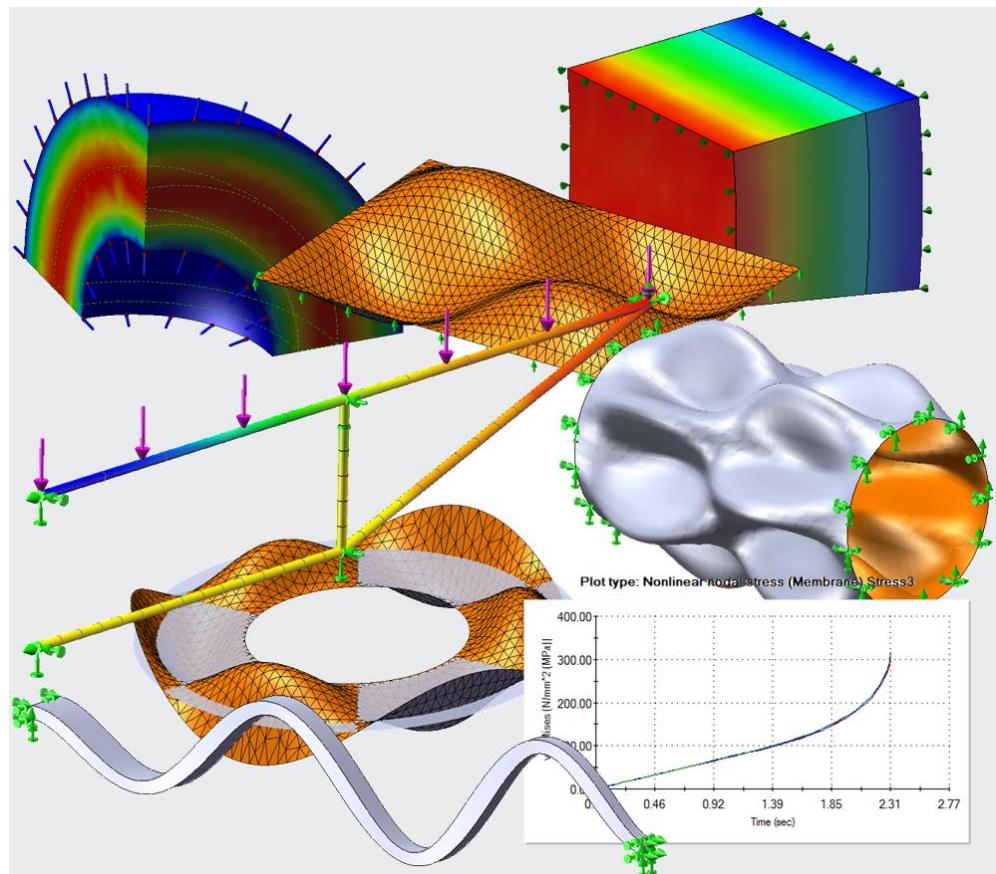


# SOLIDWORKS Simulation 2019 Validation

BASED ON THE GUIDE DE VALIDATION DES PROGICIELS DE CALCULS DE STRUCTURES, by AFNOR

## ABSTRACT

The purpose of this report is to present the accuracy of results given by SOLIDWORKS simulation 2019 using the Guide de validation des progiciels de calcul de structures (Structural Analysis Software Validation Guide) published by AFNOR (Association Française de NORmalisation, French Standardization Association). 101 validation examples (linear static analysis, vibration, dynamic response, thermal, nonlinear) from the guide are analyzed. Results given by SOLIDWORKS Simulation generally fall within 1% of the ideal solution.



The purpose of this report is to present the accuracy of results given by SOLIDWORKS Simulation 2019 using the *Guide de validation des progiciels de calcul de structures* (Structural Analysis Software Validation Guide).

This guide was published by AFNOR (Association Française de NORmalisation, French Standardization Association) and written and compiled by the SFM (Société Française des Mécaniciens).

This report compares results given by SOLIDWORKS Simulation 2019 with 101 examples representative of the *Guide de validation des progiciels de calcul de structures* published by AFNOR (Association Française de NORmalisation, French Standardization Association).

It is a compilation of 143 validation examples for Finite Elements Analysis software. The validation examples belong to a wide range of domains: linear static analysis, vibration, dynamic response, thermal, nonlinear, and fluid mechanics.

Not all of them fit in the range of analysis capabilities of SOLIDWORKS Simulation. That's the case of the validation examples in fluid dynamics, for instance. Therefore, a set of 101 examples were selected. They are presented in this report using the evaluation form template provided in the guide. In addition to the form, screen captures of the model and results have been added when useful for a better understanding. However, information about each model's geometry, material properties, loads, and boundary conditions have not been copied into this report. To obtain all the above information, the reader should refer to the guide itself.

While modeling each problem in SOLIDWORKS Simulation, the intent has been to meticulously follow the modeling guidelines recommended for each example. When not possible, an equivalent approach was used. For instance, when it was not possible to perform a study with the recommended element type, an equivalent study was set up with another element type. Wherever applicable and meaningful, however, the validation examples have been run with more than one element type.

As you will see in this report, this year again, results given by SOLIDWORKS Simulation generally fall within 1% of the reference solution.

Julien Boissat  
SOLIDWORKS Simulation Expert Technical Support Engineer

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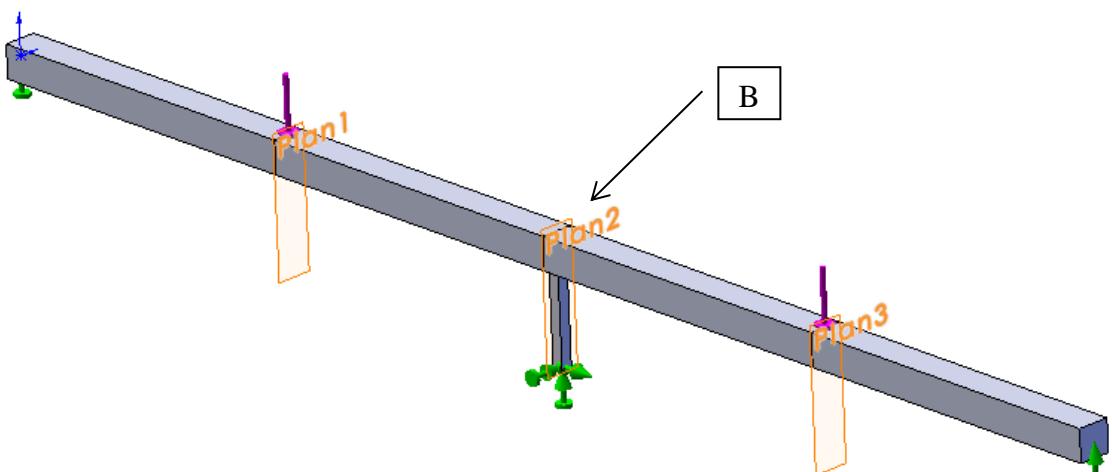
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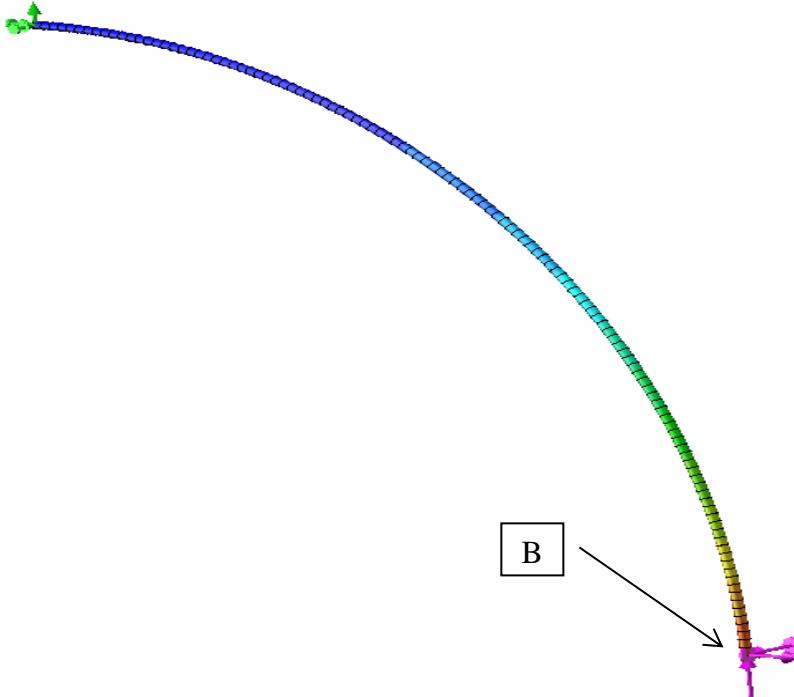
## I. **STRUCTURAL MECHANICS**

## 1. Linear static

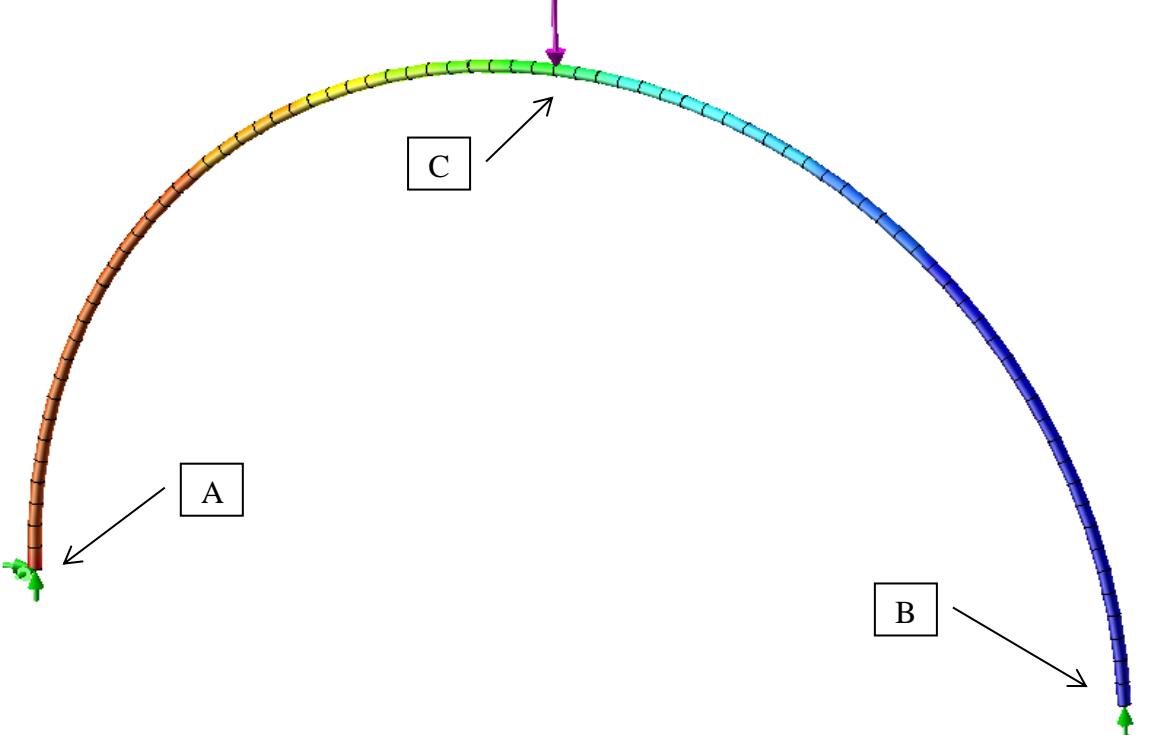
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 B3			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SLENDER BEAM WITH BOTH ENDS FIXED				
Codification: SSLL 01-89				
Test performed by : Julien BOISSAT	Date : 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : BEAM				
Number of degrees of freedom or mesh density :				
Nb of nodes = 135				
Nb of elements = 130				
Nb of DOF = 774				
Results :				
Location	Physical quantity and reference unit		Calculated value	Deviation (%)
Shear force in G	V (N)	-540	-547	1.29
Moment in G	M (Nm)	2800	2800	0
Displacement in G	v (m)	$- 4.92 \times 10^{-2}$	$- 4.92 \times 10^{-2}$	0
Axial force in A	H (N)	- 24000	- 24000	0
Comments :				

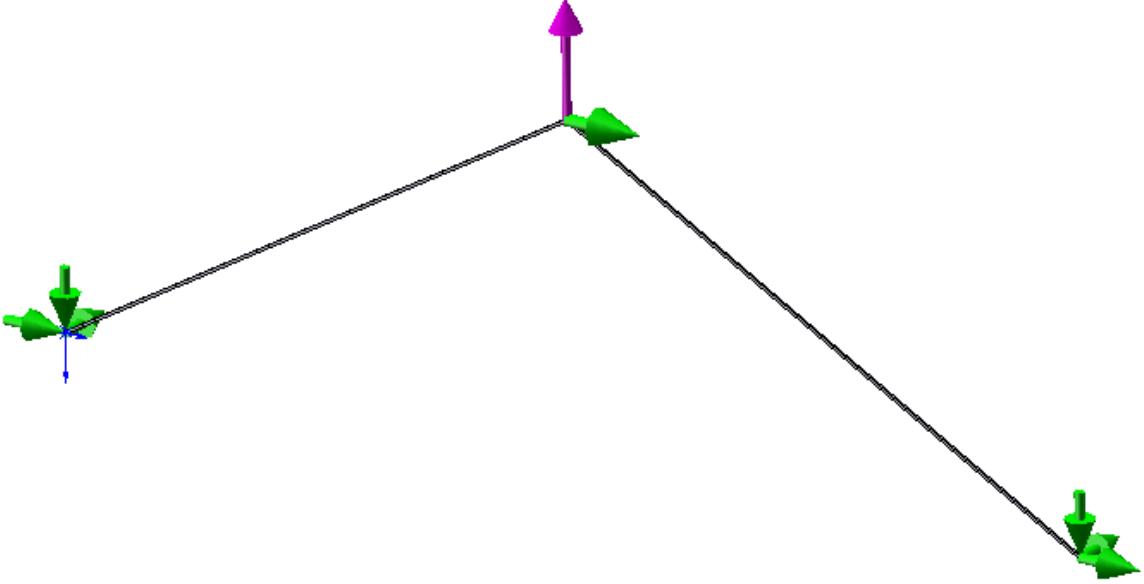
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 B3			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SLENDER BEAM ON THREE SIMPLE SUPPORTS				
Codification: SSLL 03-89				
				
Test performed by : Julien BOISSAT		Date : 3/25/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>				
Element type : BEAM				
Number of degrees of freedom or mesh density :				
Nb of nodes = 132				
Nb of elements = 126				
Nb of DOF = 753				
Results :				
Location	Physical quantity and reference unit		Calculated value	Deviation (%)
Moment in <i>B</i>	<i>M</i> (Nm)	± 63000	± 62960	.06
Displacement in <i>B</i>	<i>v</i> (m)	- 0.010	- 0.010	0
Reaction force in <i>B</i>	<i>V</i> (N)	21010	21010	0
Comments :				
The vertical beam was modeled in order to simulate the elastic support.				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 B3			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: BIMETALLIC STRIP FIXED ON BOTH ENDS CONNECTED WITH A RIGID BAR				
Codification: SSLL 05-89				
Test performed by : Julien BOISSAT		Date : 3/25/2019		
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BEAM Number of degrees of freedom or mesh density : Nb of nodes = 357 Nb of elements = 353 Nb of DOF = 2112				
Results :				
Location	Physical quantity and reference unit		Calculated value	Deviation(%)
B	$v$ (m)	-0.125	-0.123	1.6
D	$v$ (m)	-0.125	-0.123	1.6
A	$V(N)$	500	500	0
A	$M(Nm)$	500	497.5	0.5
C	$V(N)$	500	500	0
C	$M(Nm)$	500	497.5	0.5
Comments :				

EVALUATION FORM																						
Software: SOLIDWORKS Simulation		Version: 2019 B3																				
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																						
Test name: FIXED THIN ARC UNDER INPLANE BENDING Codification: SSLL 06-89																						
																						
Test performed by : Julien BOISSAT		Date : 3/25/2019																				
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BEAM Number of degrees of freedom or mesh density : Nb of nodes = 1181 Nb of elements = 590 Nb of DOF = 3540																						
Results :																						
<table border="1"> <thead> <tr> <th>Location</th> <th colspan="2">Physical quantity and reference unit</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td rowspan="3"><i>B</i></td> <td><i>u</i> (m)</td> <td>0.3791</td> <td>0.3790</td> <td>.03</td> </tr> <tr> <td><i>v</i> (m)</td> <td>0.2417</td> <td>0.2417</td> <td>0</td> </tr> <tr> <td><i>θ</i> (rad)</td> <td>0.1654</td> <td>0.1654</td> <td>0</td> </tr> </tbody> </table>					Location	Physical quantity and reference unit		Calculated value	Deviation (%)	<i>B</i>	<i>u</i> (m)	0.3791	0.3790	.03	<i>v</i> (m)	0.2417	0.2417	0	<i>θ</i> (rad)	0.1654	0.1654	0
Location	Physical quantity and reference unit		Calculated value	Deviation (%)																		
<i>B</i>	<i>u</i> (m)	0.3791	0.3790	.03																		
	<i>v</i> (m)	0.2417	0.2417	0																		
	<i>θ</i> (rad)	0.1654	0.1654	0																		
Comments :																						

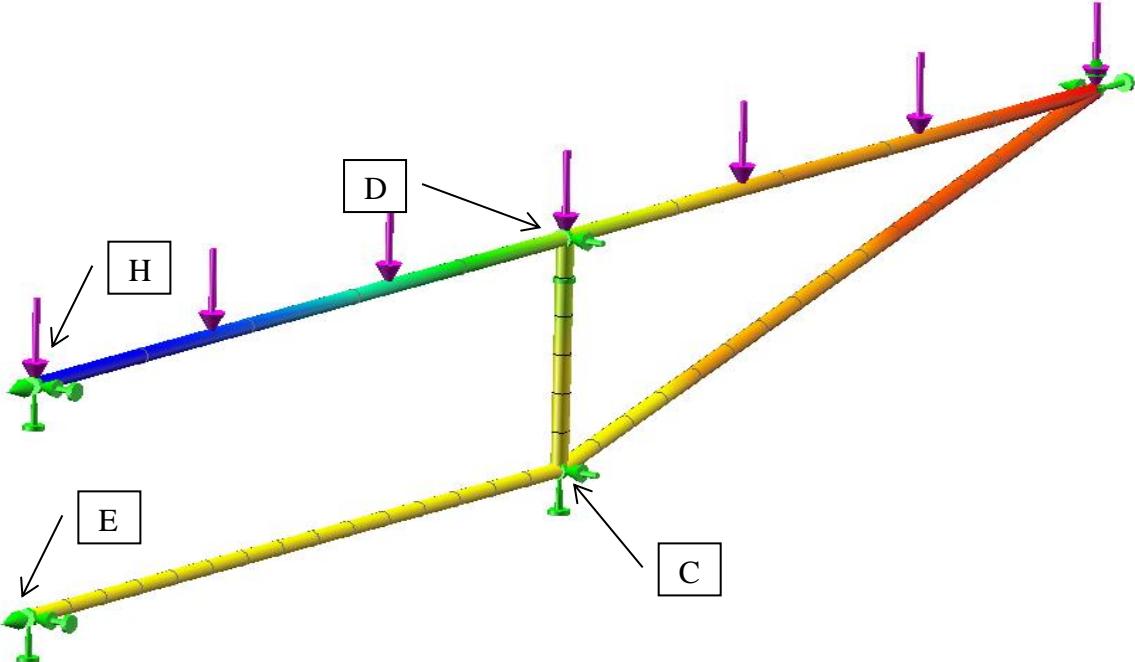
EVALUATION FORM																
Software: SOLIDWORKS Simulation	Version: 2019 B3															
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																
Test name: FIXED THIN ARC UNDER OUT OF PLANE BENDING Codification: SSLL 07-89																
Test performed by : Julien BOISSAT Date : 3/25/2019																
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BEAMS Number of degrees of freedom or mesh density : Nb of nodes = 539 Nb of elements = 269 Nb of DOF = 1614																
Results :																
<table border="1"> <thead> <tr> <th>Location</th> <th colspan="2">Physical quantity and reference unit</th> <th>Calculated value</th> <th>Deviation(%)</th> </tr> </thead> <tbody> <tr> <td>B</td> <td><math>u_B</math> (m)</td> <td>0.13462</td> <td>0.13449</td> <td>0.1</td> </tr> <tr> <td>For <math>\theta = 15^\circ</math></td> <td><math>M_t</math> (Nm) <math>M_f</math> (Nm)</td> <td>74.1180 - 96.5925</td> <td>74.183* - 96.405*</td> <td>0.09 0.19</td> </tr> </tbody> </table>		Location	Physical quantity and reference unit		Calculated value	Deviation(%)	B	$u_B$ (m)	0.13462	0.13449	0.1	For $\theta = 15^\circ$	$M_t$ (Nm) $M_f$ (Nm)	74.1180 - 96.5925	74.183* - 96.405*	0.09 0.19
Location	Physical quantity and reference unit		Calculated value	Deviation(%)												
B	$u_B$ (m)	0.13462	0.13449	0.1												
For $\theta = 15^\circ$	$M_t$ (Nm) $M_f$ (Nm)	74.1180 - 96.5925	74.183* - 96.405*	0.09 0.19												
Comments : * : Obtained by averaging the nodal values of two neighboring elements																

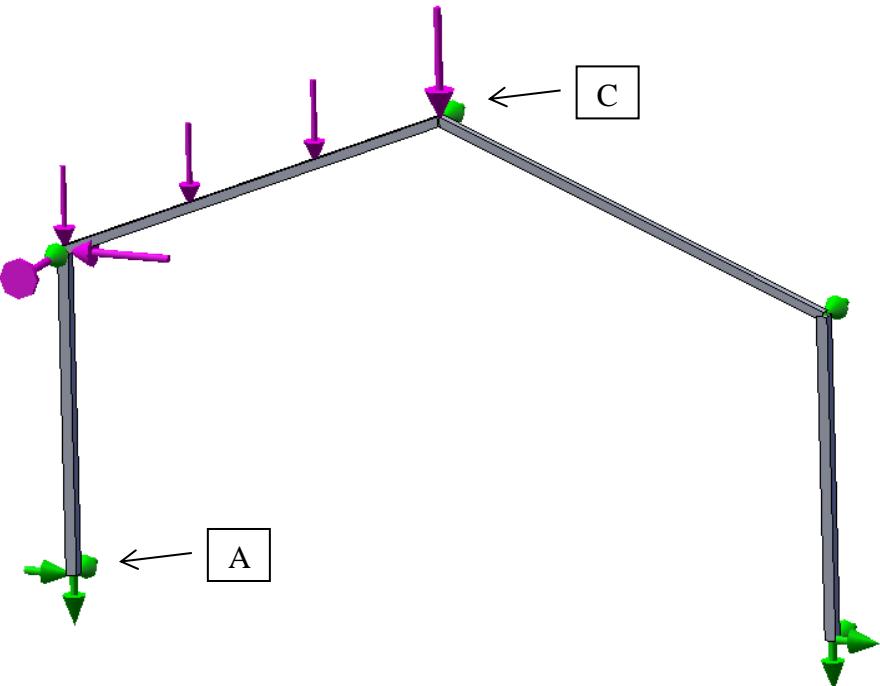
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 B3			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SIMPLY SUPPORTED THIN ARC UNDER INPLANE BENDING Codification: SSLL 08-89				
				
Test performed by : Julien BOISSAT	Date : 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : BEAM				
Number of degrees of freedom or mesh density :				
Nb of nodes = 561				
Nb of elements = 280				
Nb of DOF = 1683				
Results :				
Location	Physical quantity and reference unit		Calculated value	Deviation (%)
A	$\theta_A$ (rad)	$-3.0774 \times 10^{-2}$	$-3.0774 \times 10^{-2}$	0
B	$\theta_B$ (rad)	$3.0774 \times 10^{-2}$	$3.0774 \times 10^{-2}$	0
C	$v_C$ (m)	$-1.9206 \times 10^{-2}$	$-1.9218 \times 10^{-2}$	0.05
B	$u_B$ (m)	$5.3912 \times 10^{-2}$	$5.3923 \times 10^{-2}$	0.02
Comments :				

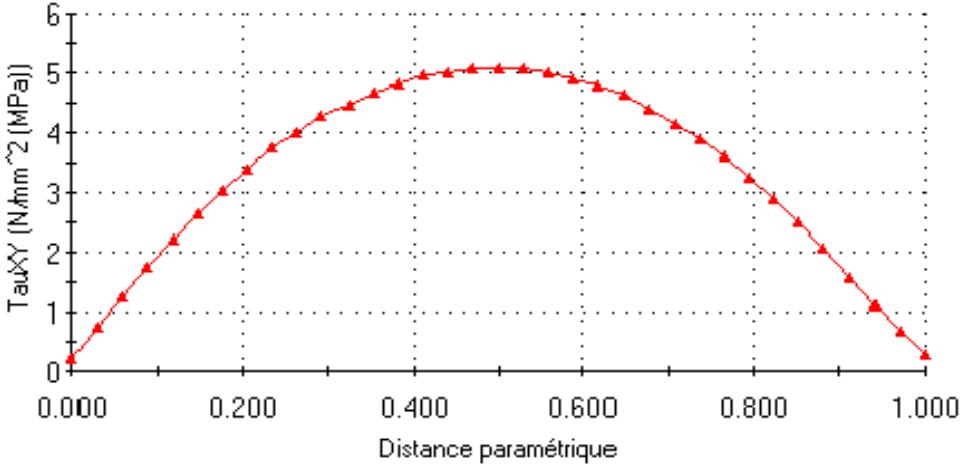
EVALUATION FORM																	
Software: SOLIDWORKS Simulation	Version: 2019 B3																
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																	
Test name: TWO BAR SYSTEM WITH THREE UNIVERSAL JOINTS Codification: SSLL 09-89																	
																	
Test performed by : Julien BOISSAT	Date : 3/25/2019																
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BAR Number of degrees of freedom or mesh density : Nb of nodes = 5 Nb of elements = 2 Nb of DOF = 3																	
Results :																	
<table border="1"> <thead> <tr> <th>Location</th> <th>Physical quantity and reference unit</th> <th>Calculated value</th> <th>Deviation(%)</th> </tr> </thead> <tbody> <tr> <td><i>C</i></td> <td><math>v_C</math> (m)</td> <td><math>-3 \times 10^{-3}</math></td> <td>0</td> </tr> <tr> <td>Bar <i>AC</i></td> <td><math>\sigma</math> (Pa)</td> <td><math>7 \times 10^7</math></td> <td>0</td> </tr> <tr> <td>Bar <i>BC</i></td> <td><math>\sigma</math> (Pa)</td> <td><math>7 \times 10^7</math></td> <td>0</td> </tr> </tbody> </table>		Location	Physical quantity and reference unit	Calculated value	Deviation(%)	<i>C</i>	$v_C$ (m)	$-3 \times 10^{-3}$	0	Bar <i>AC</i>	$\sigma$ (Pa)	$7 \times 10^7$	0	Bar <i>BC</i>	$\sigma$ (Pa)	$7 \times 10^7$	0
Location	Physical quantity and reference unit	Calculated value	Deviation(%)														
<i>C</i>	$v_C$ (m)	$-3 \times 10^{-3}$	0														
Bar <i>AC</i>	$\sigma$ (Pa)	$7 \times 10^7$	0														
Bar <i>BC</i>	$\sigma$ (Pa)	$7 \times 10^7$	0														
Comments :																	

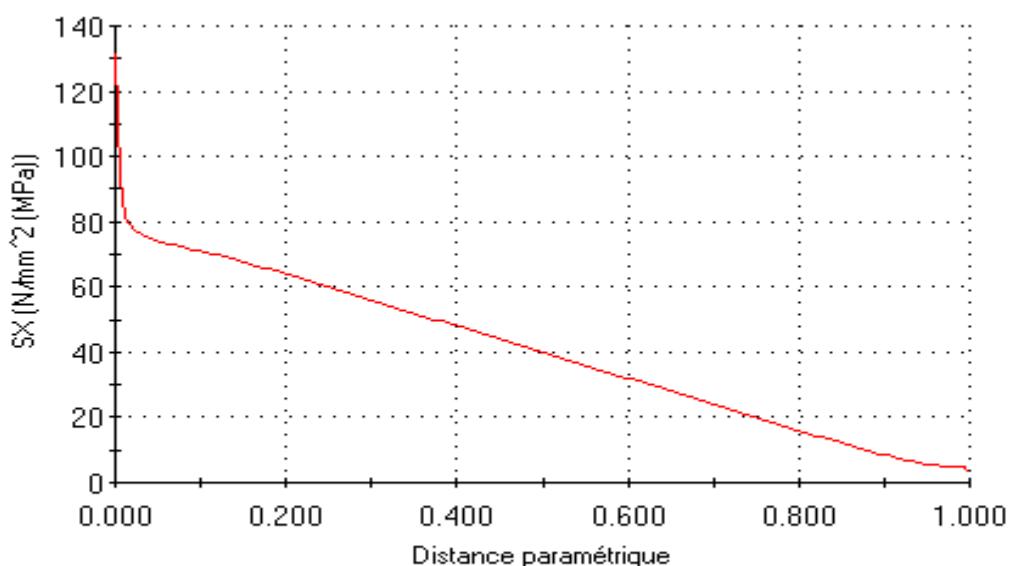
EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 B3		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.			
Test name: FRAME WITH LATERAL CONNECTIONS			
Codification: SSLL 10-89			
Test performed by : Julien BOISSAT	Date : 3/25/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Element type : BEAM			
Number of degrees of freedom or mesh density :			
Nb of nodes = 417			
Nb of elements = 411			
Nb of DOF = 2451			
Results :			
Location	Physical quantity and reference unit	Calculated value	Deviation (%)
A	$\theta$ (rad)	0.227118	0.2274
A	$M_{AB}$ (Nm)	11023.72	11021
A	$M_{AC}$ (Nm)	113.559	113.7
A	$M_{AD}$ (Nm)	-12348.588	-12347
A	$M_{AE}$ (Nm)	1211.2994	1213
Comments :			

EVALUATION FORM				
Software: SOLIDWORKS Simulation		Version: 2019 B3		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: FRAMEWORK OF ARTICULATED BASR UNDER CONCENTRATED LOAD Codification: SSLL 11-89				
Test performed by : Julien BOISSAT		Date : 3/25/2019		
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BAR Number of degrees of freedom or mesh density : Nb of nodes = 4 Nb of elements = 4 Nb of DOF = 6				
Results :				
Location	Physical quantity and reference unit		Calculated value	Deviation(%)
<i>C</i>	$u_C$ (m)	$0.26517 \times 10^{-3}$	$0.2652 \times 10^{-3}$	0.01
<i>C</i>	$v_C$ (m)	$0.08839 \times 10^{-3}$	$0.08839 \times 10^{-3}$	0
<i>D</i>	$u_D$ (m)	$3.47902 \times 10^{-3}$	$3.479 \times 10^{-3}$	0
<i>D</i>	$v_D$ (m)	$-5.60084 \times 10^{-3}$	$-5.6 \times 10^{-3}$	0.02
Comments :				

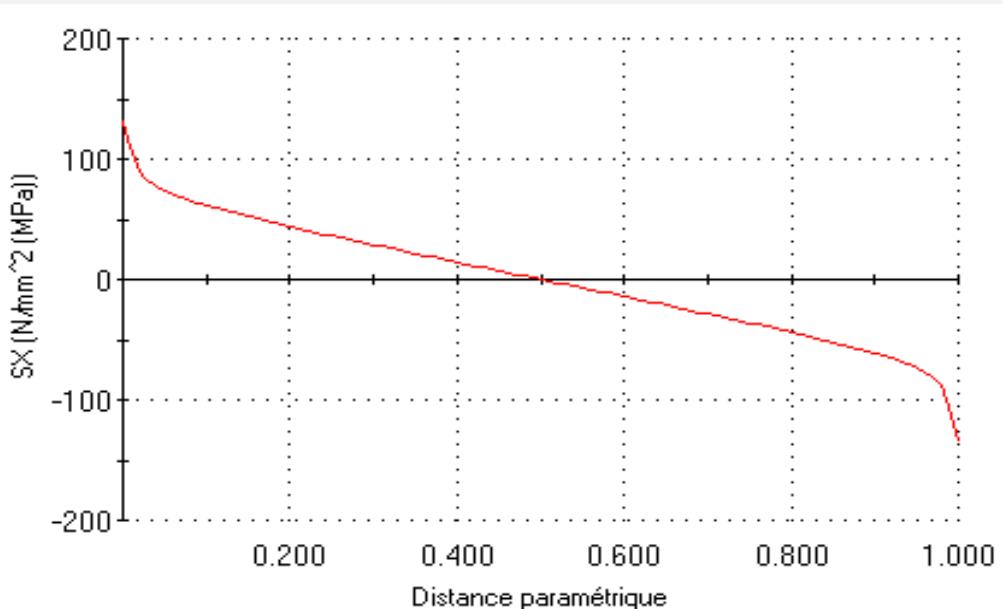
EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 B3		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.			
Test name: PRE-STRESSED BAR Codification: SSLL 13-89			
			
Test performed by : Julien BOISSAT   Date : 3/25/2019			
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BEAMS Number of degrees of freedom or mesh density : Nb of nodes = 200 Nb of elements = 196 Nb of DOF = 1164			
Results :			
Location	Physical quantity and reference unit	Calculated value	Deviation (%)
<i>CE</i>	$N$ , traction force (N)	584584	0.29
<i>H</i>	$M$ , bending moment (Nm)	49249.5	2.06
<i>D</i>	$v_D$ (m)	-0.0005428	10.75
Comments :			

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 B3		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.			
Test name: SIMPLY SUPPORTED PLANAR FRAME			
Codification: SSLL 14-89			
			
Test performed by : Julien BOISSAT	Date : 3/25/2019		
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BEAM Number of degrees of freedom or mesh density : Nb of nodes = 285 Nb of elements = 280 Nb of DOF = 1680			
Results :			
Location	Physical quantity and reference unit	Calculated value	Deviation(%)
A	V, vertical reaction (N)	31500.0	0.002
A	H, horizontal reaction (N)	20239.4	0.001
C	$v_C$ (m)	-0.03072	0.23
Comments : Typo corrected in the guide: $p=-30000N$ instead of $3000N/m$			

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 B3			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: PLATE UNDER BENDING AND SHEAR IN ITS OWN PLANE				
Codification: SSLP 01-89				
				
Test performed by : Julien BOISSAT	Date : 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 5290			
Nb of elements	= 2541			
Nb of DOF	= 31530			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
(L,y)	$v_1$	0.3413	0.35607	4.328%
(L,y)	$v_2$	0.3573	0.35608	-0.341%
				
Distribution of Shear stress along Y				



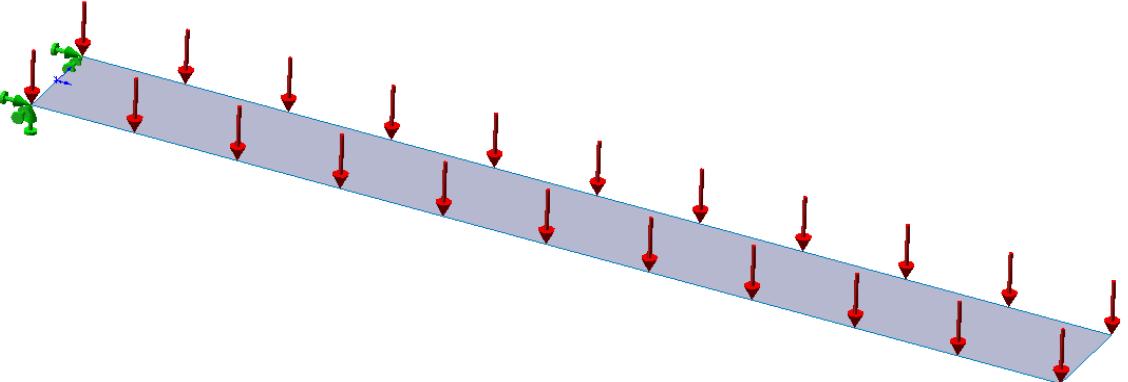
— SX (N/mm<sup>2</sup> [MPa])  
Distribution of SX stress along top edge

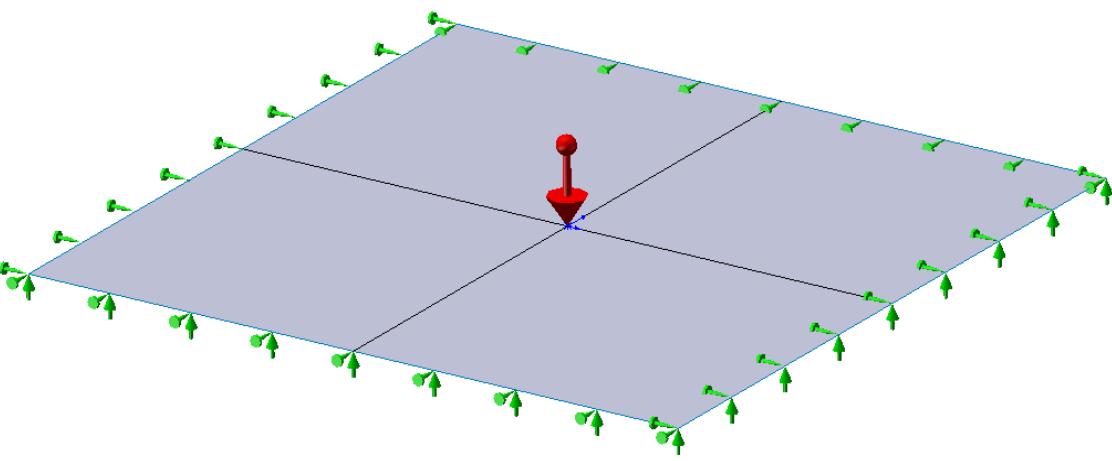


— SX (N/mm<sup>2</sup> [MPa])  
Distribution of SX stress along fixed edge

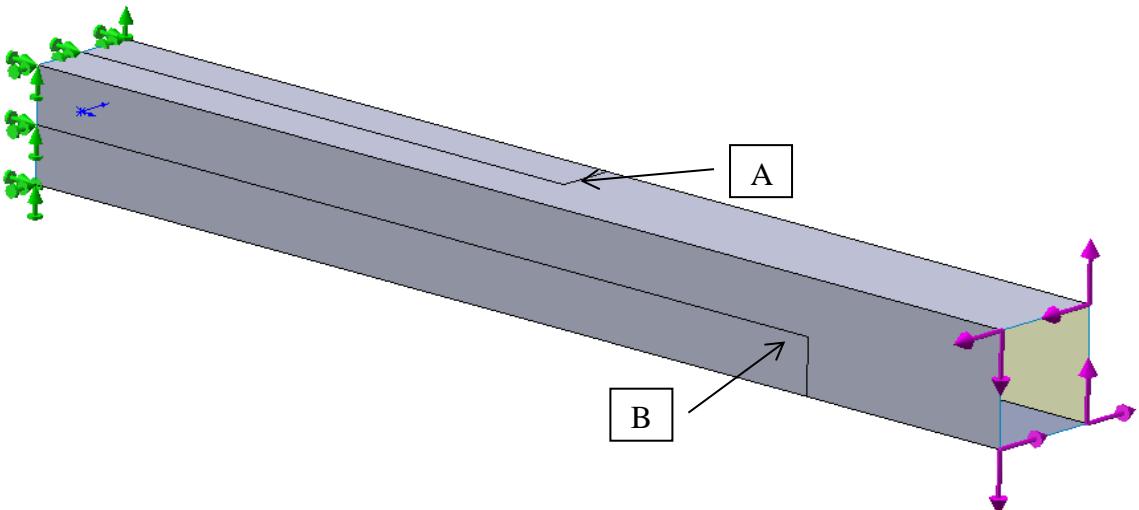
Comments :

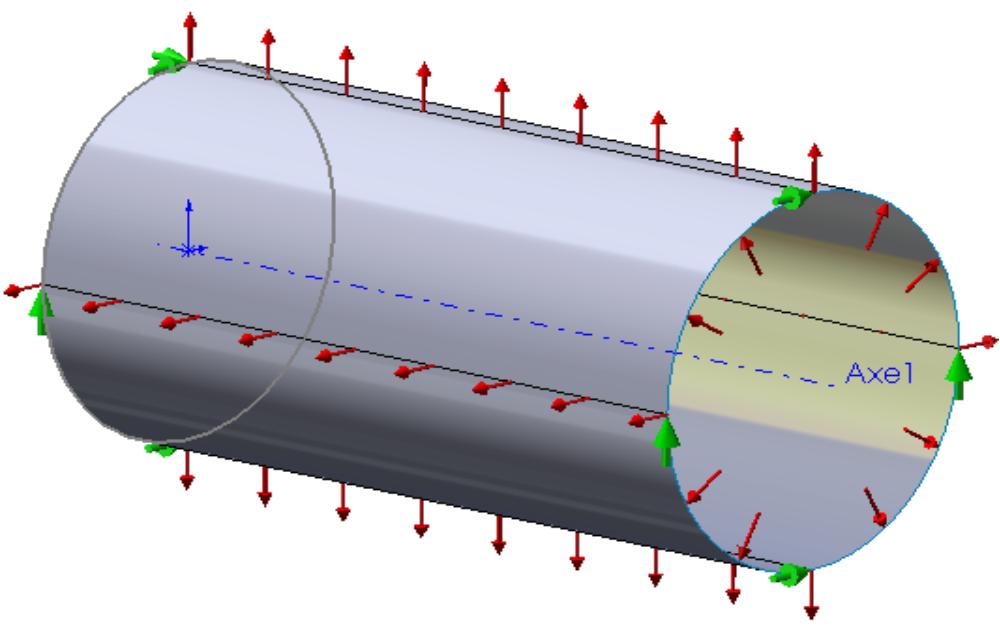
EVALUATION FORM																					
Software: SOLIDWORKS Simulation	Version: 2019 B3																				
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																					
Test name: PERFORATED PLATE UNDER SIMPLE TRACTION																					
Codification: SSLP 02-89																					
Test performed by : Julien BOISSAT	Date : 3/25/2019																				
Model used																					
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>																			
Element type : SHELL 6																					
Number of degrees of freedom or mesh density :																					
Nb of nodes = 7168																					
Nb of elements = 3424																					
Nb of DOF = 42444																					
Results :																					
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;">Location (Space-Time)</th> <th style="text-align: center; padding: 5px;">Physical quantity (unit)</th> <th style="text-align: center; padding: 5px;">Reference value</th> <th style="text-align: center; padding: 5px;">Calculated value</th> <th style="text-align: center; padding: 5px;">Deviation (%)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px;">(a,0)</td> <td style="text-align: center; padding: 5px;"><math>\sigma_{\theta\theta}</math> (N/mm<sup>2</sup>)</td> <td style="text-align: center; padding: 5px;">7.5</td> <td style="text-align: center; padding: 5px;">7.584</td> <td style="text-align: center; padding: 5px;">1.12</td> </tr> <tr> <td style="text-align: center; padding: 5px;">(a,<math>\pi/4</math>)</td> <td style="text-align: center; padding: 5px;"><math>\sigma_{\theta\theta}</math> (N/mm<sup>2</sup>)</td> <td style="text-align: center; padding: 5px;">2.5</td> <td style="text-align: center; padding: 5px;">2.513</td> <td style="text-align: center; padding: 5px;">0.52</td> </tr> <tr> <td style="text-align: center; padding: 5px;">(a,<math>\pi/2</math>)</td> <td style="text-align: center; padding: 5px;"><math>\sigma_{\theta\theta}</math> (N/mm<sup>2</sup>)</td> <td style="text-align: center; padding: 5px;">-2.5</td> <td style="text-align: center; padding: 5px;">-2.559</td> <td style="text-align: center; padding: 5px;">2.36</td> </tr> </tbody> </table>		Location (Space-Time)	Physical quantity (unit)	Reference value	Calculated value	Deviation (%)	(a,0)	$\sigma_{\theta\theta}$ (N/mm <sup>2</sup> )	7.5	7.584	1.12	(a, $\pi/4$ )	$\sigma_{\theta\theta}$ (N/mm <sup>2</sup> )	2.5	2.513	0.52	(a, $\pi/2$ )	$\sigma_{\theta\theta}$ (N/mm <sup>2</sup> )	-2.5	-2.559	2.36
Location (Space-Time)	Physical quantity (unit)	Reference value	Calculated value	Deviation (%)																	
(a,0)	$\sigma_{\theta\theta}$ (N/mm <sup>2</sup> )	7.5	7.584	1.12																	
(a, $\pi/4$ )	$\sigma_{\theta\theta}$ (N/mm <sup>2</sup> )	2.5	2.513	0.52																	
(a, $\pi/2$ )	$\sigma_{\theta\theta}$ (N/mm <sup>2</sup> )	-2.5	-2.559	2.36																	
Comments :																					
The formulas of the analytical solution are solely applicable when the length and width of the sheet are large enough compared to the diameter of the hole. The stresses away from the hole should not be affected by its presence. With the given dimensions, the ratio between the diameter and the width is equal to 0.2 which is not enough. For the formulas to be applicable, the plate should be at least 4 times larger (ratio equal to 0.05). The values in the table above are given for such a modified geometry.																					

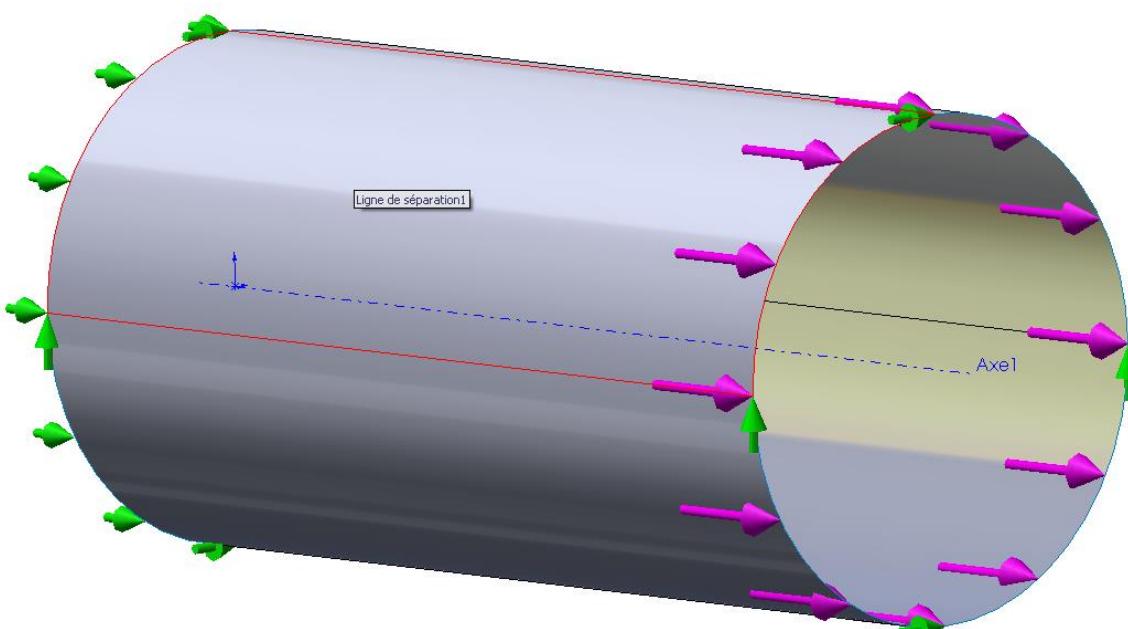
EVALUATION FORM											
Software: SOLIDWORKS Simulation	Version: 2019 B3										
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.											
Test name: CANTILEVER RECTANGULAR PLATE											
Codification: SSLS 01-89											
											
Test performed by : Julien BOISSAT	Date : 3/25/2019										
Model used											
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>									
Element type : SHELL 6											
Number of degrees of freedom or mesh density :											
Nb of nodes = 10467											
Nb of elements = 5058											
Nb of DOF = 62604											
Results :											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="padding: 5px;"><b>Location</b></th> <th style="padding: 5px;"><b>Physical quantity</b></th> <th style="padding: 5px;"><b>Reference value</b></th> <th style="padding: 5px;"><b>Calculated value</b></th> <th style="padding: 5px;"><b>Deviation (%)</b></th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;">Side <math>x = 1</math></td> <td style="padding: 5px;"><math>w</math> (m)</td> <td style="padding: 5px;">-0.0973</td> <td style="padding: 5px;">-0.0958</td> <td style="padding: 5px;">1.57</td> </tr> </tbody> </table>		<b>Location</b>	<b>Physical quantity</b>	<b>Reference value</b>	<b>Calculated value</b>	<b>Deviation (%)</b>	Side $x = 1$	$w$ (m)	-0.0973	-0.0958	1.57
<b>Location</b>	<b>Physical quantity</b>	<b>Reference value</b>	<b>Calculated value</b>	<b>Deviation (%)</b>							
Side $x = 1$	$w$ (m)	-0.0973	-0.0958	1.57							
Comments :											
Do not perform Large Displacement calculations.											

EVALUATION FORM											
Software: SOLIDWORKS Simulation	Version: 2019 B3										
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.											
Test name: SIMPLY SUPPORTED SQUARE PLATE											
Codification: SSLS 02-89											
											
Test performed by : Julien BOISSAT	Date: 3/25/2019										
Model used											
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>									
Element type : SHELL 6											
Number of degrees of freedom or mesh density :											
Nb of nodes = 4505											
Nb of elements = 2184											
Nb of DOF = 27030											
Results :											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;">Location</th> <th style="text-align: center; padding: 5px;">Physical quantity</th> <th style="text-align: center; padding: 5px;">Reference value<sup>(1)</sup></th> <th style="text-align: center; padding: 5px;">Calculated value</th> <th style="text-align: center; padding: 5px;">Deviation (%)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px;">Center <i>O</i></td> <td style="text-align: center; padding: 5px;"><i>w<sub>O</sub></i> (m)</td> <td style="text-align: center; padding: 5px;"><math>-0.1649 \times 10^{-3}</math></td> <td style="text-align: center; padding: 5px;"><math>-0.1648 \times 10^{-3}</math></td> <td style="text-align: center; padding: 5px;">0.01</td> </tr> </tbody> </table>		Location	Physical quantity	Reference value <sup>(1)</sup>	Calculated value	Deviation (%)	Center <i>O</i>	<i>w<sub>O</sub></i> (m)	$-0.1649 \times 10^{-3}$	$-0.1648 \times 10^{-3}$	0.01
Location	Physical quantity	Reference value <sup>(1)</sup>	Calculated value	Deviation (%)							
Center <i>O</i>	<i>w<sub>O</sub></i> (m)	$-0.1649 \times 10^{-3}$	$-0.1648 \times 10^{-3}$	0.01							
Comments :											
(1) "Roark's Formulas for Stress & Strain" (6 <sup>th</sup> ed. p.458) gives the following formula for a thin simply supported square plate :											
$\text{Max } y = \frac{-\alpha q b^4}{E t^3} \text{ where } b \text{ is the width, } a \text{ is the length, } t \text{ the thickness and } \alpha = -0.0444 \text{ for}$											
$\frac{b}{a} = 1 \text{ which gives a maximum displacement } y_{\max} = -0.1649 \times 10^{-3} \text{ m.}$											

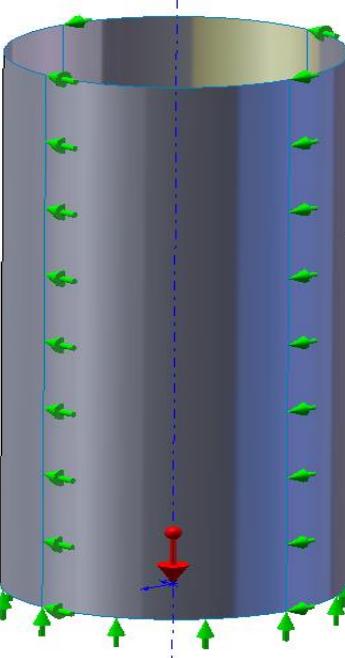
EVALUATION FORM																							
Software: SOLIDWORKS Simulation			Version: 2019 SP2																				
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																							
Test name: CIRCULAR PLATE UNDER UNIFORM PRESSURE LOAD																							
Codification: SSLS 03-89																							
Test performed by : Julien BOISSAT			Date: 3/25/2019																				
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : SHELL 6 and SHELLAX Number of degrees of freedom or mesh density :																							
SHELL 6: Nb of nodes = 10343 Nb of elements = 5082 Nb of DOF = 59922			SHELLAX Nb of nodes = 1525 Nb of elements = 510 Nb of DOF = 3040																				
Results :																							
<table border="1"> <thead> <tr> <th rowspan="2">Location</th> <th rowspan="2">Physical quantity</th> <th rowspan="2">Reference value</th> <th colspan="2">Calculated value</th> <th colspan="2">Deviation (%)</th> </tr> <tr> <th>SHELL 6</th> <th>SHELLAX</th> <th>SHELL 6</th> <th>SHELLAX</th> </tr> </thead> <tbody> <tr> <td>Center <math>O</math></td> <td><math>w_O</math> (m)</td> <td>-0.0065</td> <td>-0.0065</td> <td>-0.0065</td> <td>0</td> <td>0</td> </tr> </tbody> </table>						Location	Physical quantity	Reference value	Calculated value		Deviation (%)		SHELL 6	SHELLAX	SHELL 6	SHELLAX	Center $O$	$w_O$ (m)	-0.0065	-0.0065	-0.0065	0	0
Location	Physical quantity	Reference value	Calculated value		Deviation (%)																		
			SHELL 6	SHELLAX	SHELL 6	SHELLAX																	
Center $O$	$w_O$ (m)	-0.0065	-0.0065	-0.0065	0	0																	
Comments :																							

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 B3			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: RECTANGULAR HOLLOW BEAM UNDER TORSION				
Codification: SSLS 05-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 10292			
Nb of elements	= 5114			
Nb of DOF	= 61368			
Results :				
Location (Space-Time)	Physical quantity (unit)	Reference value	Calculated value	Deviation (%)
Point A (0.5,0,0.05)	$v$ (m)	$-0.617 \times 10^{-6}$	$-0.616 \times 10^{-6}$	0.16
	$\theta_x$ (rad)	$0.123 \times 10^{-4}$	$0.123 \times 10^{-4}$	0
	$\sigma_{xy}$ (Pa)	$-0.11 \times 10^6$	$-0.1096 \times 10^6$	0.36
Point B (0.8,-0.05,0)	$w$ (m)	$-0.987 \times 10^{-6}$	$-0.986 \times 10^{-6}$	0.1
	$\theta_x$ (rad)	$0.197 \times 10^{-4}$	$0.197 \times 10^{-4}$	0
	$\sigma_{xy}$ (Pa) <sup>(1)</sup>	$-0.11 \times 10^6$	$-0.1096 \times 10^6$	0.36
Comments :				
<sup>(1)</sup> A typo was detected in the Guide: at point B, the table should read $\sigma_{xz}$ instead of $\sigma_{xy}$ .				

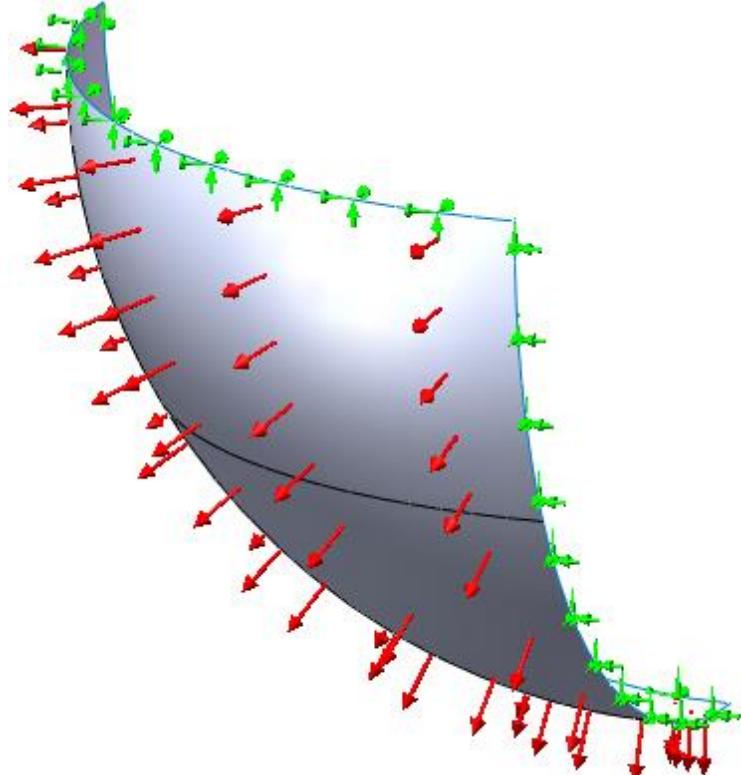
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: THIN CYLINDER UNDER UNIFORM RADIAL PRESSURE				
Codification: SSLS 06-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL6T				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 4296			
Nb of elements	= 2104			
Nb of DOF	= 25776			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
All points	$\sigma_{11}$ (Pa)	0.0	$70^{(1)}$	-
	$\sigma_{22}$ (Pa)	$5.00 \times 10^5$	$5.02 \times 10^5$	0.4
	$\delta R$ (m)	$2.38 \times 10^{-6}$	$2.38 \times 10^{-6}$	0
	$\delta L$ (m)	$-2.86 \times 10^{-6}$	$-2.86 \times 10^{-6}$	0
Comments :				
<sup>(1)</sup> $\sigma_{11} = 500$ Pa should be compared to the load and/or to $\sigma_{22}$ . The result is acceptable (ratio equal to 1/1000).				

EVALUATION FORM																										
Software: SOLIDWORKS Simulation	Version: 2019 SP2																									
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																										
Test name: THIN CYLINDER UNDER UNIFORM AXIAL PRESSURE																										
Codification: SSLS 07-89																										
																										
Test performed by : Julien BOISSAT	Date: 3/25/2019																									
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : SHELL6 Number of degrees of freedom or mesh density : Nb of nodes = 10368 Nb of elements = 5120 Nb of DOF = 62208																										
<b>Results :</b> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;"><b>Location</b></th> <th style="text-align: center; padding: 5px;"><b>Physical quantity</b></th> <th style="text-align: center; padding: 5px;"><b>Reference value</b></th> <th style="text-align: center; padding: 5px;"><b>Calculated value</b></th> <th style="text-align: center; padding: 5px;"><b>Deviation (%)</b></th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px; vertical-align: top;">All points</td> <td style="text-align: center; padding: 5px;"><math>\sigma_{11}</math> (Pa)</td> <td style="text-align: center; padding: 5px;"><math>5.00 \times 10^5</math></td> <td style="text-align: center; padding: 5px;"><math>5.00 \times 10^5</math></td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td></td> <td style="text-align: center; padding: 5px;"><math>\sigma_{22}</math> (Pa)</td> <td style="text-align: center; padding: 5px;">0.0</td> <td style="text-align: center; padding: 5px;">152 <sup>(1)</sup></td> <td style="text-align: center; padding: 5px;">-</td> </tr> <tr> <td></td> <td style="text-align: center; padding: 5px;"><math>\delta L</math> (m)</td> <td style="text-align: center; padding: 5px;"><math>9.52 \times 10^{-6}</math></td> <td style="text-align: center; padding: 5px;"><math>9.525 \times 10^{-6}</math></td> <td style="text-align: center; padding: 5px;">0.05</td> </tr> <tr> <td></td> <td style="text-align: center; padding: 5px;"><math>\delta R</math> (m)</td> <td style="text-align: center; padding: 5px;"><math>-7.14 \times 10^{-7}</math></td> <td style="text-align: center; padding: 5px;"><math>-7.155 \times 10^{-7}</math></td> <td style="text-align: center; padding: 5px;">0.14</td> </tr> </tbody> </table>		<b>Location</b>	<b>Physical quantity</b>	<b>Reference value</b>	<b>Calculated value</b>	<b>Deviation (%)</b>	All points	$\sigma_{11}$ (Pa)	$5.00 \times 10^5$	$5.00 \times 10^5$	0		$\sigma_{22}$ (Pa)	0.0	152 <sup>(1)</sup>	-		$\delta L$ (m)	$9.52 \times 10^{-6}$	$9.525 \times 10^{-6}$	0.05		$\delta R$ (m)	$-7.14 \times 10^{-7}$	$-7.155 \times 10^{-7}$	0.14
<b>Location</b>	<b>Physical quantity</b>	<b>Reference value</b>	<b>Calculated value</b>	<b>Deviation (%)</b>																						
All points	$\sigma_{11}$ (Pa)	$5.00 \times 10^5$	$5.00 \times 10^5$	0																						
	$\sigma_{22}$ (Pa)	0.0	152 <sup>(1)</sup>	-																						
	$\delta L$ (m)	$9.52 \times 10^{-6}$	$9.525 \times 10^{-6}$	0.05																						
	$\delta R$ (m)	$-7.14 \times 10^{-7}$	$-7.155 \times 10^{-7}$	0.14																						
<b>Comments :</b> <sup>(1)</sup> $\sigma_{22} = 106$ Pa should be compared to the load and/or to $\sigma_{11}$ . The result is acceptable (ratio smaller than 1/1000).																										

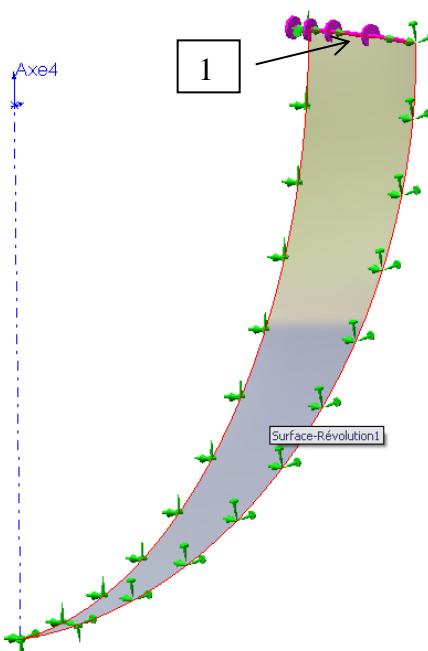
EVALUATION FORM				
Software: SOLIDWORKS Simulation		Version: 2019 SP2		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: THIN CYLINDER UNDER HYDROSTATIC PRESSURE				
Codification: SSLS 08-89				
Test performed by : Julien BOISSAT		Date: 3/25/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes = 4600 Nb of elements = 2256 Nb of DOF = 27504				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
$\forall x$	$\sigma_{11}$ (Pa)	0.0	$90^{(1)}$	-
$x = L/2$	$\sigma_{22}$ (Pa)	$5.00 \times 10^5$	$4.99 \times 10^5$	0.2
$x = L/2$	$\delta R$ (m)	$2.38 \times 10^{-6}$	$2.37 \times 10^{-6}$	0.42
$x = L$	$\delta L$ (m)	$-2.86 \times 10^{-6}$	$-2.86 \times 10^{-6}$	0
	$\psi$ (rad) <sup>(2)</sup>	$1.19 \times 10^{-6}$	$1.185 \times 10^{-6}$	0.42
Comments :				
(1) $\sigma_{11} = 640$ Pa should be compared to the load and/or to the calculated stress $\sigma_{22}$ . The result is acceptable (ratio around 1/1000).				
(2) $\psi$ (rad) Derived from $\psi = \arcsin \frac{\delta R(l)}{l} = \delta R(x = L/2)/(L/2)$				

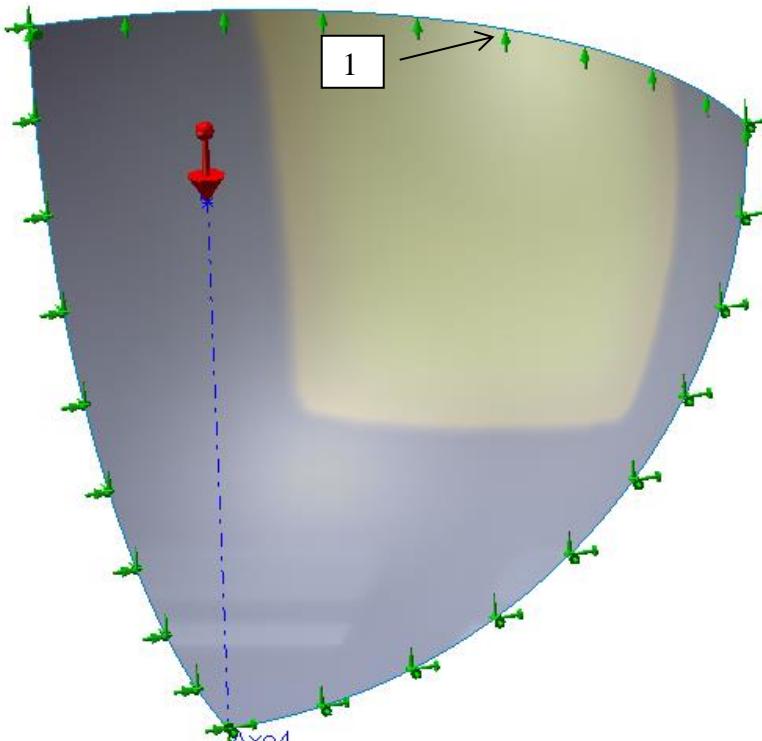
EVALUATION FORM				
Software: SOLIDWORKS Simulation		Version: 2019 SP2		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: THIN CYLINDER UNDER ITS OWN WEIGHT				
Codification: SSLS 09-89				
				
Test performed by : Julien BOISSAT		Date: 3/25/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
SHELL 6:				
Nb of nodes = 33040 Nb of elements = 16188 Nb of DOF = 198240				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
$\forall x$ $x = L$	$\sigma_{22}$ (Pa)	0.0	48 <sup>(1)</sup>	-
	$\sigma_{11}$ (Pa)	$3.14 \times 10^5$	$3.14 \times 10^5$	0
	$\delta x$ (m)	$2.99 \times 10^{-6}$	$2.99 \times 10^{-6}$	0
	$\delta R$ (m)	$-4.49 \times 10^{-7}$	$-4.49 \times 10^{-7}$	0
	$\psi$ (rad)	$-1.12 \times 10^{-7}$	$-1.15 \times 10^{-7}$	2.68
Comments :				
<sup>(1)</sup> $\sigma_{22}$ = value should be compared to the load and/or to $\sigma_{11}$ . The result is acceptable (ratio equal to 1/1000).				

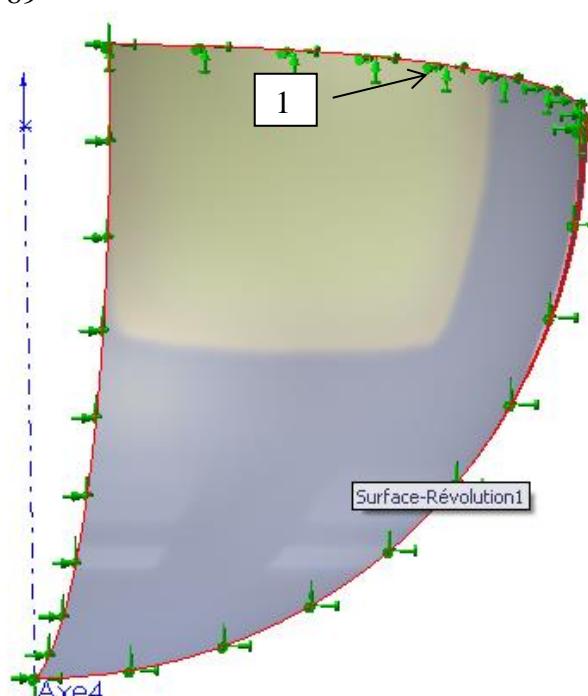
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: TORE UNDER INTERNAL UNIFORM PRESSURE Codification: SSLS 10-89				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes = 813				
Nb of elements = 374				
Nb of DOF = 4866				
Results :				
Location (Space-Time)	Physical quantity (unit)	Reference value	Calculated value	Deviation (%)
Any $r$ $r = a - b$	$\sigma_{22}$ (Pa)	$2.5 \times 10^5$	$2.51 \times 10^5$	0.40
	$\sigma_{11}$ (Pa)	$7.5 \times 10^5$	$7.46 \times 10^5$	0.53
$r = a + b$	$\delta_r$ (m)	$1.19 \times 10^{-7}$	$1.17 \times 10^{-7}$	-1.68
	$\sigma_{11}$ (Pa)	$4.17 \times 10^5$	$4.16 \times 10^5$	0.24
	$\delta_r$ (m)	$1.79 \times 10^{-6}$	$1.77 \times 10^{-6}$	-1.12
Comments :				
Any $r$ corresponds to edge 1.				
$r = a - b$ corresponds to edge 2.				
$r = a + b$ corresponds to edge 3.				

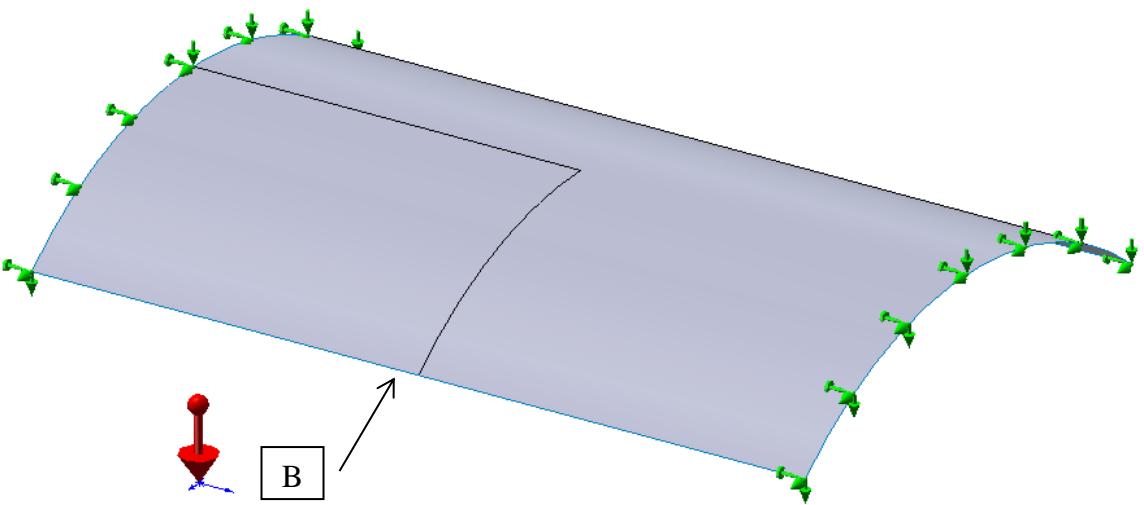
EVALUATION FORM											
Software: SOLIDWORKS Simulation	Version: 2019 SP2										
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.											
Test name: SPHERICAL CAP UNDER INTERNAL PRESSURE											
Codification: SSLS 14-89											
											
Test performed by : Julien BOISSAT	Date: 3/25/2019										
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : SHELL 6 Number of degrees of freedom or mesh density : Nb of nodes = 2359 Nb of elements = 1134 Nb of DOF = 14145											
Results :											
<table border="1"> <thead> <tr> <th>Location</th> <th>Physical quantity</th> <th>Reference value</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td>For every <math>\theta</math> <math>\theta = 90^\circ</math></td> <td><math>\sigma_{11} = \sigma_{22}</math> (Pa) <math>\delta R</math> (m)</td> <td><math>2.50 \times 10^5</math> <math>8.33 \times 10^{-7}</math></td> <td><math>2.50 \times 10^5</math> <math>8.34 \times 10^{-7}</math></td> <td>0 0.12</td> </tr> </tbody> </table>		Location	Physical quantity	Reference value	Calculated value	Deviation (%)	For every $\theta$ $\theta = 90^\circ$	$\sigma_{11} = \sigma_{22}$ (Pa) $\delta R$ (m)	$2.50 \times 10^5$ $8.33 \times 10^{-7}$	$2.50 \times 10^5$ $8.34 \times 10^{-7}$	0 0.12
Location	Physical quantity	Reference value	Calculated value	Deviation (%)							
For every $\theta$ $\theta = 90^\circ$	$\sigma_{11} = \sigma_{22}$ (Pa) $\delta R$ (m)	$2.50 \times 10^5$ $8.33 \times 10^{-7}$	$2.50 \times 10^5$ $8.34 \times 10^{-7}$	0 0.12							
Comments :											

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SPHERICAL CAP UNDER RADIAL FORCE				
Codification: SSLS 15-89				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 4755			
Nb of elements	= 2244			
Nb of DOF	= 28527			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
Mid-surface	$\sigma_{11}$ (Pa)	0	8.7	-
On external plane	$\sigma_{22}$ (Pa) $\delta R$ (m)	$9.09 \times 10^5$ $4.33 \times 10^{-6}$	$9.07 \times 10^5$ $4.33 \times 10^{-6}$	0.22 0
Comments :				

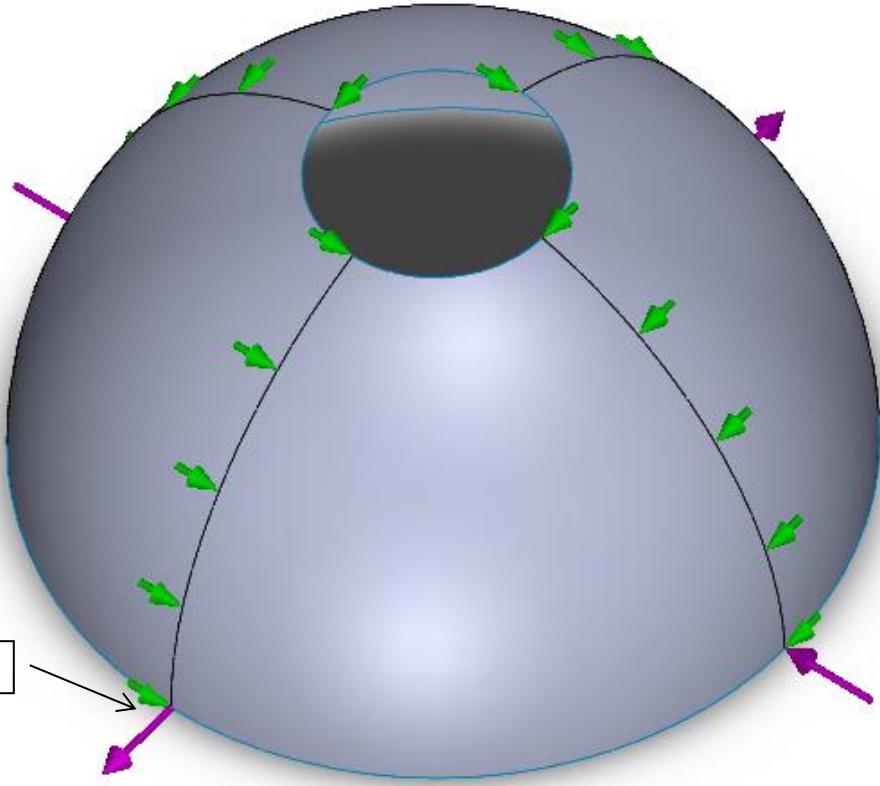
EVALUATION FORM																
Software: SOLIDWORKS Simulation	Version: 2019 SP2															
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																
Test name: SPHERICAL CAP UNDER MOMENT																
Codification: SSLS 16-89																
																
Test performed by : Julien BOISSAT	Date: 3/25/2019															
Model used																
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>															
Other <input type="checkbox"/>																
Element type : SHELL 6																
Number of degrees of freedom or mesh density :																
Nb of nodes	= 3130															
Nb of elements	= 1459															
Nb of DOF	= 18777															
Results :																
<table border="1"> <thead> <tr> <th>Location</th> <th>Physical quantity</th> <th>Reference value</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td>Outer edge</td> <td><math>\sigma_{22}</math> (Pa)</td> <td><math>8.26 \times 10^5</math></td> <td><math>8.18 \times 10^5</math></td> <td>-0.96</td> </tr> <tr> <td></td> <td><math>\delta R</math> (m)</td> <td><math>3.93 \times 10^{-6}</math></td> <td><math>3.93 \times 10^{-6}</math></td> <td>0</td> </tr> </tbody> </table>		Location	Physical quantity	Reference value	Calculated value	Deviation (%)	Outer edge	$\sigma_{22}$ (Pa)	$8.26 \times 10^5$	$8.18 \times 10^5$	-0.96		$\delta R$ (m)	$3.93 \times 10^{-6}$	$3.93 \times 10^{-6}$	0
Location	Physical quantity	Reference value	Calculated value	Deviation (%)												
Outer edge	$\sigma_{22}$ (Pa)	$8.26 \times 10^5$	$8.18 \times 10^5$	-0.96												
	$\delta R$ (m)	$3.93 \times 10^{-6}$	$3.93 \times 10^{-6}$	0												
Comments :																
Outer edge corresponds to membrane stress on edge 1.																

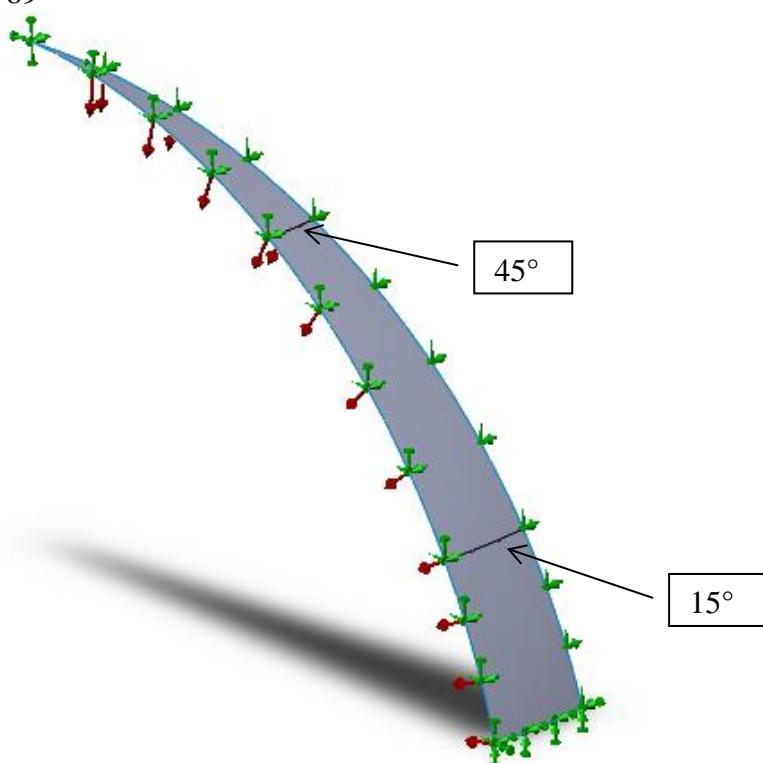
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SPHERICAL CAP UNDER ITS OWN WEIGHT				
Codification: SSLS 17-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes = 4607				
Nb of elements = 2240				
Nb of DOF = 27639				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
$\theta = 90^\circ$	$\sigma_{11}$ (Pa)	$7.85 \times 10^4$	$7.80 \times 10^4$	0.64
	$\sigma_{22}$ (Pa)	$-7.85 \times 10^4$	$-7.90 \times 10^4$	0.64
	$\delta R$ (m)	$4.86 \times 10^{-7}$	$4.88 \times 10^{-7}$	0.41
Comments : $\theta = 90^\circ$ corresponds to edge 1.				

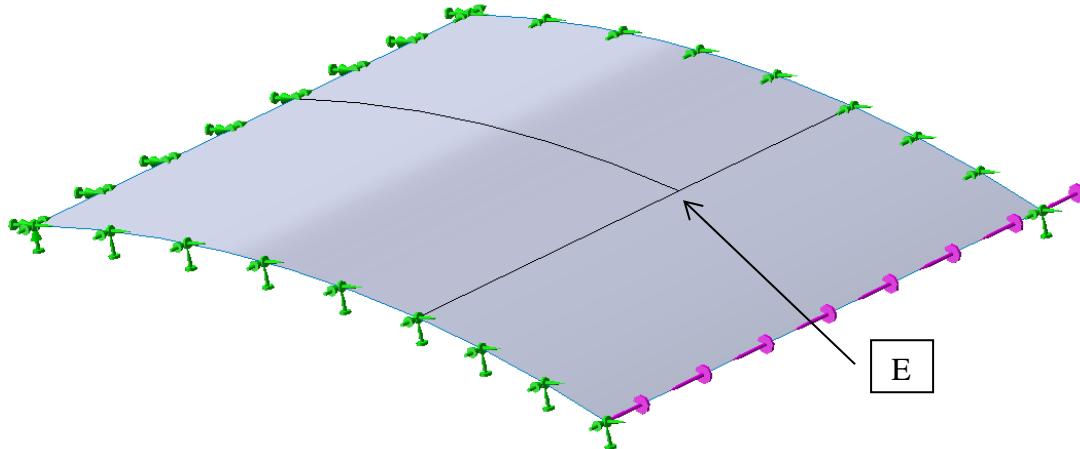
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SPHERICAL CAP UNDER IMPOSED DISPLACEMENT				
Codification: SSLS 18-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 4607			
Nb of elements	= 2240			
Nb of DOF	= 27378			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
Mid surface	$V_1$ (N) per radian	$4.62 \times 10^4$	$4.64 \times 10^4$	0.4
	$\sigma_{11}$ (Pa)	0.0	$6.9 \times 10^4$ <sup>(1)</sup>	-
	$\sigma_{22}$ (Pa)	$2.1 \times 10^7$	$2.1 \times 10^7$	0
External plane	$\sigma_{11}$ (Pa)	$3.81 \times 10^7$	$3.79 \times 10^7$	0.79
	$\sigma_{22}$ (Pa)	$3.24 \times 10^7$	$3.33 \times 10^7$	2.78
Comments :				
(1) Compared to $\sigma_{22}$ , $\sigma_{11}$ is negligible.				
Mid surface corresponds to membrane stress on edge 1.				
External plane corresponds to bottom stress on edge 1.				

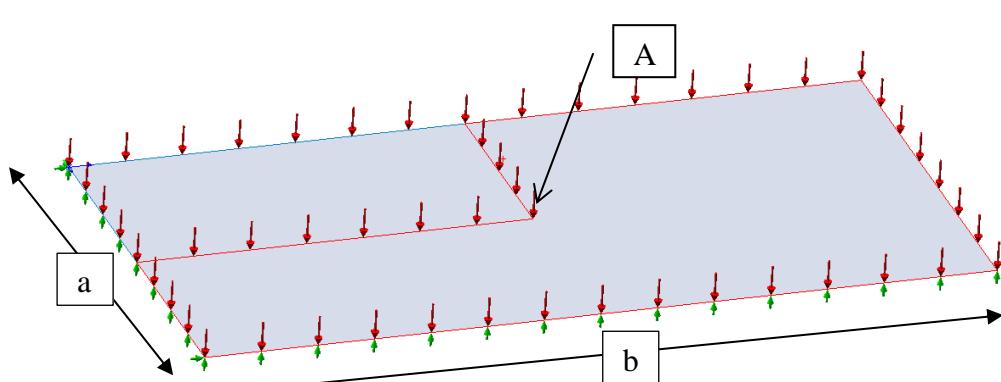
EVALUATION FORM											
Software: SOLIDWORKS Simulation	Version: 2019 SP2										
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.											
Test name: CYLINDRICAL SHELL UNDER ITS OWN WEIGHT											
Codification: SSLS 19-89											
											
Test performed by : Julien BOISSAT	Date: 3/25/2019										
Model used											
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>										
Other <input type="checkbox"/>											
Element type : SHELL 6											
Number of degrees of freedom or mesh density :											
Nb of nodes = 4565											
Nb of elements = 2214											
Nb of DOF = 27390											
Results :											
<table border="1"> <thead> <tr> <th>Location</th> <th>Physical quantity</th> <th>Reference value</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td>B</td> <td><math>w_B</math> (m)</td> <td><math>-3.70 \times 10^{-2}</math></td> <td><math>-3.6 \times 10^{-2}</math></td> <td>2.78</td> </tr> </tbody> </table>		Location	Physical quantity	Reference value	Calculated value	Deviation (%)	B	$w_B$ (m)	$-3.70 \times 10^{-2}$	$-3.6 \times 10^{-2}$	2.78
Location	Physical quantity	Reference value	Calculated value	Deviation (%)							
B	$w_B$ (m)	$-3.70 \times 10^{-2}$	$-3.6 \times 10^{-2}$	2.78							
Comments :											
In the Guide, the unit of $\gamma$ was interpreted as N/m <sup>3</sup> instead of kg/m <sup>3</sup> .											

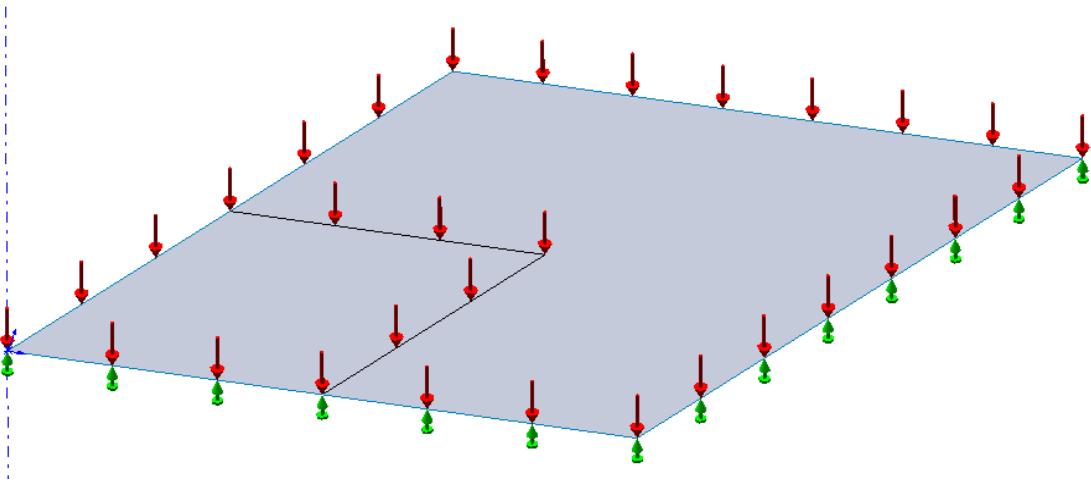
EVALUATION FORM				
Software: SOLIDWORKS Simulation		Version: 2019 SP2		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: PINCHED CYLINDRICAL SHELL				
Codification: SSLS 20-89				
Test performed by : Julien BOISSAT		Date: 3/25/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes = 4600 Nb of elements = 2240 Nb of DOF = 27600				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
A	$v$ (m), displacement in y	$-113.9 \times 10^{-3}$	$-113.7 \times 10^{-3}$	0.18
Comments :				

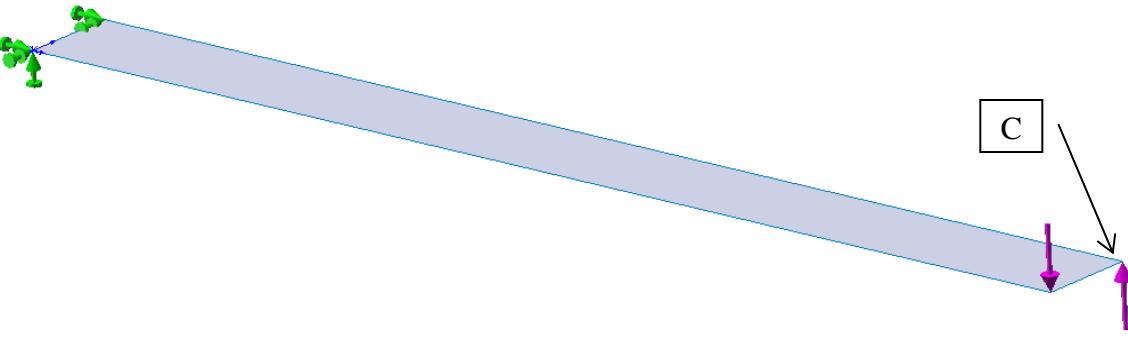
EVALUATION FORM											
Software: SOLIDWORKS Simulation	Version: 2019 SP2										
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.											
Test name: SPHERICAL SHELL WITH HOLE											
Codification: SSLS 21-89											
 <p>A</p>											
Test performed by : Julien BOISSAT	Date: 3/25/2019										
Model used											
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>									
Element type : SHELL 6											
Number of degrees of freedom or mesh density :											
Nb of nodes = 1188											
Nb of elements = 564											
Nb of DOF = 7128											
Results :											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;">Location</th> <th style="text-align: center; padding: 5px;">Physical quantity</th> <th style="text-align: center; padding: 5px;">Reference value</th> <th style="text-align: center; padding: 5px;">Calculated value</th> <th style="text-align: center; padding: 5px;">Deviation (%)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px;"><math>A(R,0,0)</math></td> <td style="text-align: center; padding: 5px;"><math>u_A</math> (m) , displacement in <math>x</math></td> <td style="text-align: center; padding: 5px;"><math>94.0 \times 10^{-3}</math></td> <td style="text-align: center; padding: 5px;"><math>96.8 \times 10^{-3}</math></td> <td style="text-align: center; padding: 5px;">2.89</td> </tr> </tbody> </table>		Location	Physical quantity	Reference value	Calculated value	Deviation (%)	$A(R,0,0)$	$u_A$ (m) , displacement in $x$	$94.0 \times 10^{-3}$	$96.8 \times 10^{-3}$	2.89
Location	Physical quantity	Reference value	Calculated value	Deviation (%)							
$A(R,0,0)$	$u_A$ (m) , displacement in $x$	$94.0 \times 10^{-3}$	$96.8 \times 10^{-3}$	2.89							
Comments :											

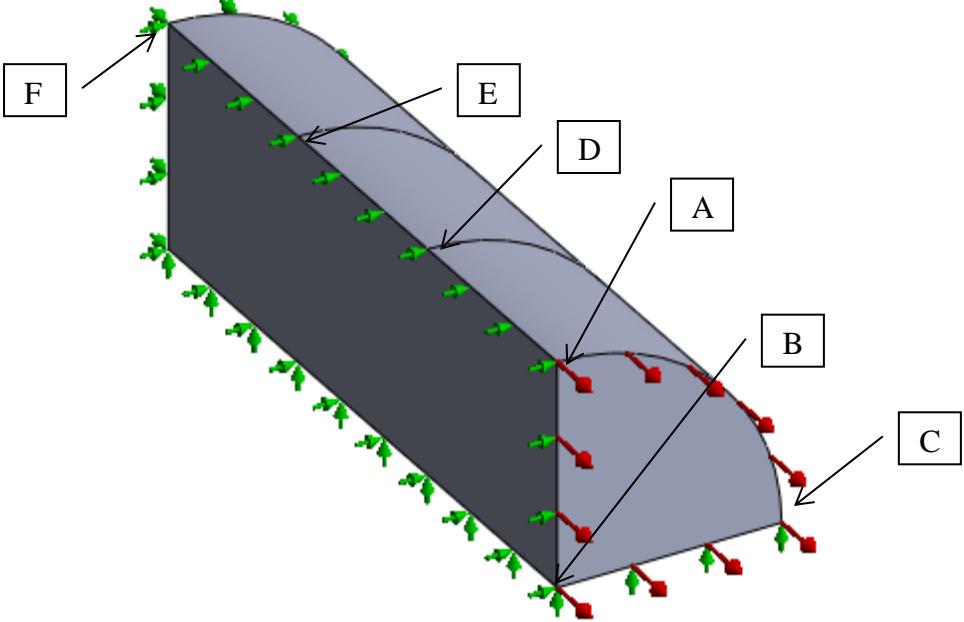
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SPHERICAL CAP UNDER EXTERNAL UNIFORM PRESSURE				
Codification: SSLS 22-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes = 10347				
Nb of elements = 4978				
Nb of DOF = 61785				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
$\psi = 15^\circ$	$u$ (m), horizontal	$-1.73 \times 10^{-3}$	$-1.76 \times 10^{-3}$	1.73
$\psi = 45^\circ$	$u$ (m), horizontal	$-1.02 \times 10^{-3}$	$-1.01 \times 10^{-3}$	0.99
$\psi = 15^\circ$	$\sigma$ (Pa), external meridian	$-0.74 \times 10^8$	$-0.69 \times 10^8$	7.25
$\psi = 45^\circ$	$\sigma$ (Pa), external meridian	$-0.68 \times 10^8$	$-0.69 \times 10^8$	1.47
Comments :				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: CYLINDRICAL MEMBRANE UNDER BENDING				
Codification: SSLS 23-89				
				
Test performed by : Julien BOISSAT		Date: 3/25/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
First and second load				
Nb of nodes = 4473 Nb of elements = 2168 Nb of DOF = 26436				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
Point E	circumferential stress on external skin (MPa)	60	59.93	-0.12
			59.80	-0.33
Comments :				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: SIMPLY SUPPORTED RECTANGULAR PLATE UNDER UNIFORM PRESSURE				
Codification: SSLS 24-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
$b/a = 1$ Nb of nodes = 899 Nb of elements = 418 Nb of DOF = 5391	$b/a = 2$ Nb of nodes = 1798 Nb of elements = 853 Nb of DOF = 10785	$b/a = 5$ Nb of nodes = 4499 Nb of elements = 2158 Nb of DOF = 26991		
Results :				
Location	Physical quantity <sup>(1)</sup>	Reference value	Calculated value	Deviation (%)
$b/a = 1.0$	$\alpha$ (deflection at A)	0.0443	0.0444	0.23
	Bending moment $\beta$	0.0479	0.0479	0
	Bending moment $\beta_1$	0.0479	0.0479	0
$b/a = 2.0$	$\alpha$ (deflection at A)	0.1106	0.1106	0
	Bending moment $\beta$	0.1017	0.1017	0
	Bending moment $\beta_1$	0.0464	0.0463	0.22
$b/a = 5.0$	$\alpha$ (deflection at A)	0.1415	0.1415	0
	Bending moment $\beta$	0.1246	0.1245	0.08
	Bending moment $\beta_1$	0.0375	0.0376	0.27
Comments :				
Values $\alpha$ , $\beta$ and $\beta_1$ are calculated from the values of $w_{\max}$ , $\sigma_x \max$ , $\sigma_y \max$ and the following formulas : $w_{\max} = \frac{\alpha p a^4}{E h^3}$ , $M_{x \max} = \beta p a^2$ and $M_{y \max} = \beta_1 p a^2$ and $\sigma_{Flex} = \frac{6M}{h^2}$ . Practically, $\beta = S X_{Bending} (\text{Point A}) / 0.06$ , $\beta_1 = S Y_{Bending} (\text{Point A}) / 0.06$ and $\alpha = w_{\max} / 10$ All in SI units.				

EVALUATION FORM											
Software: SOLIDWORKS Simulation	Version: 2019 SP2										
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.											
Test name: SIMPLY SUPPORTED RHOMB PLATE UNDER BENDING											
Codification: SSLS 25-89											
											
Test performed by : Julien BOISSAT	Date: 3/25/2019										
Model used											
<input checked="" type="checkbox"/> Finite elements <input type="checkbox"/> Boundary elements <input type="checkbox"/> Other											
Element type : SHELL 6											
Number of degrees of freedom or mesh density :											
$\alpha = 80^\circ$ N. of nodes = 4657 N. of elements=2260 N. of DOF = 27942	$\alpha = 60^\circ$ N. of nodes = 4617 N. of elements=2236 N. of DOF = 27702	$\alpha = 40^\circ$ N. of nodes = 4701 N. of elements=2266 N. of DOF = 28206	$\alpha = 30^\circ$ N. of nodes = 4729 N. of elements = 2268 N. of DOF = 28374								
Results :											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;"><b>Location</b></th> <th style="text-align: center; padding: 5px;"><b>Physical quantity</b></th> <th style="text-align: center; padding: 5px;"><b>Reference value</b></th> <th style="text-align: center; padding: 5px;"><b>Calculated value</b></th> <th style="text-align: center; padding: 5px;"><b>Deviation (%)</b></th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px;"> <math>\alpha = 80^\circ</math>  <math>\alpha = 60^\circ</math>  <math>\alpha = 40^\circ</math>  <math>\alpha = 30^\circ</math> </td> <td style="text-align: center; padding: 5px;"> <math>w_c \text{ (mm)}</math> </td> <td style="text-align: center; padding: 5px;"> <math>1.409 \times 10^{-3}</math>  <math>0.9318 \times 10^{-3}</math>  <math>0.3487 \times 10^{-3}</math>  <math>0.1485 \times 10^{-3}</math> </td> <td style="text-align: center; padding: 5px;"> <math>1.408 \times 10^{-3}</math>  <math>0.9320 \times 10^{-3}</math>  <math>0.3506 \times 10^{-3}</math>  <math>0.1503 \times 10^{-3}</math> </td> <td style="text-align: center; padding: 5px;"> -0.07  0.021  0.545  1.212 </td> </tr> </tbody> </table>		<b>Location</b>	<b>Physical quantity</b>	<b>Reference value</b>	<b>Calculated value</b>	<b>Deviation (%)</b>	$\alpha = 80^\circ$ $\alpha = 60^\circ$ $\alpha = 40^\circ$ $\alpha = 30^\circ$	$w_c \text{ (mm)}$	$1.409 \times 10^{-3}$ $0.9318 \times 10^{-3}$ $0.3487 \times 10^{-3}$ $0.1485 \times 10^{-3}$	$1.408 \times 10^{-3}$ $0.9320 \times 10^{-3}$ $0.3506 \times 10^{-3}$ $0.1503 \times 10^{-3}$	-0.07 0.021 0.545 1.212
<b>Location</b>	<b>Physical quantity</b>	<b>Reference value</b>	<b>Calculated value</b>	<b>Deviation (%)</b>							
$\alpha = 80^\circ$ $\alpha = 60^\circ$ $\alpha = 40^\circ$ $\alpha = 30^\circ$	$w_c \text{ (mm)}$	$1.409 \times 10^{-3}$ $0.9318 \times 10^{-3}$ $0.3487 \times 10^{-3}$ $0.1485 \times 10^{-3}$	$1.408 \times 10^{-3}$ $0.9320 \times 10^{-3}$ $0.3506 \times 10^{-3}$ $0.1503 \times 10^{-3}$	-0.07 0.021 0.545 1.212							
Comments :											
A typo in the guide was corrected: $E = 30 \times 10^6 \text{ Pa}$ instead of $36 \times 10^6$											

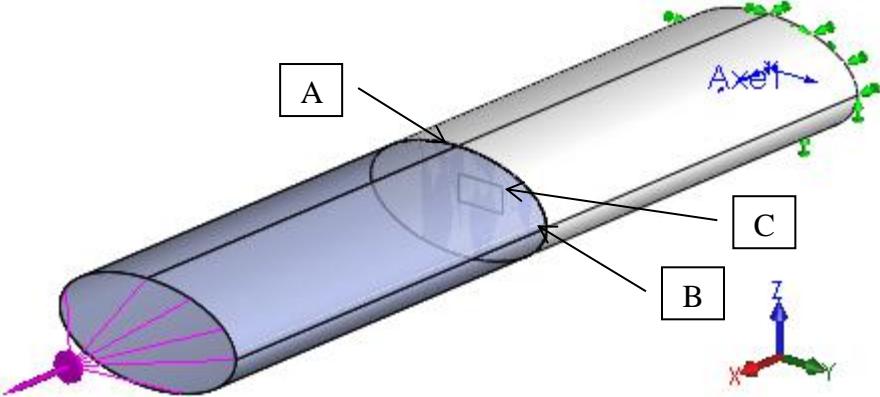
EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: PLATE UNDER NORMAL SHEAR				
Codification: SSLS 27-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : SHELL 6				
Number of degrees of freedom or mesh density :				
Nb of nodes = 9663				
Nb of elements = 4650				
Nb of DOF = 57804				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
Point C	Displacement $w$ (m)	$35.37 \times 10^{-3}$	$35.30 \times 10^{-3}$	-0.23
Comments :				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: FULL CYLINDER UNDER SIMPLE TRACTION				
Codification: SSLV 01-89				
				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 3188			
Nb of elements	= 1915			
Nb of DOF	= 9561			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
point A	$u_A$ (m)	$1.5 \times 10^{-3}$	$1.5 \times 10^{-3}$	0
point B	$u_B$ (m)	$1.5 \times 10^{-3}$	$1.5 \times 10^{-3}$	0
point C	$u_C$ (m)	$1.5 \times 10^{-3}$	$1.5 \times 10^{-3}$	0
point D	$u_D$ (m)	$1 \times 10^{-3}$	$1 \times 10^{-3}$	0
point E	$u_E$ (m)	$0.5 \times 10^{-3}$	$0.5 \times 10^{-3}$	0
point A	$w_A$ (m)	$-0.15 \times 10^{-3}$	$-0.15 \times 10^{-3}$	0
point D	$w_D$ (m)	$-0.15 \times 10^{-3}$	$-0.15 \times 10^{-3}$	0
point E	$w_E$ (m)	$-0.15 \times 10^{-3}$	$-0.15 \times 10^{-3}$	0
point F	$w_F$ (m)	$-0.15 \times 10^{-3}$	$-0.15 \times 10^{-3}$	0
Comments :				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: FULL SPHERE UNDER UNIFORM PRESSURE				
Codification: SSLV 02-89				
Test performed by : Julien BOISSAT	Date: 3/25/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 24086			
Nb of elements	= 16357			
Nb of DOF	= 72255			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
point A	$\sigma_x$ (MPa)	-100	-100.04	0.04
point B	$\sigma_y$ (MPa)	-100	-99.77	-0.230
point C	$\sigma_z$ (MPa)	-100	-100.09	0.090
point A	$u_A$ (m)	$-0.2 \times 10^{-3}$	$-0.2 \times 10^{-3}$	0
point B	$v_B$ (m)	$-0.2 \times 10^{-3}$	$-0.2 \times 10^{-3}$	0
point C	$w_C$ (m)	$-0.2 \times 10^{-3}$	$-0.2 \times 10^{-3}$	0
point A'	$\sigma_x$ (MPa)	-100	-99.973	-0.03
point B'	$\sigma_y$ (MPa)	-100	-99.867	-0.133
point C'	$\sigma_z$ (MPa)	-100	-99.901	-0.099
point A'	$u_{A'}$ (m)	$-0.1 \times 10^{-3}$	$-0.1 \times 10^{-3}$	0
point B'	$u_{B'}$ (m)	$-0.1 \times 10^{-3}$	$-0.1 \times 10^{-3}$	0
point C'	$u_{C'}$ (m)	$-0.1 \times 10^{-3}$	$-0.1 \times 10^{-3}$	0
Comments :				

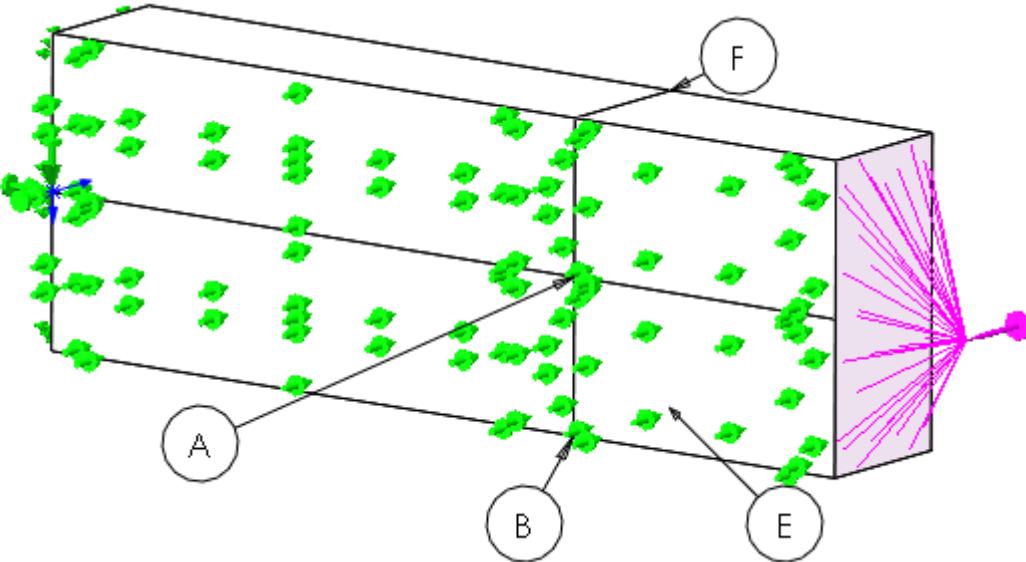
EVALUATION FORM							
Software: SOLIDWORKS Simulation				Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.							
Test name: THICK SPHERICAL TANK UNDER INTERNAL PRESSURE							
Codification: SSLV 03-89							
Test performed by : Julien BOISSAT				Date: 3/25/2019			
Model used							
<input checked="" type="checkbox"/> Finite elements		<input type="checkbox"/> Boundary elements		<input type="checkbox"/> Other			
Element type : TETRA 10 or SHELLAX							
Number of degrees of freedom or mesh density :							
TETRA 10				SHELLAX			
Nb of nodes = 11265		Nb of nodes = 2605					
Nb of elements = 7439		Nb of elements = 1246					
Nb of DOF = 33795		Nb of DOF = 5210					
Results :							
Location	Physical quantity	Reference value	Calculated value		Deviation (%)		
			SHELL 6	SHELLAX	SHELL 6	SHELLAX	
Internal edge $r = a$	$\sigma_{rr}$ (MPa)	-100	-99.082	-99.9	-0.92	-0.10	
	$\sigma_{\theta\theta}$ (MPa)	71.43	71.414	71.4	-0.02	-0.04	
	$u$ (m)	$0.4 \times 10^{-3}$	$0.4 \times 10^{-3}$	$0.4 \times 10^{-3}$	0	0	
External edge $r = b$	$\sigma_{rr}$ (MPa)	0	0.029	0	-	-	
	$\sigma_{\theta\theta}$ (MPa)	21.43	21.429	21.41	0	0.09	
	$u$ (m)	$1.5 \times 10^{-4}$	$1.5 \times 10^{-4}$	$1.5 \times 10^{-4}$	0	0	
Comments :							

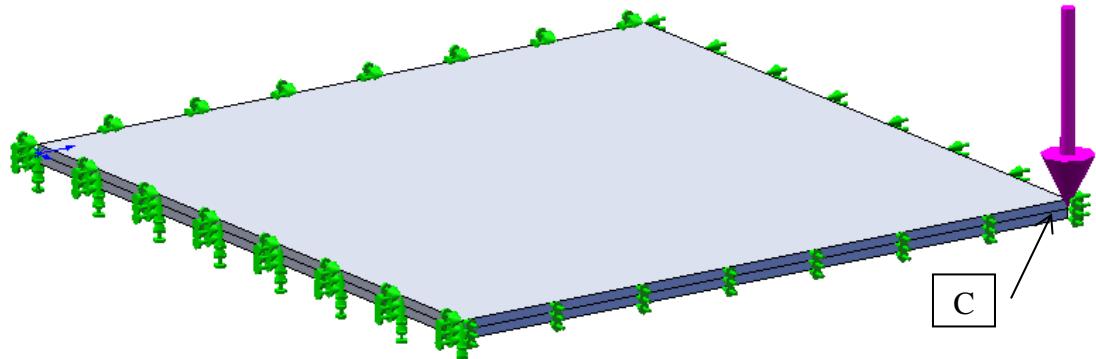
EVALUATION FORM							
Software: SOLIDWORKS Simulation			Version: 2019 SP2				
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.							
Test name: THICK INFINITE PIPE UNDER INTERNAL PRESSURE							
Codification: SSLV 04-89							
Test performed by : Julien BOISSAT			Date: 3/25/2019				
Model used							
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>			
Element type : TETRA 10 or SHELLAX							
Number of degrees of freedom or mesh density :							
TETRA 10			SHELLAX				
Nb of nodes = 11865				Nb of nodes = 2505			
Nb of elements = 7808				Nb of elements = 1202			
Nb of DOF = 35595				Nb of DOF = 5010			
Results :							
Location	Physical quantity	Reference value	Calculated value		Deviation (%)		
			SHELL 6	SHELLAX	SHELL 6	SHELLAX	
Internal wall	$\sigma_r$ (MPa)	-60	-59.71	-59.966	-0.48	-0.06	
	$\sigma_\theta$ (MPa)	100	99.96	99.973	-0.04	-0.03	
	$\tau_{\max}$ (MPa)	80	80.28	79.96	0.35	-0.05	
	$u_r$ (m)	$59 \times 10^{-6}$	$59 \times 10^{-6}$	$59 \times 10^{-6}$	0	0	
External wall	$\sigma_r$ (MPa)	0	0.02	0.005	-	-	
	$\sigma_\theta$ (MPa)	40	40	39.996	0	-0.01	
	$\tau_{\max}$ (MPa)	20	20.04	19.996	0.2	-0.02	
	$u_r$ (m)	$40 \times 10^{-6}$	$40 \times 10^{-6}$	$40 \times 10^{-6}$	0	0	
Comments :							

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: BEAM WITH ELLIPTIC CROSS SECTION UNDER TORSION				
Codification: SSLV 05-89				
				
Test performed by : Julien BOISSAT	Date: 3/26/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
Nb of nodes	= 10467			
Nb of elements	= 6604			
Nb of DOF	= 30930			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation n (%)
Point A	$\sigma_{xy}$ (MPa)	-39.5	-39.65	0.38
	$\sigma_{xz}$ (MPa)	0	0	-
	$\sigma_{x\theta}$ (MPa)	39.5	39.65	0.38
	$u$ (m)	0	0	-
	$v$ (m)	$-2.57 \times 10^{-3}$	$-2.49 \times 10^{-3}$	-3.11
	$w$ (m)	0	0	-
Point B	$\sigma_{xy}$ (MPa)	0	0	-
	$\sigma_{xz}$ (MPa)	19.8	19.73	-0.35
	$\sigma_{x\theta}$ (MPa)	19.8	19.73	-0.35
	$u$ (m)	0	0	-
	$v$ (m)	0	0	-
	$w$ (m)	$4.97 \times 10^{-3}^{(1)}$	$4.98 \times 10^{-3}$	0.20
Point C	$u$ (m)	$-9.6 \times 10^{-5}$	$-9.64 \times 10^{-5}$	0.42
Comments :				
In order to avoid singularities near the prescribed displacements, results have been obtained with a 16m beam and a measure of the results done at section $x=8m$ . It implied the modification of the Reference values using the formulas given in the validation guide.				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: RECTANGULAR SECTION SHAPE BEAM UNDER TORSION				
Codification: SSLV 06-89				
Test performed by : Julien BOISSAT	Date: 3/27/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>		
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
$L = 10 \text{ m}$	$L = 20 \text{ m}$			
Nb of nodes = 12137	Nb of nodes = 23284			
Nb of elements = 7628	Nb of elements = 14643			
Nb of DOF = 35952	Nb of DOF = 69393			
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation n (%)
Points A and B, middle of the long sides				
$L = 10 \text{ m}$	$\theta/L \text{ (rd/m)}$ $\sigma_{xy  \max} \text{ (MPa)}$	$2.78 \times 10^{-3}$ 202.6 <sup>(1)</sup>	$2.74 \times 10^{-3}$ 202.7	-1.44 0.05
$L = 20 \text{ m}$	$\theta/L \text{ (rd/m)}$ $\sigma_{xy  \max} \text{ (MPa)}$	$2.78 \times 10^{-3}$ 203.7 <sup>(1)</sup>	$2.78 \times 10^{-3}$ 202.9	0 -0.39
Comments :				
<sup>(1)</sup> The calculated $\sigma_{xy  \max}$ stress is the value found on the lines of the long sides when far enough from the extremities in order to avoid the singularities. "Roark's Formulas for Stress & Strain" (6 <sup>th</sup> ed. p.348) gives the following formula for a rectangular beam with a " $2a \times 2b$ " section ( $a \geq b$ ) :				
$\text{Max } \tau = \frac{3T}{8ab^2} \left[ 1 + 0.6095 \frac{b}{a} + 0.8865 \left( \frac{b}{a} \right)^2 - 1.8023 \left( \frac{b}{a} \right)^3 + 0.9100 \left( \frac{b}{a} \right)^4 \right]$ which gives the reference value of 203.7 MPa. This value was used in place of the one prescribed by the validation guide which used one taken from an abacus (less accurate).				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: BLOCK STRETCHED UNDER ITS OWN WEIGHT				
Codification: SSLV 07-89				
Test performed by : Julien BOISSAT	Date: 3/27/2019			
Model used				
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>			
Other <input type="checkbox"/>				
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
Nb of nodes = 9810				
Nb of elements = 6380				
Nb of DOF = 29427				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
Point B	$w_B$ (m)	$1.72 \times 10^{-6}$	$1.72 \times 10^{-6}$	0
Point B and C	$\Delta w$ (m)	$0.014 \times 10^{-6}$	$0.014 \times 10^{-6}$	0
Point A and D	$\Delta u$ (m)	$0.17 \times 10^{-6}$	$0.17 \times 10^{-6}$	0
Point A	$\sigma_{zz}$ (MPa)	0.229	0.229	0
Point E	$\sigma_{zz}$ (MPa)	0.1145	0.1148	0.26
Comments :				
$w_B$ (m) is measured in -Z direction, and hence is positive				

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: PRISMATIC BEAM UNDER PURE BENDING				
Codification: SSLV 08-89				
				
Test performed by : Julien BOISSAT	Date: 3/27/2019			
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : TETRA 10 Number of degrees of freedom or mesh density : Nb of nodes = 10221 Nb of elements = 6511 Nb of DOF = 30660				
Results :				
Location	Physical quantity	Reference value	Calculated value	Deviation (%)
Point B <sup>(1)</sup>	$\sigma_{zz}$ (MPa)	10	10	0
Point A	$u_A$ (m)	$-4 \times 10^{-4}$	$-4 \times 10^{-4}$	0
Point B	$w_B$ (m)	$2 \times 10^{-4}$	$2 \times 10^{-4}$	0
Point F or G	$v_F = -v_G$ (m)	$0.15 \times 10^{-4}$	$0.15 \times 10^{-4}$	0
Point D or E	$v_D = -v_E$ (m)	$-0.15 \times 10^{-4}$	$-0.15 \times 10^{-4}$	0
Comments :				
<sup>(1)</sup> Supposed typographic error in the validation guide: it should read "Point B" instead of "Point A" on this location to calculate $\sigma_{zz}$ (MPa).				

EVALUATION FORM					
Software: SOLIDWORKS Simulation			Version: 2019 B3		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.					
Test name: THICK PLATE WITH ITS EDGES FIXED Codification: SSLV 09-89					
					
Test performed by : Julien BOISSAT			Date: 3/27/2019		
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type : TETRA 10					
Number of degrees of freedom or mesh density :					
In both cases, meshing and calculating were done with the default parameters.					
Results :					
<b>Load : Pressure p = 1 MPa</b>					
Location		Physical quantity	Reference value	Calculated value	Deviation (%)
$\lambda = 10$	H20	$w_C$ (m) Note: $w_C$ (m) is measured in -Z direction, and hence is positive	$0.76231 \times 10^{-4}$	$0.7740 \times 10^{-4}$	1.17
	Q4		$0.78661 \times 10^{-4}$		1.96
	Ana.		$0.6552 \times 10^{-4}$		17.70
$\lambda = 20$	H20		$0.53833 \times 10^{-3}$	$0.5485 \times 10^{-3}$	1.72
	Q4		$0.55574 \times 10^{-3}$		1.46
	Ana.		$0.52416 \times 10^{-3}$		4.47
$\lambda = 50$	H20		$0.80286 \times 10^{-2}$	$0.8234 \times 10^{-2}$	2.43
	Q4		$0.8348 \times 10^{-2}$		1.49
	Ana.		$0.81900 \times 10^{-2}$		0.42
$\lambda = 75$	H20		$0.26861 \times 10^{-1}$	$0.2766 \times 10^{-1}$	2.75
	Q4		$0.28053 \times 10^{-1}$		1.61
	Ana.		$0.27641 \times 10^{-1}$		0.15
$\lambda = 100$	H20		$0.63389 \times 10^{-1}$	$0.6534 \times 10^{-1}$	0.53
	Q4		$0.66390 \times 10^{-1}$		5.03
	Ana.		$0.65520 \times 10^{-1}$		3.77

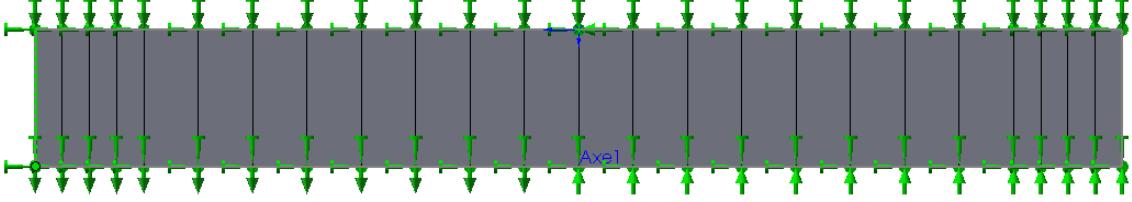
**Load : Concentrated force  $F = 1 \times 10^6 \text{ N}$** 

Location		Physical quantity	Reference value	Calculated value <sup>(1)</sup>	Deviation (%)
$\lambda = 10$	H20	$w_C \text{ (m)}$ Note: $w_C \text{ (m)}$ is measured in -Z direction, and hence is positive	$0.42995 \times 10^{-3}$	$0.4261 \times 10^{-3}$	2.38
	Q4		$0.41087 \times 10^{-3}$		2.15
	Ana.		$0.29146 \times 10^{-3}$		44.00
$\lambda = 20$	H20		$0.25352 \times 10^{-2}$	$0.2606 \times 10^{-2}$	2.24
	Q4		$0.25946 \times 10^{-2}$		0.10
	Ana.		$0.23317 \times 10^{-2}$		11.16
$\lambda = 50$	H20		$0.35738 \times 10^{-1}$	$0.3700 \times 10^{-1}$	3.42
	Q4		$0.37454 \times 10^{-1}$		1.32
	Ana.		$0.36433 \times 10^{-1}$		1.45
$\lambda = 75$	H20		0.11837	0.12326	4.16
	Q4		0.12525		1.56
	Ana.		0.12296		0.28
$\lambda = 100$	H20		0.27794	0.2909	4.59
	Q4		0.29579		1.72
	Ana.		0.29146		0.26

**Comments :**

- <sup>(1)</sup> The values in the above table are the average of the calculated values on the vertical edge (thickness) going through Point C because a concentrated force creates a singularity. The test is clearly a success : it shows plainly the growing deviation between a calculated displacement with a “thin PLATE type” analytical solution and the displacement calculated with the SOLIDWORKS Simulation 3D model when the slenderness ratio decreases.

## 2. Non linear static

EVALUATION FORM				
Software: SOLIDWORKS Simulation	Version: 2019 SP2			
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.				
Test name: RECTANGLE UNDER PURE BENDING (PLANE STRESS, PERFECT PLASTICITY)				
Codification: SSNP 11-89				
				
Test performed by : Julien BOISSAT		Date: 3/27/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>
Element type :SHELL				
Number of degrees of freedom or mesh density :				
Nb of nodes = 100				
Nb of elements = 144				
Nb of DOF = 249				
Results :				
$u_A$ (mm)	Value type	Reference value	Calculated value	Deviation (%)
0.02875	$\sigma_{xx}^O$ (MPa)	483.0	466.3	-3.46
	$M_O$ (N.m)	805.0	789	-2.04
0.05 0.1 0.15 0.2 0.3 0.4 0.5	$M$	1074	1059	-1.35
	$M$	1174	1163	-9.78
	$M$	1193	1182	-2.56
	$M$	1199	1186	-1.07
	$M$	1204	1192	-0.96
	$M$	1205	1193	-1.00
	$M$	1206	1193	-1.08
↓	$\sigma_{xx}^L$	483	- <sup>(1)</sup>	-
$\infty$	$M_L$	1207.5	-	-
Comments :				
(1) The software cannot create an infinite displacement. Moreover, in order to obtain convergence, a non-zero tangent modulus was used.				

EVALUATION FORM					
Software: SOLIDWORKS Simulation	Version: 2019 SP2				
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.					
Test name: CYLINDER UNDER PRESSURE (PLANE STRAIN, PERFECT ELASTOPLASTICITY)					
Codification: SSNP 13-89					
Test performed by : Julien BOISSAT			Date: 3/27/2019		
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type :PLANE 2D					
Number of degrees of freedom or mesh density :					
Nb of nodes = 2706					
Nb of elements = 1237					
Nb of DOF = 7836					
Results :					
Pressure $p$ (MPa)	Radius $r$ (mm)	Physical quantity (MPa)	Reference value	Calculated value	Deviation (%)
100 (elasticity)	1	$\sigma_r$	-100	-99.33	0.67
	1.5		-25.93	-25.96	0.11
	2		0	0.03	-
	1	$\sigma_\theta$	166.7	165.98	0.43
	1.5		92.59	92.68	0.10
	2		66.7	66.77	0.10
Starts yielding		$p_y$	129.68	131	1.02
Complete yield		$p_{lim}$	240.11	239.99	-0.39

Fig1: Tube starts yielding on inner face

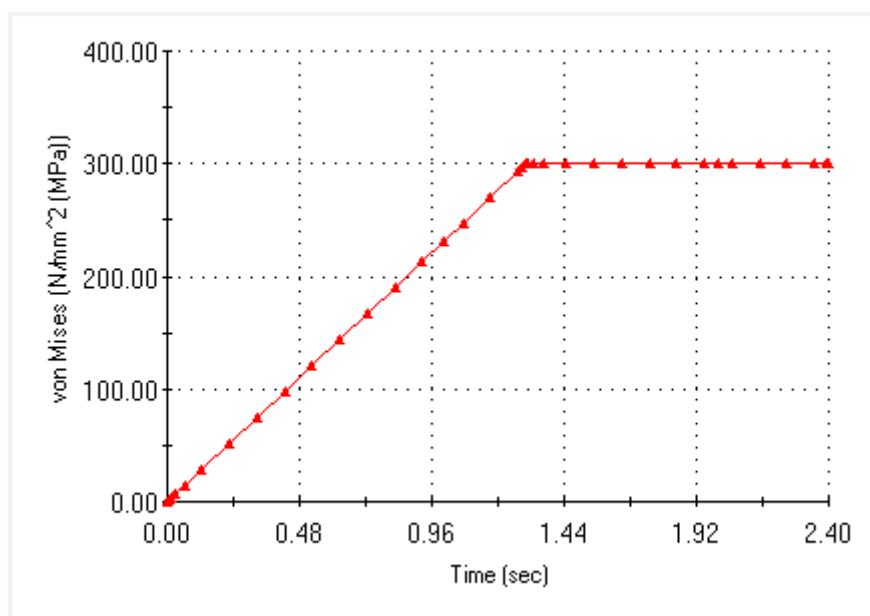
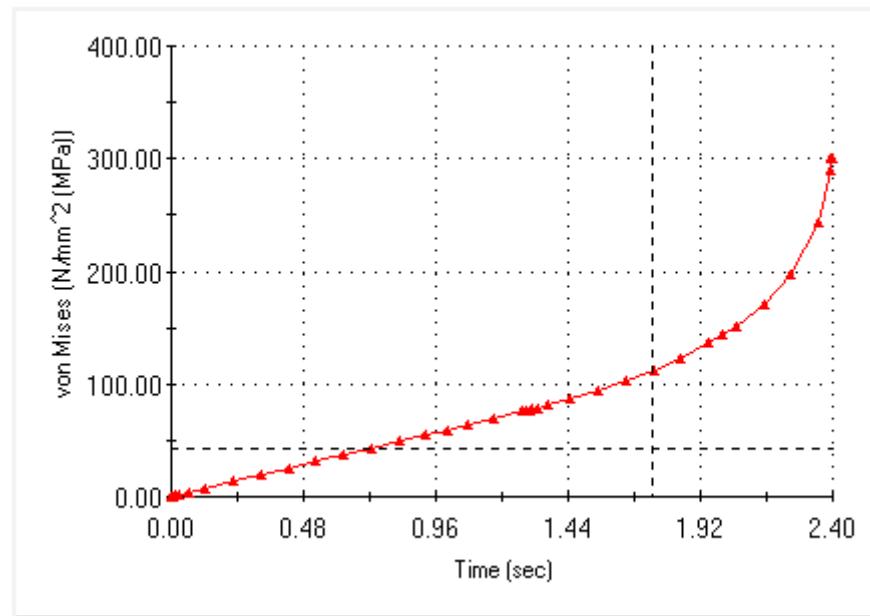
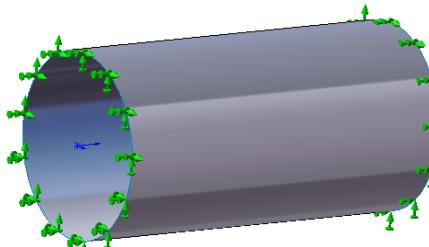
**Plot type: Nonlinear nodal stress Onset of Yielding**

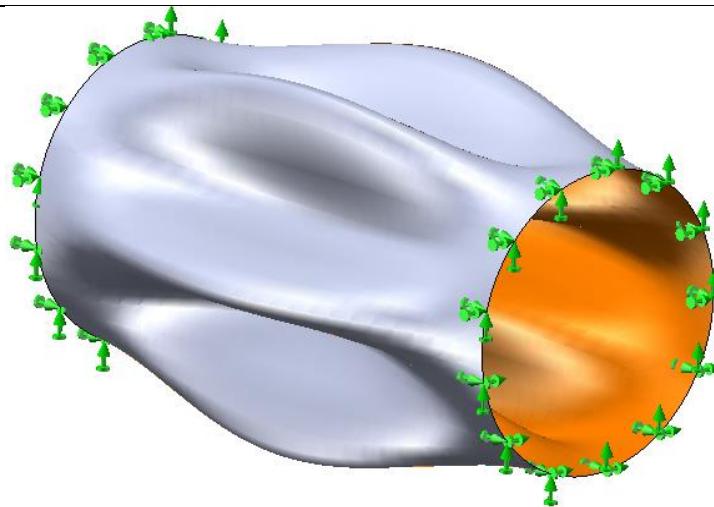
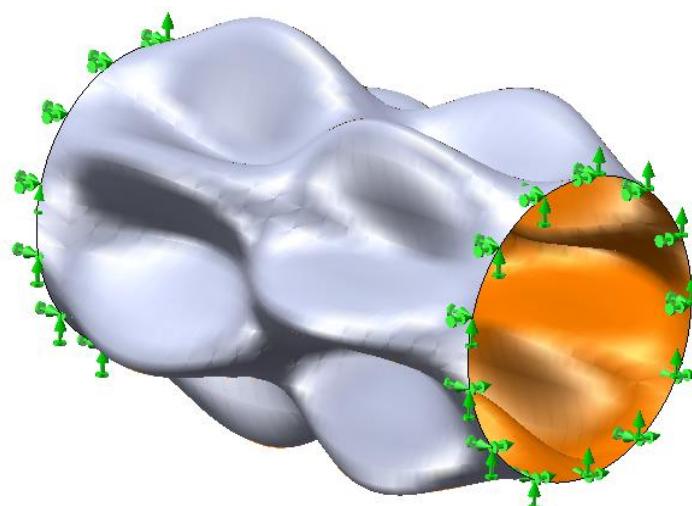
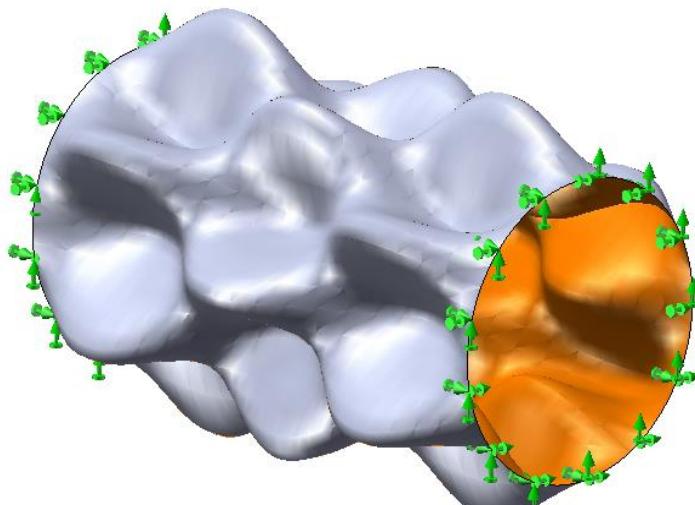
Fig2: Tube finishes yielding on outer face

**Plot type: Nonlinear nodal stress Complete yield**

Comments :

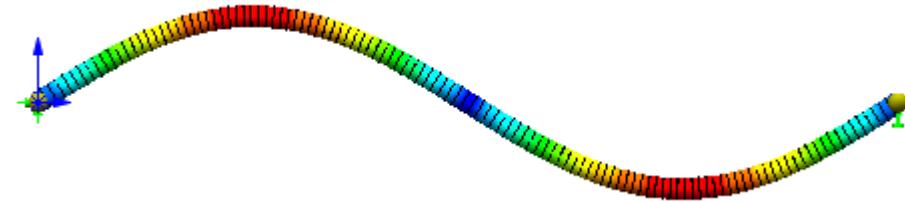
### 3. Linear dynamic

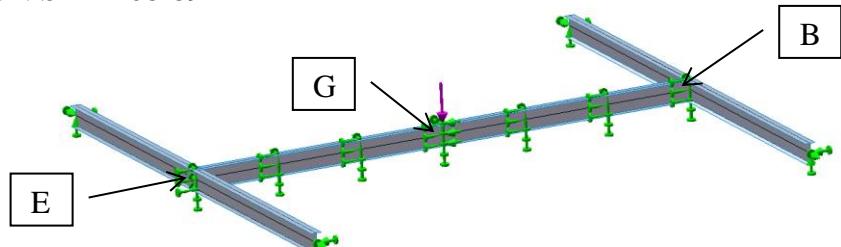
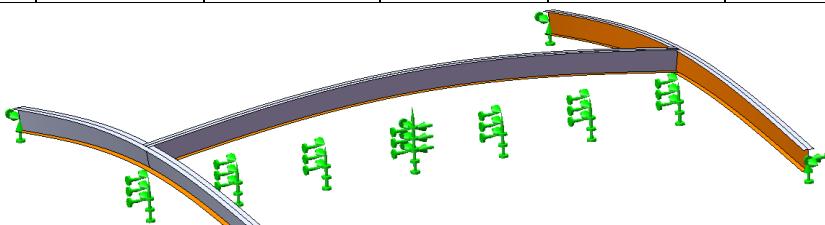
EVALUATION FORM													
Software: SOLIDWORKS Simulation				Version: 2019 SP2									
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.													
Test name: THIN CYLINDER FIXED ON BOTH ENDS													
Codification: SDLA 01-89													
													
Test performed by : Julien BOISSAT				Date: 3/27/2019									
Model used													
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>									
Element type : SHELL 6													
Number of degrees of freedom or mesh density :													
Nb of nodes = 4464													
Nb of elements = 2190													
Nb of DOF = 25776													
Results : Reference values													
Frequency (Hz)		<b>n = 2</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>12</b>	<b>14</b>					
<i>m</i> = 1	<i>E</i>	-	700	525	720	1095	1559	2118					
	<i>C</i>	1925.5	771.1	538.5	719.6	1081.8	1549.7	2108.5					
	<i>S</i>	2772	880	568	742	1104	1573	2132					
2	<i>E</i>	-	1620	980	900	1140	-	-					
	<i>C</i>	3929.0	1775.8	1041.5	922.3	1165.6	1595.4	2140.9					
	<i>S</i>	5251	2088	1121	952	1189	1620	2167					
3	<i>E</i>	-	-	1650	1350	1325	1711	2225					
	<i>C</i>	5892.7	2968.0	1764.9	1323.4	1361.3	1698.7	2207.5					
	<i>S</i>	6997	3441	1915	1368	1383	1720	2233					
Calculated values (Hz)		<b>n = 2</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>12</b>	<b>14</b>					
<i>m</i> = 1	Result Deviation(%)	1921.8 0.19	766.3 0.63	534.6 0.71	717.4 0.31	1079.4 0.22	1545 0.30	2099.1 0.45					
	Result Deviation(%)	3914.4 0.38	1760.5 0.87	1025.9 1.50	910.5 1.30	1157 0.74	1586.5 0.57	2127.4 0.63					
2	Result Deviation(%)	5859 0.58	2934 1.16	1730 2.00	1292.1 2.41	1336.7 1.84	1677.2 1.28	2185.2 1.02					

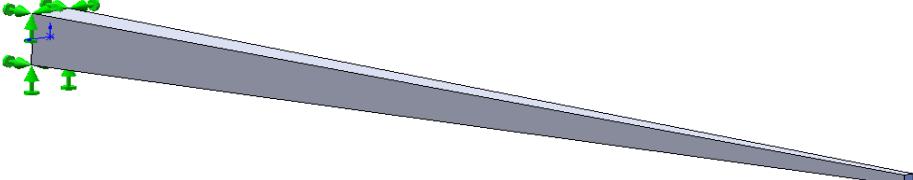
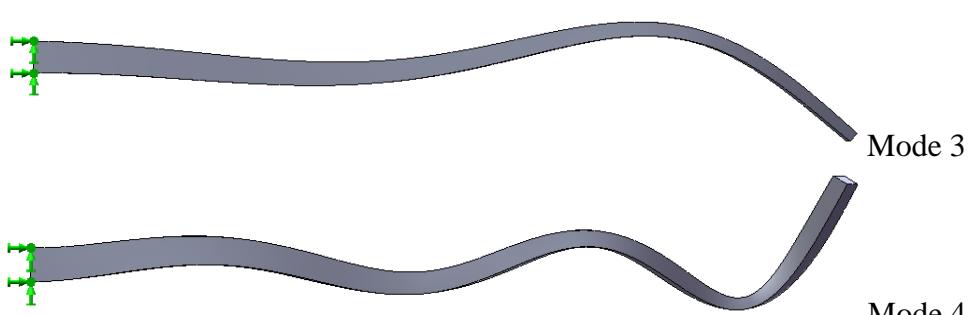
 $m = 1, n = 6$  $m = 2, n = 6$  $m = 3, n = 6$ **Comments :**

The deviation was calculated checking the results of SOLIDWORKS Simulation against the results « average of the 2 codes » (marked as “C” in the table).

EVALUATION FORM					
Software: SOLIDWORKS Simulation			Version: 2019 SP2		
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.					
Test name: SLENDER FOLDED BEAM, ONE END FIXED THE OTHER FREE					
Codification: SDLL 02-89					
Test performed by : Julien BOISSAT			Date: 3/27/2019		
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type : BEAM					
Number of degrees of freedom or mesh density :					
Nb of nodes = 151					
Nb of elements = 150					
Nb of DOF = 888					
Results :					
Nature of the vibration mode		Frequency (Hertz)			Deviation (%)
i	Order	Reference value	Calculated value		
1	1,2	11.76	11.725	2.73	
2	3,4	105.88	103.98	1.53	
3	5,6	294.10	294.41	-0.38	
4	7,8	576.44	565.32	-2.96	
<p>Order 2</p> <p>Order 4</p>					
Comments :					
The model was made with an arbitrary angle of 1° for the fold as it wasn't specified in the test description.					
Using respectively the average frequency of modes (1,2), (3,4), (5,6) and (7,8).					

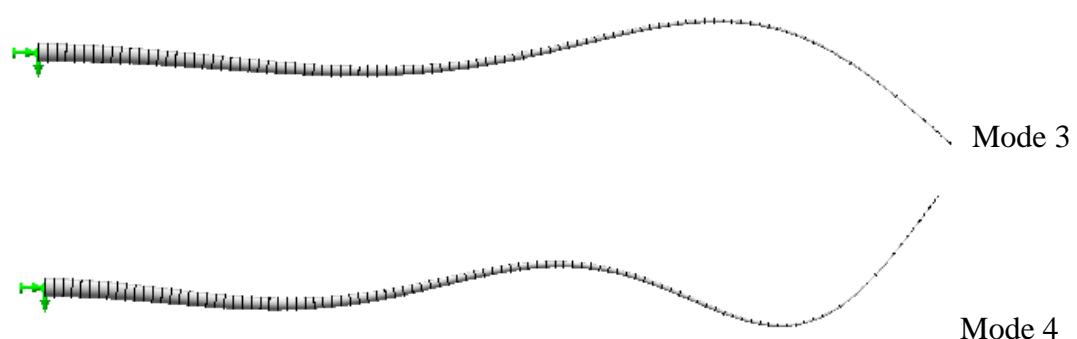
EVALUATION FORM																																			
Software: SOLIDWORKS Simulation			Version: 2019 SP2																																
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.																																			
Test name: SLENDER BEAM ON TWO SIMPLE SUPPORTS UNDER AXIAL FORCE Codification: SDLL 05-89																																			
																																			
Test performed by : Julien BOISSAT			Date: 3/27/2019																																
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : BEAM Number of degrees of freedom or mesh density : Nb of nodes = 119 Nb of elements = 117 Nb of DOF = 705																																			
Results : <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: left; padding-bottom: 5px;">Nature of the vibration mode</th> <th colspan="2" style="text-align: center; padding-bottom: 5px;">Frequency (Hertz)</th> <th colspan="2" style="text-align: center; padding-bottom: 5px;">Deviation (%)</th> </tr> <tr> <th colspan="2"></th> <th style="text-align: center;">Reference</th> <th style="text-align: center;">Calculated</th> <th colspan="2"></th> </tr> </thead> <tbody> <tr> <td rowspan="2" style="vertical-align: middle; text-align: center;"><math> F_x  = 0</math></td> <td style="vertical-align: middle; text-align: center;">Bending 1</td> <td style="text-align: center;">28.702</td> <td style="text-align: center;">28.69</td> <td style="text-align: center;">0.04</td> </tr> <tr> <td style="vertical-align: middle; text-align: center;">Bending 2</td> <td style="text-align: center;">114.807</td> <td style="text-align: center;">114.57</td> <td style="text-align: center;">0.21</td> </tr> <tr> <td rowspan="2" style="vertical-align: middle; text-align: center;"><math> F_x  = 10^5 \text{ N}</math></td> <td style="vertical-align: middle; text-align: center;">Bending 1</td> <td style="text-align: center;">22.434</td> <td style="text-align: center;">22.422</td> <td style="text-align: center;">0.05</td> </tr> <tr> <td style="vertical-align: middle; text-align: center;">Bending 2</td> <td style="text-align: center;">109.080</td> <td style="text-align: center;">108.85</td> <td style="text-align: center;">0.21</td> </tr> </tbody> </table>  <p style="text-align: center;"><math> F_x  = 0 \text{ N}</math>, Bending 1</p>  <p style="text-align: center;"><math> F_x  = 10^5 \text{ N}</math>, Bending 2</p>						Nature of the vibration mode		Frequency (Hertz)		Deviation (%)				Reference	Calculated			$ F_x  = 0$	Bending 1	28.702	28.69	0.04	Bending 2	114.807	114.57	0.21	$ F_x  = 10^5 \text{ N}$	Bending 1	22.434	22.422	0.05	Bending 2	109.080	108.85	0.21
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		Reference	Calculated																																
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$ F_x  = 10^5 \text{ N}$	Bending 1	22.434	22.422	0.05																															
	Bending 2	109.080	108.85	0.21																															
Comments :																																			

EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 SP2				
Computer configuration used: Lenovo ThinkPad W540, Windows 10 x64, Intel i7 vPro core, 16Gb RAM, Graphics Card Intel® HD Graphics 4600.						
Test name: PLANAR FRAME MADE OF I BEAMS Codification: SDLL 08-89						
						
Test performed by : Julien BOISSAT			Date: 3/28/2019			
Model used						
<input checked="" type="checkbox"/> Finite elements		<input type="checkbox"/> Boundary elements		<input type="checkbox"/> Other		
Element type : SHELL						
Number of degrees of freedom or mesh density :						
Nb of nodes = 5473						
Nb of elements = 2524						
Nb of DOF = 63486 <span style="color: red;">32814</span>						
Results :						
Order of the vibration mode	Frequency (Hertz)		Vibration mode $w_B / w_G$		Deviation (%)	
	Reference	Calculated	Reference	Calculated	Frequency	$w_B / w_G$
1	16.456	16.466	1.213	1.16	0.08	4.35
2	38.165	37.159	-0.412	-0.422	2.64	2.54
						
Mode 1						
Dynamic response :						
Point	Value type (m)	Values		Deviation (%)		
		Reference	Calculated			
$B, E$	$w_B$ max	$-9.8 \times 10^{-2}$	$-1.02 \times 10^{-1}$	3.92		
$G$	$w_G$ max	$-12.5 \times 10^{-2}$	$-12.4 \times 10^{-2}$	0.81		
$G$	$w_B + w_G$ max	$-2.27 \times 10^{-1}$	$-2.26 \times 10^{-1}$	0.44		
Comments :						
$w_B$ is the deflection of the lateral beam at its center.						
$w_G$ is the deflection of the central beam at its center. Therefore $w_G =$ vertical displacement of point G - $w_B$						

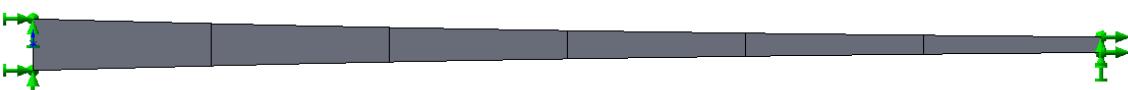
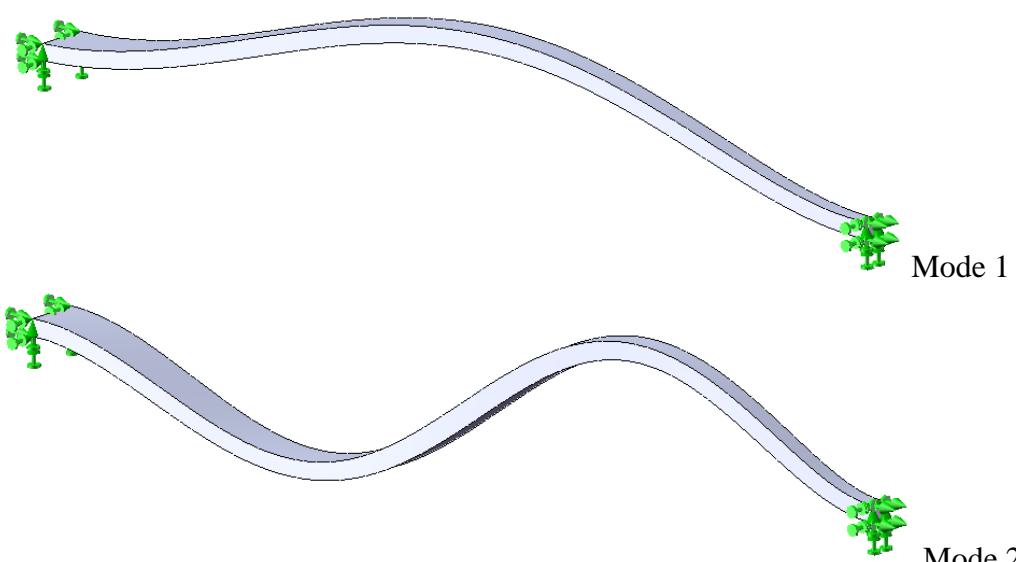
EVALUATION FORM																																																								
Software: SOLIDWORKS Simulation				Version: 2019 SP2																																																				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																																																								
Test name: SLENDER BEAM WITH VARIABLE RECTANGULAR SECTION, ONE END FIXED THE OTHER FREE																																																								
Codification: SDLL 09-89																																																								
																																																								
Test performed by : Julien BOISSAT				Date: 3/28/2019																																																				
Model used																																																								
<input checked="" type="checkbox"/> Finite elements		<input type="checkbox"/> Boundary elements		<input type="checkbox"/> Other																																																				
Element type : TETRA10 and BEAM																																																								
Number of degrees of freedom or mesh density :																																																								
TETRA10				BEAM																																																				
$\beta = 4$																																																								
Nb of nodes = 11686				Nb of nodes = 201																																																				
Nb of elements = 6691				Nb of elements = 100																																																				
Nb of DOF = 34743				Nb of DOF = 600																																																				
$\beta = 5$																																																								
Nb of nodes = 13362				Nb of nodes = 201																																																				
Nb of elements = 7980				Nb of elements = 100																																																				
Nb of DOF = 39717				Nb of DOF = 600																																																				
Results :																																																								
TETRA10 elements:																																																								
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2" style="width: 15%;">Nature of the vibration mode</th> <th colspan="2" style="width: 30%;">Frequency (Hertz) <math>\beta = 4</math></th> <th colspan="2" style="width: 30%;">Frequency (Hertz) <math>\beta = 5</math></th> <th colspan="2" style="width: 20%;">Deviation (%)</th> </tr> <tr> <th style="width: 15%;">Reference</th> <th style="width: 15%;">Calculated</th> <th style="width: 15%;">Reference</th> <th style="width: 15%;">Calculated</th> <th style="width: 10%;"><math>\beta = 4</math></th> <th style="width: 10%;"><math>\beta = 5</math></th> </tr> </thead> <tbody> <tr> <td rowspan="5" style="vertical-align: top;">Bending</td> <td>1</td> <td>54.18</td> <td>54.19</td> <td>56.55</td> <td>56.56</td> <td>0.02</td> <td>0.02</td> </tr> <tr> <td>2</td> <td>171.94</td> <td>171.56</td> <td>175.79</td> <td>175.43</td> <td>-0.22</td> <td>-0.20</td> </tr> <tr> <td>3</td> <td>384.40</td> <td>381.97</td> <td>389.01</td> <td>386.57</td> <td>-0.63</td> <td>-0.63</td> </tr> <tr> <td>4</td> <td>697.24</td> <td>688.61</td> <td>702.36</td> <td>693.67</td> <td>-1.24</td> <td>-1.24</td> </tr> <tr> <td>5</td> <td>1112.28</td> <td>1090.1</td> <td>1117.63</td> <td>1095.5</td> <td>-1.99</td> <td>-1.98</td> </tr> </tbody> </table>								Nature of the vibration mode	Frequency (Hertz) $\beta = 4$		Frequency (Hertz) $\beta = 5$		Deviation (%)		Reference	Calculated	Reference	Calculated	$\beta = 4$	$\beta = 5$	Bending	1	54.18	54.19	56.55	56.56	0.02	0.02	2	171.94	171.56	175.79	175.43	-0.22	-0.20	3	384.40	381.97	389.01	386.57	-0.63	-0.63	4	697.24	688.61	702.36	693.67	-1.24	-1.24	5	1112.28	1090.1	1117.63	1095.5	-1.99	-1.98
Nature of the vibration mode	Frequency (Hertz) $\beta = 4$		Frequency (Hertz) $\beta = 5$		Deviation (%)																																																			
	Reference	Calculated	Reference	Calculated	$\beta = 4$	$\beta = 5$																																																		
Bending	1	54.18	54.19	56.55	56.56	0.02	0.02																																																	
	2	171.94	171.56	175.79	175.43	-0.22	-0.20																																																	
	3	384.40	381.97	389.01	386.57	-0.63	-0.63																																																	
	4	697.24	688.61	702.36	693.67	-1.24	-1.24																																																	
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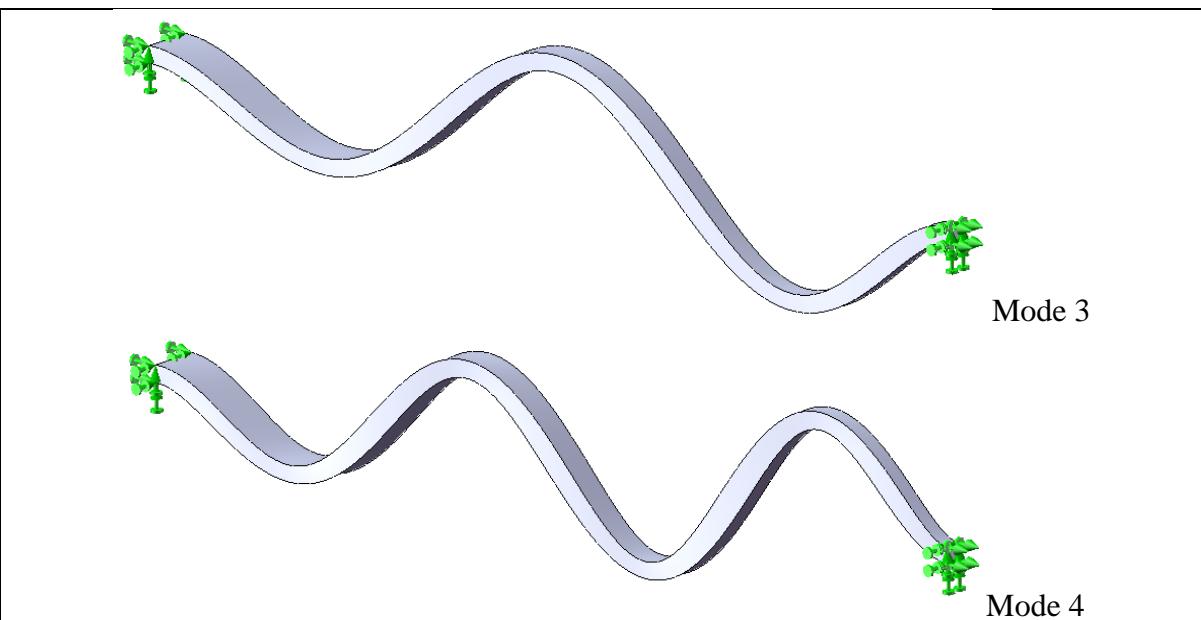
BEAM elements:

Nature of the vibration mode		Frequency (Hertz) $\beta = 4$		Frequency (Hertz) $\beta = 5$		Deviation (%)	
		Reference	Calculated	Reference	Calculated	$\beta = 4$	$\beta = 5$
Bending	1	54.18	54.21	56.55	56.57	0.06	0.04
	2	171.94	171.93	175.79	175.76	-0.01	-0.02
	3	384.40	383.76	389.01	388.17	-0.17	-0.22
	4	697.24	694.11	702.36	698.49	-0.45	-0.55
	5	1112.28	1103.1	1117.63	1106.7	-0.83	-0.98



Comments :

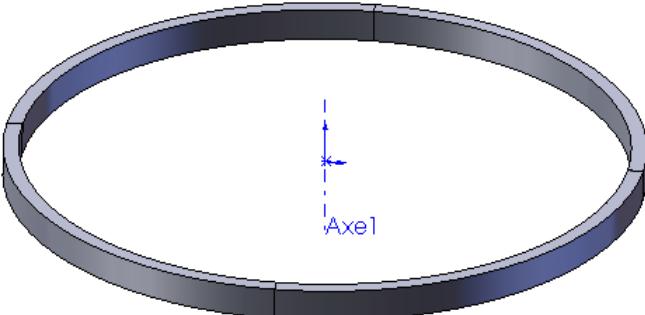
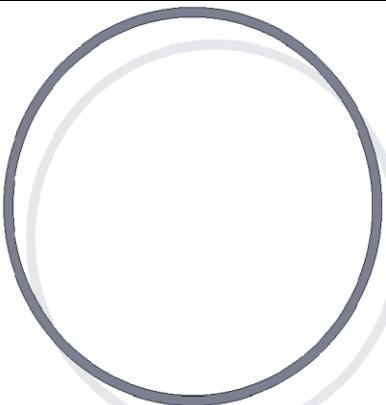
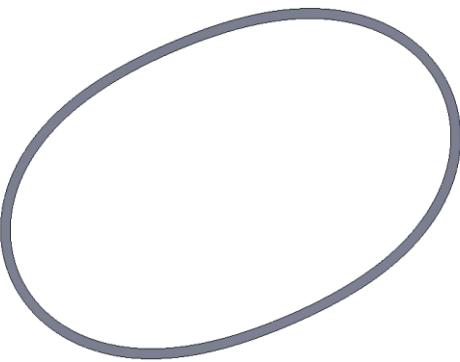
EVALUATION FORM					
Software: SOLIDWORKS Simulation	Version: 2019 PR1				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: SLENDER BEAM WITH VARIABLE RECTANGULAR SECTION, BOTH ENDS FIXED					
Codification: SDLL 10-89					
					
Test performed by : Julien BOISSAT	Date: 3/29/2019				
Model used					
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>				
Other <input type="checkbox"/>					
Element type : TETRA10 and BEAM					
Number of degrees of freedom or mesh density :					
TETRA10 Nb of nodes = 15051 Nb of elements = 8761 Nb of DOF = 44817		BEAM Nb of nodes = 541 Nb of elements = 270 Nb of DOF = 1614			
Results :					
Vibration mode	Frequency of reference (Hz)	Frequency Calculated (Hz)		Deviation (%)	
		TETRA10	BEAM	TETRA10	BEAM
1	143.303	146.13	145.85	1.97	1.78
2	396.821	399.8	399.37	0.75	0.64
3	779.425	779.61	779.34	0.02	0.01
4	1289.577	1282.2	1282.5	0.57	0.55
					

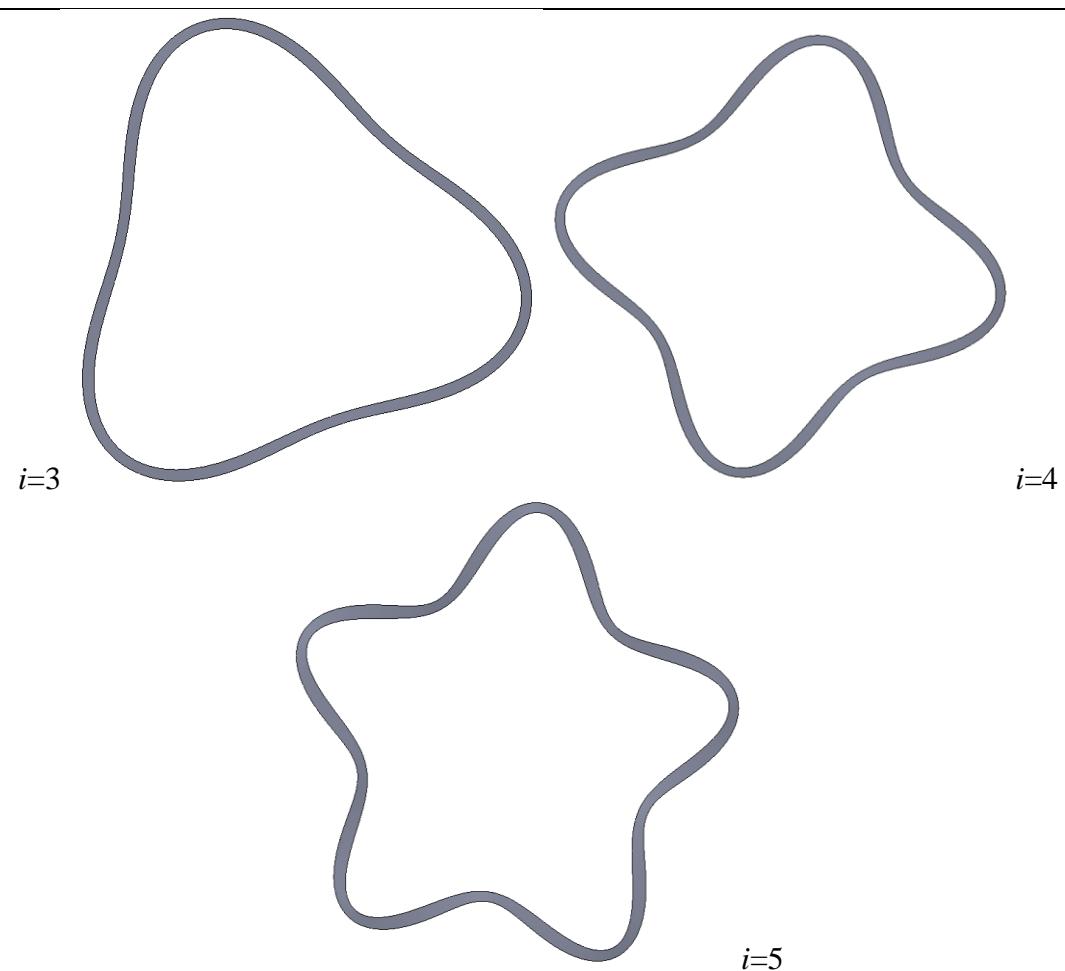


Order of the vibration mode		Vibration mode $\varphi_i(x)$						
		x = 0.	0.1	0.2	0.3	0.4	0.5	0.6
1	Reference	0	0.237	0.703	1	0.859	0.354	0
	TETRA10	0	0.236	0.703	1.000	0.861	0.356	0
	Deviation(%)	0	0.27	0.03	0.00	0.21	0.60	0
	BEAM	0	0.240	0.708	1.000	0.857	0.354	0
	Deviation(%)	-	1.24	0.67	0.00	0.24	0.01	-
2	Reference	0	-0.504	-0.818	0	1	0.752	0
	TETRA10	0	-0.503	-0.822	-0.004	1.000	0.755	0
	Deviation(%)	0	0.14	0.48	-	0.00	0.38	0
	BEAM	0	-0.506	-0.814	0.012	1.000	0.748	0
	Deviation(%)	-	0.47	0.48	-	0.00	0.58	-
3	Reference	0	0.67	0.21	-0.831	0.257	1	0
	TETRA10	0	0.669	0.214	-0.831	0.252	1.000	0
	Deviation(%)	0	0.14	1.71	0.01	1.84	0.00	0
	BEAM	0	0.674	0.194	-0.834	0.271	1.000	0
	Deviation(%)	-	0.65	7.57	0.33	5.42	0.00	-
4	Reference	0	-0.67	0.486	0	-0.594	1	0
	TETRA10	0	-0.674	0.486	0.005	-0.598	1.000	0
	Deviation(%)	0	0.52	0.02	-	0.61	0.00	0
	BEAM	0	-0.668	0.502	-0.026	-0.579	1.000	0
	Deviation(%)	-	0.28	3.32	-	2.54	0.00	-

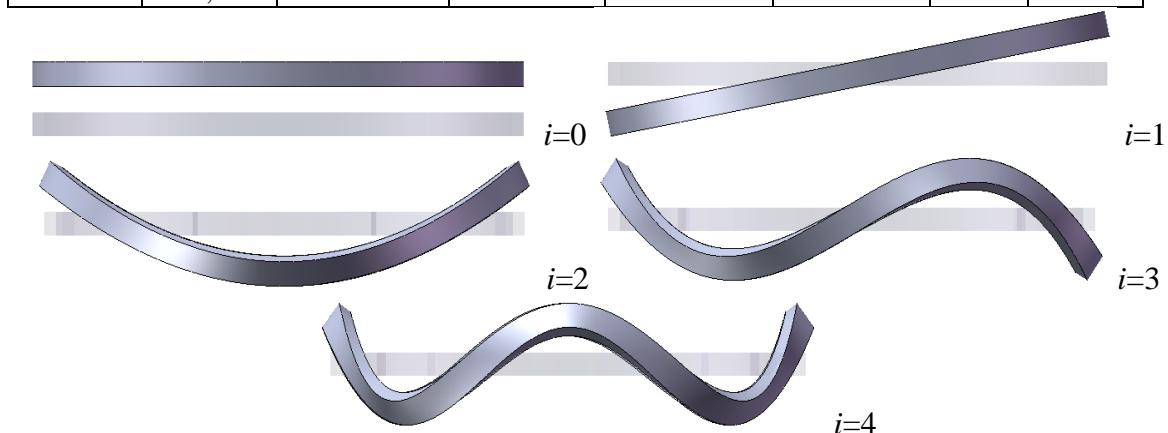
Comments :

$\varphi_i(x)$  is the value of the lateral displacement of the mode shape (normalized so that the value is 1 at the location of the max lateral displacement), at  $x$ .  $x$  is the distance along the beam length taken from the large cross section.

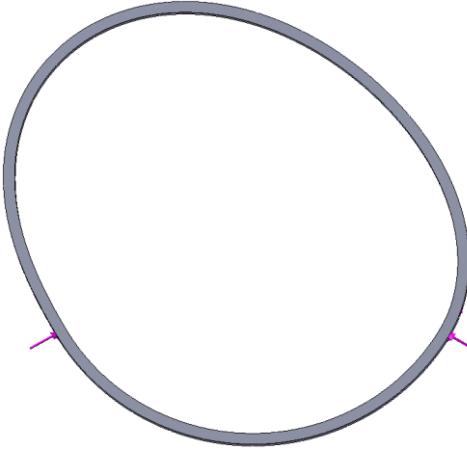
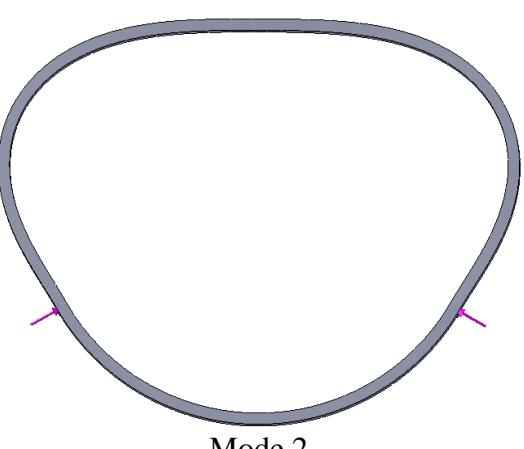
EVALUATION FORM							
Software: SOLIDWORKS Simulation				Version: 2019 SP2			
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.							
Test name: THIN CIRCULAR RING COMPLETELY FREE Codification: SDLL 11-89							
							
Test performed by : Julien BOISSAT				Date: 3/29/2019			
Model used							
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>			
Element type : TETRA10 and BEAM							
Number of degrees of freedom or mesh density :							
Solid elements:				Beam elements			
Nb of nodes = 13955				Nb of nodes = 400			
Nb of elements = 7401				Nb of elements = 200			
Nb of DOF = 41865				Nb of DOF = 1200			
Results :							
In plane							
Nature of the vibration mode		Frequency (Hz)				Deviation (%)	
<i>i</i>	Order	Reference value		Calculated value		Solid	Beam
				Solid	Beam		
0,1	1,2,3	0.	0	0	0	-	-
2	4,5	318.38	319.15	317.99	319.15	0.12	0.24
3	6,7	900.46	900.49	897.7	900.49	0.31	0.00
4	8,9	1726.55	1720.4	1716.6	1720.4	0.58	0.36
5	10,11	2792.21	2769.6	2766.4	2769.6	0.92	0.81
							
i=1				i=2			

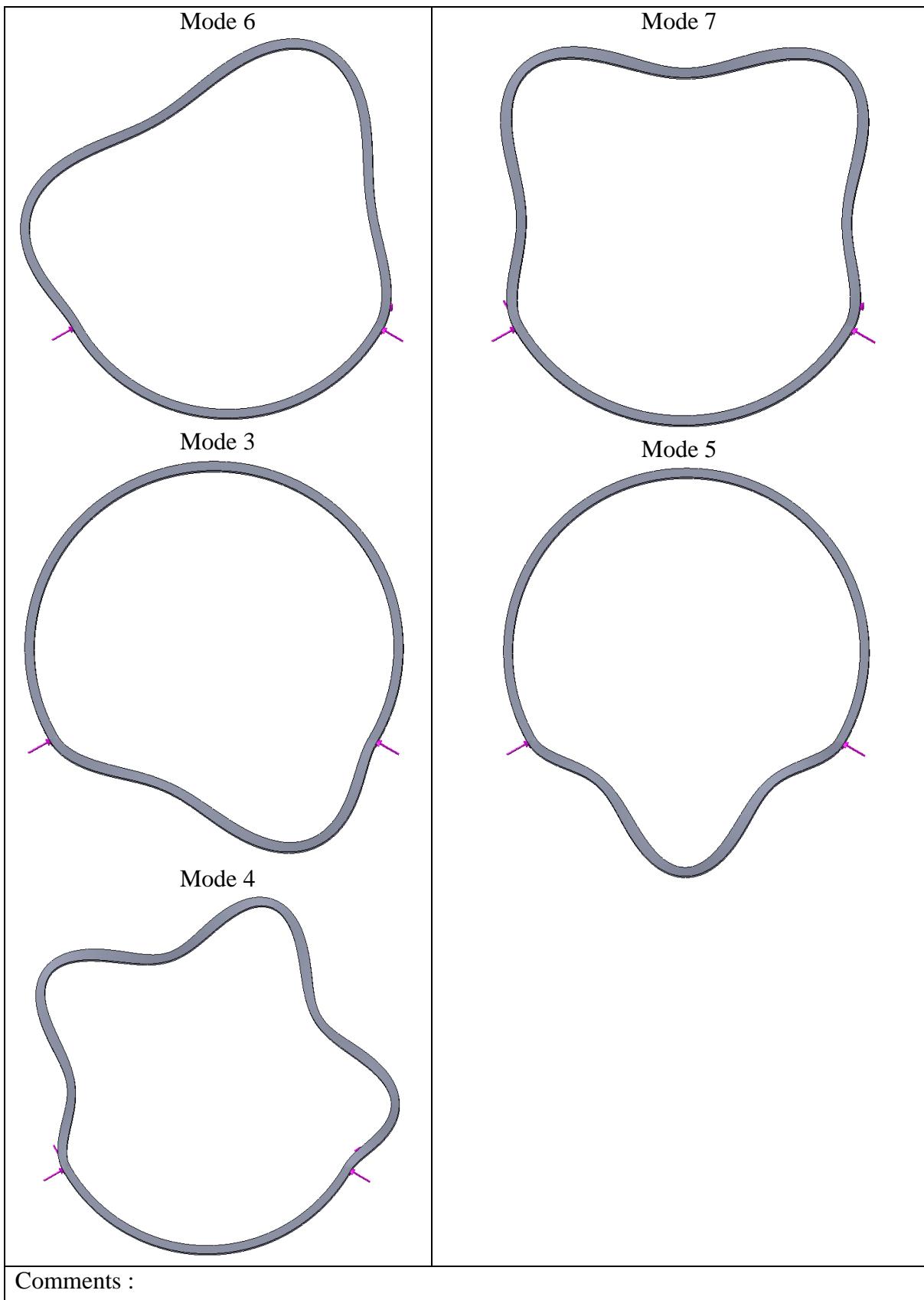


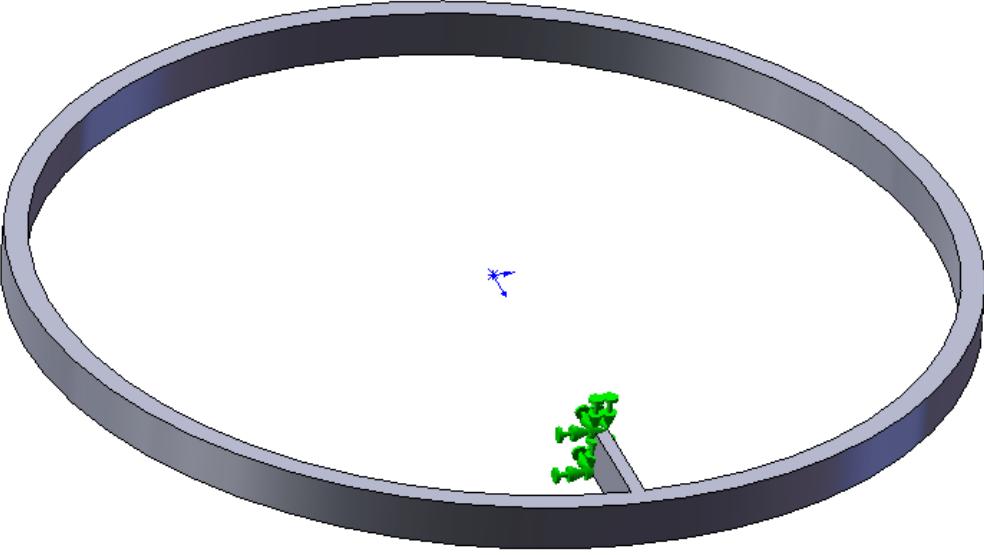
Out of plane							
Nature of the vibration mode		Frequency (Hz)				Deviation (%)	
$i$	Order	Reference value		Calculated value		Solid	Beam
				Solid	Beam		
0,1	1,2,3	0	0	0	0	-	-
2	4,5	510	508.5	510	508.6	0.20	0.47
3	6,7	1572	1577.5	1572	1577.6	1.13	0.78
4	8,9	3116	3150.8	3116	3151	2.14	1.04

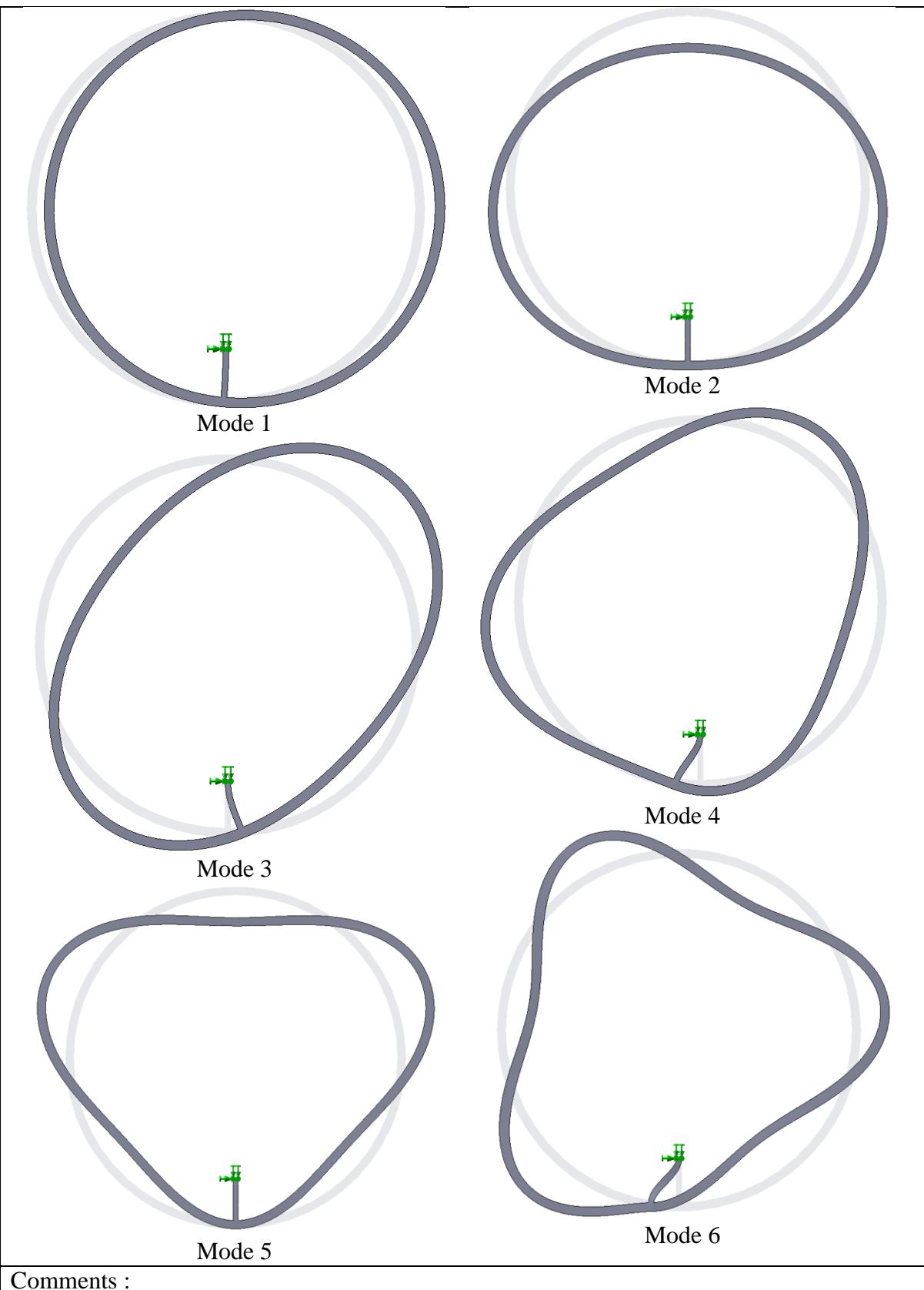


Comments :

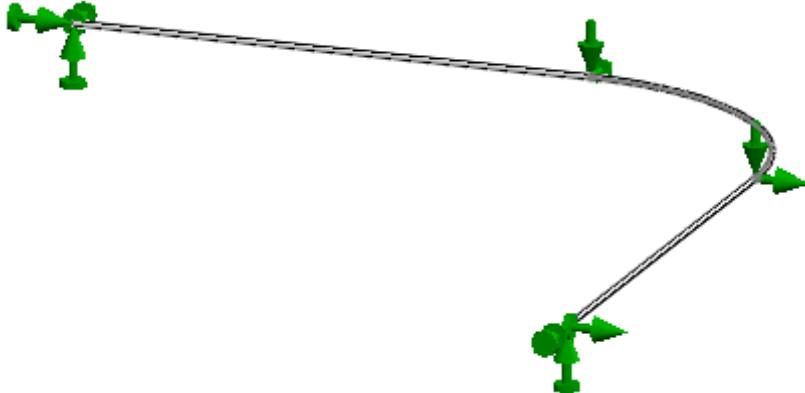
EVALUATION FORM							
Software: SOLIDWORKS Simulation				Version: 2019 SP2			
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.							
Test name: THIN CIRCULAR RING FIXED AT TWO POINTS							
Codification: SDLL 12-89							
Test performed by : Julien BOISSAT				Date: 3/29/2019			
Model used							
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>			
Element type : TETRA10 and BEAM							
Number of degrees of freedom or mesh density :							
Solid elements				Beam elements			
Nb of nodes = 14374		Nb of nodes = 432					
Nb of elements = 7666		Nb of elements = 216					
Nb of DOF = 43398		Nb of DOF = 1284					
Results :							
Order of the vibration mode		Frequency (Hz)				Deviation (%)	
<i>j</i>	<i>i</i>	Reference value	Calculated value		Solid	Beam	
			Solid	Beam			
1	anti	1	235.3	235.6	235.9	0.13	0.25
2	sym	1	575.3	574.5	575.8	0.14	0.09
3	anti	2	1105.7	1101.5	1104.2	0.38	0.14
4	anti	3	1405.6	1400.8	1403.6	0.34	0.14
5	sym	2	1751.1	1737.5	1741.9	0.78	0.53
6	anti	4	2557.0	2529.3	2535	1.08	0.86
7	sym	3	2801.5	2726.5	2737.3	2.68	2.35
Antisymmetric modes				Symmetric modes			
 Mode 1				 Mode 2			

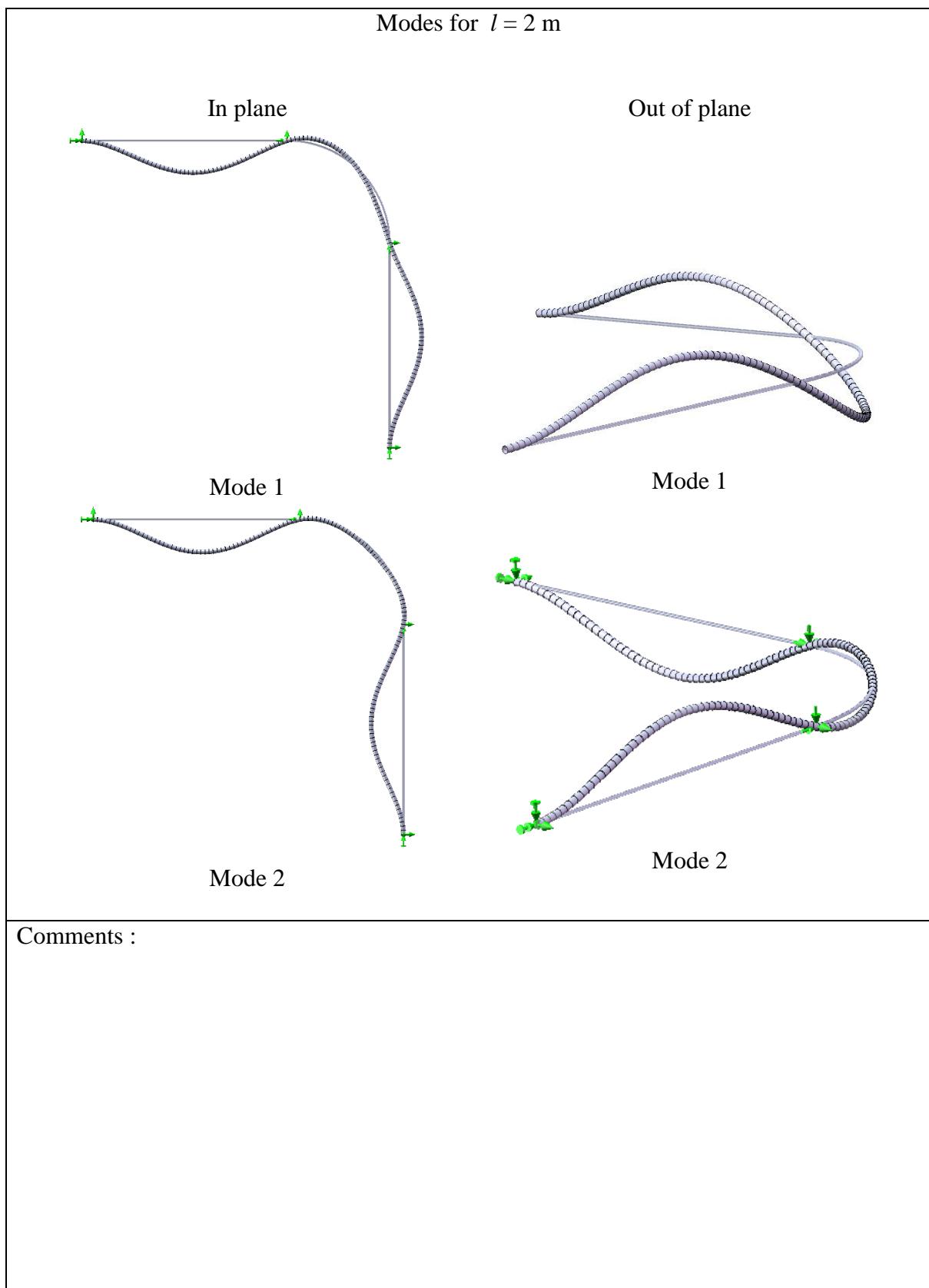


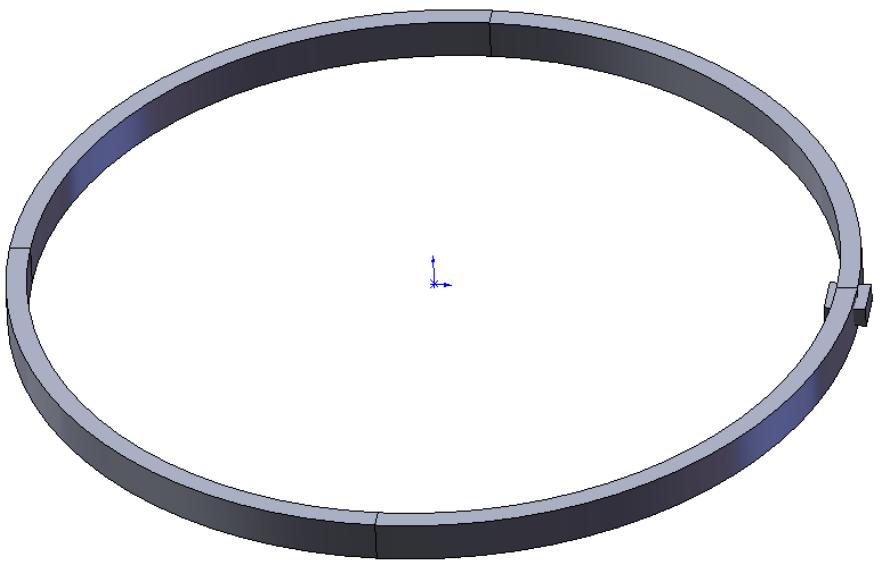
EVALUATION FORM					
Software: SOLIDWORKS Simulation	Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: THIN CIRCULAR RING FIXED BY AN ELASTIC LEG Codification: SDLL 13-89					
					
Test performed by : Julien BOISSAT	Date: 3/29/2019				
Model used					
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>			
Element type : TETRA10					
Number of degrees of freedom or mesh density :					
Solid elements	Shell elements				
Nb of nodes = 15149	Nb of nodes = 8672				
Nb of elements = 8174	Nb of elements = 3830				
Nb of DOF = 45366	Nb of DOF = 51990				
Results :					
Nature of the vibration mode	Frequency (Hz)			Deviation (%)	
	Reference value	Calculated value		Solid	Shell
		Solid	Shell		
1 anti	28.8	30.0	29.9	4.00	3.82
2 sym	189.3	189.8	190.1	0.26	0.42
3 anti	268.8	268.7	269	0.04	0.07
4 anti	641.0	660.0	655.1	2.88	2.20
5 sym	682.0	681.8	683.2	0.03	0.18
6 anti	1063.0	1100	1092.2	3.48	2.75



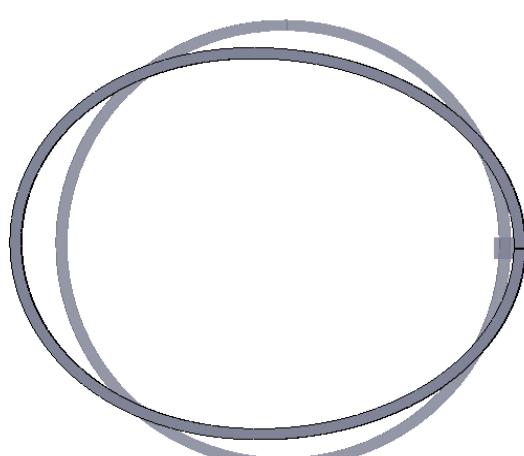
Comments :

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: VIBRATION MODES OF AN ELBOWED PIPE Codification: SDLL 14-89			
			
Test performed by : Julien BOISSAT		Date: 3/29/2019	
Model used			
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>	
Element type : BEAMS			
Number of degrees of freedom or mesh density :			
$l = 0 \text{ m}$ Nb of nodes = 561 Nb of elements = 280 Nb of DOF = 1674	$l = 0.6 \text{ m}$ Nb of nodes = 659 Nb of elements = 416 Nb of DOF = 2490	$l = 2 \text{ m}$ Nb of nodes = 829 Nb of elements = 646 Nb of DOF = 3870	
Results :			
Nature of the vibration mode	Frequency (Hz)		Deviation (%)
	Reference	Calculated	
$l = 0 \text{ m}$	Out of plane 1	44.23	0.23
	In plane 1	119	0.44
	Out of plane 2	125	0.72
	In plane 2	227	0.41
$l = 0.6 \text{ m}$	Out of plane 1	33.4	0.57
	In plane 1	94	0.07
	Out of plane 2	100	1.20
	In plane 2	180	1.52
$l = 2 \text{ m}$	Out of plane 1	17.9	1.40
	In plane 1	24.8	1.49
	Out of plane 2	25.3	1.42
	In plane 2	27	1.00

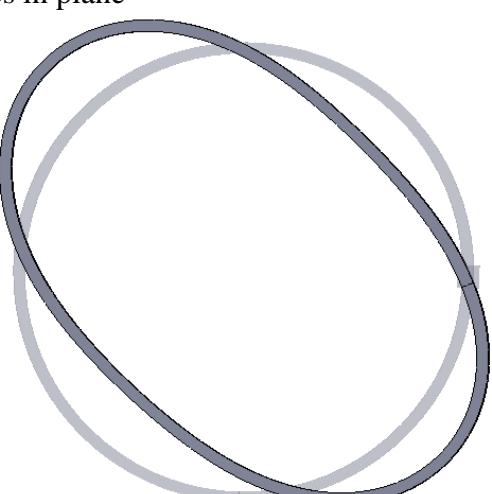


EVALUATION FORM				
Software: SOLIDWORKS Simulation		Version: 2019 B3		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.				
Test name: THIN FREE RING WITH A PUNCTUAL MASS Codification: SDLL 16-89				
				
Test performed by : Julien BOISSAT		Date: 3/29/2019		
Model used				
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>				
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
Nb of nodes = 13896				
Nb of elements = 7360				
Nb of DOF = 41829				
Results :				
<b>Order of the vibration mode</b>  In plane  Transverse	Frequency (Hz)		Deviation (%)	
	Reference	Calculated		
	In plane			
	1,2,3	0.	0	-
	Sym 4	227.29	227.63	0.12
	Anti 5	297.87	296.34	0.51
	Sym 6	718.42	717.27	0.16
	Anti 7	873.88	860.16	1.57
	Transverse			
1,2,3	0.	0	-	
4	409.8	409.21	0.15	
5	510.2	508.21	0.38	

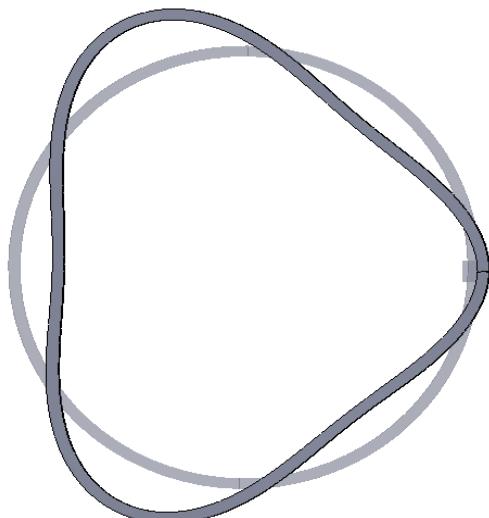
## Vibration modes in plane



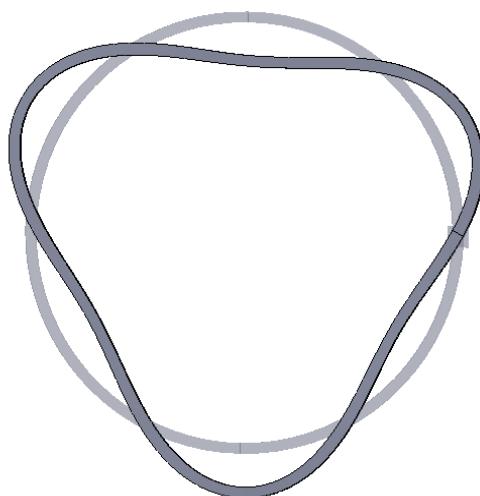
Mode 4



Mode 5



Mode 6

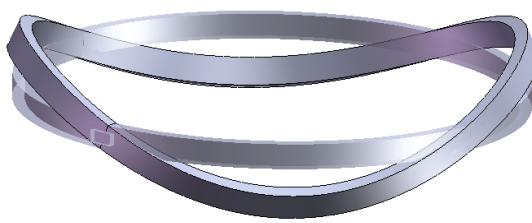


Mode 7

## Vibration modes out of plane

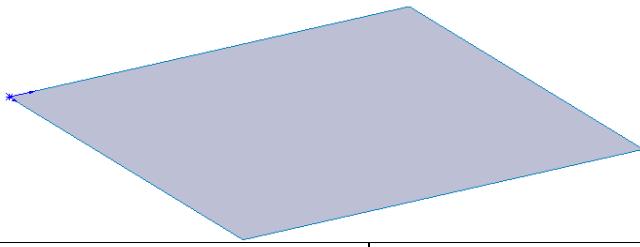
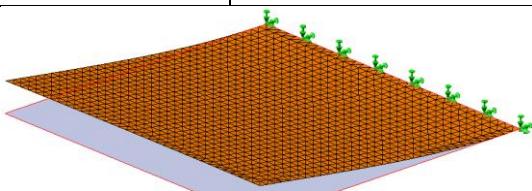
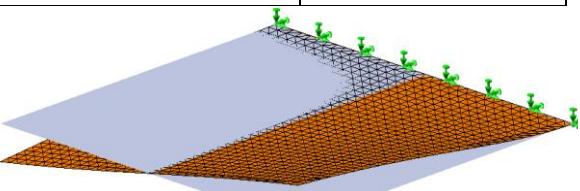
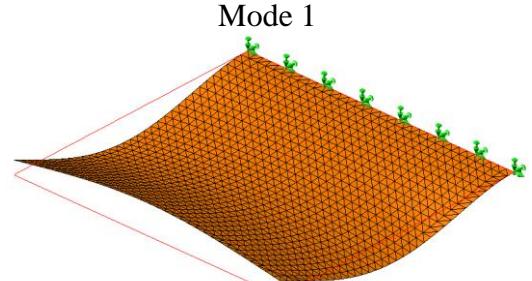
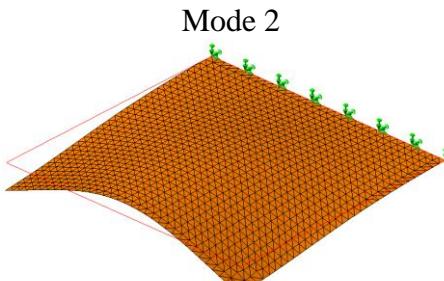


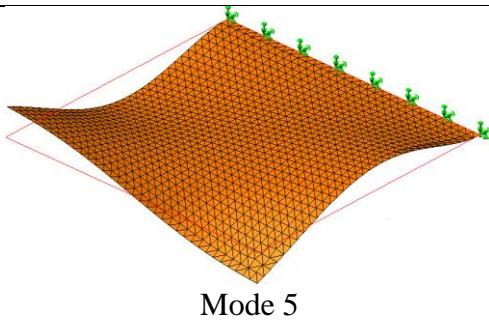
Mode 4



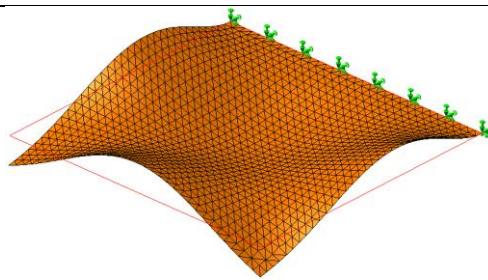
Mode 5

Comments :

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: THIN SQUARE PLATE WITH 3 OR 4 FREE EDGES			
Codification: SDLS 01-89			
			
Test performed by : Julien BOISSAT		Date: 4/2/2019	
Model used			
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>	
Other <input type="checkbox"/>			
Element type : SHELL 6			
Number of degrees of freedom or mesh density :			
1.Fixed edge		2.Free	
Nb of nodes	= 4629	Nb of nodes	= 4629
Nb of elements	= 2246	Nb of elements	= 2246
Nb of DOF	= 27360	Nb of DOF	= 27774
Results : 1.Fixed edge			
Order of the vibration mode i	Frequency (Hertz)		Deviation (%)
	Reference value	Calculated value	
1	8.7266	8.6733	0.61
2	21.3042	21.252	0.25
3	53.5542	53.16	0.74
4	68.2984	67.913	0.57
5	77.7448	77.312	0.56
6	136.0471	135.27	0.57
 			
 			



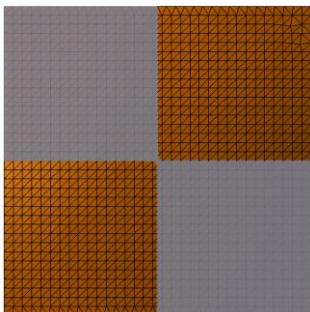
Mode 5



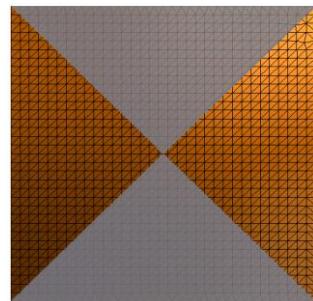
Mode 6

2.Free

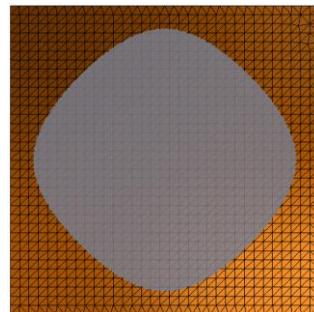
Order of the vibration mode i	Frequency (Hertz)		Deviation (%)
	Reference value	Calculated value	
7	33.7119	33.645	0.20
8	49.4558	48.922	1.09
9	61.0513	60.604	0.74
10	87.5160	86.864	0.75
11	87.5160	86.907	0.7



Mode 7



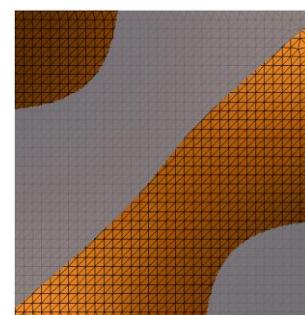
Mode 8



Mode 9

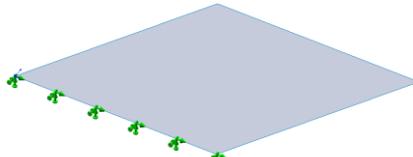
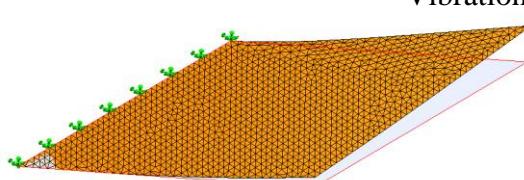
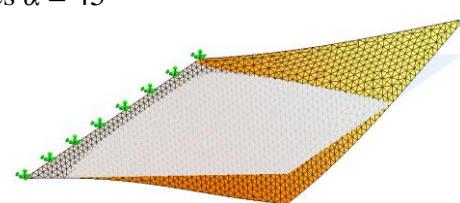


Mode 10

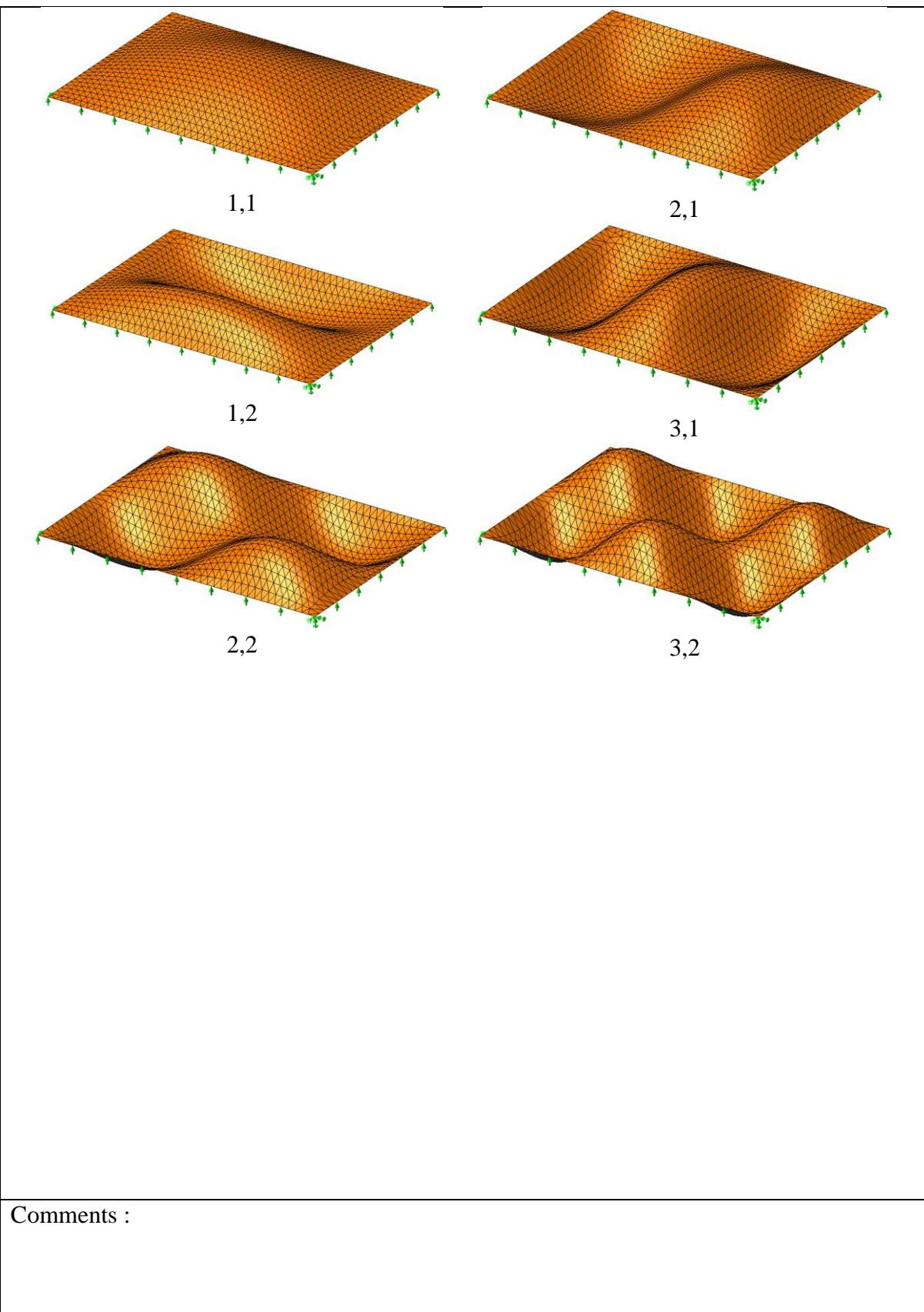


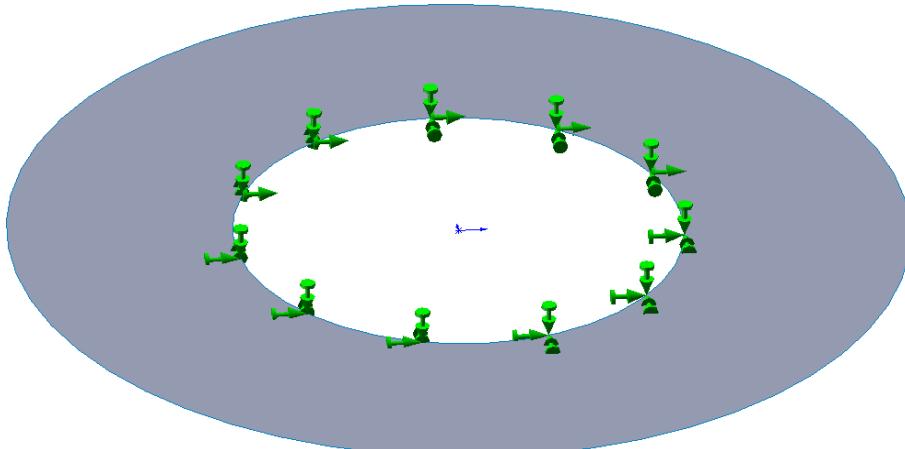
Mode 11

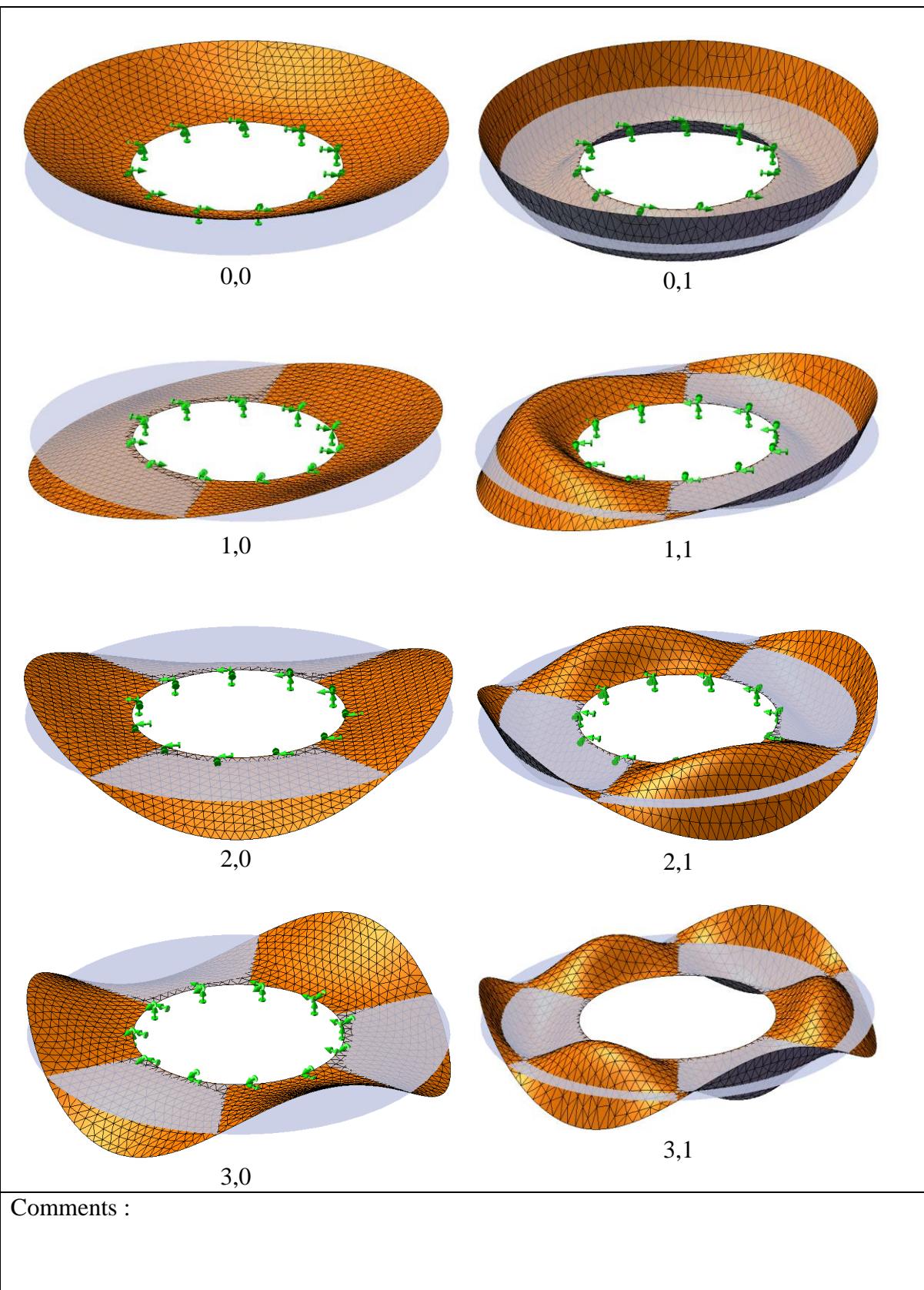
Comments :

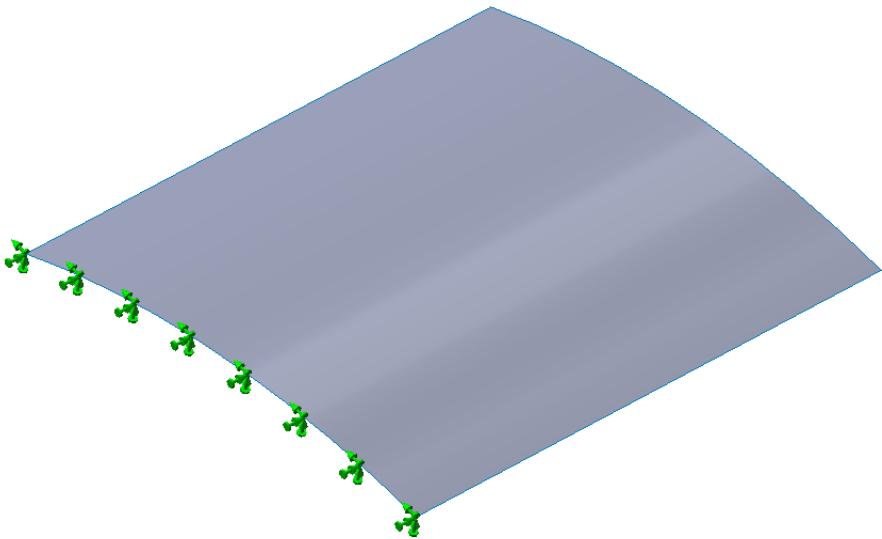
EVALUATION FORM					
Software: SOLIDWORKS Simulation			Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: THIN RHOMBOID PLATE FIXED ON ONE EDGE					
Codification: SDLS 02-89					
					
Test performed by : Julien BOISSAT			Date: 4/2/2019		
Model used					
<input checked="" type="checkbox"/> Finite elements		<input type="checkbox"/> Boundary elements		<input type="checkbox"/> Other	
Element type : SHELL 6					
Number of degrees of freedom or mesh density :					
$\alpha = 0^\circ$ Nb of nodes = 6561 Nb of elements = 3200 Nb of DOF = 38880			$\alpha = 15^\circ$ Nb of nodes = 6381 Nb of elements = 3110 Nb of DOF = 37800		
$\alpha = 30^\circ$ Nb of nodes = 5701 Nb of elements = 2770 Nb of DOF = 33720			$\alpha = 45^\circ$ Nb of nodes = 4737 Nb of elements = 2288 Nb of DOF = 27936		
Results :					
Nature of the vibration mode $\alpha$ $i$		Frequency (Hertz)		Deviation (%)	
		Reference value	Calculated value		
$\alpha = 0^\circ$	1	8.6734	8.6734	0	
	2	21.253	21.253	0	
$\alpha = 15^\circ$	1	8.9990	8.9538	2.04	
	2	22.1714	21.728	0.84	
$\alpha = 30^\circ$	1	9.8987	9.8159	0.84	
	2	25.4651	23.513	8.30	
$\alpha = 45^\circ$	1	11.15	11.264	-1.01	
	2	27	28.103	-3.91	
Vibration modes $\alpha = 45^\circ$					
 $f_1 = 11.26 \text{ Hz}$			 $f_2 = 28.1 \text{ Hz}$		
Comments :					

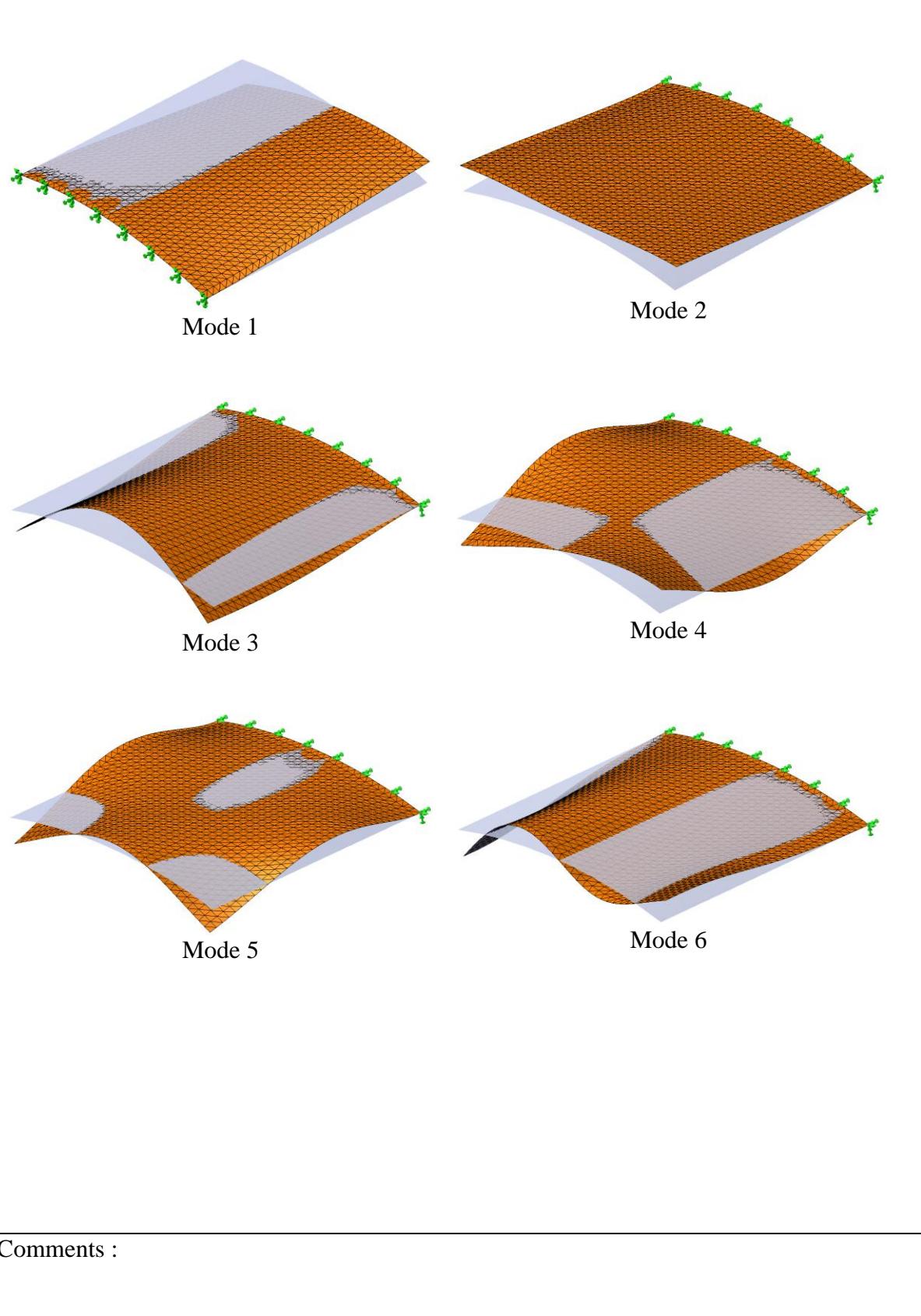
EVALUATION FORM					
Software: SOLIDWORKS Simulation			Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: THIN RECTANGULAR PLATE SIMPLY SUPPORTED ON EDGES					
Codification: SDLS 03-89					
Test performed by : Julien BOISSAT			Date: 4/2/2019		
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type : SHELL 6					
Number of degrees of freedom or mesh density :					
Nb of nodes = 4491					
Nb of elements = 2176					
Nb of DOF = 26940					
Results :					
Nature of the vibration mode <i>i</i> <i>j</i>		Frequency (Hertz)		Deviation (%)	
		Reference value	Calculated value		
1	1	35.63	35.62	0.03	
2	1	68.51	68.49	0.03	
1	2	109.62	109.58	0.04	
3	1	123.32	123.25	0.06	
2	2	142.51	142.41	0.07	
3	2	197.32	197.11	0.11	

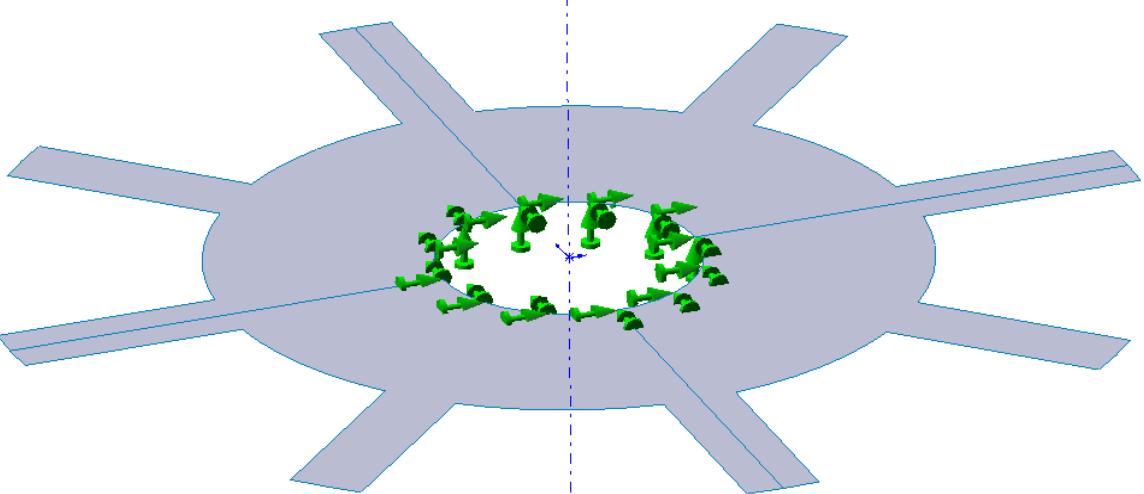


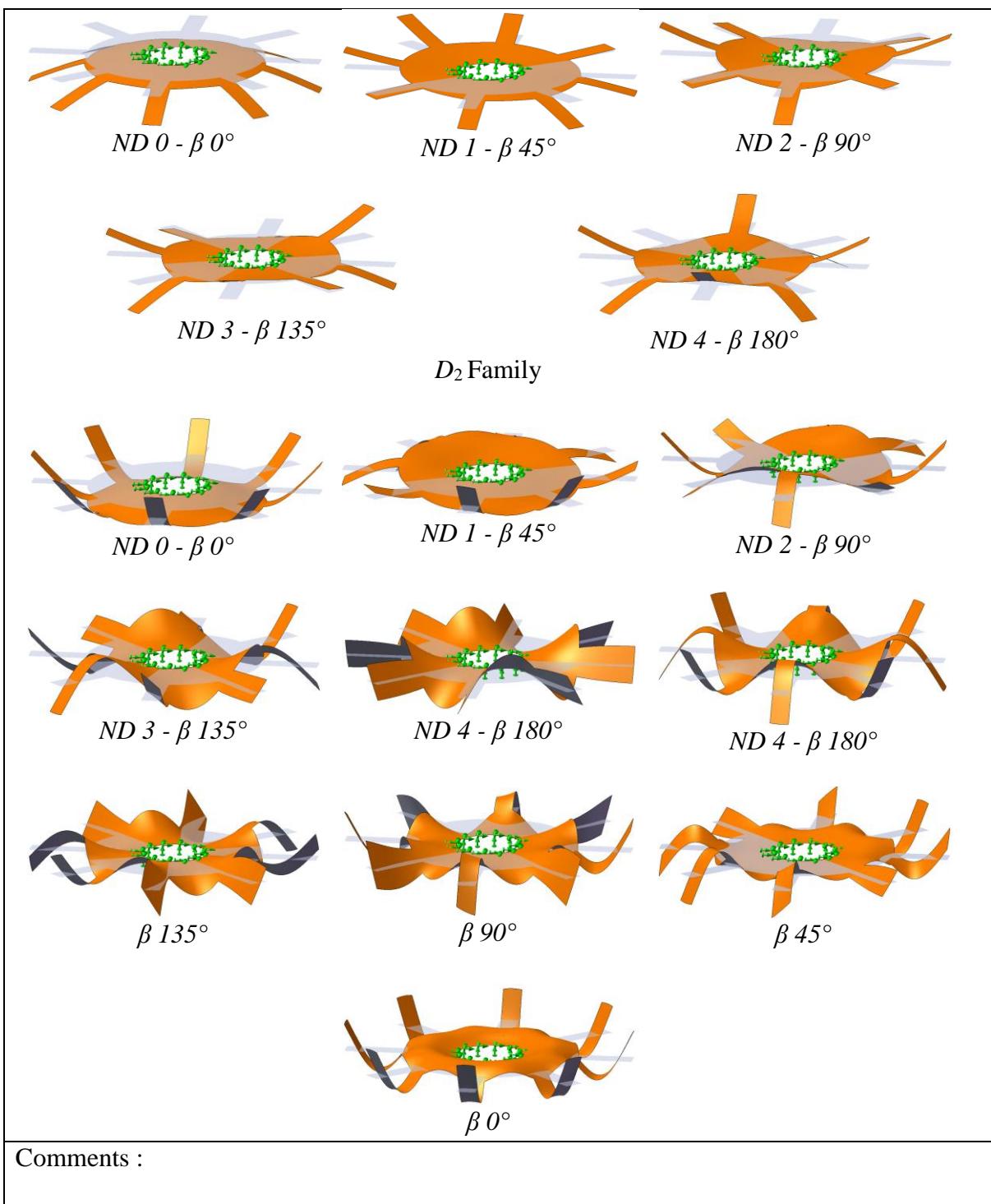
EVALUATION FORM					
Software: SOLIDWORKS Simulation			Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: THIN RING SHAPED PLATE FIXED ON INNER EDGE					
Codification: SDLS 04-89					
					
Test performed by : Julien BOISSAT			Date: 4/2/2019		
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : SHELL 6 Number of degrees of freedom or mesh density : Nb of nodes = 4642 Nb of elements = 2218 Nb of DOF = 27024					
Results :					
Nature of the vibration mode <i>i</i> <i>j</i>		Frequency (Hertz)		Deviation (%)	
		Reference value	Calculated value		
0	0	79.26	79.34	0.10	
0	1	518.85	516.37	0.48	
1	0	81.09	80.95	0.17	
1	1	528.61	526.68	0.37	
2	0	89.63	89.56	0.08	
2	1	559.09	556.98	0.38	
3	0	112.79	113.04	0.22	
3	1	609.70	607.96	0.29	

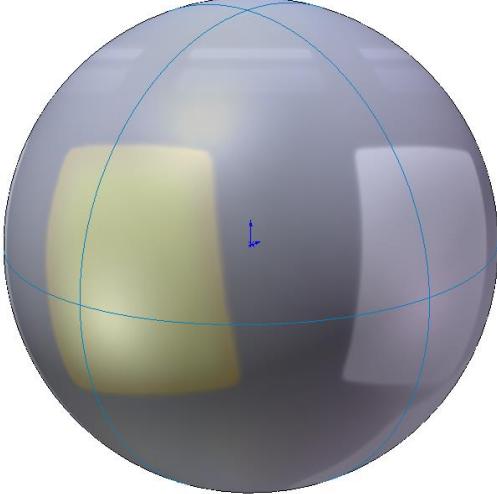


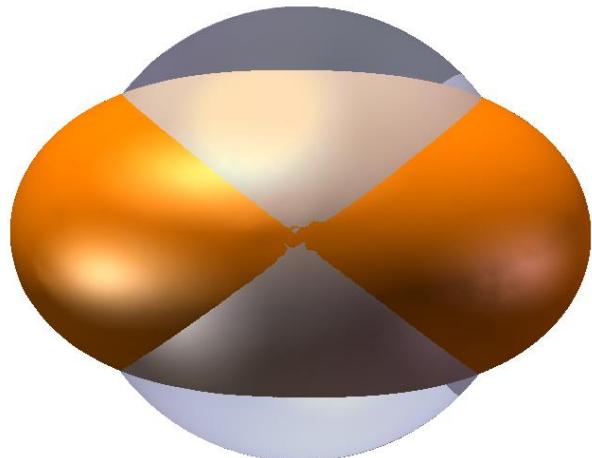
EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: COMPRESSOR BLADE: THIN SHELL FIXED-FREE			
Codification: SDLS 05-89			
			
Test performed by : Julien BOISSAT		Date: 4/2/2019	
Model used			
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>	
Other <input type="checkbox"/>			
Element type : SHELL 6			
Number of degrees of freedom or mesh density :			
Nb of nodes = 4629			
Nb of elements = 2246			
Nb of DOF = 27360			
Results :			
Nature of the vibration mode	Frequency (Hertz)		Deviation (%)
	Reference value	Calculated value	
1	85.6	85.9	0.35
2	134.5	138.4	2.82
3	259.0	246.9	4.90
4	351.0	342.4	2.51
5	395.0	386.4	2.23
6	531.0	528.2	0.53



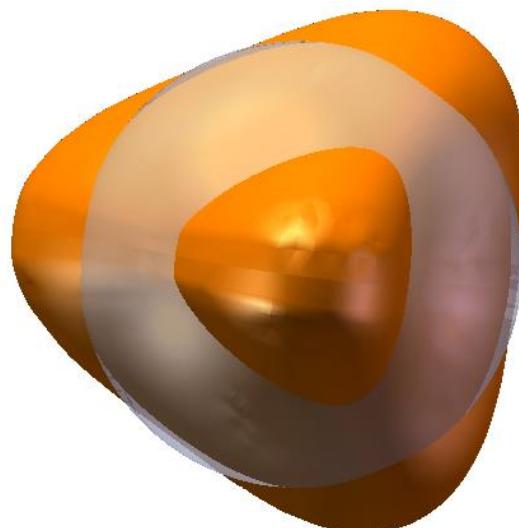
EVALUATION FORM							
Software: SOLIDWORKS Simulation				Version: 2019 SP2			
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.							
Test name: THIN WINGED CIRCULAR PLATE							
Codification: SDLS 06-89							
							
Test performed by : Julien BOISSAT				Date: 4/2/2019			
Model used							
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>			
Element type : SHELL 6							
Number of degrees of freedom or mesh density :							
Nb of nodes = 8796							
Nb of elements = 4164							
Nb of DOF = 52104							
Results :							
Nature of the vibration mode Torsion Bending		Frequency (Hertz)				Deviation (%)	
		Reference value		Calculated value			
		$D_1$	$D_2$	$D_1$	$D_2$		
$ND$	$\beta$ ( $^{\circ}$ )						
0	0	267.2	902	280.49	948.92	4.74	4.94
1	45	264.7	901	279.8	954.76	5.40	5.63
2	90	295.1	971	304.8	1017.3	3.18	4.55
3	135	361.1	1210	365.09	1242.5	1.09	2.62
4	180	--	1663		1679.4		0.98
4	180	390.5	1643	393.92	1670.8	0.87	1.66
	135	--	2189		2215.4		1.19
	90	--	2627		2681.9		2.05
	45	--	2783		2902.7		4.12
	0	--	2805		2932.6		4.35
$D_1$ Family							



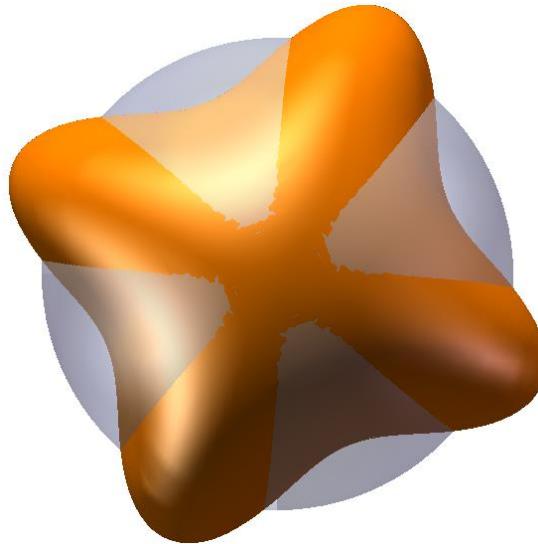
EVALUATION FORM							
Software: SOLIDWORKS Simulation				Version: 2019 SP2			
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.							
Test name: THIN SPHERE COMPLETELY IMMERSED IN A PERFECT AND INCOMPRESSIBLE FLUID							
Codification: SDLS 07-89							
							
Test performed by : Julien BOISSAT				Date: 4/2/2019			
Model used							
<input checked="" type="checkbox"/> Finite elements		<input type="checkbox"/> Boundary elements		<input type="checkbox"/> Other			
Element type : SHELL 6							
Number of degrees of freedom or mesh density :							
<b>In the void</b>							
$t/R = 0.04$ Nb of nodes = 4242 Nb of elements = 2120 Nb of DOF = 25452				$t/R = 0.004$ Nb of nodes = 10130 Nb of elements = 5064 Nb of DOF = 60780			
Results :							
<b>In vacuum</b>							
Nature of the vibration mode		Frequency (Hertz)				Deviation (%)	
		Reference value		Calculated value			
		$t/R = 0.04$	$t/R = 0.004$	$t/R = 0.04$	$t/R = 0.004$		
$i$	$j$						
2	0	237.25	236.71	237.41	236.93	0.07	0.09
3	0	282.85	280.49	283.15	280.56	0.11	0.03
4	0	305.24	297.65	305.39	297.8	0.05	0.05
5	0	324.17	306.16	324.16	306.44	0	0.09
6	0	346.76	311.10	346.52	311.41	0.07	0.1
7	0	376.68	314.35	376.55	314.71	0.03	0.11
8	0	416.0	316.77	415.17	317.28	0.20	0.16
9	0	465.75	318.80	463.85	319.26	0.41	0.14
10	0	526.20	320.71	522.84	321.41	0.64	0.22



$i = 2$

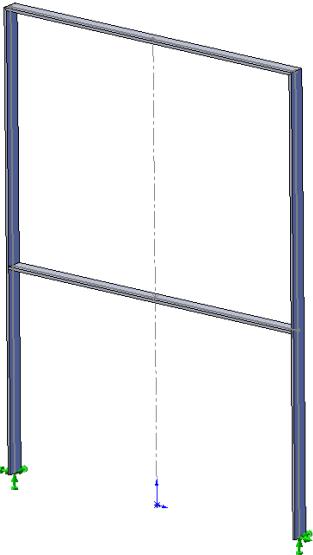


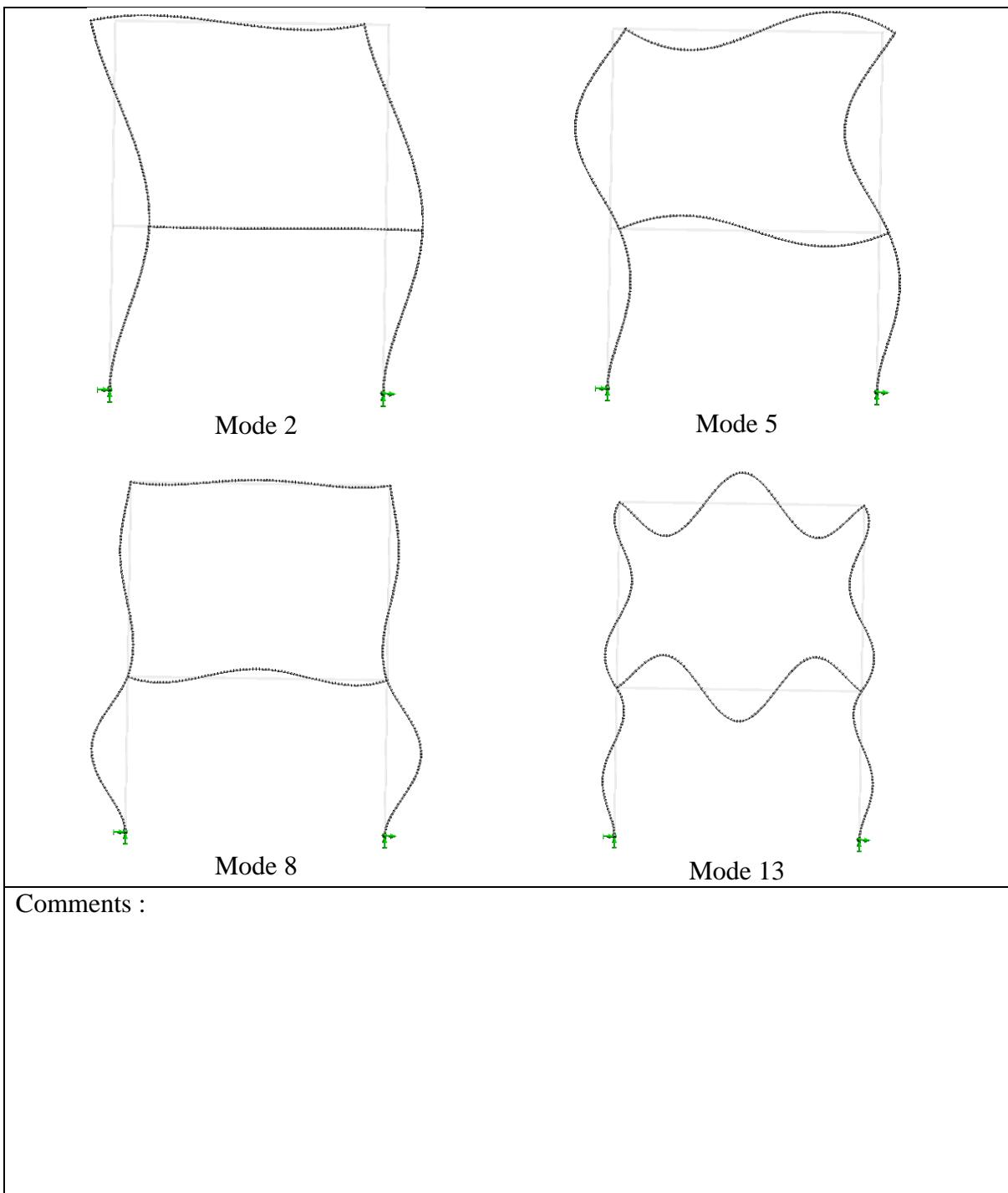
$i = 3$

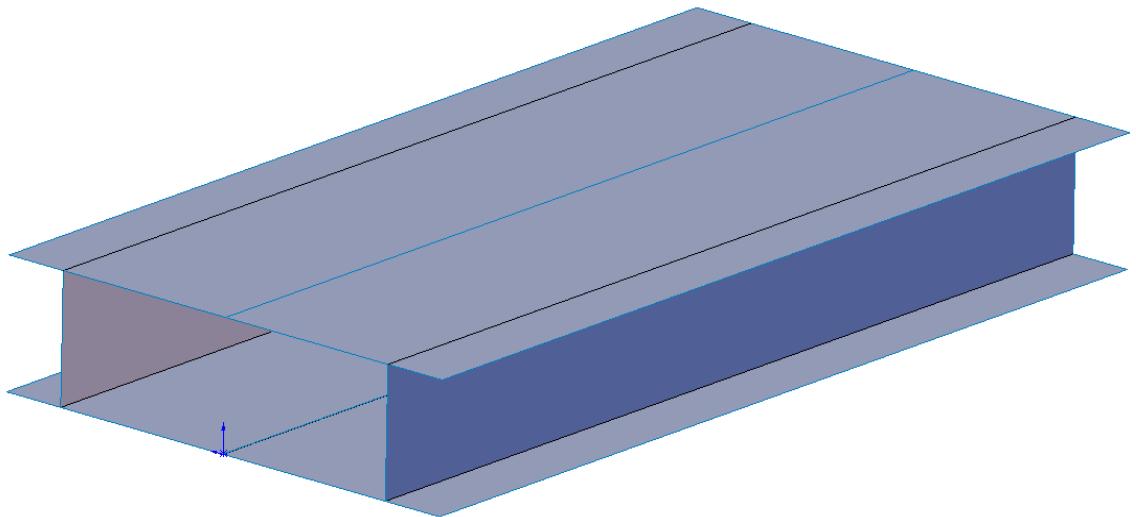


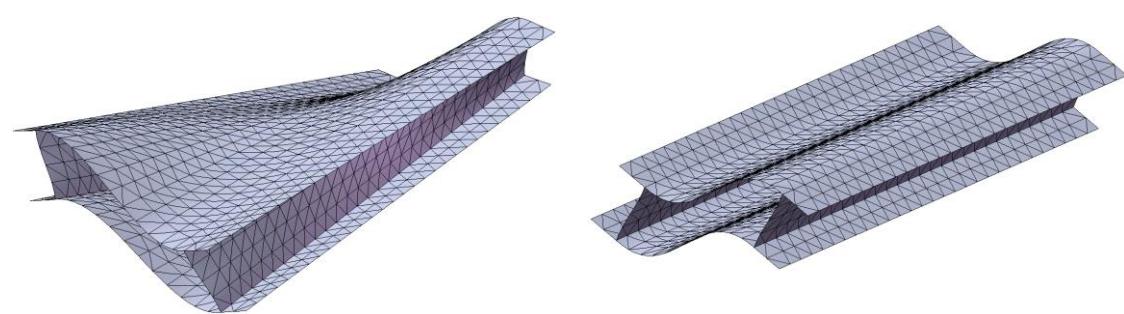
$i = 4$

Comments : The simulation of the immersed sphere is out of the software's range.

EVALUATION FORM																																																													
Software: SOLIDWORKS Simulation	Version: 2019 SP2																																																												
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																																																													
Test name: BENDING OF SYMMETRICAL FRAME																																																													
Codification: SDLX 01-89																																																													
																																																													
Test performed by : Julien BOISSAT		Date: 4/2/2019																																																											
<p>Model used</p> <p>Finite elements <input checked="" type="checkbox"/>      Boundary elements <input type="checkbox"/>      Other <input type="checkbox"/></p> <p>Element type : BEAM</p> <p>Number of degrees of freedom or mesh density :</p> <p>Nb of nodes = 389</p> <p>Nb of elements = 385</p> <p>Nb of DOF = 2292</p>																																																													
<p>Results :</p> <table border="1"> <thead> <tr> <th rowspan="2">Nature of the vibration mode <i>i</i></th> <th colspan="2">Frequency (Hertz)</th> <th rowspan="2">Deviation (%)</th> </tr> <tr> <th>Reference value</th> <th>Calculated value</th> </tr> </thead> <tbody> <tr><td>1 anti</td><td>8.8</td><td>8.8</td><td>0.00</td></tr> <tr><td>2 anti</td><td>29.4</td><td>29.5</td><td>0.34</td></tr> <tr><td>3 sym</td><td>43.8</td><td>43.8</td><td>0.00</td></tr> <tr><td>4 sym</td><td>56.3</td><td>56.56</td><td>0.46</td></tr> <tr><td>5 anti</td><td>96.2</td><td>95.97</td><td>0.24</td></tr> <tr><td>6 sym</td><td>102.6</td><td>102.8</td><td>0.19</td></tr> <tr><td>7 anti</td><td>147.1</td><td>146.6</td><td>0.34</td></tr> <tr><td>8 sym</td><td>174.8</td><td>174.6</td><td>0.11</td></tr> <tr><td>9 anti</td><td>178.8</td><td>178.8</td><td>0.00</td></tr> <tr><td>10 anti</td><td>206</td><td>206.5</td><td>0.24</td></tr> <tr><td>11 sym</td><td>266.4</td><td>264.7</td><td>0.64</td></tr> <tr><td>12 anti</td><td>320</td><td>318.1</td><td>0.60</td></tr> <tr><td>13 sym</td><td>335</td><td>333.1</td><td>0.57</td></tr> </tbody> </table>				Nature of the vibration mode <i>i</i>	Frequency (Hertz)		Deviation (%)	Reference value	Calculated value	1 anti	8.8	8.8	0.00	2 anti	29.4	29.5	0.34	3 sym	43.8	43.8	0.00	4 sym	56.3	56.56	0.46	5 anti	96.2	95.97	0.24	6 sym	102.6	102.8	0.19	7 anti	147.1	146.6	0.34	8 sym	174.8	174.6	0.11	9 anti	178.8	178.8	0.00	10 anti	206	206.5	0.24	11 sym	266.4	264.7	0.64	12 anti	320	318.1	0.60	13 sym	335	333.1	0.57
Nature of the vibration mode <i>i</i>	Frequency (Hertz)		Deviation (%)																																																										
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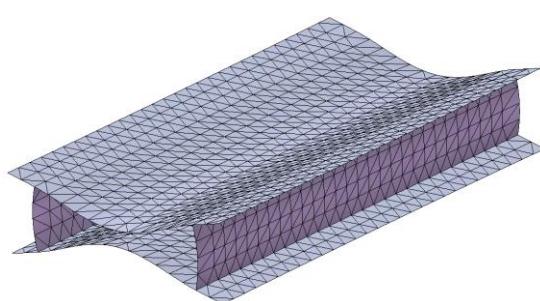


EVALUATION FORM					
Software: SOLIDWORKS Simulation		Version: 2019 SP2			
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: ASSEMBLY OF THIN RECTANGULAR SHAPED SHEETS					
Codification: SDLX 03-89					
					
Test performed by : Julien BOISSAT			Date: 4/3/2019		
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type : SHELL 6					
Number of degrees of freedom or mesh density :					
Nb of nodes = 4600 Nb of elements = 2260 Nb of DOF = 27600					
Results :					
Nature of the vibration mode <i>i</i>	Frequency (Hertz)			Deviation (%)	
	Experimental	Finite elements model	Calculated value	w.r.t. Exp.	w.r.t. FEM
1	606	$584 \pm 1\%$	585	3.59	0.17
2	760	$826 \pm 1.5\%$	826	7.99	0
3	865	$855 \pm 1.7\%$	852	1.53	0.35
4	944	$911 \pm 2\%$	912	3.51	0.11
5	1113	$1113 \pm 3.6\%$	1107	0.54	0.54
6	1144	$1136 \pm 4\%$	1157	1.12	1.82

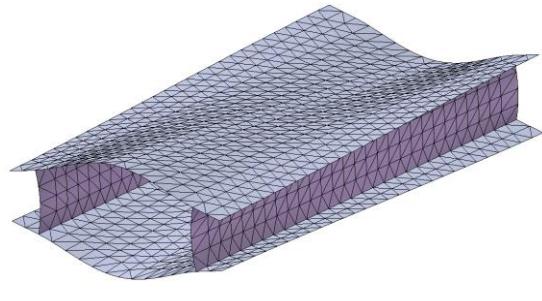


Mode 1

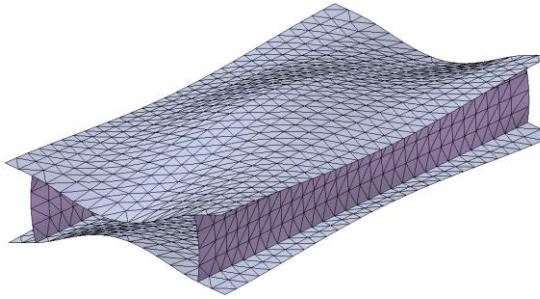
Mode 2



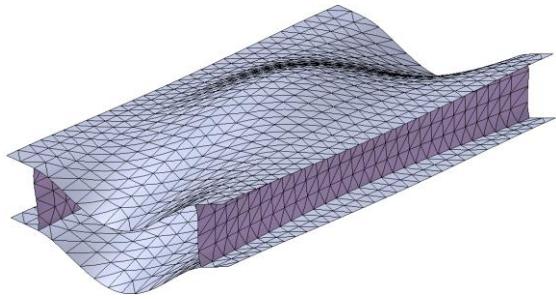
Mode 3



Mode 4



Mode 5



Mode 6

Comments :

## **II. THERMAL**

## 1. Linear steady state thermal

### EVALUATION FORM

Software: SOLIDWORKS Simulation | Version: 2019 B3  
 Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.

Test name: PIPE: PRESCRIBED TEMPERATURES

Codification: TPLA 01-89



Test performed by : Julien BOISSAT | Date: 4/3/2019

Model used

Finite elements

Boundary elements

Other

Element type : TRIANG

Number of degrees of freedom or mesh density :

#### 2D - Extruded

Nb of nodes = 2921

Nb of nodes = 6615

Nb of elements = 1370

Nb of elements = 3140

Nb of DOF = 2599

Nb of DOF = 5985

#### 2D – Axi-symmetric

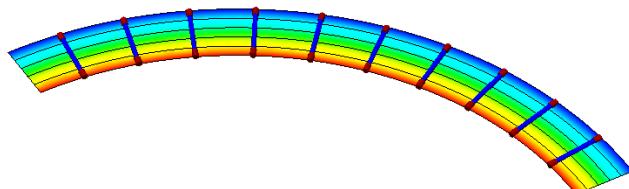
Results :

<b><i>r</i> (m)</b>	<b>2D - Extruded</b>		<b>Calculated values</b>		<b>Deviation (%)</b>	
	<b>T</b> (°C)	<b>φ</b> (W/m <sup>2</sup> )	<b>T</b> (°C)	<b>φ</b> (W/m <sup>2</sup> )		
0.3	100	1729.91	100	1729.94	0	0
0.31	82.98	1674.11	82.98	1674.07	0	0
0.32	66.51	1621.79	66.51	1621.73	0	0
0.33	50.54	1572.64	50.54	1572.61	0	0
0.34	35.04	1526.39	35.04	1526.27	0	0.01
0.35	20	1482.78	20	1482.67	0	0.01

Reference value of the output flux  $\Phi/l = 3260.80 \text{ W/m}$

Calculated value  $\Phi/l = 3260.23 \text{ W/m}$

Deviation (%) = 0.02



Temperature plot:

2D – Axi-symmetric						
<b>r</b> (m)	Reference values		Calculated values		Deviation (%)	
	<b>T</b> (°C)	$\phi$ (W/m <sup>2</sup> )	<b>T</b> (°C)	$\phi$ (W/m <sup>2</sup> )		
0.3	100	1729.91	100	1729.83	0	0
0.31	82.98	1674.11	82.98	1674.04	0	0
0.32	66.51	1621.79	66.51	1621.73	0	0
0.33	50.54	1572.64	50.54	1572.59	0	0
0.34	35.04	1526.39	35.04	1526.34	0	0
0.35	20	1482.78	20	1482.73	0	0

Reference value of the output flux  $\Phi/l = 3260.80$  W/m

Calculated value  $\Phi/l = 3260.80$  W/m

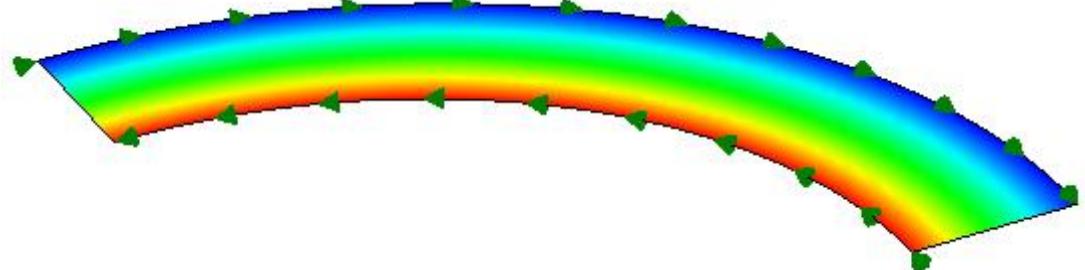
Deviation (%) = 0



#### Comments :

The Reference value of the output flux  $\Phi/l$  is the heat flux for a 1m extrusion thickness, and for the entire cross section.

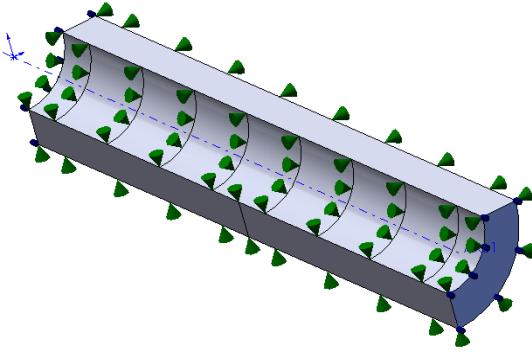
EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: PIPE : PRESCRIBED TEMPERATURE, CONVECTION						
Codification: TPLA 02-89						
Test performed by : Julien BOISSAT		Date: 4/3/2019				
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : SHELL6						
Number of degrees of freedom or mesh density :						
Nb of nodes = 1180						
Nb of elements = 533						
Nb of DOF = 1069						
Results :						
<i>r</i> (m)	Reference values		Calculated values		Deviation (%)	
	<i>T</i> (°C)	<i>φ</i> (W/m <sup>2</sup> )	<i>T</i> (°C)	<i>φ</i> (W/m <sup>2</sup> )	0	0.01
0.3	66.49	1005.29	66.49	1005.2	0	0.01
0.31	56.60	972.89	56.60	972.83	0	0.01
0.32	47.03	942.46	47.03	942.43	0	0
0.33	37.75	913.90	37.75	913.87	0	0
0.34	28.74	887.02	28.74	887.00	0	0
0.35	20	861.6	20	861.57	0	0
Reference value of the output flux $\Phi/l = 1894.94 \text{ W/m}$						
Calculated value $\Phi/l = 1894.92 \text{ W/m}$						
Deviation (%) = 0						
Comments :						
The Reference value of the output flux $\Phi/l$ is the heat flux for a 1m extrusion thickness, and for the entire cross section.						

EVALUATION FORM																									
Software: SOLIDWORKS Simulation	Version: 2019 SP2																								
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																									
Test name: PIPE : CONVECTION																									
Codification: TPLA 03-89																									
																									
Test performed by : Julien BOISSAT	Date: 4/3/2019																								
Model used																									
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>																								
Other <input type="checkbox"/>																									
Element type : SHELL6																									
Number of degrees of freedom or mesh density :																									
Nb of nodes = 2147																									
Nb of elements = 1008																									
Nb of DOF = 2147																									
Results :																									
<table border="1"> <thead> <tr> <th>Physical quantity</th> <th>Reference value</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td><math>T_i</math> (°C)</td> <td>272.27</td> <td>272.35</td> <td>0.03</td> </tr> <tr> <td><math>T_e</math> (°C)</td> <td>205.05</td> <td>204.51</td> <td>0.27</td> </tr> <tr> <td><math>\varphi_i</math> (W/m<sup>2</sup>)</td> <td>34160.01</td> <td>34146.32</td> <td>0.04</td> </tr> <tr> <td><math>\varphi_e</math> (W/m<sup>2</sup>)</td> <td>26276.93</td> <td>26198.90</td> <td>0.30</td> </tr> <tr> <td><math>\Phi/l</math> (W/m)</td> <td>64390.11</td> <td>64364.26</td> <td>0.04</td> </tr> </tbody> </table>		Physical quantity	Reference value	Calculated value	Deviation (%)	$T_i$ (°C)	272.27	272.35	0.03	$T_e$ (°C)	205.05	204.51	0.27	$\varphi_i$ (W/m <sup>2</sup> )	34160.01	34146.32	0.04	$\varphi_e$ (W/m <sup>2</sup> )	26276.93	26198.90	0.30	$\Phi/l$ (W/m)	64390.11	64364.26	0.04
Physical quantity	Reference value	Calculated value	Deviation (%)																						
$T_i$ (°C)	272.27	272.35	0.03																						
$T_e$ (°C)	205.05	204.51	0.27																						
$\varphi_i$ (W/m <sup>2</sup> )	34160.01	34146.32	0.04																						
$\varphi_e$ (W/m <sup>2</sup> )	26276.93	26198.90	0.30																						
$\Phi/l$ (W/m)	64390.11	64364.26	0.04																						
Comments :																									
The Reference value of the output flux $\Phi/l$ is the heat flux for a 1m extrusion thickness, and for the entire cross section.																									

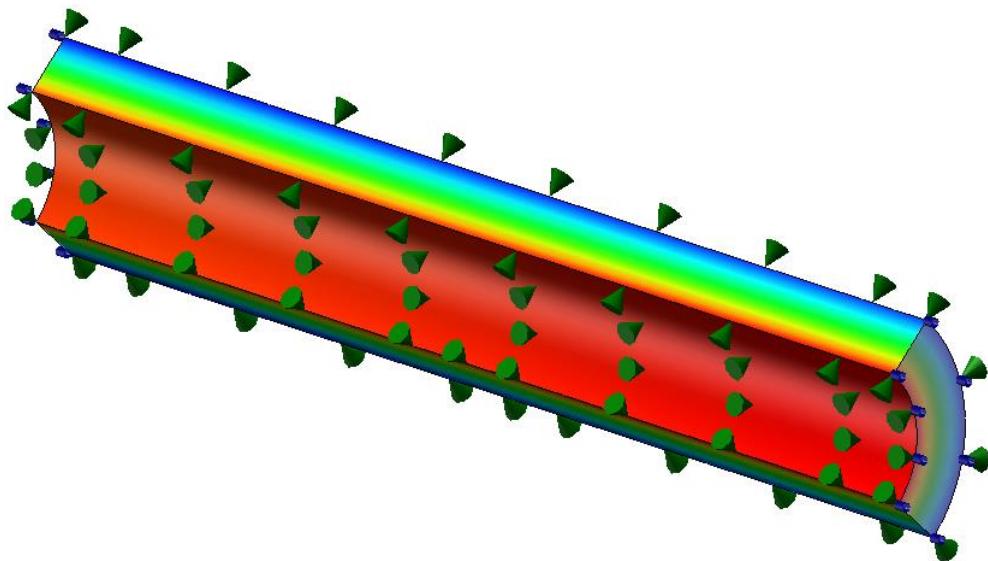
EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: POWER OUTPUT IN A PIPE						
Codification: TPLA 04-89						
Test performed by : Julien BOISSAT			Date: 4/3/2019			
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : TRIANG						
Number of degrees of freedom or mesh density :						
Nb of nodes = 2619						
Nb of elements = 1252						
Nb of DOF = 2461						
Results :						
<b><i>r</i> (m)</b>	<b>Reference value</b>		<b>Calculated values</b>		<b>Deviation (%)</b>	
	<b>T (°C)</b>	<b><math>\phi</math> (W/m<sup>2</sup>)</b>	<b>T (°C)</b>	<b><math>\phi</math> (W/m<sup>2</sup>)</b>		
1.0	20.00	-58.2	20.00	-58.16	0	0.07
1.2	28.73	-30.17	28.73	-30.17	0	0
1.5	32.62	2.87	32.62	2.878	0	0.28
Comments :						

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: CYLINDRICAL BAR WITH FLUX DENSITY			
Codification: TPLA 05-89			
Test performed by : Julien BOISSAT	Date: 4/3/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>	
Element type : TETRA 10			
Number of degrees of freedom or mesh density :			
Nb of nodes	= 25788		
Nb of elements	= 15387		
Nb of DOF	= 25642		
Results :			
<i>z</i> (m)	Reference value <i>T</i> (°C)	Calculated value <i>T</i> (°C)	Deviation (%)
0.0	0.00	0.00	-
0.1	-4.00	-4.00	0
0.2	4.00	4.00	0
0.3	24.00	24.00	0
0.4	56.00	56.00	0
0.5	100.00	100.0	0
0.6	156.00	156.0	0
0.7	224.00	224.0	0
0.8	304.00	304.0	0
0.9	396.00	396.0	0
1.0	500.00	500.0	0
Comments :			

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: CYLINDRICAL BAR WITH CONVECTION			
Codification: TPLA 06-89			
Test performed by : Julien BOISSAT		Date: 4/3/2019	
Model used			
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>	
Other <input type="checkbox"/>			
Element type : TETRA 10			
Number of degrees of freedom or mesh density :			
Nb of nodes = 25788			
Nb of elements = 15387			
Nb of DOF = 25642			
Results :			
<i>z</i> (m)	Reference value <i>T</i> (°C)	Calculated value <i>T</i> (°C)	Deviation (%)
0.0	0.00	0.00	-
0.1	0.37	0.37	0
0.2	0.97	0.97	0
0.3	2.19	2.19	0
0.4	4.78	4.79	0.21
0.5	10.39	10.40	0.10
0.6	22.56	22.56	0
0.7	48.95	48.95	0
0.8	106.21	106.2	0.01
0.9	230.44	230.3	0.06
1.0	500.00	500.0	0
Comments :			

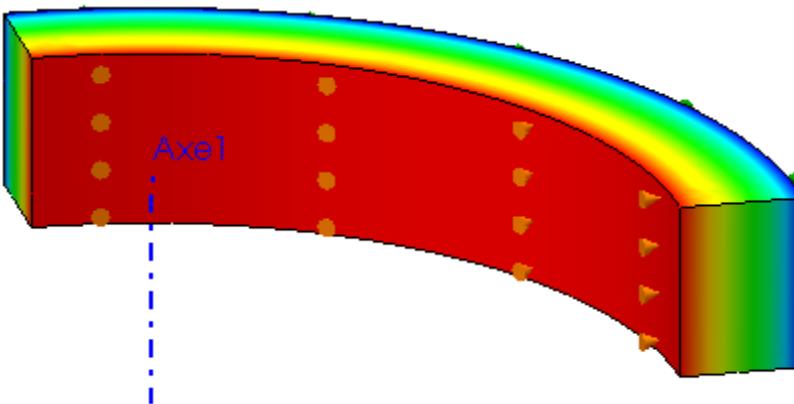
EVALUATION FORM				
Software: SOLIDWORKS Simulation		Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.				
Test name: ORTHOTROPIC PIPE				
Codification: TPLA 07-89				
				
Test performed by : Julien BOISSAT		Date: 4/3/2019		
Model used				
<input checked="" type="checkbox"/> Finite elements		<input type="checkbox"/> Boundary elements	<input type="checkbox"/> Other	
Element type : TETRA 10				
Number of degrees of freedom or mesh density :				
Nb of nodes = 40898				
Nb of elements = 26460				
Nb of DOF = 40898				
Results :				
<b><i>z (m)</i></b>	<b><i>r (m)</i></b>	<b>Reference value <i>T</i> (°C)</b>	<b>Calculated value <i>T</i> (°C)</b>	<b>Deviation(%)</b>
0	0.030	100.01	100.8	0.78
	0.035	81.90	82.95	1.27
	0.040	66.22	67.34	1.66
	0.045	52.38	53.39	1.89
	0.050	40.00	40.74	1.82
1/2	0.030	102.51	102.6	0.09
	0.035	84.40	84.44	0.05
	0.040	68.72	68.76	0.06
	0.045	54.88	54.91	0.05
	0.050	42.51	42.54	0.07
1	0.030	105.01	104.4	0.58
	0.035	86.90	85.93	1.13
	0.040	71.22	70.18	1.48
	0.045	57.38	56.43	1.68
	0.050	45.01	44.33	1.53

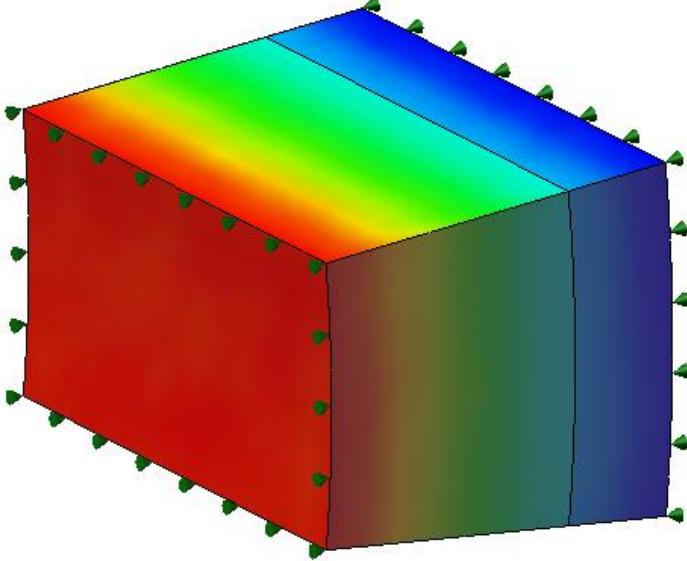
$\forall r, \varphi_z (\text{W/m}^2)$	-500	-	-
$\forall z, \varphi_{Ri} (\text{W/m}^2)$	11310	11310	0
$\forall z, \varphi_{Re} (\text{W/m}^2)$	6786	6778.8	-0.11

**Comments :**

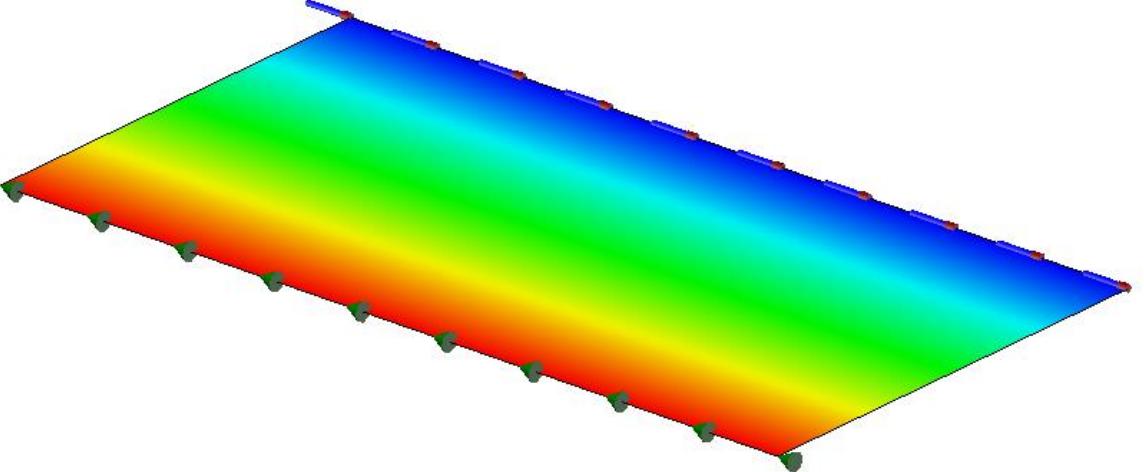
In order to satisfy the boundary conditions, the face was split and the convection was applied separately to each strip because the software does not currently allow ambient temperature variation for convection as a boundary condition.

Because of this, the heat flux in Z is not uniform and the corresponding value  $\forall r, \varphi_z (\text{W/m}^2)$  for is unavailable.

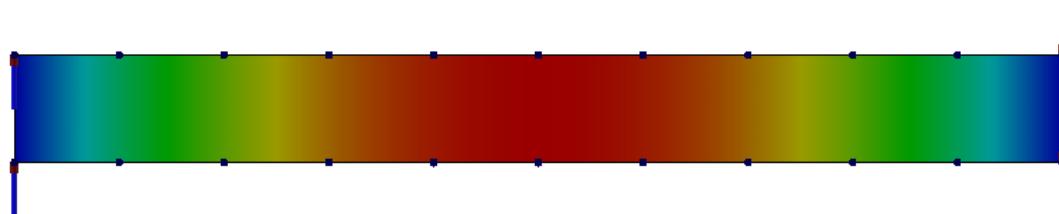
EVALUATION FORM					
Software: SOLIDWORKS Simulation	Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: TWO-MATERIAL PIPE : CONVECTION					
Codification: TPLA 08-89					
					
Test performed by : Julien BOISSAT			Date: 4/3/2019		
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type : TETRA 10					
Number of degrees of freedom or mesh density :					
Solid elements			Axisymmetric shell elements		
Nb of nodes	= 6500		Nb of nodes	= 2623	
Nb of elements	= 4063		Nb of elements	= 1260	
Nb of DOF	= 6500		Nb of DOF	= 2623	
Results :					
Physical quantity	Reference value	Calculated value		Deviation (%)	
		Solid	Shell	Solid	Shell
		$T_i$ (°C)	25.42	25.42	25.42
$T_m$ (°C)	17.69	17.69	17.69	0	
$T_e$ (°C)	12.11	12.11	12.11	0	
$\varphi_i$ (W/m <sup>2</sup> )	6687.44	6686.2	6687.4	0.02	
$\varphi_m$ (W/m <sup>2</sup> )	5732.09	5731.1	5732	0.02	
$\varphi_e$ (W/m <sup>2</sup> )	5422.25	5421.4	5422.2	0.02	
$\Phi/l$ (W/m)	12605.52	12603.2	12605.5	0.02	
Comments :					
The Reference value of the output flux $\Phi/l$ is the heat flux for a 1m extrusion thickness, and for the entire cross section.					

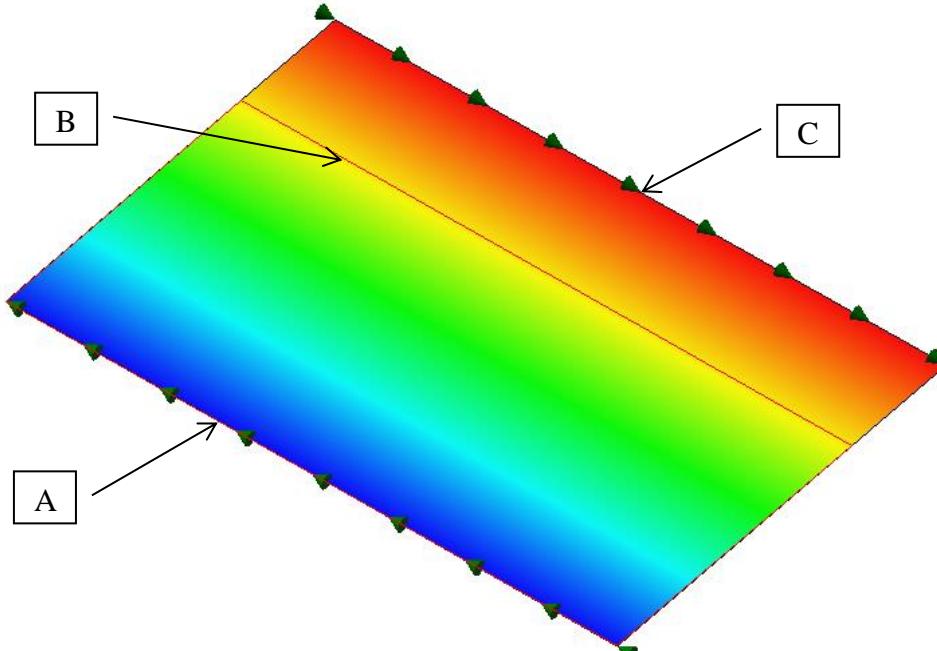
EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: TWO-MATERIAL PIPE : CONVECTION, THERMAL CONTACT RESISTANCE Codification: TPLA 09-89			
			
Test performed by : Julien BOISSAT	Date: 4/3/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : TETRA 10			
Number of degrees of freedom or mesh density :			
Nb of nodes = 12061			
Nb of elements = 7645			
Nb of DOF = 12061			
Results :			
Physical quantity	Reference value	Calculated value	Deviation
$T_i$ (°C)	25.11	25.11	0
$T^1_m$ (°C)	17.33	17.33	0
$T^2_m$ (°C)	5.91	5.91	0
$T_e$ (°C)	0.3	0.3	0
$\varphi_i$ (W/m <sup>2</sup> )	6732.90	6732.7	0
$\varphi_m$ (W/m <sup>2</sup> )	5771.06	5770.9	0
$\varphi_e$ (W/m <sup>2</sup> )	5459.11	5459	0
$\Phi/l$ (W/m)	12691.23	12691.08	0
Comments :			
The Reference value of the output flux $\Phi/l$ is the heat flux for a 1m extrusion thickness, and for the entire cross section.			

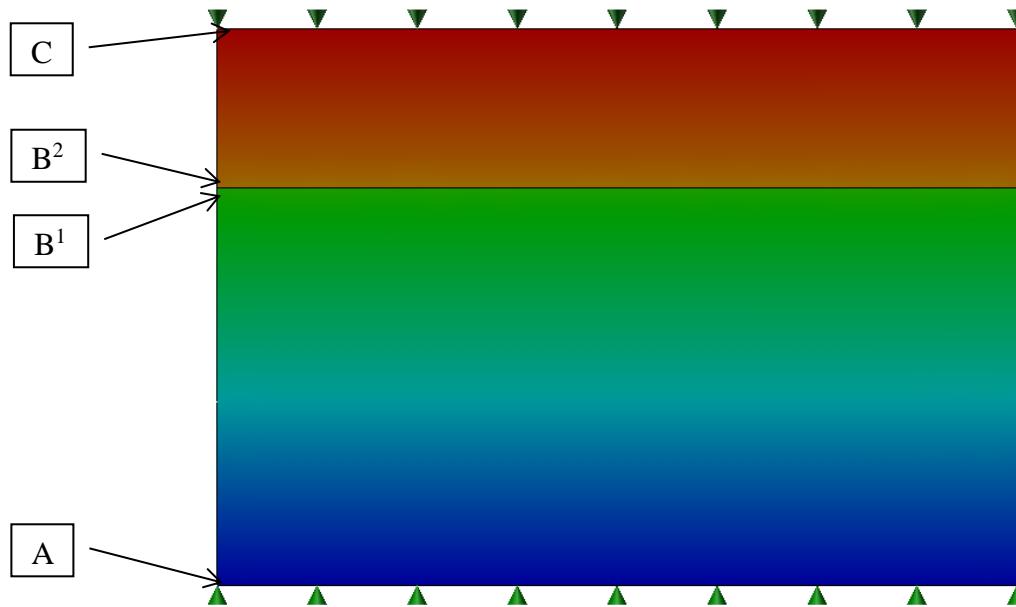
EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: SIMPLE WALL : PRESCRIBED TEMPERATURES			
Codification: TPLL 01-89			
Test performed by : Julien BOISSAT		Date: 4/3/2019	
Model used			
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>	
Other <input type="checkbox"/>			
Element type : SHELL			
Number of degrees of freedom or mesh density :			
Nb of nodes = 5151			
Nb of elements = 2500			
Nb of DOF = 4949			
Results :			
Location <i>x</i> (m)	Temperature <i>T</i> (°C)	Calculated value	Deviation (%)
0.00	100.0	100.0	0
0.01	84.0	84.0	0
0.02	68.0	68.0	0
0.03	52.0	52.0	0
0.04	36.0	36.0	0
0.05	20.0	20.0	0
Reference value of heat flux from face A to face B $\phi = 1200 \text{ W/m}^2$			
Calculated value $\phi = 1200 \text{ W/m}^2$			
Deviation (%) = 0			
Comments :			

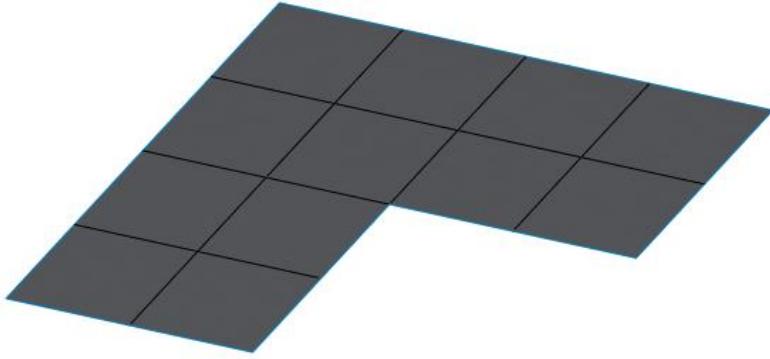
EVALUATION FORM																													
Software: SOLIDWORKS Simulation	Version: 2019 SP2																												
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																													
Test name: SIMPLE WALL : PRESCRIBED TEMPERATURES, CONVECTION Codification: TPLL 02-89																													
																													
Test performed by : Julien BOISSAT	Date: 4/3/2019																												
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : SHELL Number of degrees of freedom or mesh density : Nb of nodes = 5151 Nb of elements = 2500 Nb of DOF = 5050																													
Results : <table border="1"> <thead> <tr> <th>Location <i>x</i> (m)</th> <th>Temperature <i>T</i> (°C)</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr><td>0.00</td><td>73.33</td><td>73.33</td><td>0</td></tr> <tr><td>0.01</td><td>62.67</td><td>62.67</td><td>0</td></tr> <tr><td>0.02</td><td>52</td><td>52</td><td>0</td></tr> <tr><td>0.03</td><td>41.33</td><td>41.33</td><td>0</td></tr> <tr><td>0.04</td><td>30.67</td><td>30.67</td><td>0</td></tr> <tr><td>0.05</td><td>20</td><td>20</td><td>0</td></tr> </tbody> </table>		Location <i>x</i> (m)	Temperature <i>T</i> (°C)	Calculated value	Deviation (%)	0.00	73.33	73.33	0	0.01	62.67	62.67	0	0.02	52	52	0	0.03	41.33	41.33	0	0.04	30.67	30.67	0	0.05	20	20	0
Location <i>x</i> (m)	Temperature <i>T</i> (°C)	Calculated value	Deviation (%)																										
0.00	73.33	73.33	0																										
0.01	62.67	62.67	0																										
0.02	52	52	0																										
0.03	41.33	41.33	0																										
0.04	30.67	30.67	0																										
0.05	20	20	0																										
Reference value of heat flux from face A to face B $\varphi = 800 \text{ W/m}^2$ Calculated value $\varphi = 800 \text{ W/m}^2$ Deviation (%) = 0																													
Comments :																													

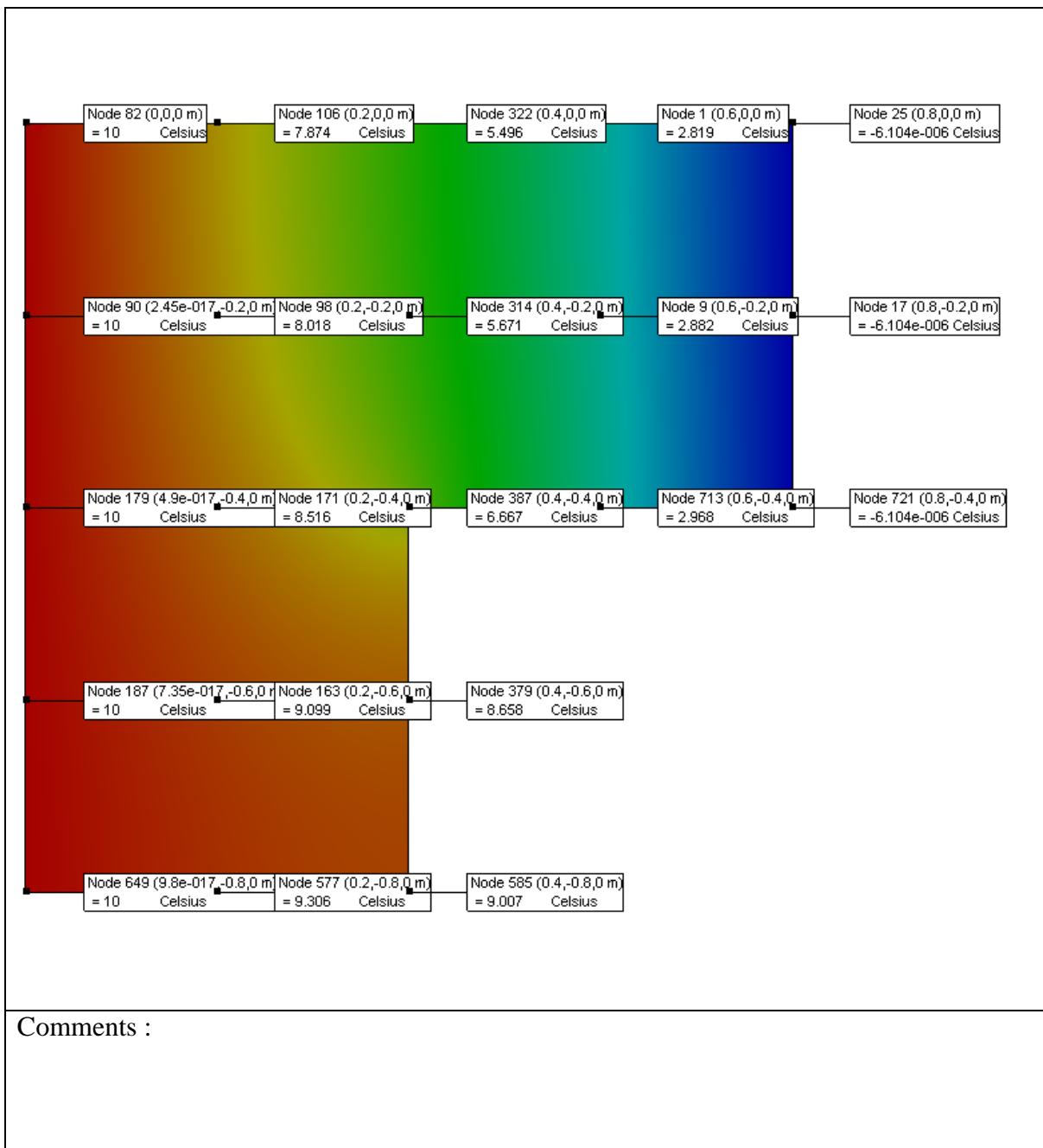
EVALUATION FORM																	
Software: SOLIDWORKS Simulation	Version: 2019 SP2																
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																	
Test name: SIMPLE WALL : CONVECTION Codification: TPLL 03-89																	
Test performed by : Julien BOISSAT	Date: 4/3/2019																
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : TRIANG Number of degrees of freedom or mesh density : Nb of nodes = 741 Nb of elements = 336 Nb of DOF = 741																	
Results :																	
<table border="1"> <thead> <tr> <th>Location</th> <th>Reference value</th> <th>Calculated value</th> <th>Deviation(%)</th> </tr> </thead> <tbody> <tr> <td><math>T_A</math> (°C)</td> <td>21.71</td> <td>21.71</td> <td>0</td> </tr> <tr> <td><math>T_B</math> (°C)</td> <td>416.57</td> <td>416.57</td> <td>0</td> </tr> <tr> <td><math>\varphi</math> (W/m<sup>2</sup>)</td> <td>834.2</td> <td>834.27</td> <td>0.01</td> </tr> </tbody> </table>		Location	Reference value	Calculated value	Deviation(%)	$T_A$ (°C)	21.71	21.71	0	$T_B$ (°C)	416.57	416.57	0	$\varphi$ (W/m <sup>2</sup> )	834.2	834.27	0.01
Location	Reference value	Calculated value	Deviation(%)														
$T_A$ (°C)	21.71	21.71	0														
$T_B$ (°C)	416.57	416.57	0														
$\varphi$ (W/m <sup>2</sup> )	834.2	834.27	0.01														
Comments :																	

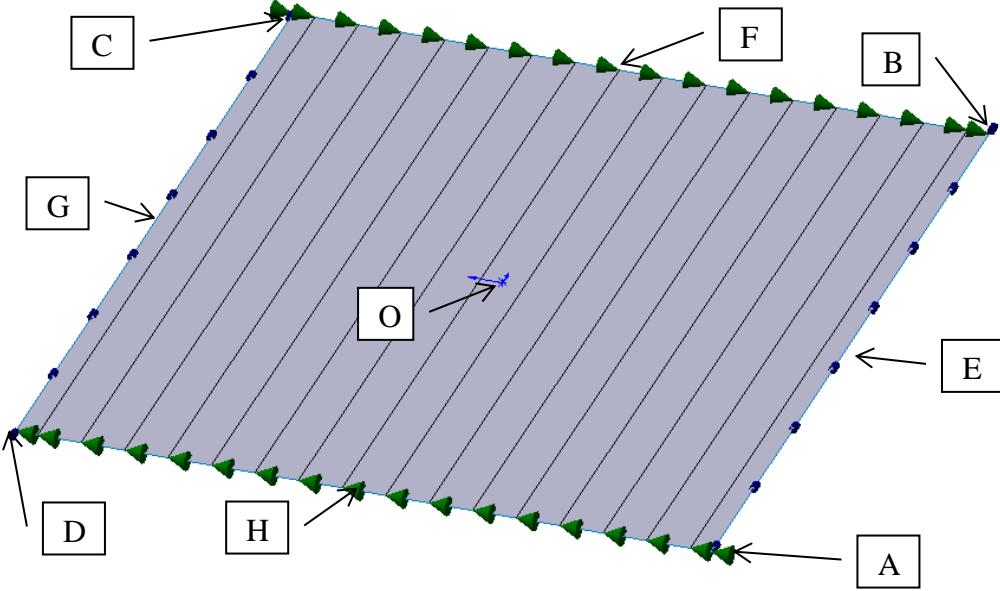
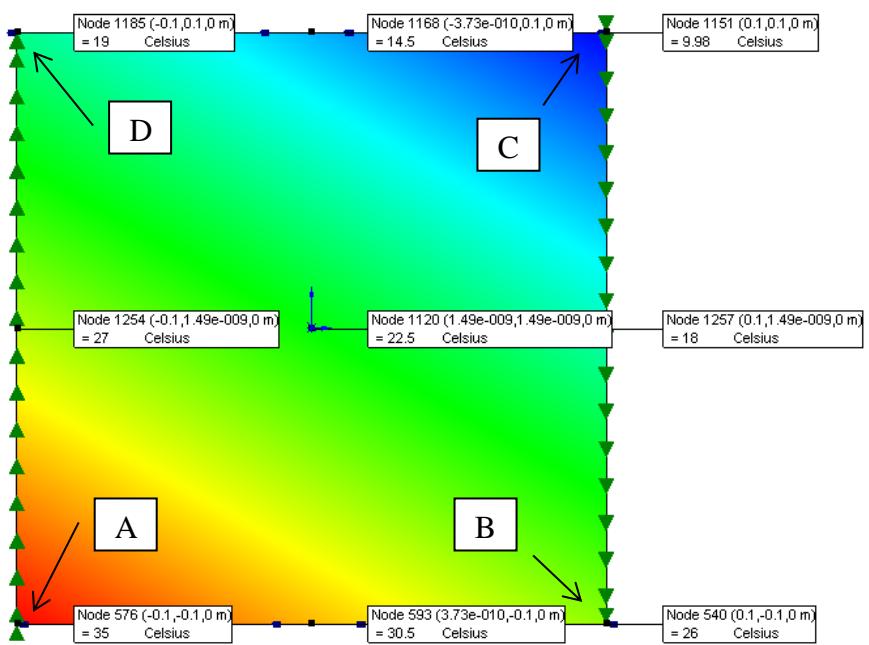
EVALUATION FORM																																			
Software: SOLIDWORKS Simulation		Version: 2019 SP2																																	
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																																			
Test name: POWER OUTPUT IN A BAR Codification: TPLL 04-89																																			
																																			
Test performed by : Julien BOISSAT		Date: 4/3/2019																																	
Model used																																			
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>																															
Element type : SHELL																																			
Number of degrees of freedom or mesh density :																																			
Nb of nodes = 4221																																			
Nb of elements = 2000																																			
Nb of DOF = 4179																																			
Results :																																			
<table border="1"> <thead> <tr> <th>Location <math>x</math> (m)</th> <th colspan="2">Reference value</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td>0.0</td> <td rowspan="3"><math>T</math> (°C)</td> <td>20.0</td> <td>20.0</td> <td>0</td> </tr> <tr> <td>0.2</td> <td>28.0</td> <td>28.0</td> <td>0</td> </tr> <tr> <td>0.5</td> <td>32.5</td> <td>32.5</td> <td>0</td> </tr> <tr> <td>0.0</td> <td rowspan="3"><math>\varphi</math> (W/m<sup>2</sup>)</td> <td>-50.0</td> <td>-50.0</td> <td>0</td> </tr> <tr> <td>0.2</td> <td>-30.0</td> <td>-30.0</td> <td>0</td> </tr> <tr> <td>0.5</td> <td>0.0</td> <td>0.0</td> <td>0</td> </tr> </tbody> </table>					Location $x$ (m)	Reference value		Calculated value	Deviation (%)	0.0	$T$ (°C)	20.0	20.0	0	0.2	28.0	28.0	0	0.5	32.5	32.5	0	0.0	$\varphi$ (W/m <sup>2</sup> )	-50.0	-50.0	0	0.2	-30.0	-30.0	0	0.5	0.0	0.0	0
Location $x$ (m)	Reference value		Calculated value	Deviation (%)																															
0.0	$T$ (°C)	20.0	20.0	0																															
0.2		28.0	28.0	0																															
0.5		32.5	32.5	0																															
0.0	$\varphi$ (W/m <sup>2</sup> )	-50.0	-50.0	0																															
0.2		-30.0	-30.0	0																															
0.5		0.0	0.0	0																															
Comments :																																			

EVALUATION FORM																					
Software: SOLIDWORKS Simulation	Version: 2019 SP2																				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000																					
Test name: TWO-MATERIAL WALL : CONVECTION																					
Codification: TPLL 05-89																					
																					
Test performed by : Julien BOISSAT	Date: 4/3/2019																				
Model used																					
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>																				
Other <input type="checkbox"/>																					
Element type : SHELL																					
Number of degrees of freedom or mesh density :																					
Nb of nodes	= 4617																				
Nb of elements	= 2240																				
Nb of DOF	= 4617																				
Results :																					
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;">Location</th> <th style="text-align: center; padding: 5px;">Reference value</th> <th style="text-align: center; padding: 5px;">Calculated value</th> <th style="text-align: center; padding: 5px;">Deviation(%)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px;"><math>T_A</math> (°C)</td> <td style="text-align: center; padding: 5px;">25</td> <td style="text-align: center; padding: 5px;">25</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>T_B</math> (°C)</td> <td style="text-align: center; padding: 5px;">85</td> <td style="text-align: center; padding: 5px;">85</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>T_C</math> (°C)</td> <td style="text-align: center; padding: 5px;">103</td> <td style="text-align: center; padding: 5px;">103</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>\varphi</math> (W/m<sup>2</sup>)</td> <td style="text-align: center; padding: 5px;">-900</td> <td style="text-align: center; padding: 5px;">-900</td> <td style="text-align: center; padding: 5px;">0</td> </tr> </tbody> </table>		Location	Reference value	Calculated value	Deviation(%)	$T_A$ (°C)	25	25	0	$T_B$ (°C)	85	85	0	$T_C$ (°C)	103	103	0	$\varphi$ (W/m <sup>2</sup> )	-900	-900	0
Location	Reference value	Calculated value	Deviation(%)																		
$T_A$ (°C)	25	25	0																		
$T_B$ (°C)	85	85	0																		
$T_C$ (°C)	103	103	0																		
$\varphi$ (W/m <sup>2</sup> )	-900	-900	0																		
Comments :																					

EVALUATION FORM																									
Software: SOLIDWORKS Simulation	Version: 2019 SP2																								
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																									
Test name: TWO-MATERIAL WALL : CONVECTION, THERMAL CONTACT RESISTANCE Codification: TPLL 06-89																									
																									
Test performed by : Julien BOISSAT	Date: 4/3/2019																								
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : TETRA10 Number of degrees of freedom or mesh density : Nb of nodes = 11633 Nb of elements = 6971 Nb of DOF = 11633																									
Results : <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;">Location</th> <th style="text-align: center; padding: 5px;">Reference value</th> <th style="text-align: center; padding: 5px;">Calculated value</th> <th style="text-align: center; padding: 5px;">Deviation (%)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; padding: 5px;"><math>T_A</math> (°C)</td> <td style="text-align: center; padding: 5px;">25</td> <td style="text-align: center; padding: 5px;">25</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>T_{B^1}</math> (°C)</td> <td style="text-align: center; padding: 5px;">85</td> <td style="text-align: center; padding: 5px;">85</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>T_{B^2}</math> (°C)</td> <td style="text-align: center; padding: 5px;">118.75</td> <td style="text-align: center; padding: 5px;">118.75</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>T_C</math> (°C)</td> <td style="text-align: center; padding: 5px;">136.75</td> <td style="text-align: center; padding: 5px;">136.75</td> <td style="text-align: center; padding: 5px;">0</td> </tr> <tr> <td style="text-align: center; padding: 5px;"><math>\varphi</math> (W/m²)</td> <td style="text-align: center; padding: 5px;">-900</td> <td style="text-align: center; padding: 5px;">-900</td> <td style="text-align: center; padding: 5px;">0</td> </tr> </tbody> </table>		Location	Reference value	Calculated value	Deviation (%)	$T_A$ (°C)	25	25	0	$T_{B^1}$ (°C)	85	85	0	$T_{B^2}$ (°C)	118.75	118.75	0	$T_C$ (°C)	136.75	136.75	0	$\varphi$ (W/m²)	-900	-900	0
Location	Reference value	Calculated value	Deviation (%)																						
$T_A$ (°C)	25	25	0																						
$T_{B^1}$ (°C)	85	85	0																						
$T_{B^2}$ (°C)	118.75	118.75	0																						
$T_C$ (°C)	136.75	136.75	0																						
$\varphi$ (W/m²)	-900	-900	0																						
Comments :																									

EVALUATION FORM		
Software: SOLIDWORKS Simulation	Version: 2019 SP2	
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.		
Test name: L SHAPED PLATE WITH GEOMETRIC SINGULARITY		
Codification: TPLP 01-89		
		
Test performed by : Julien BOISSAT	Date: 4/3/2019	
Model used		
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>	Other <input type="checkbox"/>
Element type : SHELL 6		
Number of degrees of freedom or mesh density :		
Nb of nodes	= 3201	
Nb of elements	= 1536	
Nb of DOF	= 3103	
Results :		
Reference value $T$ ( $^{\circ}$ C)	Calculated value $T$ ( $^{\circ}$ C)	Deviation (%)
10	10	0
10	10	0
10	10	0
10	10	0
10	10	0
7.869	7.874	-0.06
8.018	8.018	0
8.514	8.516	-0.02
9.001	9.099	-1.09
9.316	9.306	0.11
5.495	5.496	-0.02
5.680	5.671	0.16
6.667	6.667	0
8.640	8.658	-0.21
9.009	9.007	0.02
2.816	2.819	-0.11
2.881	2.882	-0.03
2.972	2.968	0.13
0	0	0
0	0	0
0	0	0

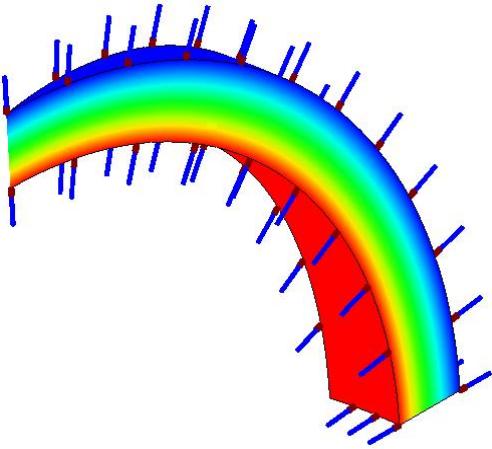


EVALUATION FORM	
Software: SOLIDWORKS Simulation	Version: 2019 SP2
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.	
Test name: ORTHOTROPIC SQUARE	
Codification: TPLP 02-89	
	
Test performed by : Julien BOISSAT	Date: 4/3/2019
Model used	
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>
Other <input type="checkbox"/>	
Element type : SHELL 6	
Number of degrees of freedom or mesh density :	
Nb of nodes	= 4575
Nb of elements	= 2206
Nb of DOF	= 4575
Results :	
	

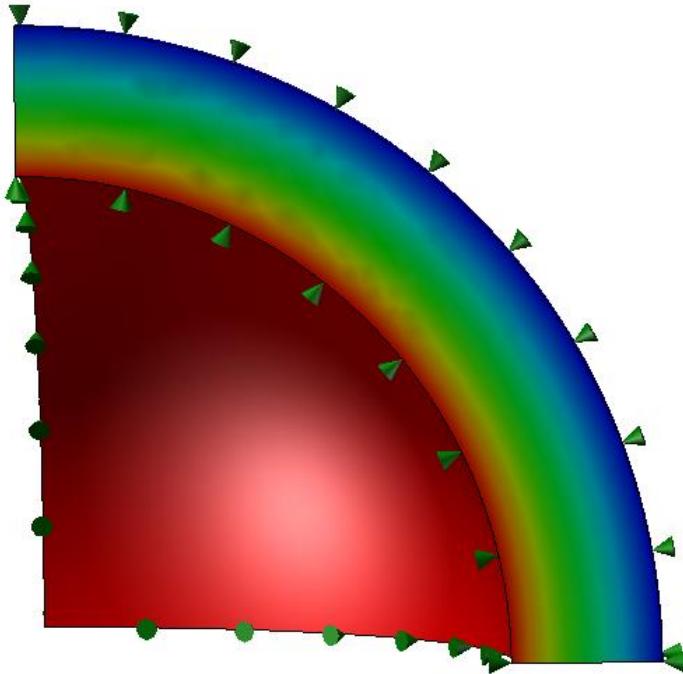
<b>Point</b>	<b>Reference value <math>T</math> (°C)</b>	<b>Calculated value <math>T</math> (°C)</b>	<b>Deviation (%)</b>
O	22.5	22.5	0
A	35.0	35.0	0
B	26.0	26.0	0
C	10.0	9.98	0.2
D	19.0	19.0	0
E	30.5	30.5	0
F	18.0	18.0	0
G	14.5	14.5	0
H	27.0	27.0	0
$\varphi_x$ (W/m <sup>2</sup> )	45.0	45.0	0
$\varphi_y$ (W/m <sup>2</sup> )	60.0	60.0	0

## Comments :

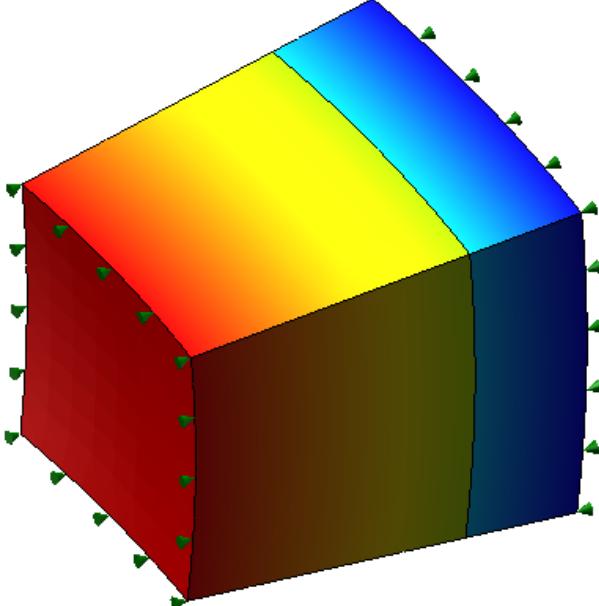
In order to apply the convection boundary condition, the edges in short were split in many shorter edged. The convection boundary condition was then applied separately to each one.

EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 B3				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: HOLLOW SPHERE: PRESCRIBED TEMPERATURES						
Codification: TPLV 01-89						
						
Test performed by : Julien BOISSAT		Date: 4/3/2019				
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : TETRA 10 and TRIANG						
Number of degrees of freedom or mesh density :						
TETRA10			TRIANG			
Nb of nodes	= 7478		Nb of nodes	= 770		
Nb of elements	= 4445		Nb of elements	= 345		
Nb of DOF	= 6235		Nb of DOF	= 630		
Results :						
TETRA 10						
$r$ (m)	Reference value		Calculated value		Deviation (%)	
	$T$ (°C)	$\phi$ (W/m <sup>2</sup> )	$T$ (°C)	$\phi$ (W/m <sup>2</sup> )		
0.3	100.00	1866.67	100.00	1866.77	0	0.01
0.31	81.94	1748.18	81.94	1748.07	0	0.01
0.32	65.00	1640.63	65.00	1640.72	0	0.01
0.33	49.09	1542.70	49.09	1542.79	0	0.01
0.34	34.12	1453.29	34.12	1453.15	0	0.01
0.35	20.00	1371.43	20.00	1370.8	0	0.05
TRIANG						
$r$ (m)	Reference value		Calculated value		Deviation (%)	
	$T$ (°C)	$\phi$ (W/m <sup>2</sup> )	$T$ (°C)	$\phi$ (W/m <sup>2</sup> )		
0.3	100.00	1866.67	100.00	1867.46	0	0.04
0.31	81.94	1748.18	81.94	1748.21	0	0
0.32	65.00	1640.63	65.00	1640.67	0	0
0.33	49.09	1542.70	49.09	1542.74	0	0
0.34	34.12	1453.29	34.12	1453.34	0	0
0.35	20.00	1371.43	20.00	1370.63	0	0.06
Comments :						

EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: HOLLOW SPHERE: PRESCRIBED TEMPERATURES, CONVECTION						
Codification: TPLV 02-89						
Test performed by : Julien BOISSAT		Date: 4/3/2019				
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : TETRA 10						
Number of degrees of freedom or mesh density :						
Nb of nodes = 7472						
Nb of elements = 4441						
Nb of DOF = 6765						
Results :						
$r$ (m)	Reference value		Calculated value		Deviation (%)	
	$T$ (°C)	$\phi$ (W/m <sup>2</sup> )	$T$ (°C)	$\phi$ (W/m <sup>2</sup> )		
0.3	65.00	1050	65.00	1050.08	0	0.01
0.31	54.84	983.35	54.84	983.26	0	0.01
0.32	45.31	922.85	45.31	922.86	0	0
0.33	36.36	867.77	36.36	867.75	0	0
0.34	27.94	817.47	27.94	817.45	0	0
0.35	20.00	771.43	20.00	771.31	0	0.02
Comments :						

EVALUATION FORM					
Software: SOLIDWORKS Simulation		Version: 2019 SP2			
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.					
Test name: HOLLOW SPHERE: CONVECTION					
Codification: TPLV 03-89					
					
Test performed by : Julien BOISSAT		Date: 4/3/2019			
Model used					
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>	
Element type : TETRA 10 and TRIANG					
Number of degrees of freedom or mesh density :					
Solid elements			Axisymmetric shell elements		
Nb of nodes	= 11372		Nb of nodes	= 2697	
Nb of elements	= 7252		Nb of elements	= 1276	
Nb of DOF	= 11372		Nb of DOF	= 2697	
Results :					
Physical quantity	Reference value	Calculated value		Deviation (%)	
		Solid	Shell	Solid	Shell
		$T_i$ (°C)	250.28	250.28	250.27
$T_e$ (°C)	184.34	184.34	184.34	0	0
$\varphi_i$ (W/m <sup>2</sup> )	37458.77	37421.75	37448.18	0.10	0.03
$\varphi_e$ (W/m <sup>2</sup> )	21939.36	21923.73	21935.36	0.07	0.02
$\Phi$ (W)	42364.87	42364.8	42364	0	0
Comments :					

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: TWO-MATERIAL HOLLOW SPHERE : CONVECTION			
Codification: TPLV 04-89			
Test performed by : Julien BOISSAT	Date: 4/3/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : TETRA 10			
Number of degrees of freedom or mesh density :			
Nb of nodes = 8923			
Nb of elements = 5498			
Nb of DOF = 8923			
Results :			
Physical quantity	Reference value	Calculated value	Deviation (%)
$T_i$ (°C)	25.06	25.06	0
$T_m$ (°C)	17.84	17.84	0
$T_e$ (°C)	13.16	13.16	0
$\varphi_i$ (W/m <sup>2</sup> )	6740.53	6729.3	-0.17
$\varphi_m$ (W/m <sup>2</sup> )	4952.23	4948.2	-0.08
$\varphi_e$ (W/m <sup>2</sup> )	4431.32	4430.9	-0.01
$\Phi$ (W)	7623.36	7623.36	0
Comments :			

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: TWO-MATERIAL HOLLOW SPHERE: CONVECTION, THERMAL CONTACT RESISTANCE			
Codification: TPLV 05-89			
			
Test performed by : Julien BOISSAT	Date: 4/3/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : TETRA 4			
Number of degrees of freedom or mesh density :			
Nb of nodes = 10982			
Nb of elements = 6973			
Nb of DOF = 10982			
Results :			
Physical quantity	Reference value	Calculated value	Deviation (%)
$T_i$ (°C)	25.02	25.02	0
$T_m^1$ (°C)	17.79	17.79	0
$T_m^2$ (°C)	7.87	7.87	0
$T_e$ (°C)	3.18	3.18	0
$\varphi_i$ (W/m <sup>2</sup> )	6747.33	6746.8	0.01
$\varphi_m$ (W/m <sup>2</sup> )	4957.22	4956.9	0.01
$\varphi_e$ (W/m <sup>2</sup> )	4435.79	4435.5	0.01
$\Phi$ (W)	7631.04	7630.45	0
Comments :			

EVALUATION FORM						
Software: SOLIDWORKS Simulation	Version: 2019 B3					
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: POWER OUTPUT IN A HOLLOW SPHERE						
Codification: TPLV 06-89						
Test performed by : Julien BOISSAT			Date: 4/3/2019			
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : TETRA 10						
Number of degrees of freedom or mesh density :						
Nb of nodes = 11231 Nb of elements = 7431 Nb of DOF = 9817						
Results :						
$r$ (m)	Reference value		Calculated value		Deviation (%)	
	$T$ (°C)	$\Phi$ (W)	$T$ (°C)	$\Phi$ (W)		
1.0	20.00	-837.8	20.00	-837.8	0	0
1.2	29.33	-532.8	29.33	-532.8	0	0
1.5	32.50	157.1	32.50	157.1	0	0
Comments :						

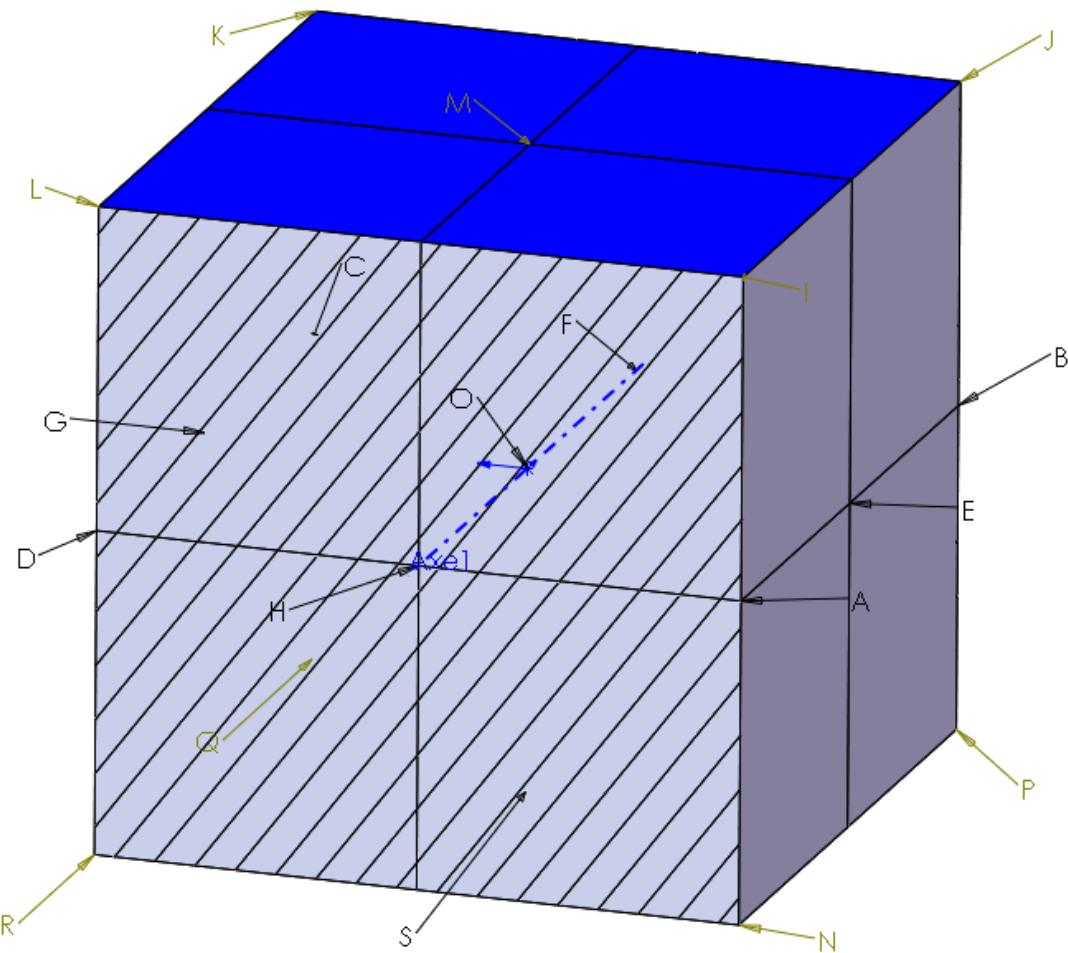
## EVALUATION FORM

Software: SOLIDWORKS Simulation Version: 2019 SP2

Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.

Test name: ORTHOTROPIC CUBE

Codification: TPLV 07-89



Test performed by : Julien BOISSAT Date: 4/4/2019

Model used

Finite elements Boundary elements Other 

Element type : TETRA 10

Number of degrees of freedom or mesh density :

Nb of nodes = 67289

Nb of elements = 46596

Nb of DOF = 67289

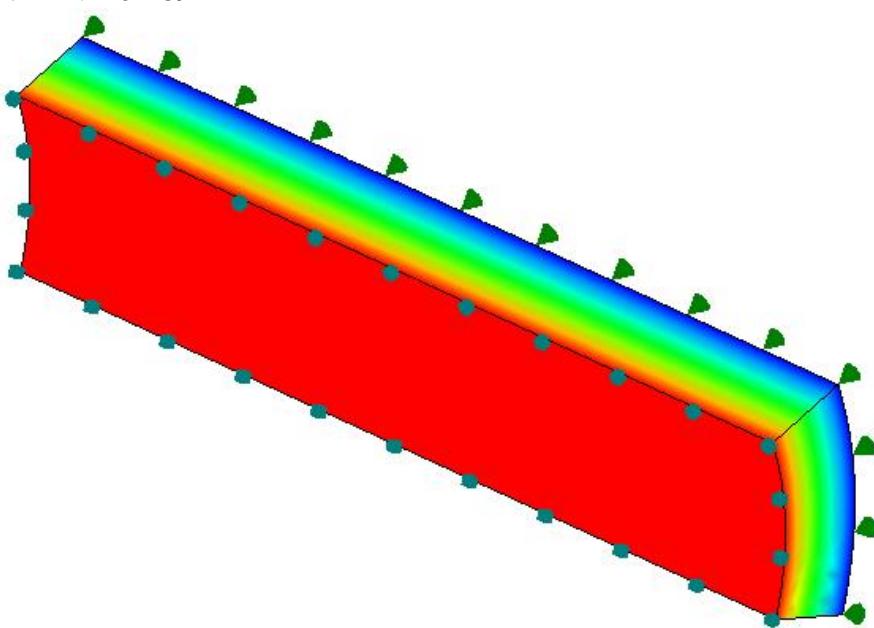
Results :

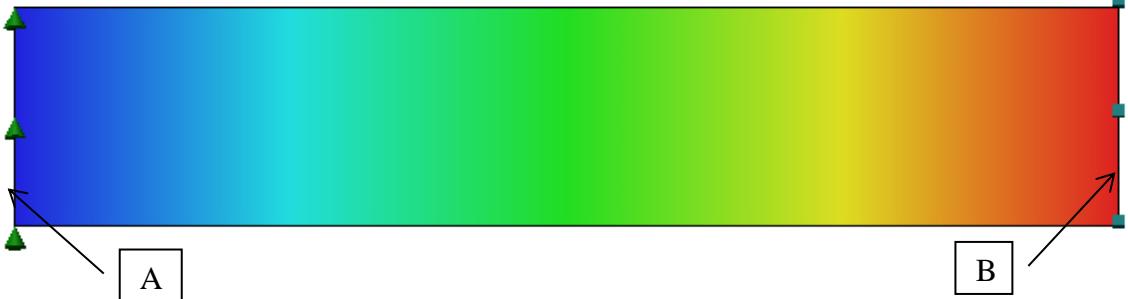
Point	Reference value $T$ (°C)	Calculated value $T$ (°C)	Deviation (%)
O	22.5	22.5	0
A	35.0	35.0	0
B	26.0	26.0	0
C	10.0	10.0	0
D	19.0	19.0	0
E	30.5	30.5	0
F	18.0	18.0	0
G	14.5	14.5	0
H	27.0	27.0	0
I	29.0	29.0	0
J	20.0	20.0	0
K	4.0	4.0	0
L	13.0	13.0	0
M	16.5	16.5	0
N	41.0	41.0	0
P	32.0	32.0	0
Q	16.0	16.0	0
R	25.0	25.0	0
S	28.5	28.5	0
$\varphi_x$ (W/m <sup>2</sup> )	45.0 = Cte	45.0	0
$\varphi_y$ (W/m <sup>2</sup> )	60.0 = Cte	60.0	0
$\varphi_z$ (W/m <sup>2</sup> )	30.0 = Cte	30.0	0

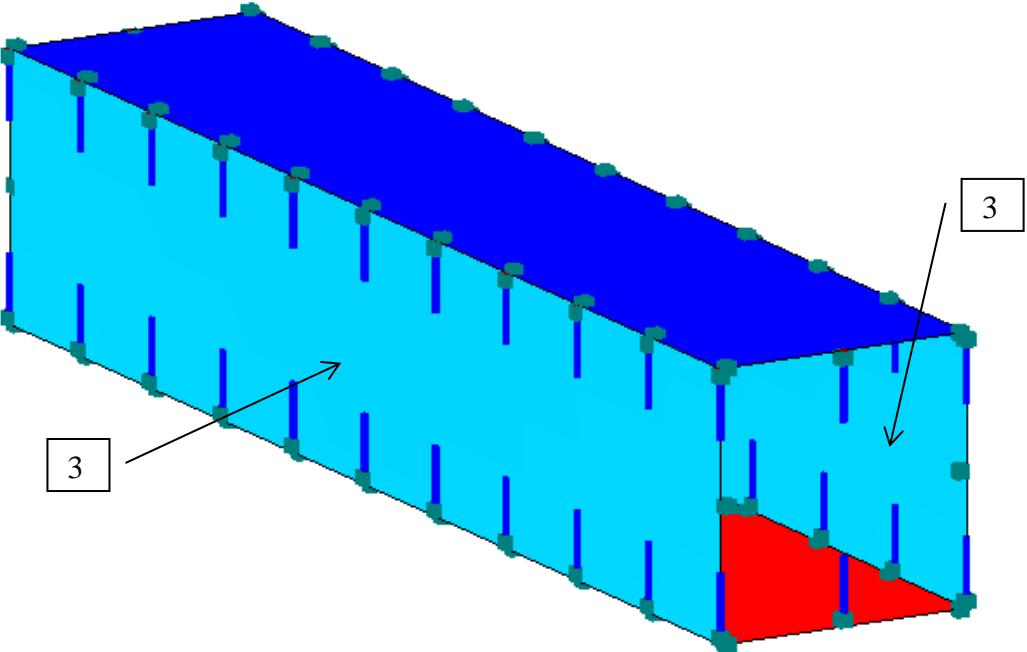
Comments :

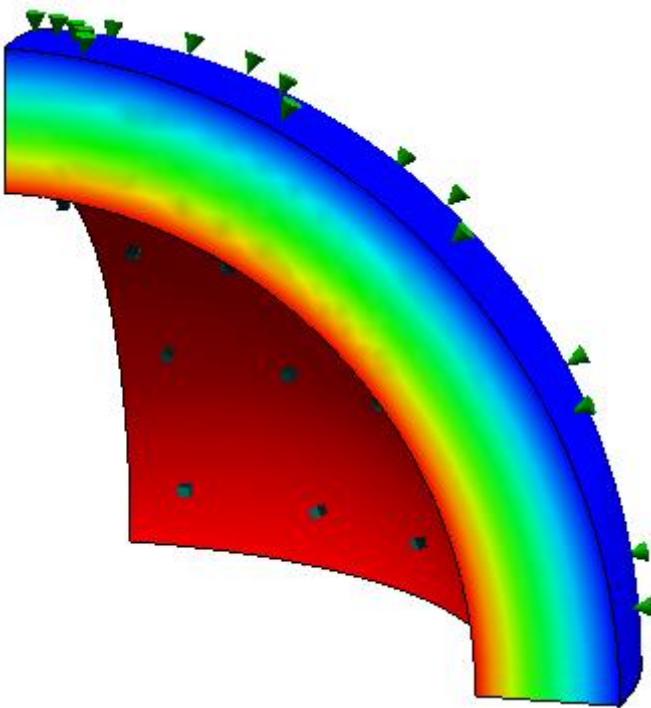
In order to satisfy the boundary conditions, we had to split the faces and apply the convection separately to each small face because the software does not allow ambient temperature variation for convection as a boundary condition.

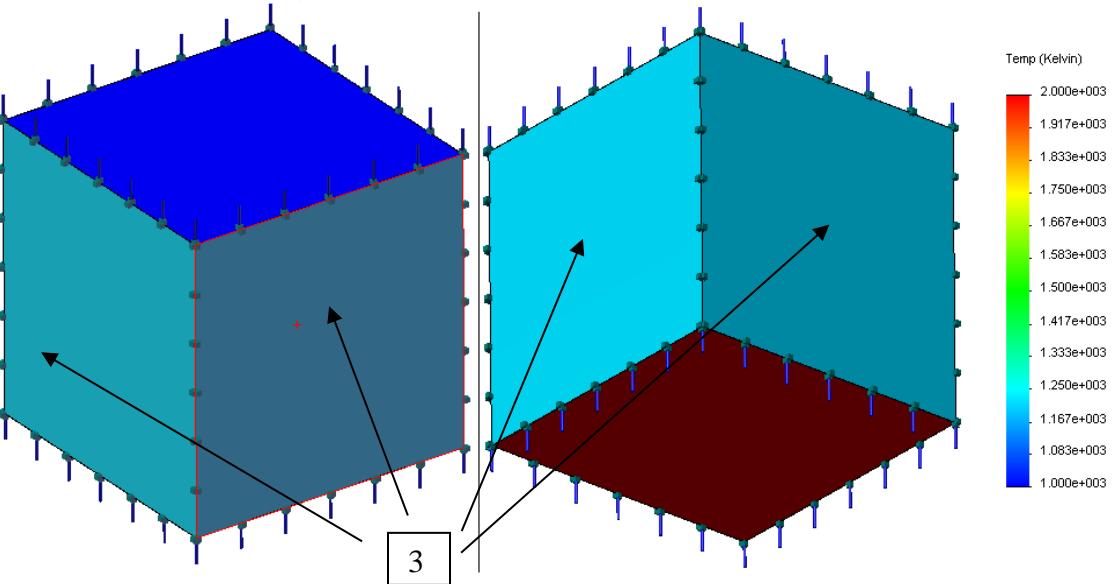
## 2. Non linear steady state thermal

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: PIPE : CONVECTION, RADIATION			
Codification: TPNA 01-89			
			
Test performed by : Julien BOISSAT	Date: 4/4/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : TETRA 10			
Number of degrees of freedom or mesh density :			
Nb of nodes = 8413			
Nb of elements = 5164			
Nb of DOF = 8413			
Results :			
Physical quantity	Reference value	Calculated value	Deviation (%)
$T_i$ (°C)	105.55	104.7	-0.81
$T_e$ (°C)	82.56	81.93	-0.76
$\varphi_i$ (W/m <sup>2</sup> )	-11577.49	-11455.2	-1.06
$\varphi_e$ (W/m <sup>2</sup> )	-8822.98	-8790.55	-0.37
$\Phi$ (W)	21807.15	21605	-0.93
Comments :			
The negative reference values for $\varphi_i$ and $\varphi_e$ indicate that their direction corresponds to the negative radial direction. Hence reporting values opposite to those given by the software for the radial direction.			

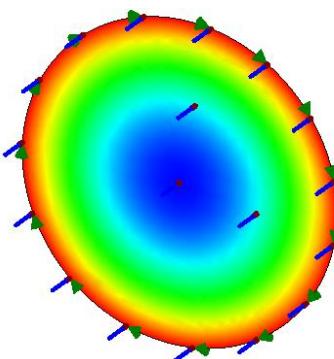
EVALUATION FORM																	
Software: SOLIDWORKS Simulation	Version: 2019 SP2																
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.																	
Test name: SIMPLE WALL : CONVECTION, RADIATION Codification: TPNL 01-89																	
																	
Test performed by : Julien BOISSAT	Date: 4/4/2019																
Model used Finite elements <input checked="" type="checkbox"/> Boundary elements <input type="checkbox"/> Other <input type="checkbox"/> Element type : SHELL Number of degrees of freedom or mesh density : Nb of nodes = 4515 Nb of elements = 2168 Nb of DOF = 4515																	
Results :																	
<table border="1"> <thead> <tr> <th>Location</th> <th>Reference value</th> <th>Calculated value</th> <th>Deviation (%)</th> </tr> </thead> <tbody> <tr> <td><math>T_A</math> (°C)</td> <td>28.56</td> <td>28.55</td> <td>0.04</td> </tr> <tr> <td><math>T_B</math> (°C)</td> <td>488.27</td> <td>488.15</td> <td>0.02</td> </tr> <tr> <td><math>\varphi</math> (W/m<sup>2</sup>)</td> <td>971.20</td> <td>971.05</td> <td>0.02</td> </tr> </tbody> </table>		Location	Reference value	Calculated value	Deviation (%)	$T_A$ (°C)	28.56	28.55	0.04	$T_B$ (°C)	488.27	488.15	0.02	$\varphi$ (W/m <sup>2</sup> )	971.20	971.05	0.02
Location	Reference value	Calculated value	Deviation (%)														
$T_A$ (°C)	28.56	28.55	0.04														
$T_B$ (°C)	488.27	488.15	0.02														
$\varphi$ (W/m <sup>2</sup> )	971.20	971.05	0.02														
Comments :																	

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 B3		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: RADIATION IN A SQUARE CAVITY			
Codification: TPNP 01-89			
			
Test performed by : Julien BOISSAT	Date: 4/4/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : SHELL			
Number of degrees of freedom or mesh density :			
Nb of nodes	= 608		
Nb of elements	= 968		
Nb of DOF	= 1272		
Results :			
Location	Reference value $T$ (K)	Calculated value	Deviation (%)
Lateral face (3)	1192	1208.5	1.38
Comments :			

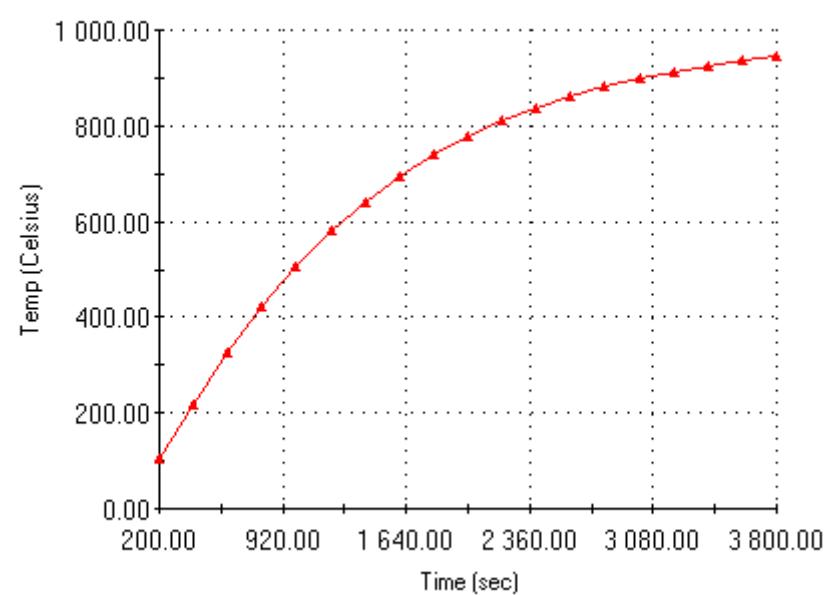
EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: HOLLOW SPHERE: CONVECTION, RADIATION			
Codification: TPNV 01-89			
			
Test performed by : Julien BOISSAT	Date: 4/4/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : TETRA10			
Number of degrees of freedom or mesh density :			
Nb of nodes	= 11421		
Nb of elements	= 7298		
Nb of DOF	= 11421		
Results :			
Physical quantity	Reference value	Calculated value	Deviation (%)
$T_i$ (°C)	91.74	91.04	-0.76
$T_e$ (°C)	71.13	70.70	-0.60
$\varphi_i$ (W/m <sup>2</sup> )	11666.60	11545	-1.04
$\varphi_e$ (W/m <sup>2</sup> )	6825.85 <sup>(1)</sup>	6763.6	-0.91
$\Phi$ (W)	13194.61	13069.6	-0.95
Comments :			
<sup>(1)</sup> Typo in the validation guide. Reference value $\varphi_e$ was checked with the formula $\varphi_e = h_e (T_e - T_{e^e})$			

EVALUATION FORM									
Software: SOLIDWORKS Simulation	Version: 2019 SP2								
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.									
Test name: RADIATION IN A CUBIC CAVITY									
Codification: TPNV 02-89									
									
Test performed by : Julien BOISSAT	Date: 4/4/2019								
Model used									
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>								
Other <input type="checkbox"/>									
Element type : SHELL 6									
Number of degrees of freedom or mesh density :									
Nb of nodes = 586									
Nb of elements = 252									
Nb of DOF = 628									
Results :									
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; padding: 5px;"><b>Location</b></th> <th style="text-align: center; padding: 5px;"><b>Reference value <i>T</i> (K)</b></th> <th style="text-align: center; padding: 5px;"><b>Calculated value <i>T</i> (K)</b></th> <th style="text-align: center; padding: 5px;"><b>Deviation (%)</b></th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;">Face (3) lateral</td> <td style="padding: 5px; text-align: center;">1223.4</td> <td style="padding: 5px; text-align: center;">1223.3</td> <td style="padding: 5px; text-align: center;">-0.008</td> </tr> </tbody> </table>		<b>Location</b>	<b>Reference value <i>T</i> (K)</b>	<b>Calculated value <i>T</i> (K)</b>	<b>Deviation (%)</b>	Face (3) lateral	1223.4	1223.3	-0.008
<b>Location</b>	<b>Reference value <i>T</i> (K)</b>	<b>Calculated value <i>T</i> (K)</b>	<b>Deviation (%)</b>						
Face (3) lateral	1223.4	1223.3	-0.008						
Comments :									

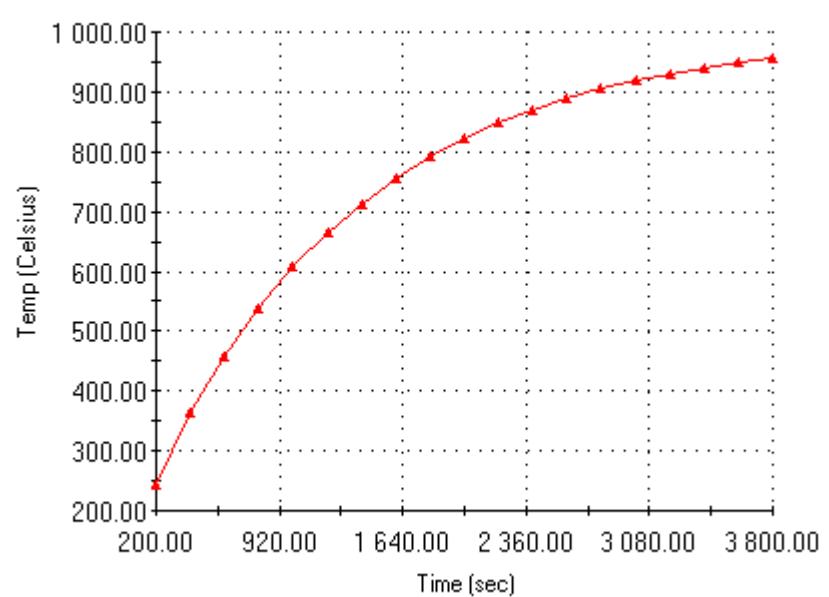
### 3. Transient linear THERMAL

EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: CYLINDER : HEAT TRANSFER BY CONVECTION						
Codification: TTLA 01-89						
						
Test performed by : Julien BOISSAT			Date: 4/4/2019			
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : SHELL						
Number of degrees of freedom or mesh density :						
Nb of nodes = 1325						
Nb of elements = 630						
Nb of DOF = 1325						
Results :						
Time (s)	Reference values $T$ (°C)		Calculated value $T$ (°C)		Deviation (%)	
	Outer face	At center	Outer face	At center		
600	461	314	459	326	0.35	3.96
800	550	412	539	424	1.97	2.91
1000	637	510	607	508	4.73	0.36
1200	686	588	665	580	3.13	1.32
1400	735	657	714	642	2.89	2.32
1600	774	706	756	694	2.36	1.66
1800	813	755	792	739	2.64	2.10
2200	873	828	848	810	2.84	2.17
2600	910	880	889	862	2.25	2.08
3000	936	917	920	899	1.76	1.93
3400	951	941	941	927	1.01	1.52
3800	970	959	957	947	1.30	1.29

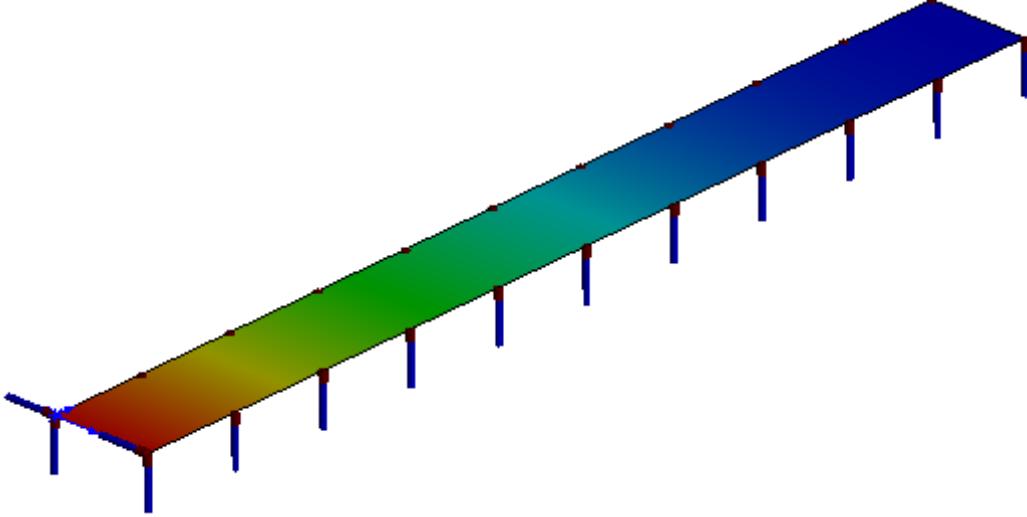
Temperature at center  
**Transient Sensor Graph**



Temperature on outer face  
**Transient Sensor Graph**

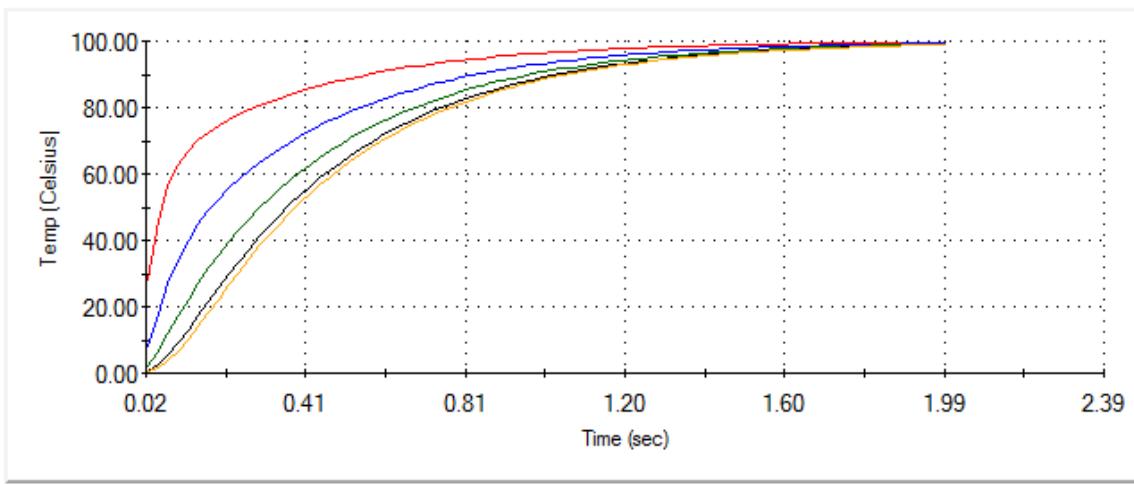


Comments :

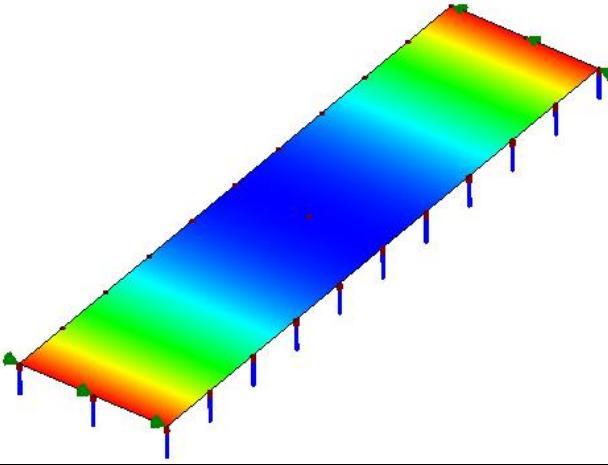
EVALUATION FORM									
Software: SOLIDWORKS Simulation					Version: 2019 SP2				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.									
Test name: WALL UNDER THERMAL SHOCK									
Codification: TTLL 01-89									
									
Test performed by : Julien BOISSAT					Date: 4/4/2019				
Model used									
Finite elements <input checked="" type="checkbox"/>			Boundary elements <input type="checkbox"/>			Other <input type="checkbox"/>			
Element type : SHELL									
Number of degrees of freedom or mesh density :									
Nb of nodes = 1111									
Nb of elements = 500									
Nb of DOF = 1100									
Results :									
<b><math>T(x,t)</math> <math>n=45</math></b>	<b>Reference values</b>			<b>Calculated values</b>			<b>Deviation (%)</b>		
	<b><math>x</math> (m)</b>			<b><math>x</math> (m)</b>			<b><math>x</math> (m)</b>		
$t$ (s)	0.2	0.4	0.6	62.49	34.27	17.26	4.56	7.74	4.88
0.1	62.49	34.27	17.26	74.61	52.46	35.82	1.29	2.57	3.09
0.2	74.61	52.46	35.82	80.64	63.31	49.71	0.67	1.47	2.24
0.3	80.64	63.31	49.71	84.87	71.25	60.46	0.54	1.19	1.87
0.4	84.87	71.25	60.46	88.11	77.39	68.88	0.48	1.05	1.59
0.5	88.11	77.39	68.88	90.65	82.21	75.51	0.44	0.92	1.37
0.6	90.65	82.21	75.51	92.64	86.00	80.73	0.40	0.80	1.18
0.7	92.64	86.00	80.73	94.21	88.98	84.83	0.34	0.69	1.00
0.8	94.21	88.98	84.83	95.44	91.33	88.06	0.30	0.60	0.86
0.9	95.44	91.33	88.06	96.41	93.17	90.60	0.26	0.51	0.72
1	96.41	93.17	90.60	97.78	95.77	94.18	0.19	0.37	0.52
1.2	97.78	95.77	94.18	98.62	97.38	96.39	0.14	0.26	0.36

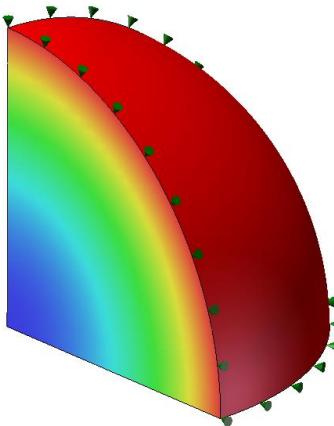
1.4	98.62	97.38	96.39	98.62	97.38	96.39	0.14	0.26	0.36	
1.6	99.15	98.38	97.77	99.15	98.38	97.77	0.09	0.19	0.25	
1.8	99.47	98.99	98.62	99.47	98.99	98.62	0.07	0.13	0.18	
2	99.67	99.38	99.14	99.67	99.38	99.14	0.05	0.08	0.12	

$T(x,t)$ $n=45$	Reference values		Calculated values		Deviation (%)	
	$x$ (m)		$x$ (m)		$x$ (m)	
$t$ (s)	0.8	1	0.8	1	0.8	1
0.1	8.09	5.07	8.92	6.49	10.30	28.06
0.2	26.37	22.77	25.71	22.35	2.49	1.84
0.3	42.27	39.32	41.08	38.13	2.81	3.03
0.4	54.87	52.55	53.55	51.17	2.41	2.62
0.5	64.74	62.92	63.43	61.55	2.03	2.18
0.6	72.45	71.03	71.21	69.73	1.71	1.83
0.7	78.47	77.36	77.34	76.18	1.44	1.53
0.8	83.18	82.31	82.17	81.25	1.22	1.29
0.9	86.86	86.18	85.96	85.24	1.03	1.09
1	89.73	89.20	88.95	88.38	0.87	0.92
1.2	93.73	93.41	93.16	92.80	0.61	0.65
1.4	96.17	95.98	95.76	95.54	0.43	0.46
1.6	97.66	97.54	97.37	97.24	0.29	0.31
1.8	98.57	98.50	98.37	98.29	0.20	0.21
2	99.13	99.08	98.99	98.94	0.14	0.14



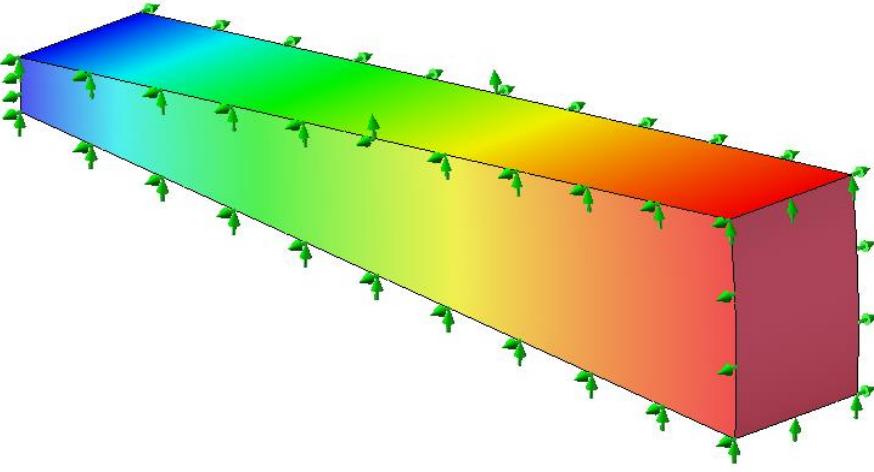
Comments :

EVALUATION FORM						
Software: SOLIDWORKS Simulation		Version: 2019 B1				
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.						
Test name: PLATE : HEAT TRANSFER BY CONVECTION						
Codification: TTLL 02-89						
						
Test performed by : Julien BOISSAT			Date: 4/4/2019			
Model used						
Finite elements <input checked="" type="checkbox"/>		Boundary elements <input type="checkbox"/>		Other <input type="checkbox"/>		
Element type : SHELL						
Number of degrees of freedom or mesh density :						
Nb of nodes = 10251						
Nb of elements = 5000						
Nb of DOF = 10251						
Results :						
Time (s)	Reference temperatures(°C)		Calculated temperatures(°C)		Deviations (%)	
	On surface	At center	On surface	At center		
800	412	264	394	245	4.45	7.33
1000	461	314	441	303	4.30	3.34
1500	559	451	544	432	2.68	4.31
2000	647	550	628	536	2.95	2.52
2500	711	637	696	621	2.06	2.44
3000	764	710	752	691	1.54	2.66
3500	814	765	798	748	1.99	2.23
4000	848	813	835	794	1.53	2.30
5000	902	877	890	863	1.32	1.59
6000	936	920	927	909	0.98	1.22
7000	958	948	951	939	0.70	0.92
8000	972	966	968	960	0.46	0.67
Comments:						

EVALUATION FORM										
Software: SOLIDWORKS Simulation					Version: 2019 SP2					
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.										
Test name: SPHERE : HEAT TRANSFER BY CONVECTION										
Codification: TTLV 01-89										
										
Test performed by : Julien BOISSAT					Date: 4/4/2019					
Model used										
Finite elements <input checked="" type="checkbox"/>					Boundary elements <input type="checkbox"/>			Other <input type="checkbox"/>		
Element type : TETRA 10 and SHELLAX										
Number of degrees of freedom or mesh density :										
TETRA 10					SHELLAX					
Nb of nodes = 23554			Nb of nodes = 1341							
Nb of elements = 16004			Nb of elements = 634							
Nb of DOF = 23554			Nb of DOF = 1341							
Results :										
Time (s)	Reference temperature $T$ (°C)		Calculated value $T$ (°C)				Deviations (%)			
	On surface	At center	On surface		At center		On surface		At center	
			3D	2D	3D	2D	3D	2D	3D	2D
400	461	334	458	458	323	323	0.65	0.66	3.41	3.42
600	608	500	577	577	470	470	5.07	5.07	6.05	6.06
800	696	618	670	670	586	586	3.74	3.75	5.19	5.20
1000	774	706	742	742	677	677	4.09	4.10	4.15	4.16
1200	828	774	799	799	748	748	3.52	3.53	3.41	3.42
1400	868	828	843	843	803	803	2.88	2.89	3.02	3.03
1600	902	872	877	877	846	846	2.73	2.73	2.96	2.97
1800	923	902	904	904	880	880	2.02	2.03	2.45	2.45
2000	942	923	925	925	906	906	1.77	1.78	1.81	1.82
2200	956	942	942	942	927	927	1.50	1.50	1.61	1.62
2400	962	956	954	954	943	943	0.78	0.79	1.37	1.38
Comments :										

### **III. THERMOMECHANICS**

#### 4. Linear static

EVALUATION FORM			
Software: SOLIDWORKS Simulation	Version: 2019 SP2		
Computer configuration used: Lenovo ThinkStation S20, Windows 7 x64, Intel Xeon W3565, 12Gb RAM, graphics card NVIDIA Quadro 2000.			
Test name: THICK PIPE SUBMITTED TO A THERMAL GRADIENT			
Codification: HSLA 03-89			
 <p>A 3D finite element model of a thick-walled pipe. The pipe has a rectangular cross-section and is oriented diagonally. The top surface shows a color gradient from blue (cold) to red (hot), indicating a thermal gradient. Boundary conditions are applied at the top and bottom edges, represented by small green arrows pointing outwards. To the right of the plot is a vertical color bar labeled "SZ (N/mm^2 (MPa))" with a scale ranging from -1.304e+002 to 1.261e+001.</p>			
Test performed by : Julien BOISSAT	Date: 4/4/2019		
Model used			
Finite elements <input checked="" type="checkbox"/>	Boundary elements <input type="checkbox"/>		
Other <input type="checkbox"/>			
Element type : TETRA 10			
Number of degrees of freedom or mesh density :			
Nb of nodes = 11361			
Nb of elements = 7238			
Nb of DOF = 34083			
Results :			
Location	Physical quantity and reference unit	Calculated value	Deviation (%)
$r = R_i$	$\sigma_\theta$ (Pa)	$-100.86 \times 10^6$	-0.07
	$\sigma_z$ (Pa)	$-130.26 \times 10^6$	0.00
	$u_r$ (m)	$7.644 \times 10^{-6}$	0.00
$r = R_e$	$\sigma_\theta$ (Pa)	$42.00 \times 10^6$	0.00
	$\sigma_z$ (Pa)	$12.6 \times 10^6$	0.06
	$u_r$ (m)	$30.6 \times 10^{-6}$	0.30
Comments :			

**IV. BIBLIOGRAPHY**

Roark and Timoshenko books  
are classic references used by  
many engineers.

**Title :** Guide de validation des progiciels de calcul de structures

**Author :** Société Française des Mécaniciens

**Editor :** Association Française de Normalisation (AFNOR)

**Language :** French

**ISSN:** 0297-4827

**ISBN-10:** 2124866117

**ISBN-13:** 978-2124866113

**Title :** ROARK's Formulas for Stress & Strain 6<sup>th</sup> edition

**Author :** Warren C. Young

**Editor :** McGRAW-HILL INTERNATIONAL EDITIONS

**Language :** English

**ISBN-10:** 0071003738

**Title :** Théorie des plaques et coques (Theory of plates and shells)

**Author :** S. Timoshenko, S. Woinowsky-Krieger

**Editor :** DUNOD

**Language :** French

**Library** polytechnique Ch. Beranger N° 5768 – 2<sup>nd</sup> trimestre  
1968

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