	09/12/2021 12:13	IPM File	5 KB
Lin_buckle.log	09/12/2021 12:13	Text Document	1 KB
Lin_buckle.msg	09/12/2021 12:13	Outlook Item	144 KB
Lin_buckle.odb	09/12/2021 12:13	ODB File	4,921 KB
Lin_buckle.prt	09/12/2021 12:13	PRT File	2,099 KB
Lin_buckle.sim	09/12/2021 12:13	SIM File	1,119 KB
Lin_buckle.sta	09/12/2021 12:13	STA File	1 KB

Analytical calculation:

10	P_cr	1115.29 kN	m	12.8216

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Sim 2: Buckle simulation (fine mesh)

Name: Step-1

Type: Buckle

Basic | Other

Description:

NIgeom: Off

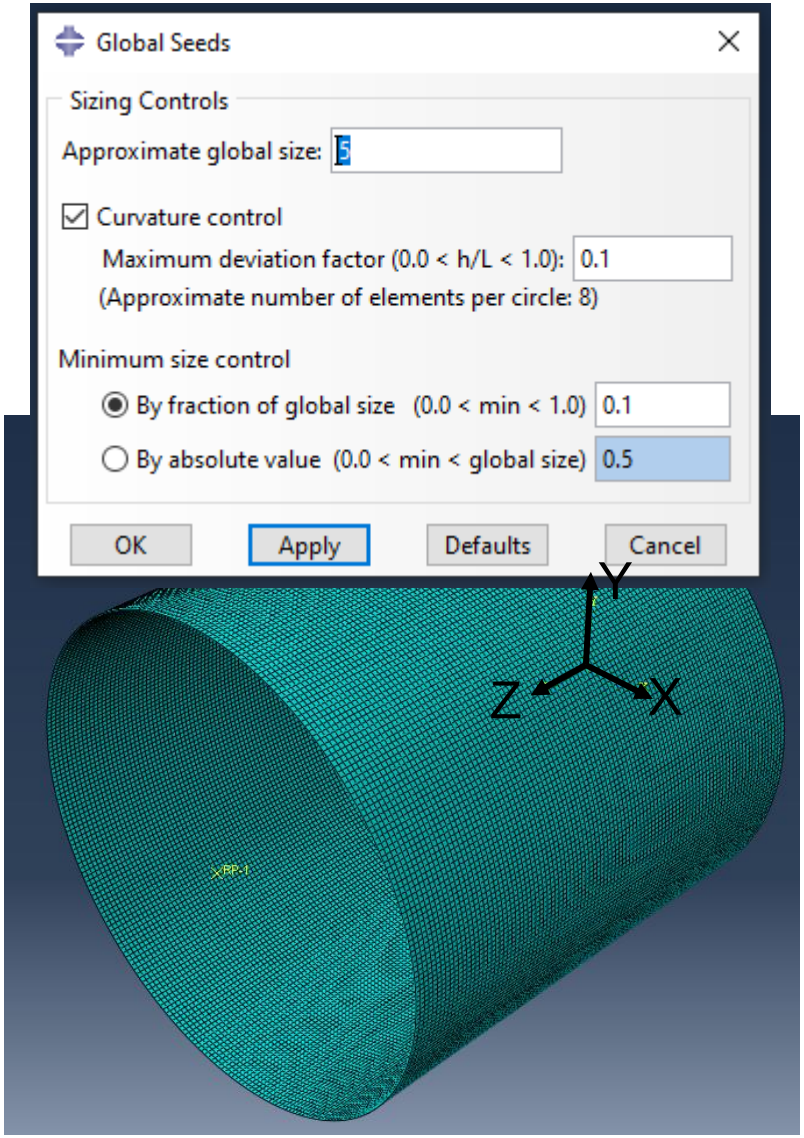
Eigensolver: ○ Lanczos ◉ Subspace

Number of eigenvalues requested: 3

☐ Maximum eigenvalue of interest:

Vectors used per iteration: 6

Maximum number of iterations: 6500



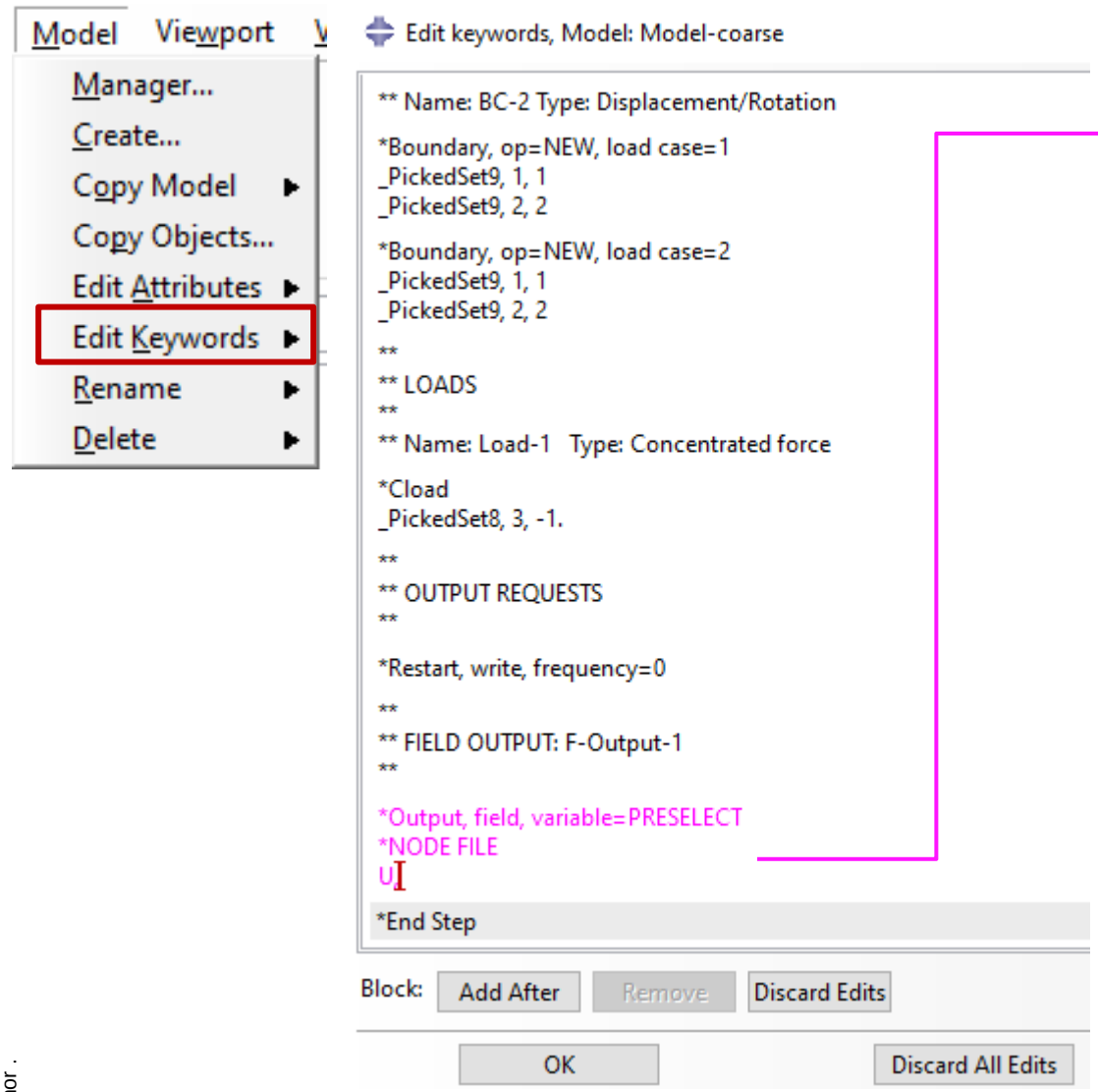
On the free RP:

$U_Y = U_Y = UR_X = UR_Y = UR_Z = 0$

$P_z = -1$

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Sim 2: Buckle simulation (fine mesh)

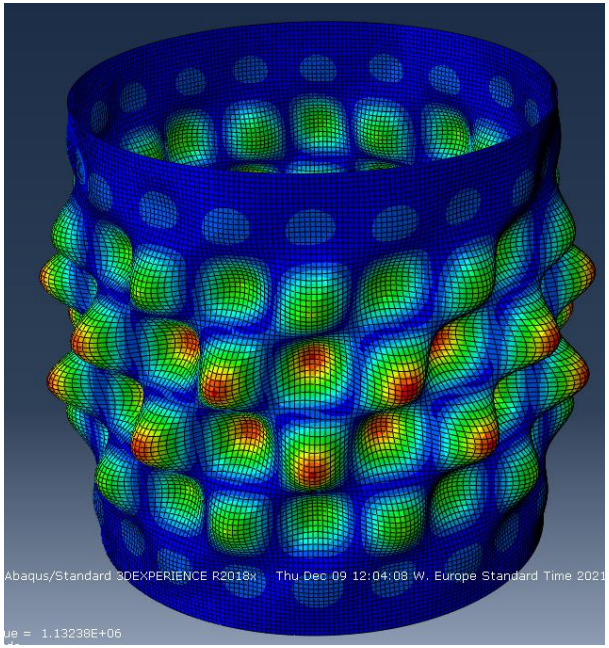


Abaqus will create a file (.fil) in which the nodal displacements will be stored.

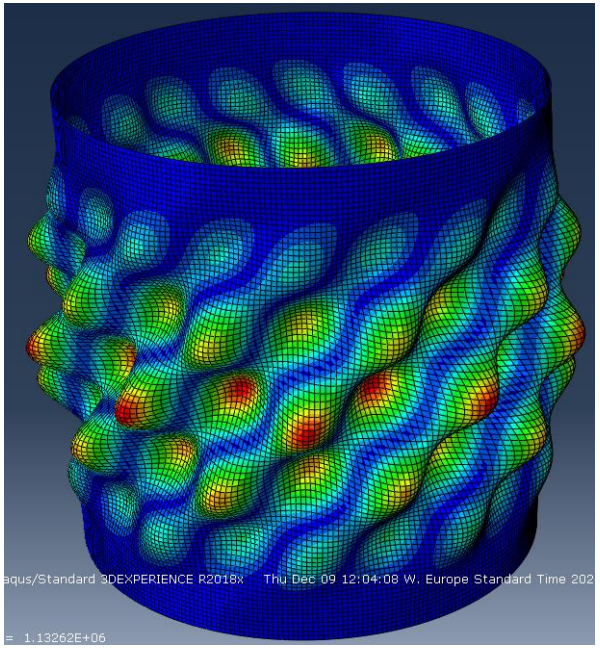
Note: files with .fil extension are not editable with text editors

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

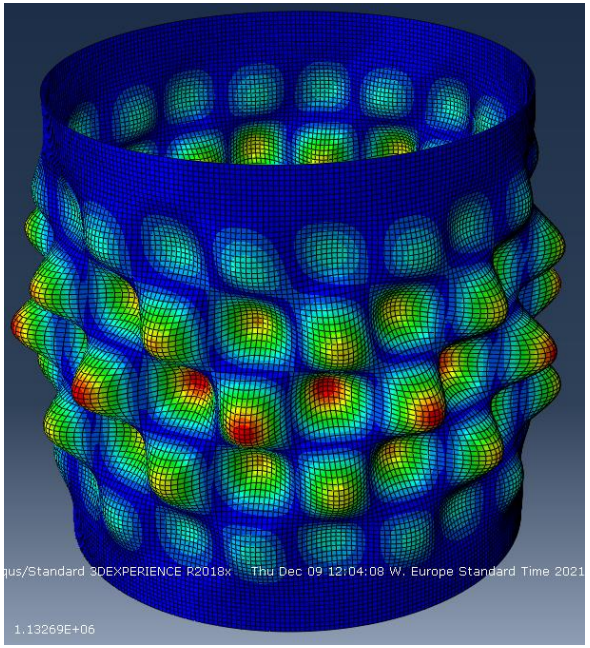
Sim 2: Buckle simulation (fine mesh)



Step: Step-1
Mode 1: EigenValue = 1.13238E+06



Step: Step-1
Mode 2: EigenValue = 1.13262E+06



Step: Step-1
Mode 3: EigenValue = 1.13269E+06

Previous values with coarse mesh:

Step: Step-1
Mode 1: EigenValue = 1.14676E+06

Step: Step-1
Mode 2: EigenValue = 1.14696E+06

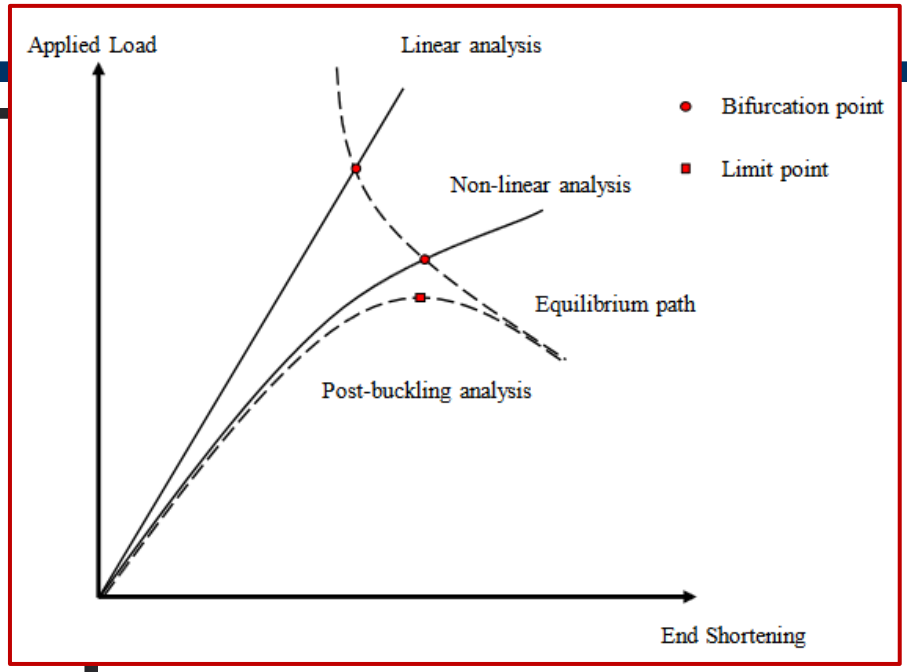
Step: Step-1
Mode 3: EigenValue = 1.14712E+06

Analytical calculation:

10	P_cr	1115.29	kN

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Buckling of cylindrical shells



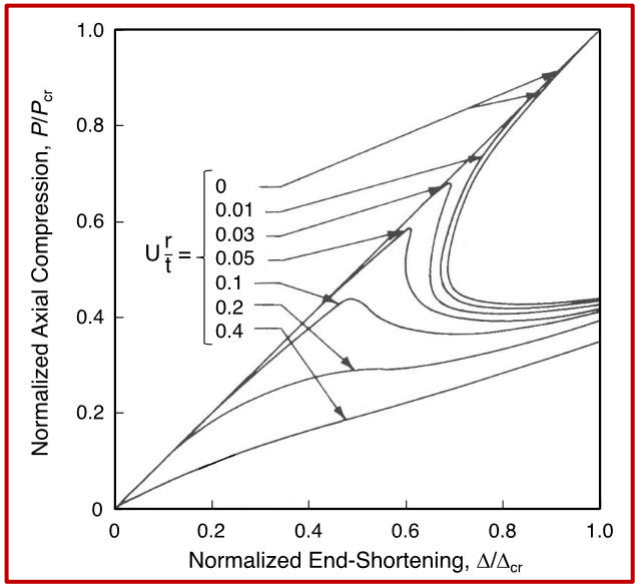
NASA/SP-8007-2020/REV 2

Buckling of Thin-Walled Circular Cylinders

September 1965
August 1968 – first revision
November 2020 – second revision

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

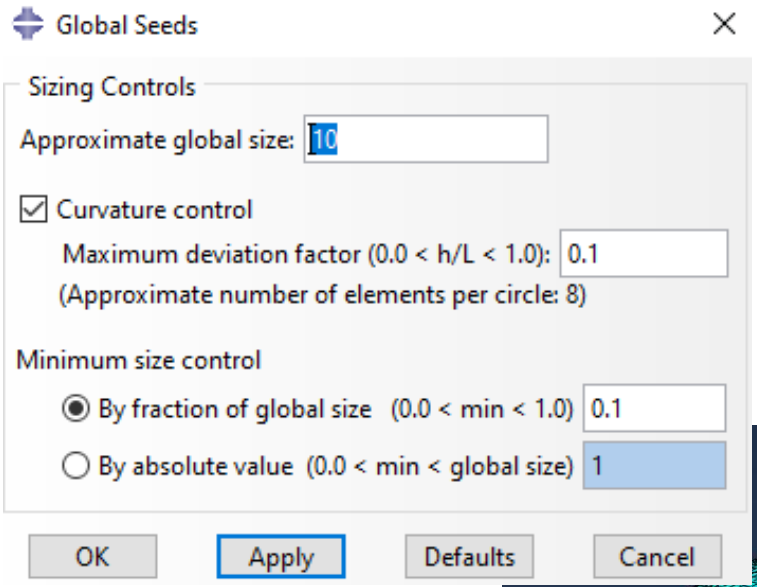


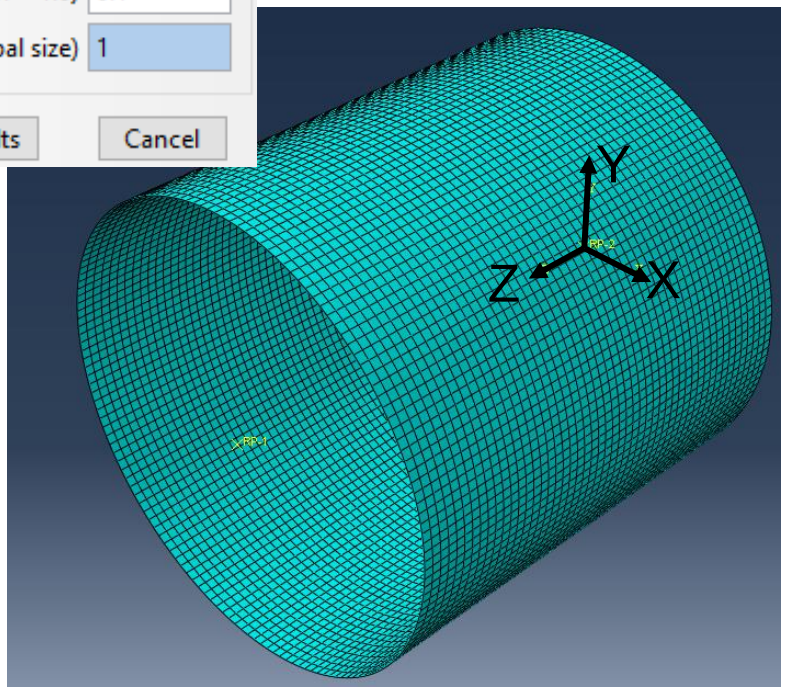
This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

NON-LINEAR CRUSHING SIMULATIONS WITH IMPERFECTIONS

Sim 3: Non-linear crushing (coarse)





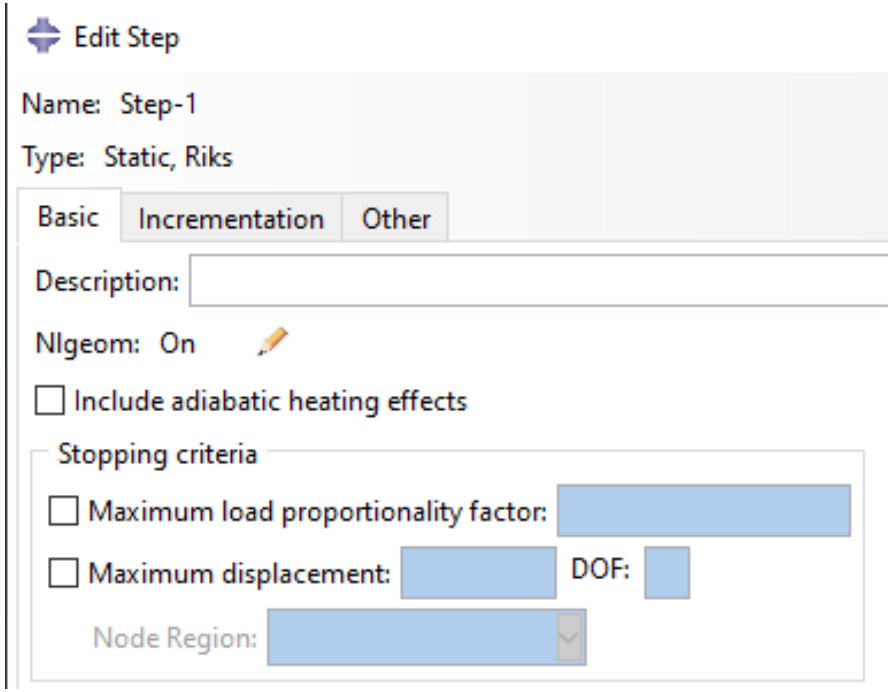
On the free RP:

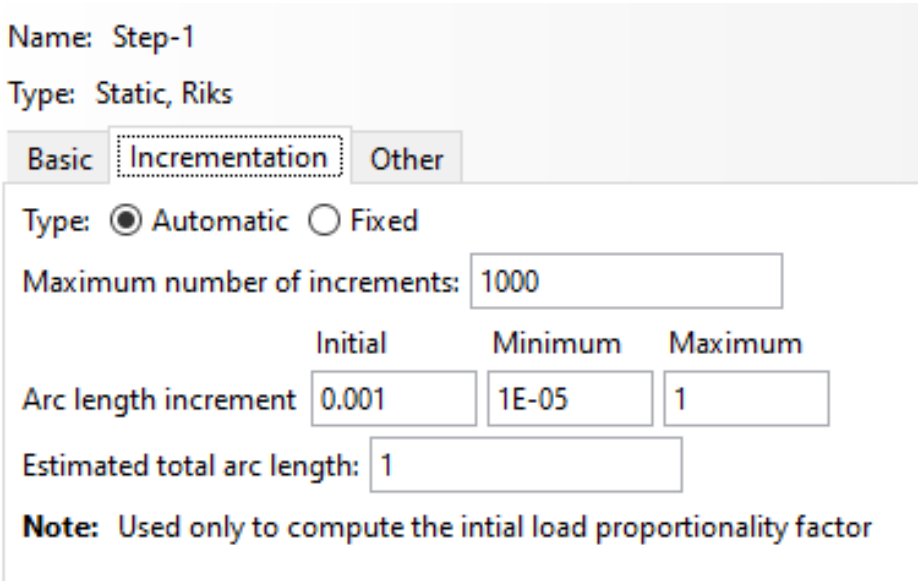
$U_Y = U_Y = UR_X = UR_Y = UR_Z = 0$

P_z = -1.2E+06

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Sim 3: Non-linear crushing (coarse)

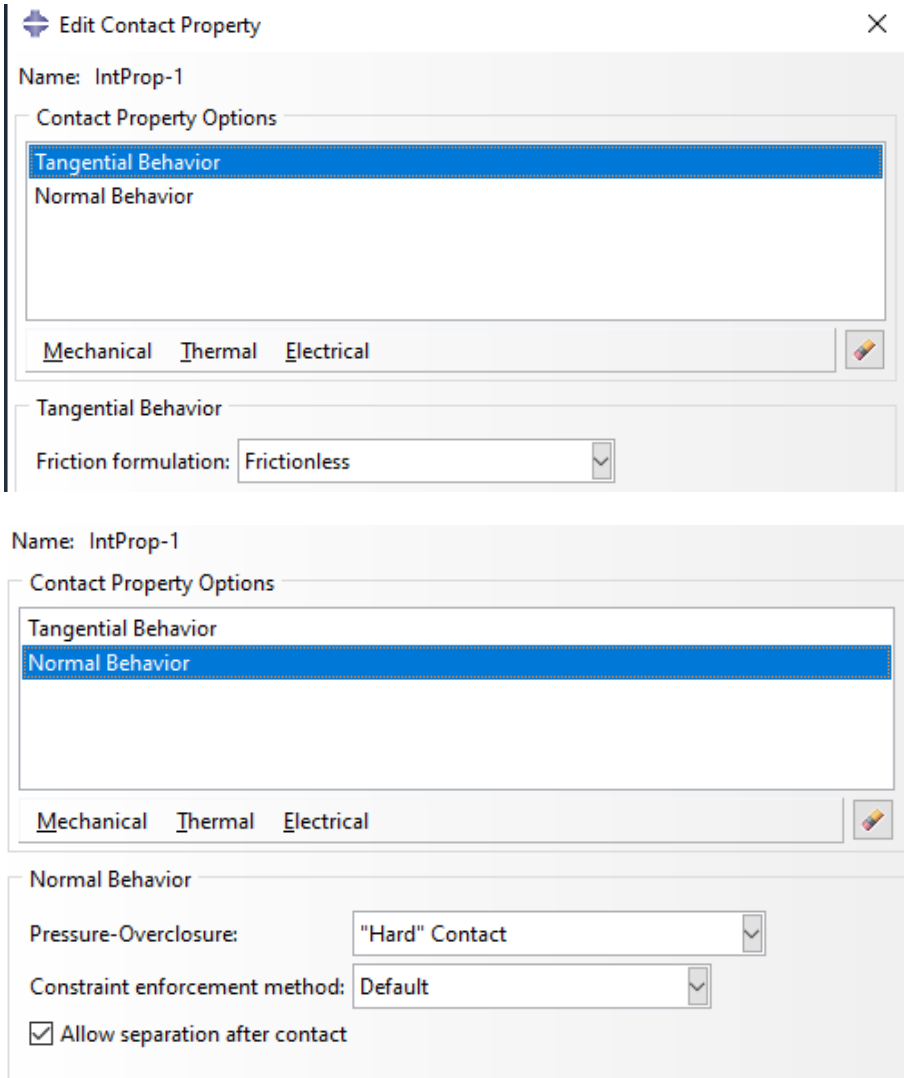


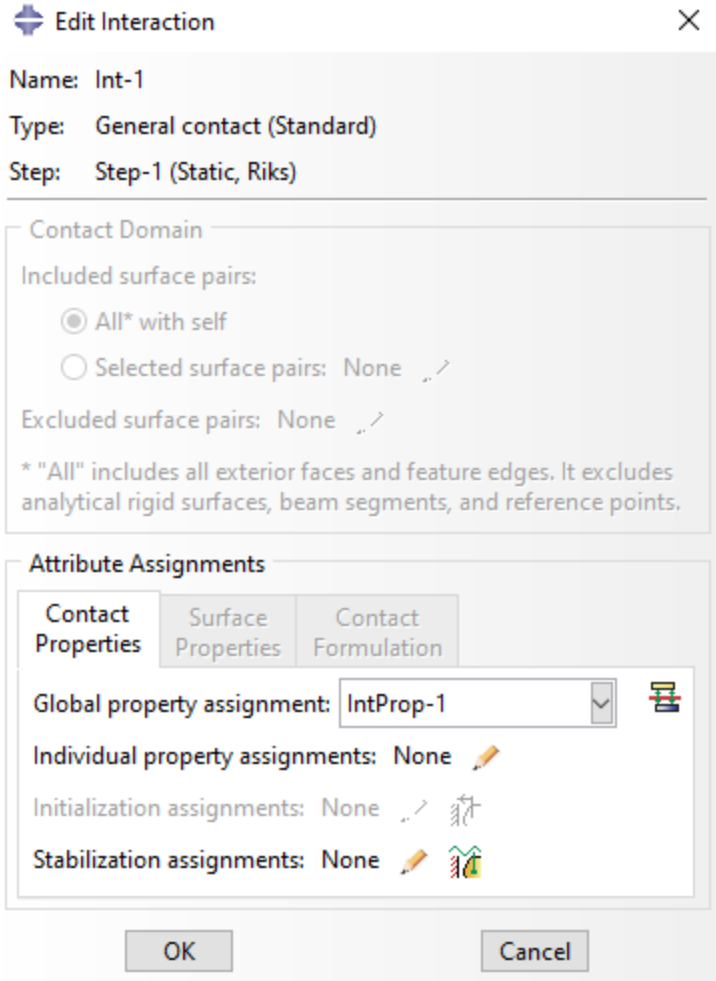


This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

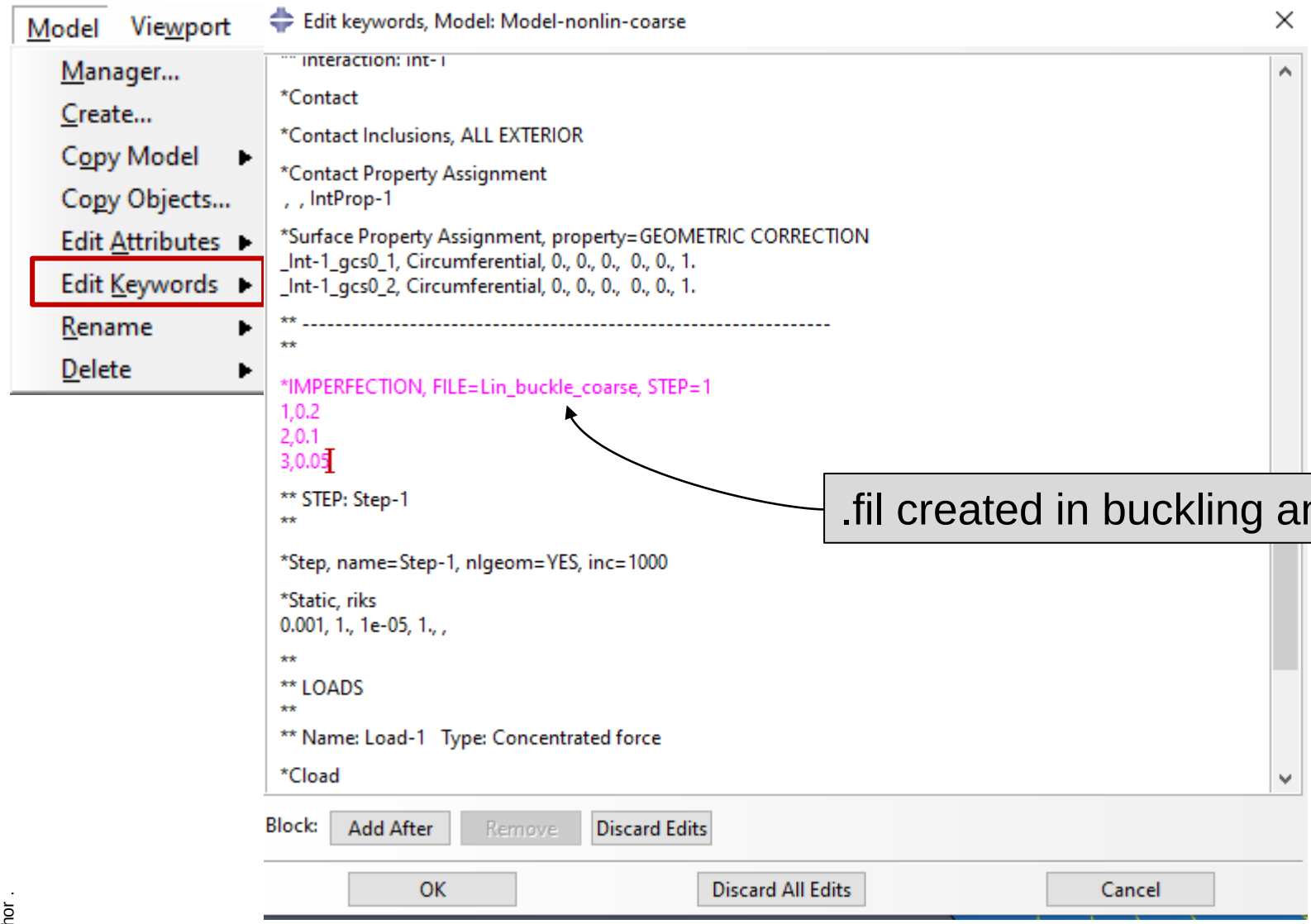
Sim 3: Non-linear crushing (coarse)

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .



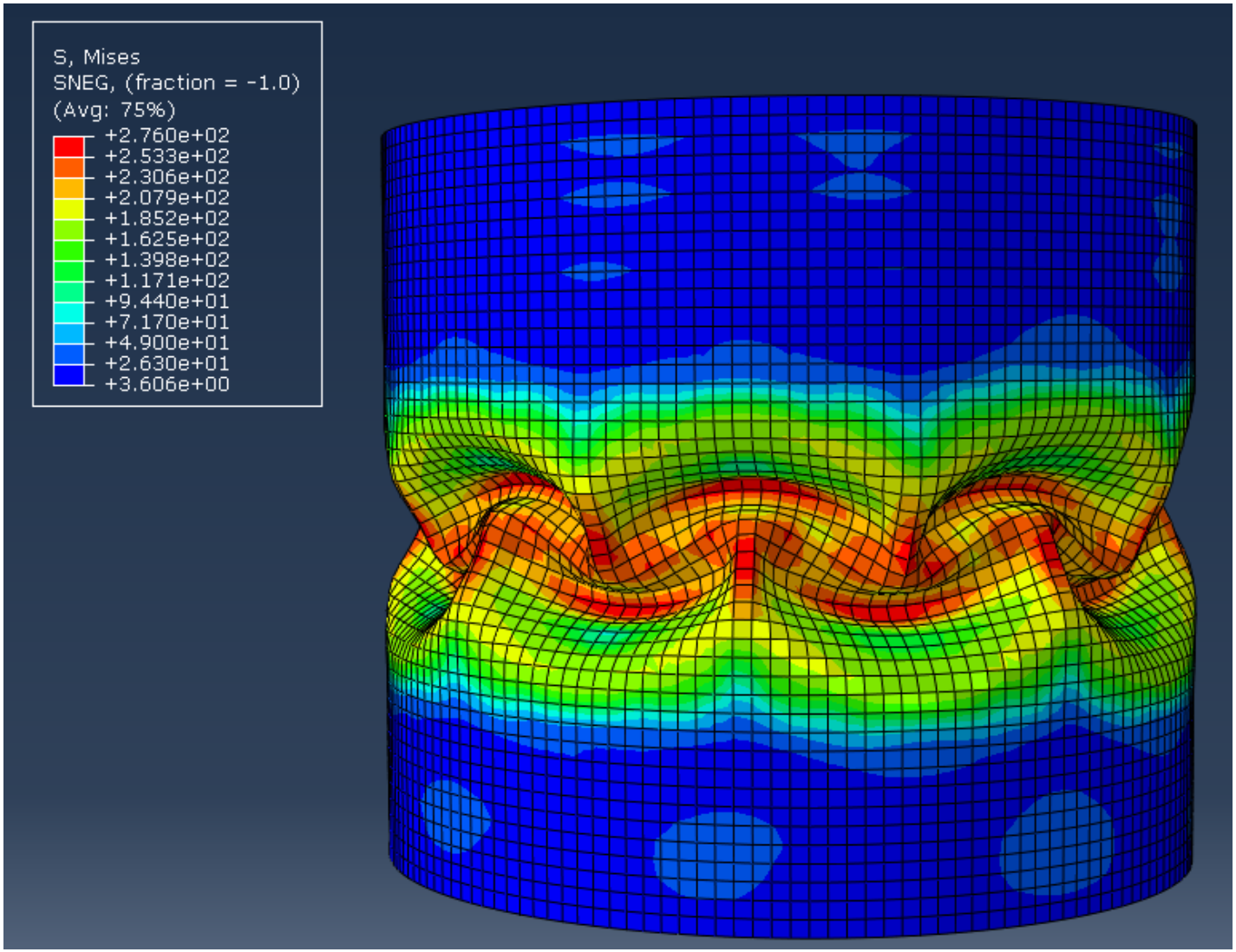


Sim 3: Non-linear crushing (coarse)



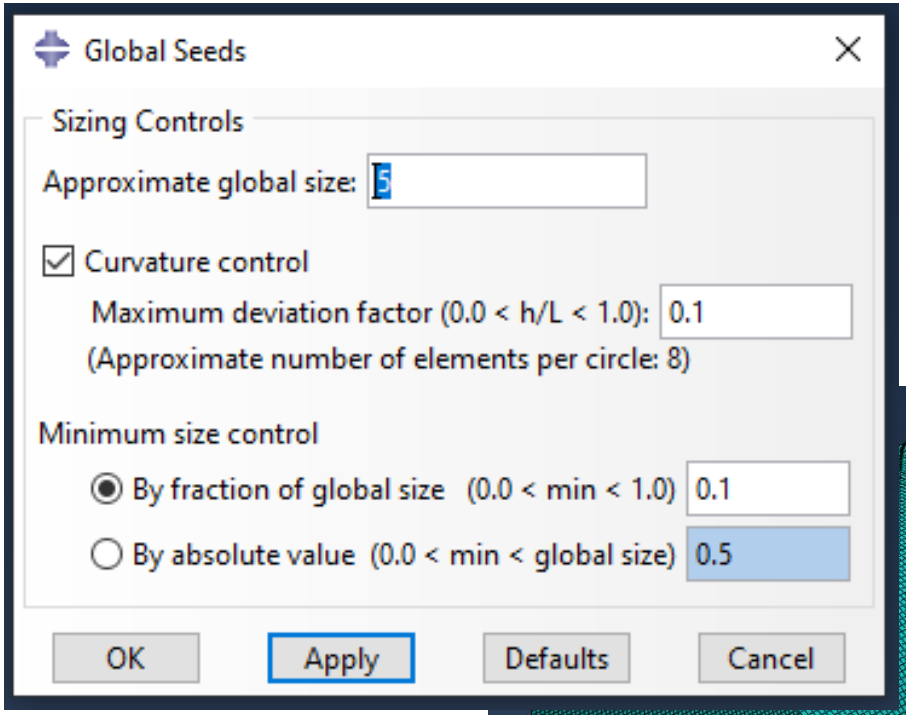
This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

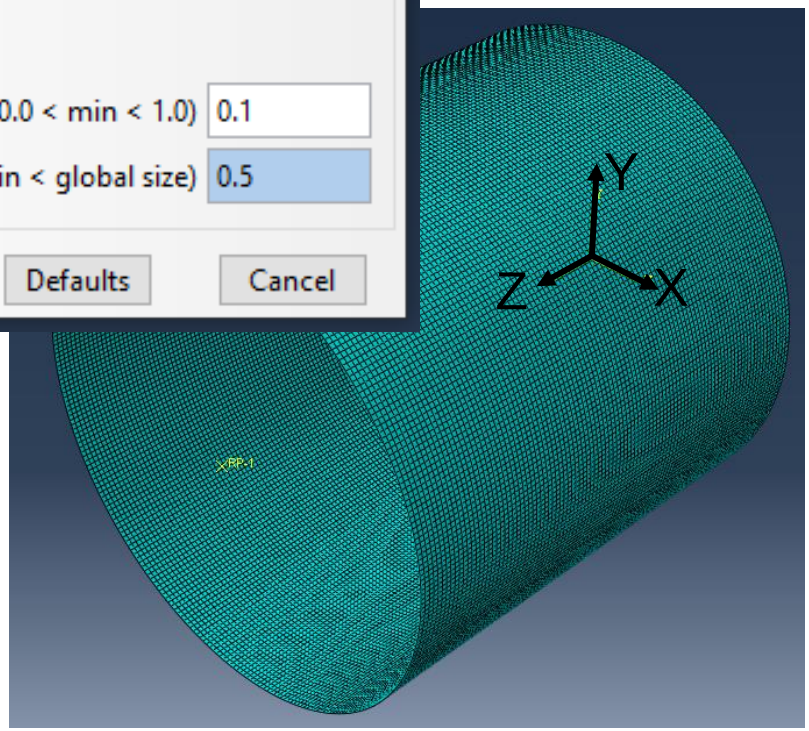
Sim 3: Non-linear crushing (coarse)



This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Sim 4: Non-linear crushing (fine)





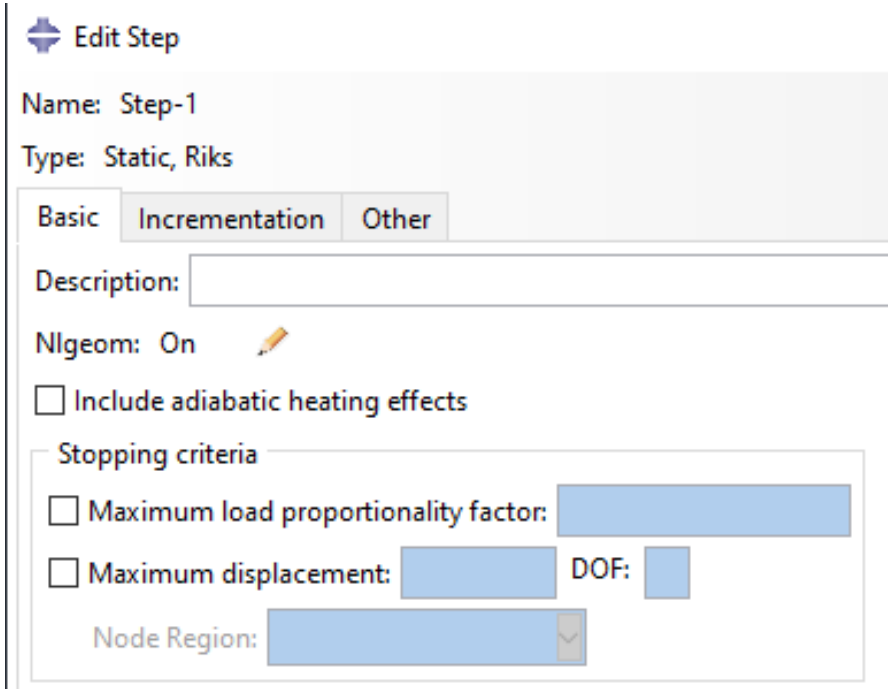
On the free RP:

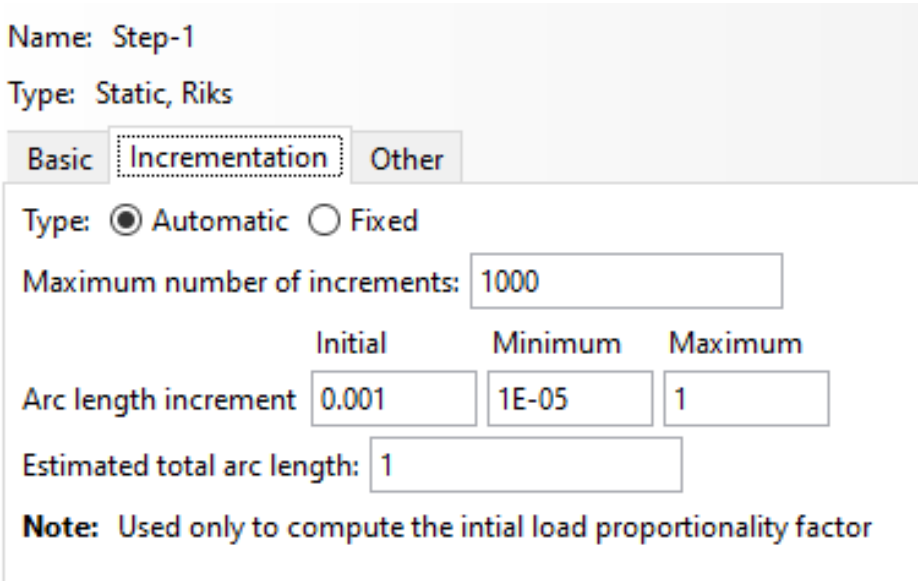
$U_Y = U_Y = UR_X = UR_Y = UR_Z = 0$

P_z = -1.2E+06

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Sim 4: Non-linear crushing (fine)

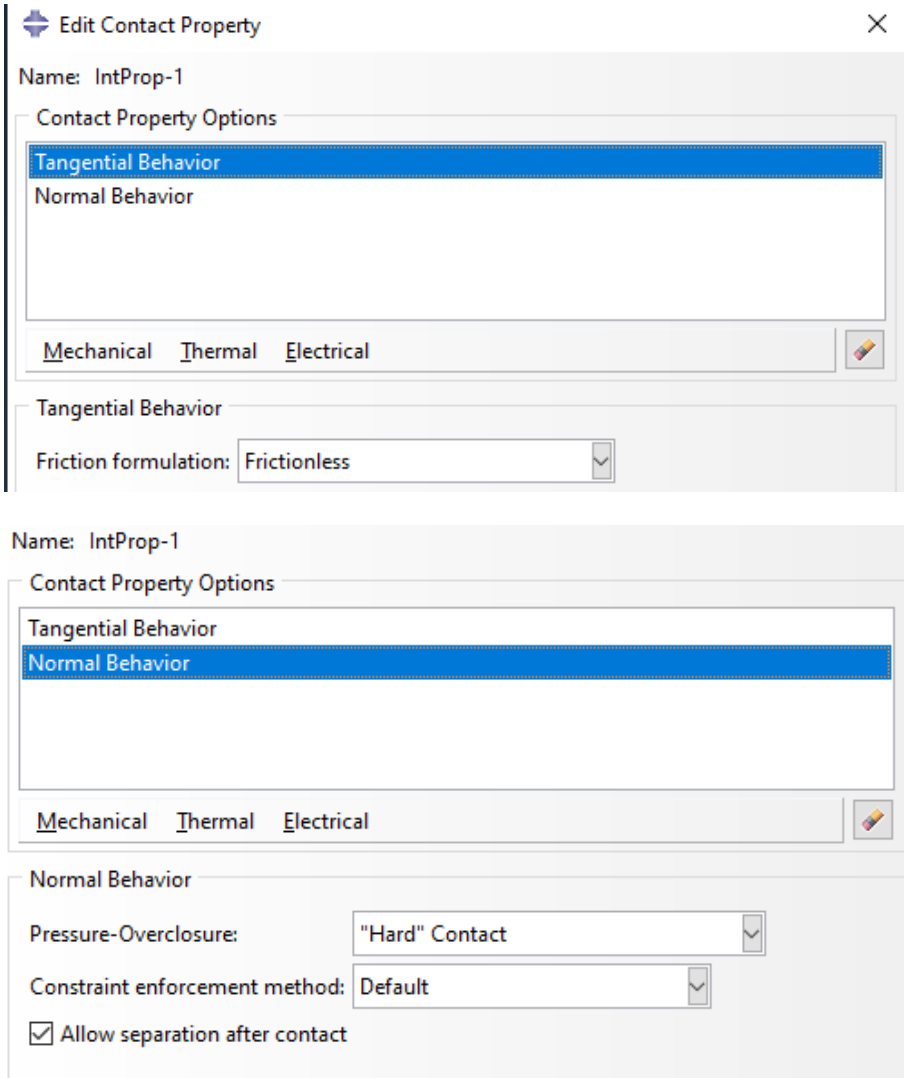


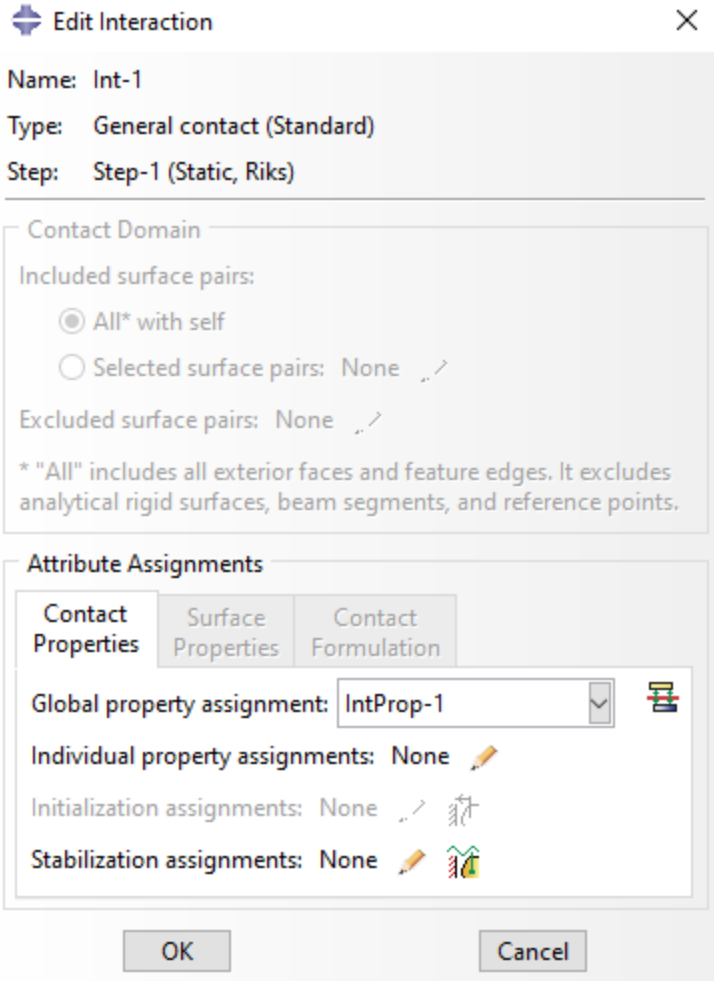


This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

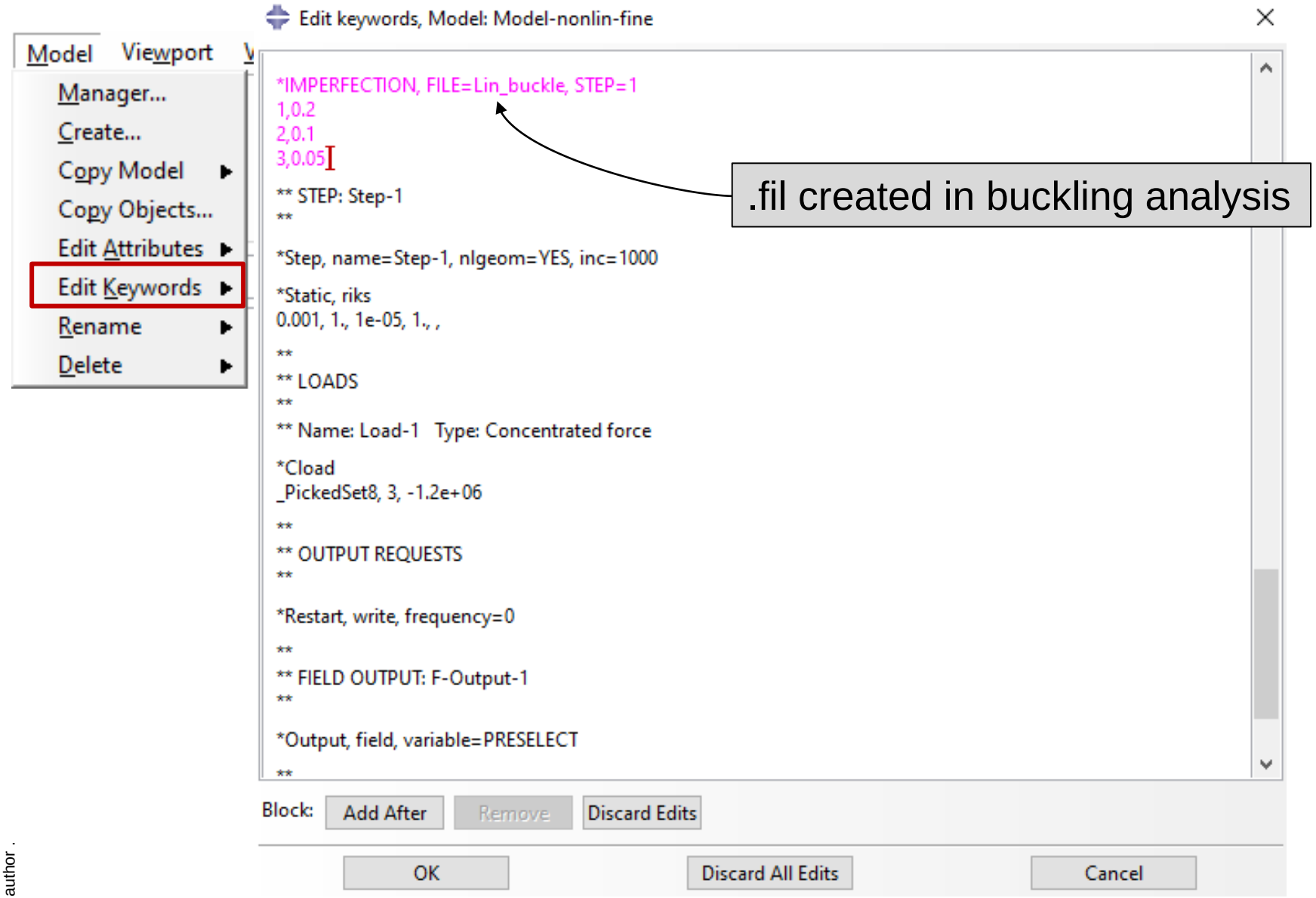
Sim 4: Non-linear crushing (fine)

This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .



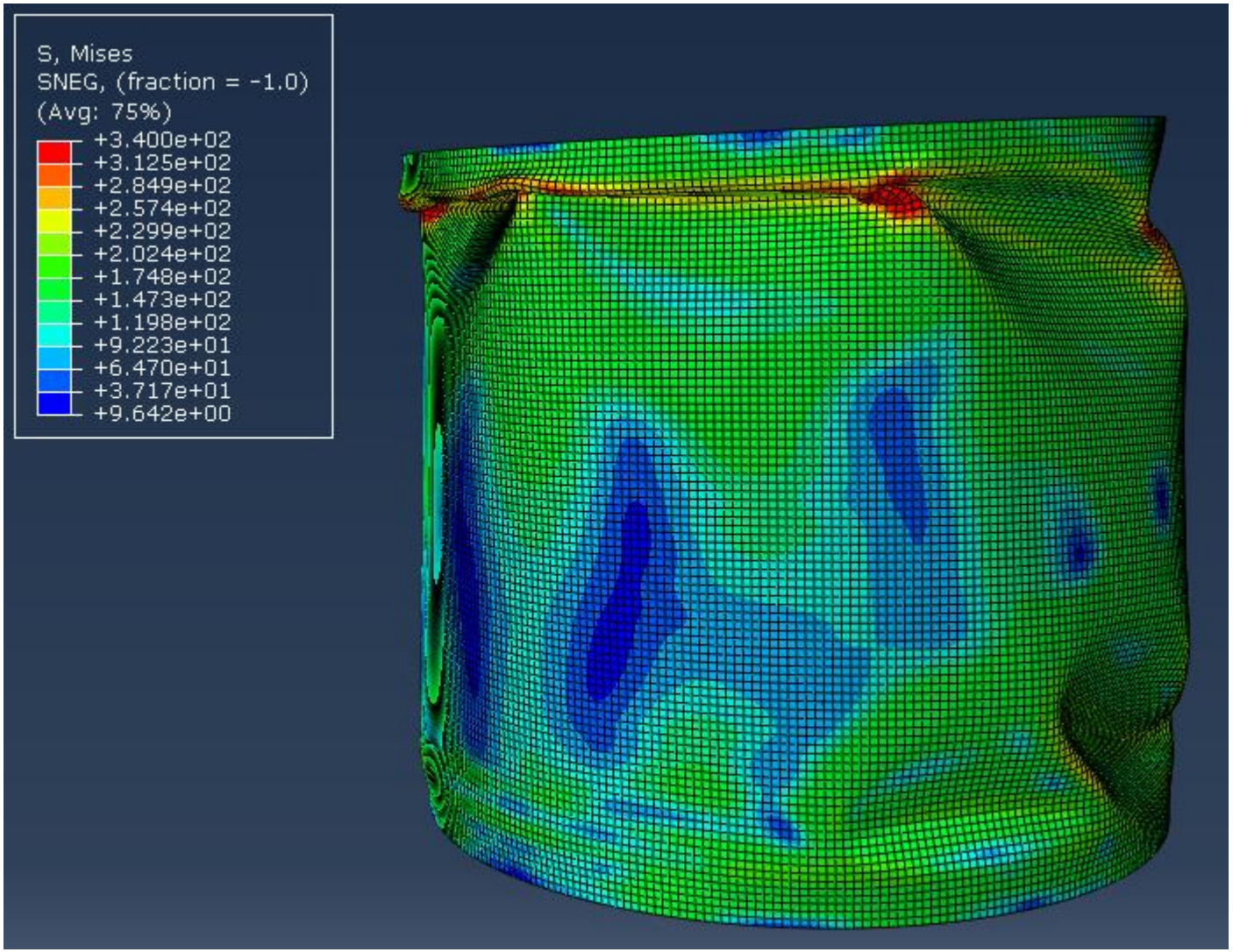


Sim 4: Non-linear crushing (fine)



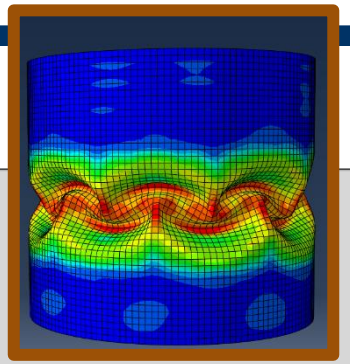
This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

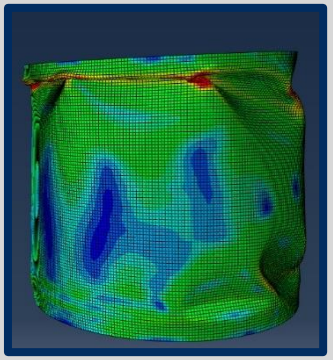
Sim 4: Non-linear crushing (fine)



This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .

Comparison of solutions





This document is distributed by Andrea Bernasconi to the students of the course Finite Element Simulation for Mechanical Design for personal use only, as teaching/learning materials. Any other use is forbidden without the written consent of the author .