

RamSeries - Validation 48

Three-layer sandwich shell

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1. Validation Case 48 - Three layered sandwich shell

1.1. Model Description

The present validation case deals with the strength analysis of a three-layers sandwich shell. A schematic representation of the shell geometry is shown in the figure below.

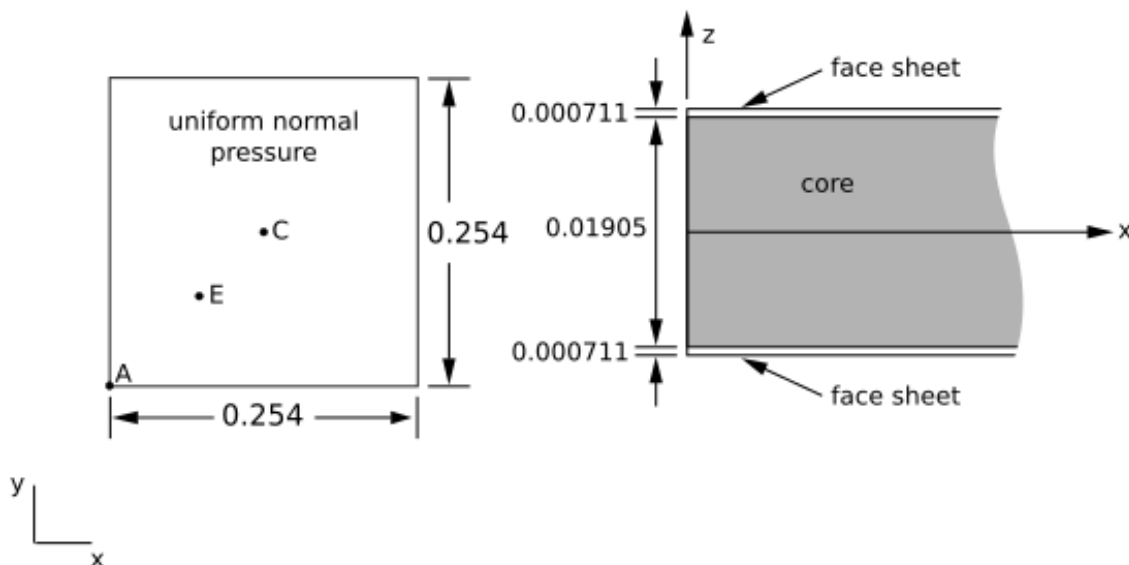


Fig.1. Schematic representation of the three-layered sandwich panel under analysis. a) Top view of the squared shell. Loading conditions consist in a uniformly distributed pressure load. The panel is simply supported at all four edges. b) Transverse section of the panel showing a thick core surrounded by two thin plates at both sides. All units are in meters.

The shell is simply supported on all four edges and is loaded by a uniform normal pressure in the downward vertical direction (this is in the negative direction along the global Z axis). Hence, due to the symmetry of the problem, just one-quarter of the sandwich shell is modeled using appropriate symmetry conditions.

Two different materials are used in this model. The first one to define the face sheets of the sandwich shell and the second one to define the core of the panel. Both can be defined in RamSeries as orthotropic materials with the following properties. Damage and breaking stress properties have no effect for the present linear test case. Hence, they are ignored here.

Face sheet properties	[psi]	[Pa]
E1	1.000E+07	6.895E+10
E2	4.000E+06	2.758E+10
G12	1.875E+06	1.293E+10
G13	1.875E+06	1.293E+10
G23	1.875E+06	1.293E+10
nu12	0.30	
nu21	0.12	
Core properties	[psi]	[Pa]
E1	10	68947.57
E2	10	68947.57
G12	10	68947.57
G13	3.00E+04	2.07E+08
G23	1.20E+04	8.27E+07
nu12	0	
nu21	0	

Table 1. Material properties of the outer face sheets and of the core of the sandwich panel under analysis.

Next, a new laminate representing the sandwich panel under analysis must be constructed using the composite materials defined above in the form of orthotropic materials. The definition of the new laminate is shown in the figure below.

Laminate definition

Laminate name: Three-layers-sandwich

Constitutive model: Classic

Material: Face_sheet

Sequence: 1

Number of layers: 1

Thickness: 0.001830 m

Fiber angle: 0.0 deg

Total laminate thickness: 0.020472 m

Laminate composition

Material	Angle	Thickness	Layers
Face_...	0.0	0.000711	1
Core	0.0	0.019050	1
Face_...	0.0	0.000711	1

Visual description

Composite layer

E_Glass_Epoxy

Face_sheet

Core

Face_sheet

Fig.2. Laminate's definition window. In this case, the sandwich panel under analysis consists on a thick core material's layer (yellow ply in the laminate's visual description) surrounded by two thin plates (in blue in the laminate's visual description).

Next, the laminate we have created must be assigned to the surface that geometrically models the shell under analysis.

The applied load condition simply consists on a vertical pressure load $P = -689475.7$ Pa.

1.2. Results

The present test case is a benchmark model recommended by the NAFEMS in order to verify the implementation of the classical lamination theory (CLT) in finite element analysis software packages. Both, NAFEMS and ABAQUS results reported in [1] are compared here against those obtained with the CLT implementation of RamSeries. In particular, the maximum displacement (uz) that occurs at the center of the shell and the $s11$ stress component in the bottom face of the laminate are compared.

Model	uz at C [inch.]	uz at C [m]	S11 at C [psi]	S11 at C [Pa]
NAFEMS	-0.1230	-0.0031242	34449	2.3752e8
S8R	-0.1220	-0.0030988	35307	2.4343e8
Composite SC6R	-0.1200	-0.0030480	34687	2.3916e8
Stacked SC6R	-0.1290	-0.0032766	35382	2.4395e8
Composite SC8R	-0.1220	-0.0030988	35312	2.4347e8
Stacked SC8R	-0.1310	-0.0033274	36118	2.4902e8
RamSeries (Quad)	-0.1229	-0.0031217	36902	2.5443e8

Table 1. Comparison of results obtained using the classical lamination theory implemented in RamSeries for modelling the structural behavior of laminated composites. Vertical displacement and S11 component of stress at the center of the bottom face of the shell are compared against the results reported in [1] concerning the various formulations and element types used in ABAQUS.

It can be observed that both the displacement and the stress results obtained with RamSeries are in accordance with the values reported by NAFEMS and also with those obtained with ABAQUS.

Note that the default outputs of RamSeries are the stresses at the bottom and top surfaces of the shells, where bottom and top refer to the lower and upper faces of the shells as determined by their Z local axis (see Figures 3 and 4 below). But in the case of a laminated shell, these default results actually correspond to the mid-plane of the first (bottom) and last (top) laminate plies.

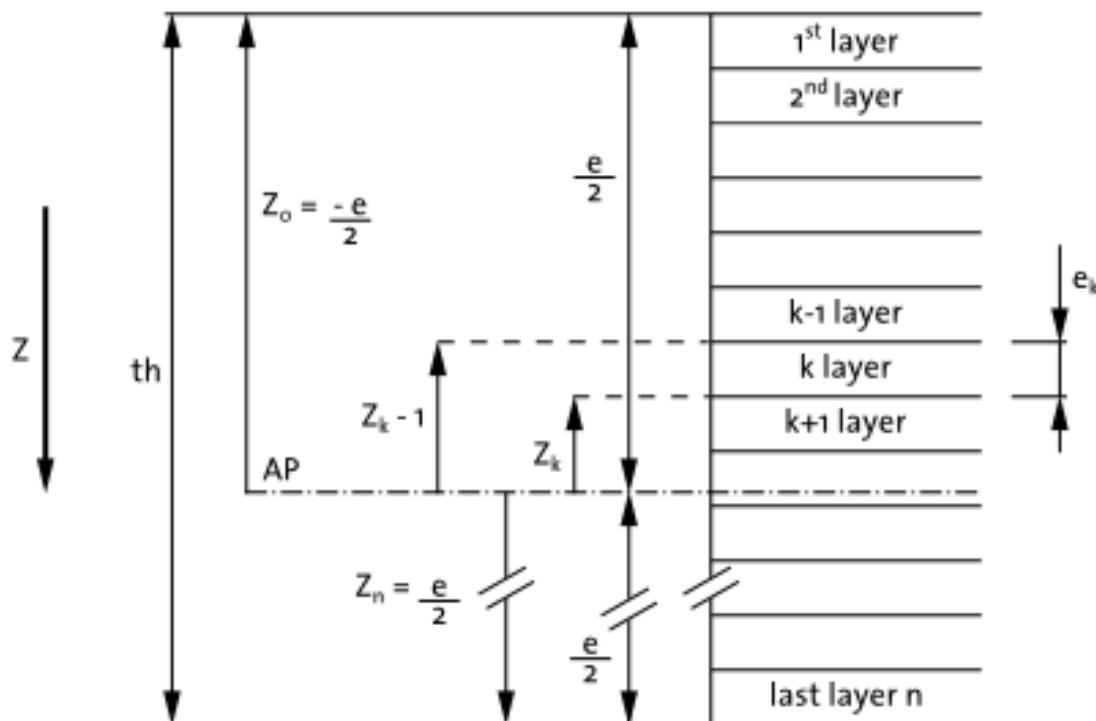


Fig.3. Through-thickness schematic representation of a generic laminate with n composite layers. The plies are numbered from bottom (1st layer) to top (last layer n), thus corresponding to the lowest and highest local Z coordinates respectively.

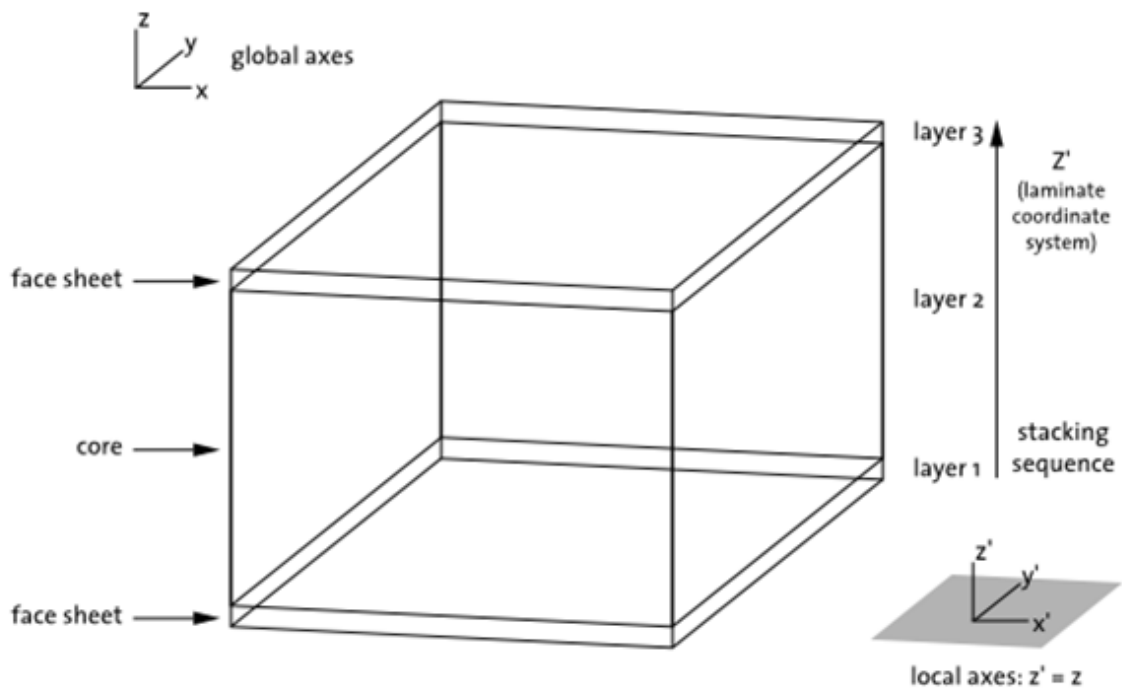


Fig.4. Schematic representation of the sandwich panel under analysis. The laminate's layer 1 corresponds to the bottom face of the shell, while layer 3 corresponds to the top face of the shell.

The default stresses' results for the sandwich shell under analysis are presented schematically in the following figure. It can be observed that, as expected, the bottom shell's surface (layer 1) is under traction while the top shell's surface (layer 3) is under compression.

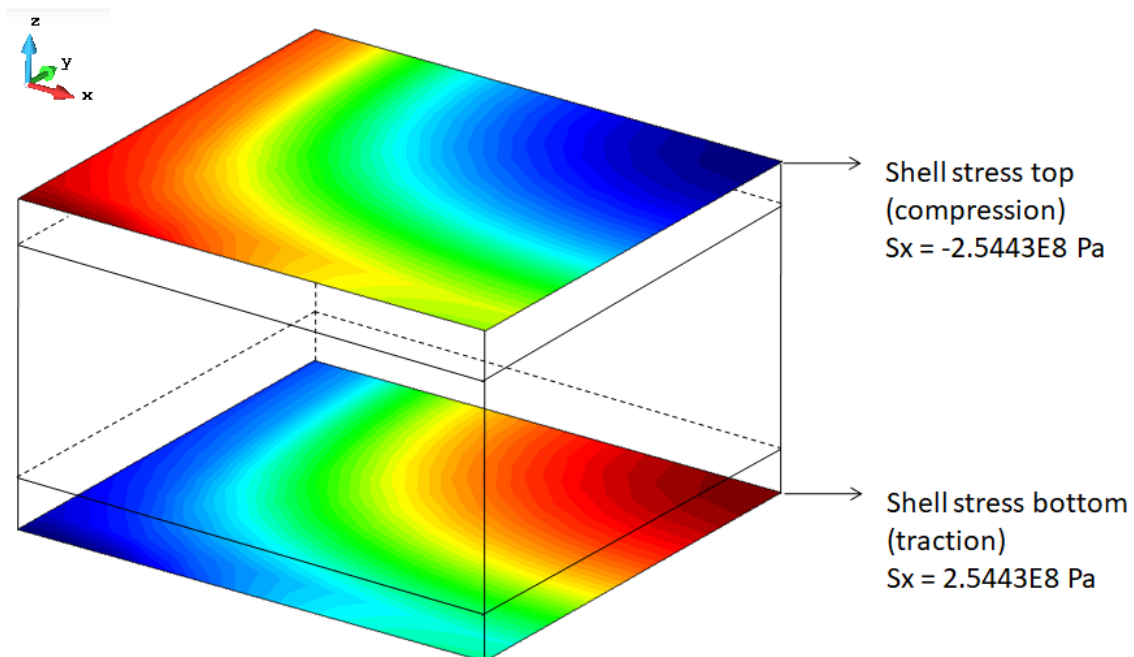


Fig.5. Default stresses results in RamSeries (shell's top and bottom faces).

Additionally, detailed results within individual layers of the laminate can also be assessed. In the figure 6 below, detailed stress results are presented for the extreme plies (top and bottom) of the laminate.

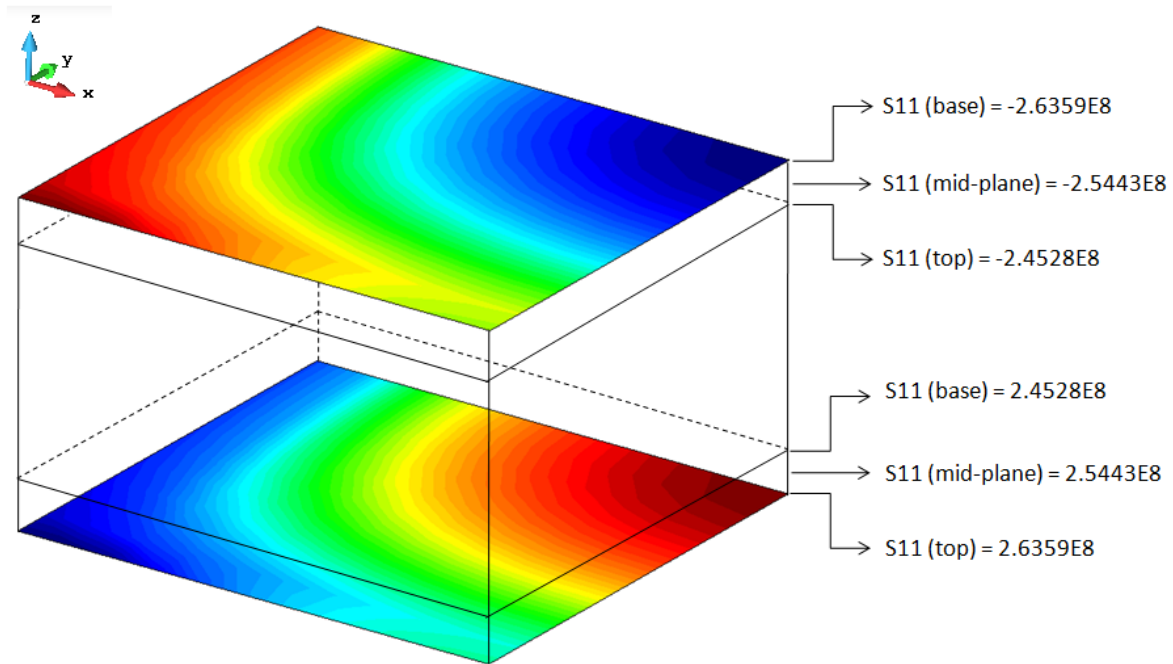


Fig.6. Laminate stiffness matrix characteristics allow to compute the stresses, strains and failure criteria results within individual layers. In this case for instance, stress results are postprocessed in the extreme layers of the sandwich panel so that mid-plane, base and top values can be assessed individually within each selected ply.

In addition to the classical lamination theory (CLT), RamSeries also provides a more advanced formulation for the analysis of composite laminates. The results obtained using these formulation, named herein RoM/SP-RoM for the sake of brevity, are summarized in the following table and compared against the results of the CLT formulation.

Model	uz at C [m]	S11 at C [Pa]
NAFEMS	-0.0031242	2.3752e8
RamSeries - CLT	-0.0031217	2.5443e8
RamSeries - RoM	-0.0031217	2.6267E8
RamSeries - SPRoM	-0.0032286	2.6832E8

Table 2. Comparison of results obtained using the various formulations available in RamSeries for modelling the structural behavior of laminated composites. a) Vertical displacement at the center of the shell. b) S11 component of stress at the center of the bottom face of the shell.

1.3. Validation Summary

CompassFEM version	14.0.2
Tdyn solver version	14.0.2
RamSeries solver version	14.0.2
Benchmark status	Successfull
Last validation date	18/09/2018

1.4. References

[1] [Abaqus 6.10 NAFEMS benchmark. Three-layer sandwich shell under normal pressure loading](#)