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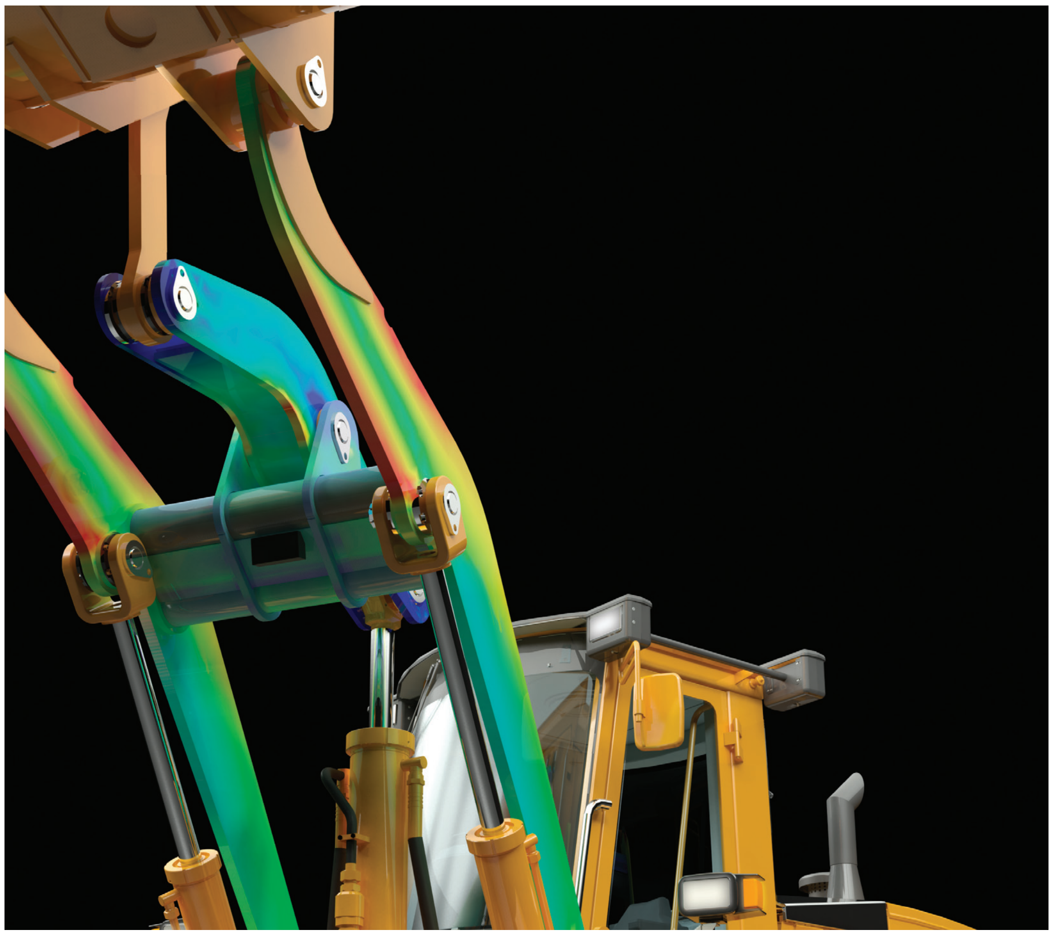
INVENTOR® SIMULATION
WHITE PAPER

# 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.

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## 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

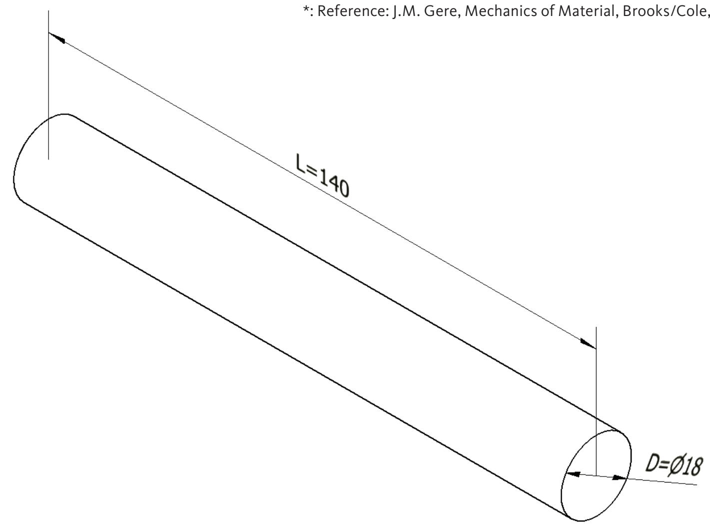
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

### 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

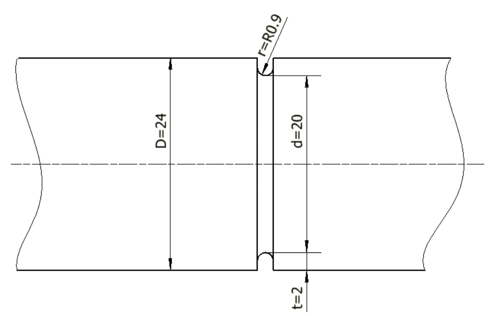
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

### 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/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**Dimensions**

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

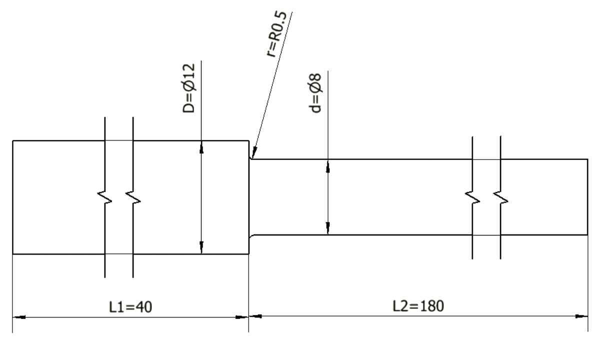
**Load value**

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/mm³ |
| 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

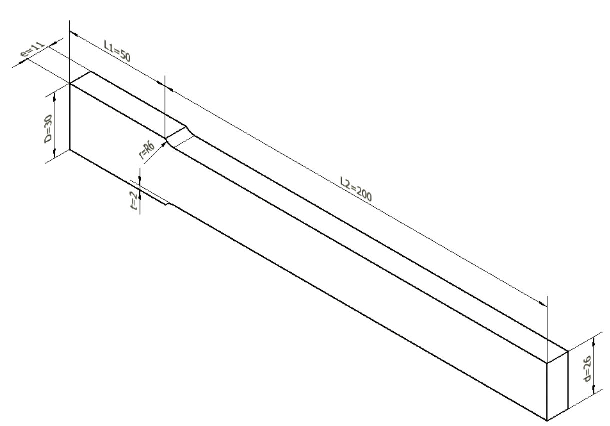
**Load value**

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/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**Dimensions**

L = 240 mm

**H = 24 mm**
**d = 9 mm**
**e = 12 mm**

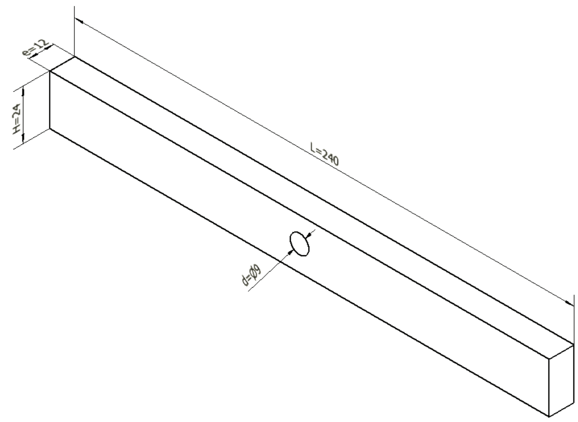
**Load value**

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/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**Dimensions**

D = 1000 mm
d = 30 mm
e = 10 mm

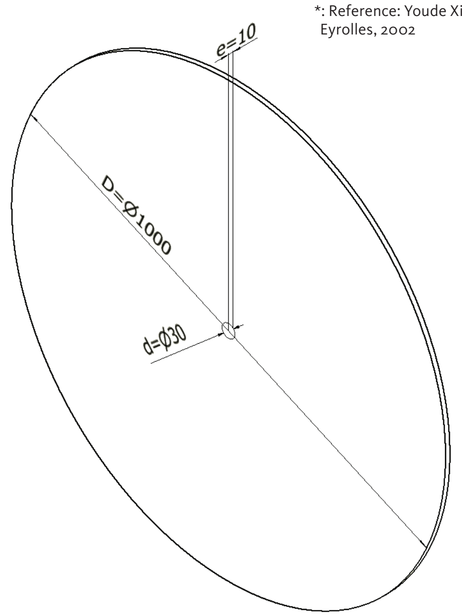
**Load Value**

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**

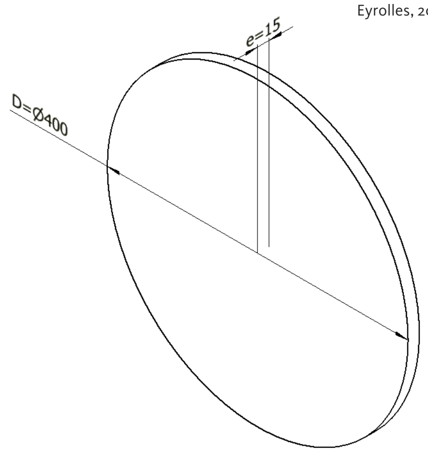
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**Dimensions**

D = 400 mm
e = 15 mm

**Load value**

P = 0.6MPa




**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**

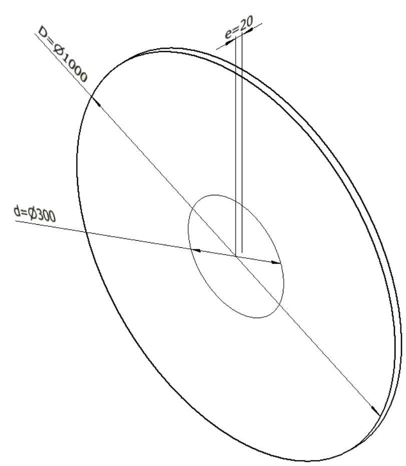
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**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**

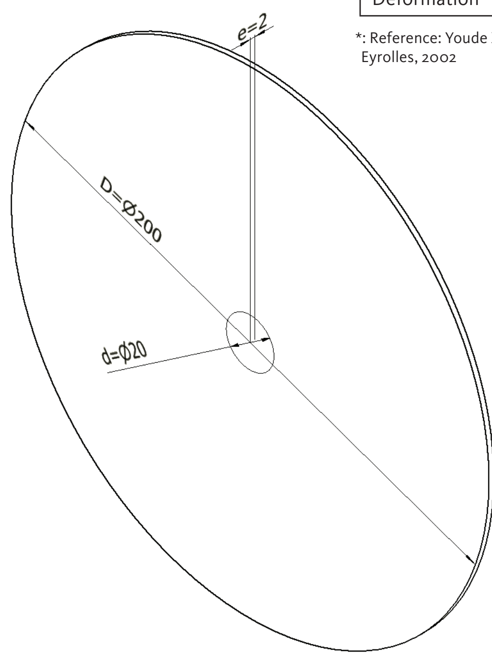
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**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**

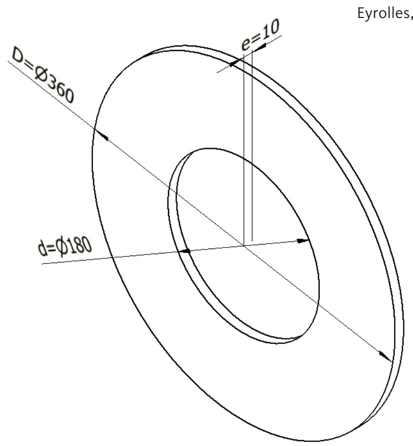
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**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**

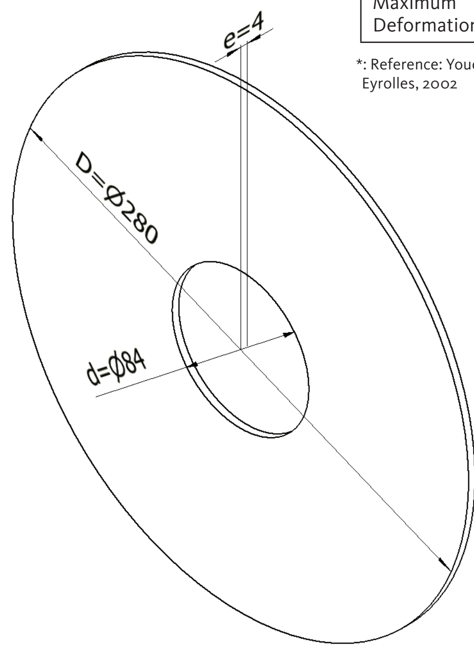
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**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**

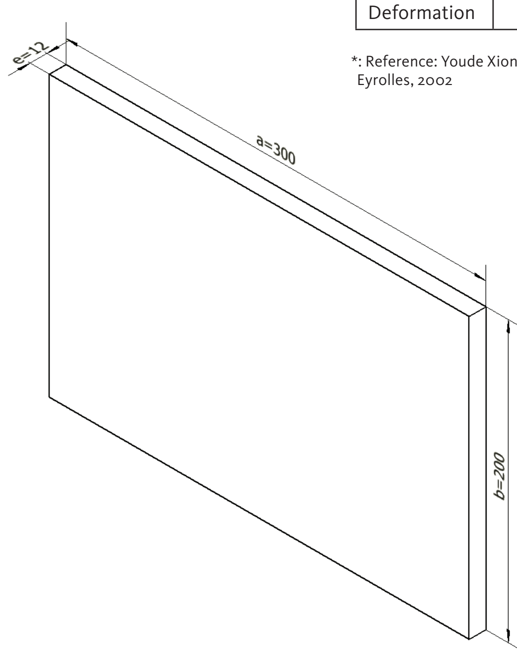
| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| Tensile Yield Strength | 207.0 MPa |

**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

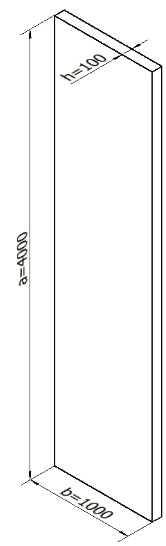
Natural frequencies are studied in this case for a rectangular plate. The length of the rectangular plate is 4000 mm, the width is 1000 mm, and the thickness is 100 mm. All edges of the plate are free.

### Material data

| Steel | |
|---|---|
| Young's Modulus | 2.1e+005 MPa |
| Poisson's Ratio | 0.3 |
| Mass Density | 7.85e-006 kg/mm³ |
| 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/mm³ |
| Tensile Yield Strength | 275.8 MPa |

### Dimensions

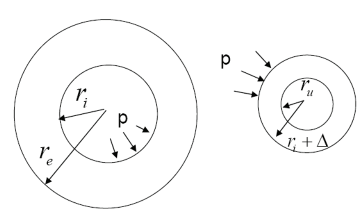
ru = 50 mm
ri = 60 mm
re = 70 mm
Δr = 1 mm
L (length of cylinders) = 100 mm

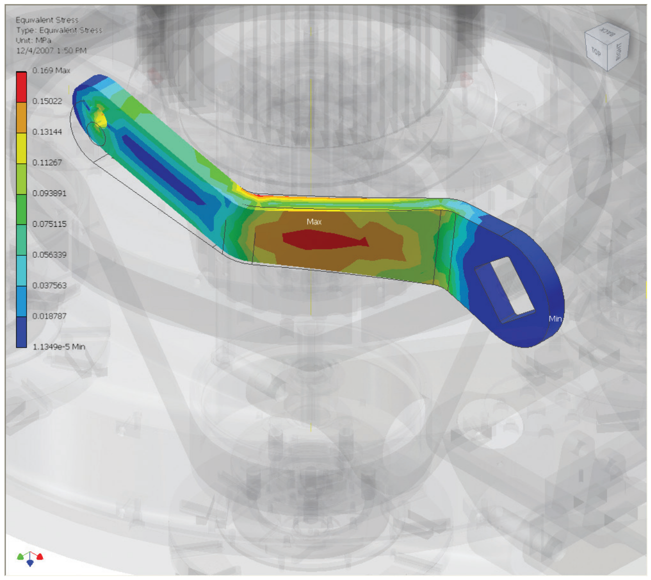
### Results from Stress Analysis

| | 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

$r_u = 50\ mm$
$r_i = 60\ mm$
$r_e = 70\ mm$
$\Delta = 1\ mm$






## 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.

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