

Inventor® Stress Analysis Results Validation



Introduction

This document contains several cases that compare Autodesk® Inventor® 2010 Stress Analysis default results against experimental or analytical ones.

Each case contains several sections, namely, case description, material data, dimensions, load value, results from stress analysis and corresponding references. Comparisons against stress, deformation, natural frequencies, and contact pressure for shrink fit contact are included in this document. All cases used the SI system of units.

1. Cylinder under Tensile

Case description

A cylinder under tensile is examined in this case. The length of the cylinder is 140 mm and the diameter is 18 mm. A fixed constraint is added on one end of the cylinder. A uniform tensile force load with magnitude 40000 N is applied on the other end of the cylinder.

Material data

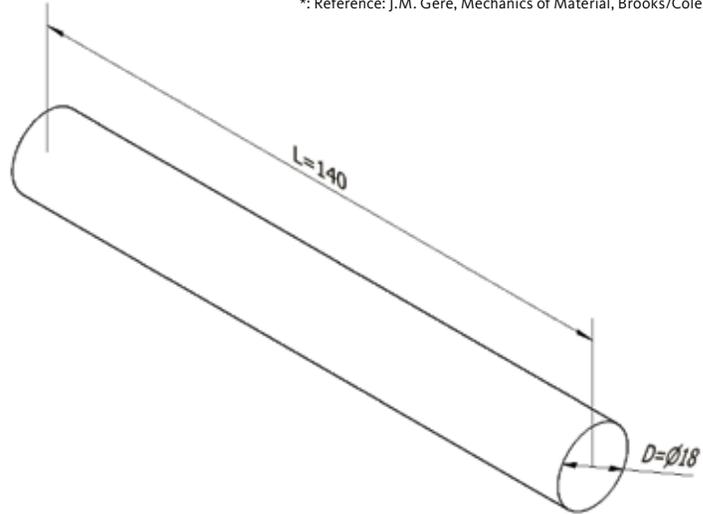
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

L = 140 mm
D = 18 mm

Load value

F = 40000 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Deformation	0.1049 mm	0.1046 mm	-0.29%

*: Reference: J.M. Gere, Mechanics of Material, Brooks/Cole, 2001.

2. Cylinder with Gorge under Tensile

Case description

This deformation is for a cylinder with gorge under tensile. The length of the cylinder is 200 mm, the diameter is 24 mm. There is a gorge in the middle of the cylinder with the dimension shown in the following image. A fixed constraint is added on one end of the cylinder. A uniform tensile force load with magnitude 20000 N is applied on the other end of the cylinder.

Material data

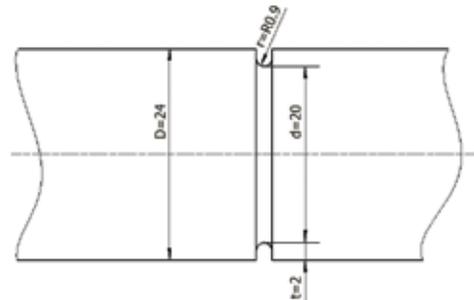
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 24 mm
d = 20 mm
r = 0.9 mm
t = 2 mm
L (length) = 200 mm
with $t = (D-d)/2$

Load value

F = 20000 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Deformation	4.210e-2 mm	4.254e-2 mm	1.05%

*: Reference: R.E. Peterson, Stress Concentration Factors, John Wiley & Sons, 1974

3. Cylinder with Shoulder Fillet under Tensile

Case description

This deformation is for a cylinder with a shoulder fillet under tensile. There are two connected coaxial sections of the cylinder. The section with the larger diameter is 12 mm, the length of the portion is 40 mm. The section with the smaller diameter is 8 mm and the length of the portion is 180 mm. Between the two portions, there is a fillet with a radius 0.5 mm. A fixed constraint is added on one end of the cylinder. A uniform tensile force load with a magnitude 3000 N is applied on the other end of the cylinder.

Material data

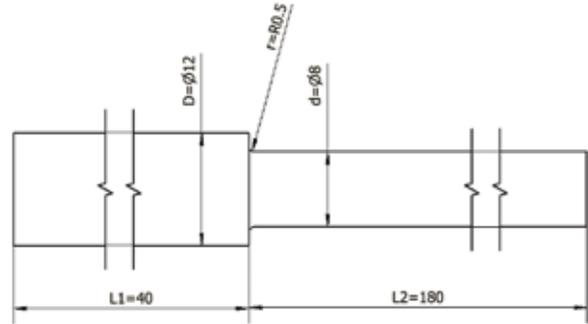
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 12 mm
 d = 8 mm
 r = 0.5 mm
 L1 = 40 mm
 L2 = 180 mm

Load value

F = 3000 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Deformation	5.621e-2 mm	5.641e-2 mm	0.36%

*: Reference: R.E. Peterson, Stress Concentration Factors, John Wiley & Sons, 1974

4. Beam with Shoulder Fillet under Tensile

Case description

The stress and deformation in this case are for a beam with shoulder fillet under tensile. There are two connected portions of the beam. The section with the larger width is 30 mm. The length of the portion is 50 mm. The section with the smaller width is 26 mm. The length of the portion is 200 mm. Two beam portions are connected with two fillets with a diameter of 6 mm each. The thickness of the beam is 11 mm. A fixed constraint is added on one end of the beam. A uniform tensile force load with magnitude 30000 N is applied on the other end of the beam.

Material data

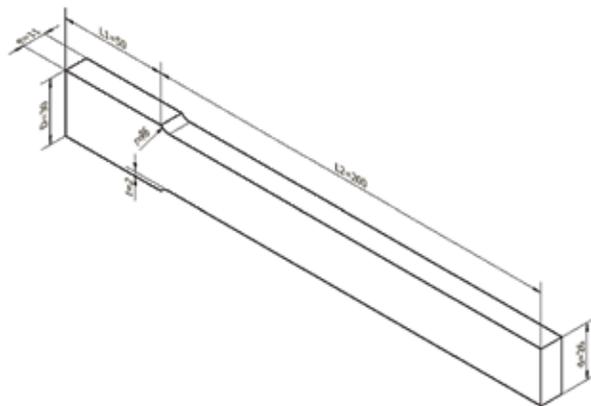
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 30 mm
 d = 26 mm
 r = 6 mm
 t = 2 mm
 L1 = 50 mm
 L2 = 200 mm
 e = 11 mm

Load value

F = 30000 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	157.3 MPa	161.2 MPa	2.48%
Maximum Deformation	0.1216 mm	0.1213 mm	-0.25%

*: Reference: R.E. Peterson, Stress Concentration Factors, John Wiley & Sons, 1974

5. Beam with Hole under Tensile

Case description

The stress and deformation are for a beam with a hole in the center under tensile. The length of the beam is 240 mm, the height is 24 mm, and the thickness is 12 mm. The hole is in the center of the beam with 9 mm as the diameter. A fixed constraint is added on one end of the beam. A uniform tensile force load with magnitude 8500 N is applied on the other end of the beam.

Material data

Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

L = 240 mm

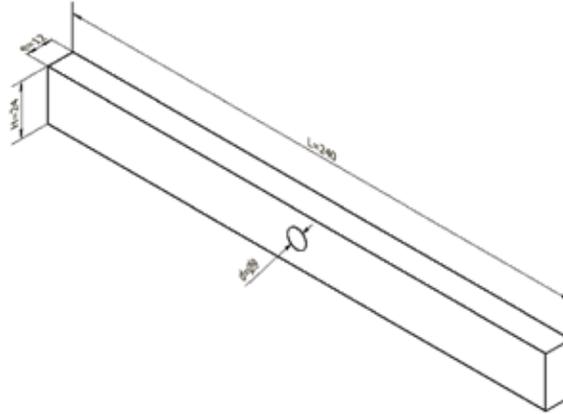
H = 24 mm

d = 9 mm

e = 12 mm

Load value

F = 8500 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	106.7 MPa	104.7 MPa	-1.87%
Maximum Deformation	3.449e-2 mm	3.486e-2 mm	1.07%

*: Reference: R.E. Peterson, Stress Concentration Factors, John Wiley & Sons, 1974

6. Circular Plate - Case 1 under Compression

Case description

The stress and deformation are for a circular plate under compression. The diameter of the circular plate is 1000 mm and the thickness is 10 mm. A fixed constraint is added on the external cylindrical face of the plate. A uniform compressive force load with magnitude 1000 N is applied on a central area of the plate. The central area has a 30 mm diameter

Material data

Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

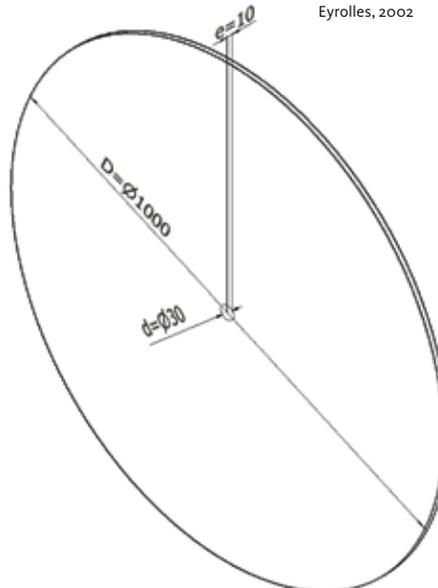
D = 1000 mm

d = 30 mm

e = 10 mm

Load Value

F = 1000 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 default	% difference
Maximum Stress	21.9 MPa	19.07 MPa	-12.9%
Maximum Deformation	0.258 mm	0.254 mm	-1.55%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

7. Circular Plate - Case 2 under Compression

Case description

The stress and deformation are for a circular plate under pressure. The diameter of the circular plate is 400 mm and the thickness of it is 15 mm. A fixed constraint is added on the external cylindrical face of the plate. A uniform pressure load with a magnitude 0.6 MPa is applied on one side of the plate.

Material data

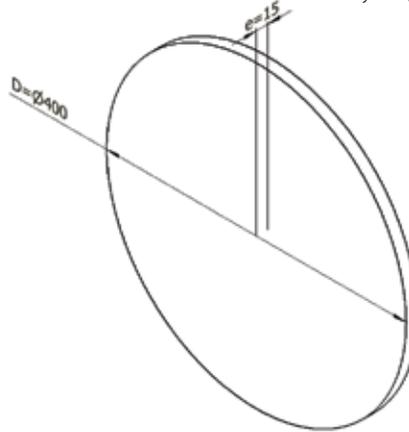
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 400 mm
e = 15 mm

Load value

P = 0.6 MPa



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	80 MPa	77.61 MPa	-2.99%
Maximum Deformation	0.232 mm	0.231 mm	-0.43%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

8. Circular Plate - Case 3 under Compression

Case description

The stress and deformation are for a circular plate under pressure. The diameter of the circular plate is 1000 mm and the thickness of it is 20 mm. A fixed constraint is added on the external cylindrical face of the plate. A uniform pressure load with magnitude 0.1 MPa is applied on a plate-coaxial area with a diameter 300 mm which is on one side of the plate.

Material data

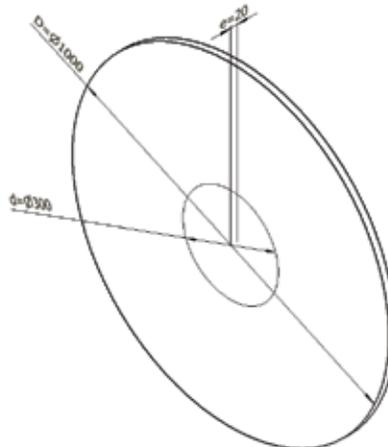
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 1000 mm
d = 300 mm
e = 20 mm

Load value

P = 0.1 MPa



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	13.43 MPa	13.23 MPa	-1.49%
Maximum Deformation	0.189 mm	0.187 mm	-1.06%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

9. Circular Plate - Case 4 under Compression

Case description

The stress and deformation are for a circular plate under compression. The diameter of the circular plate is 200 mm and the thickness is 2 mm. A fixed constraint is added on the external cylindrical face of the plate. A uniform force load with a magnitude 100 N is applied on the edge of a plate-coaxial circle with a diameter 20 mm.

Material data

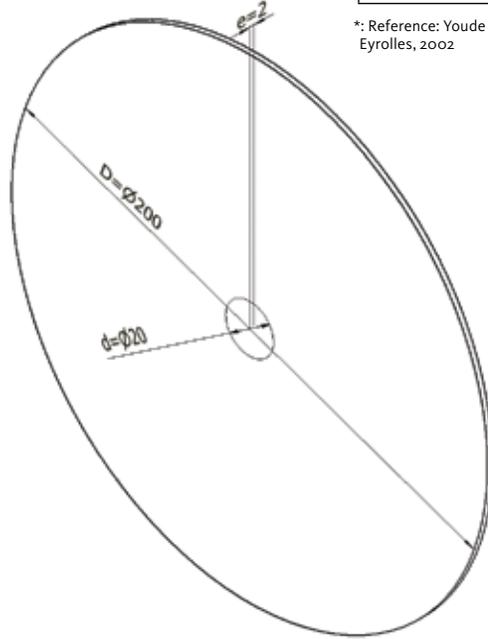
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 200 mm
d = 20 mm
e = 2 mm

Load value

F = 100 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	28.05 MPa	28.81 MPa	2.71%
Maximum Deformation	0.122 mm	0.121 mm	-0.82%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

10. Ring - Case 1 under Compression

Case description

The stress and deformation are for a ring under pressure. The diameter of the outer diameter of the ring is 360 mm, the inner diameter is 180 mm and the thickness is 10 mm. A fixed constraint is added on the external cylindrical face of the ring. A uniform pressure load with a magnitude 0.5 MPa is applied on one side of the ring.

Material data

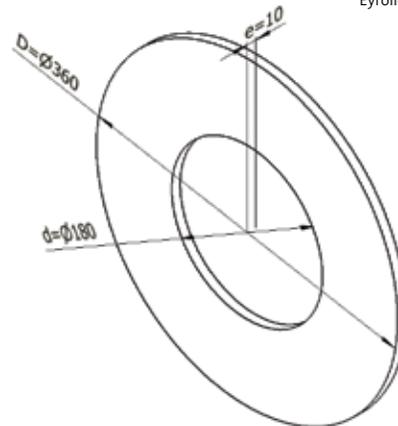
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 360 mm
d = 180 mm
e = 10 mm

Load value

P = 0.5 MPa



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	77.76 MPa	67.83 MPa	-12.77%
Maximum Deformation	0.145 mm	0.141 mm	-2.76%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

11. Ring - Case 2 under Compression

Case description

The stress and deformation are for a ring under compression. The diameter of the outer diameter of the ring is 280 mm, the inner diameter is 84 mm, and the thickness is mm. A fixed constraint is added on the external cylindrical face of the ring. A uniform compressive force load with magnitude 3000 N is applied on the inner circular edge.

Material data

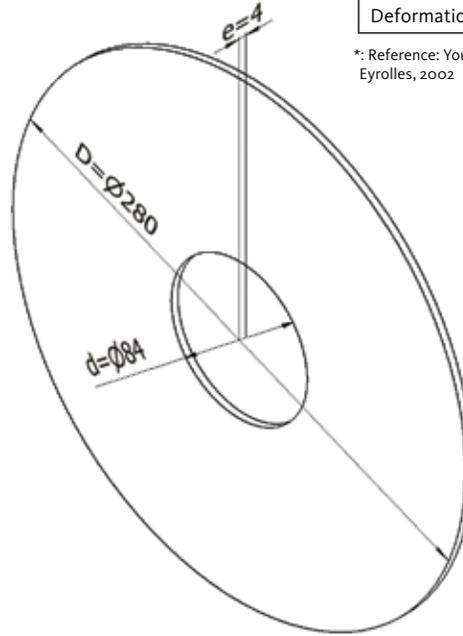
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

D = 280 mm
d = 84 mm
e = 4 mm

Load value

F = 3000 N



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	149.4 MPa	153.9 MPa	3.01%
Maximum Deformation	0.8356 mm	0.8325 mm	-0.37%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

12. Rectangular Plate under Compression

Case description

The stress and deformation are for a rectangular plate under pressure. The length of the plate is 300 mm, the width is 200 mm, and the thickness is 12 mm. Fixed constraints are added on four side faces of the plate. A uniform pressure load with a magnitude 0.6 MPa is applied on the face of the plate.

Material data

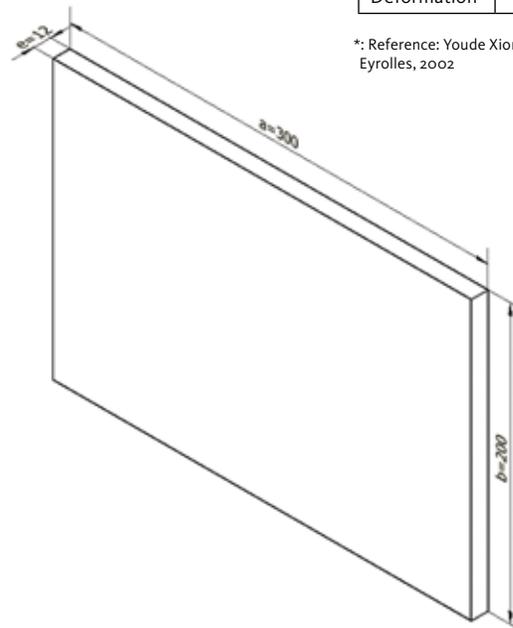
Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

a = 300 mm
b = 200 mm
e = 12 mm

Load value

P = 0.6 MPa



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Maximum Stress	75.30 MPa	67.32 MPa	-10.59%
Maximum Deformation	6.309e-2 mm	6.406e-2 mm	1.53%

*: Reference: Youde Xiong, Formulaire de resistance des materiaux, Eyrolles, 2002

13. Rectangular Plate's Natural Frequencies

Case description

Natural frequencies are studied in this case for a rectangular plate. The length of the rectangular plate is 4000 mm, the width is 1000 mm, and the thickness is 100 mm. All edges of the plate are free.

Material data

Steel	
Young's Modulus	2.1e+005 MPa
Poisson's Ratio	0.3
Mass Density	7.85e-006 kg/mm ³
Tensile Yield Strength	207.0 MPa

Dimensions

a = 4000 mm
b = 1000 mm
h = 100 mm



Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Mode 1**	33.78 Hz	33.50 Hz	-0.83%
Mode 2	82.28 Hz	79.42 Hz	-3.48%
Mode 3	92.99 Hz	91.89 Hz	-1.18%
Mode 4	170.06 Hz	163.82 Hz	-3.67%

*: Reference: C.M. Wang, W.X. Wu, C. Shu, T. Utsunomiya, LSFD method for accurate vibration modes and modal stress-resultants of freely vibrating plates that model VLFS, Computers and Structures 84 (2006) 2329–2339

** : Because all the edges are free for the plate, the first 6 modes are rigid modes and are not counted in this case.

14. Cylinders with Shrink Fit Contact

Case description

The contact pressure is for two cylinders assembled by shrink fit. The length, 100 mm, is the same for both cylinders. For the small cylinder, the internal radius is 50 mm and the outer diameter is 60 mm. For the large cylinder, the internal diameter is 61 mm, and the outer diameter is 70 mm. A frictionless constraint is added on one end for each cylinder. The contact between the two cylinders is Shrink Fit / Sliding.

Material data

Steel, High Strength Low Alloy	
Young's Modulus	2.0e+005 MPa
Poisson's Ratio	0.287
Mass Density	7.84e-006 kg/mm ³
Tensile Yield Strength	275.8 MPa

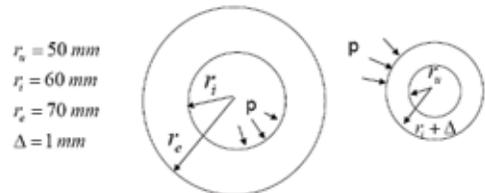
Dimensions

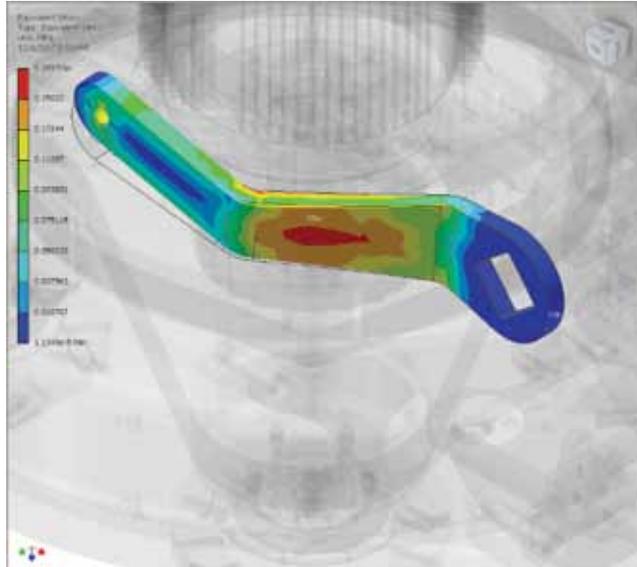
r_i = 50 mm
r_i = 60 mm
r_e = 70 mm
Δr = 1 mm
L (length of cylinders) = 100 mm

Results from Stress Analysis

	Comparison Results*	Inventor 2010 Default	Percentage Difference
Contact Pressure	276 MPa	288 MPa	4.35%

*: Reference: Joseph Edward Shigley, Charles R. Mischke, Mechanical Engineering Design, McGraw-Hill, Inc. 1990





Conclusion

Easy-to-use and tightly integrated motion simulation and stress analysis in Autodesk® Inventor® Professional software help you to predict how a design will work under real-world conditions before building it. A comprehensive simulation environment provides support for motion simulation and static and modal finite element analysis at both the part and assembly level. Results from dynamic simulation allow engineers to use FEA more effectively by leveraging the reaction forces to set up the conditions for finite element stress analysis.

Inventor takes you beyond 3D to Digital Prototyping. For more information, please visit: www.autodesk.com/inventor.