STRENGTH ANALYSIS OF HONEYCOMB SANDWICH STRUCTURES

THREE POINT BENDING AND CHRUSHING TESTS OF HONEYCOMB CORE SANDWICH PANELS

APPLICANT: GÁBOR KOLTAI

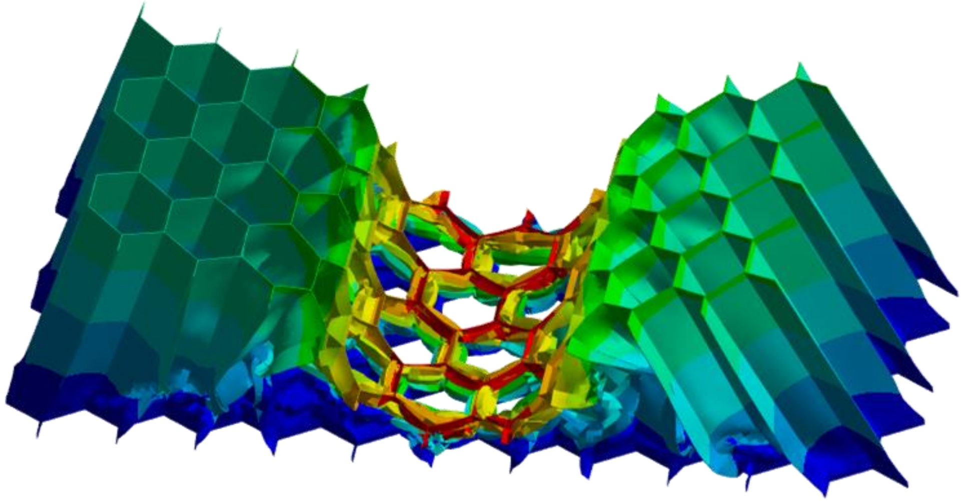
CONSULTANT: DR. SZABOLCS JÓNÁS

INSTITUTION: BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS

FACULTY: FACULTY OF MECHANICAL ENGINEERING (GPK)

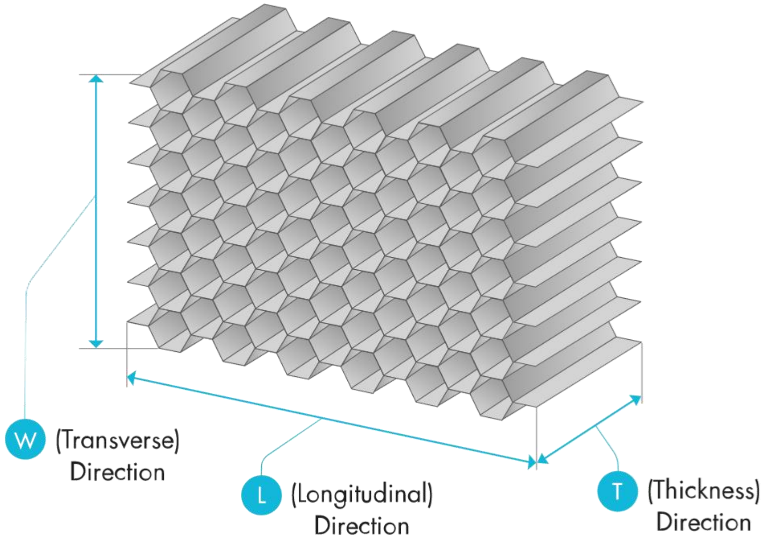
E-MAIL: KOLTAIGABOR98@GMAIL.COM

PHONE: 06203109554

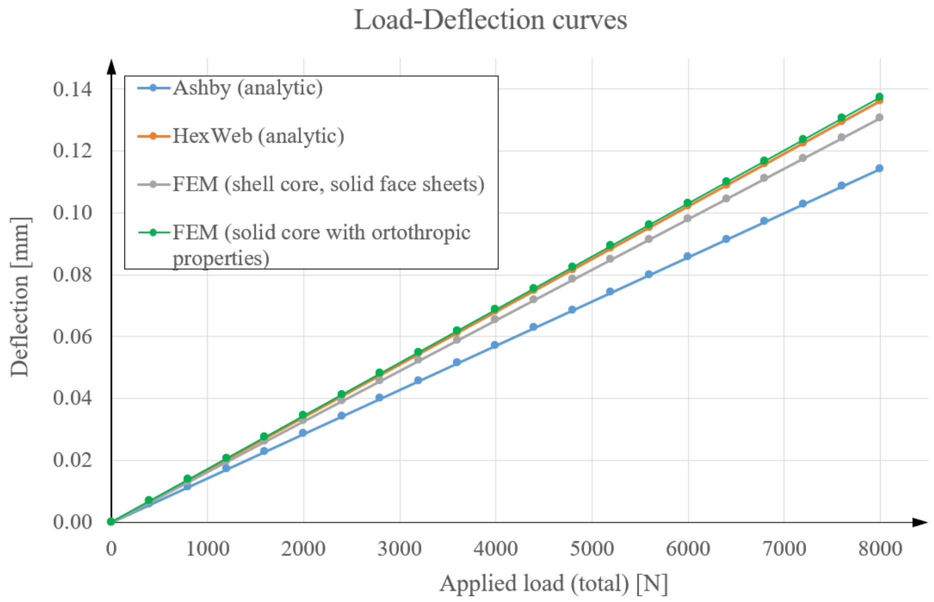


THREE POINT BENDING TESTS

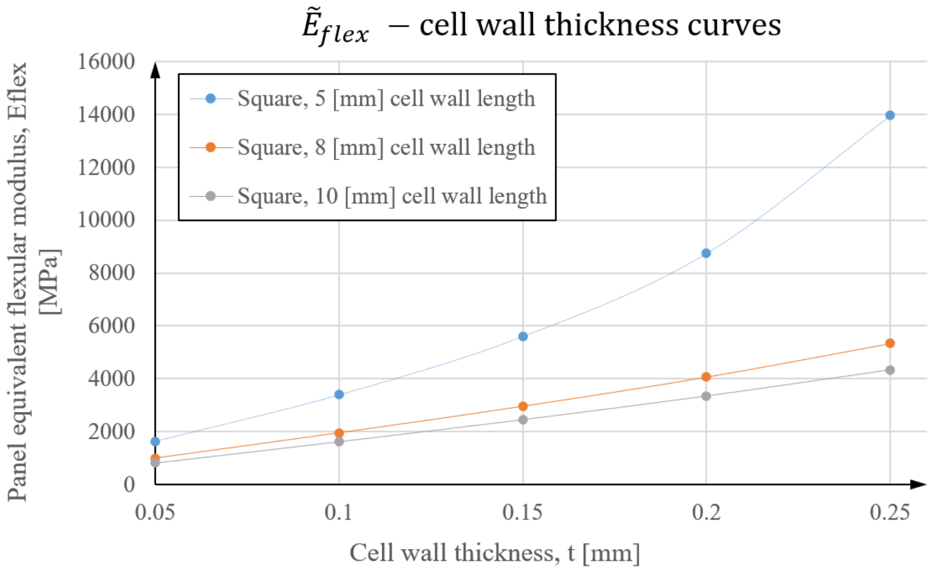
- The objective of the project was to measure the deflection (δ) of the sandwich panel due to a given load. By knowing the deflection of the panel, the material properties in the X3 (or T) direction, namely the shear modulus of the core (G_c) and the equivalent flexural modulus ($\tilde{E}_{flex}$) of the panel, can be calculated.
- In case of hexagonal core structure, the deflection can be calculated analytically, which can be used to validate the results and check the accuracy of the FEM model.
- The model can be used to determine the material properties of different honeycomb shapes. During my thesis, I examined double-walled hexagons, triangles, squares and rectangles, with varying cell sizes and cell wall thicknesses.



Source: corex-honeycomb.com



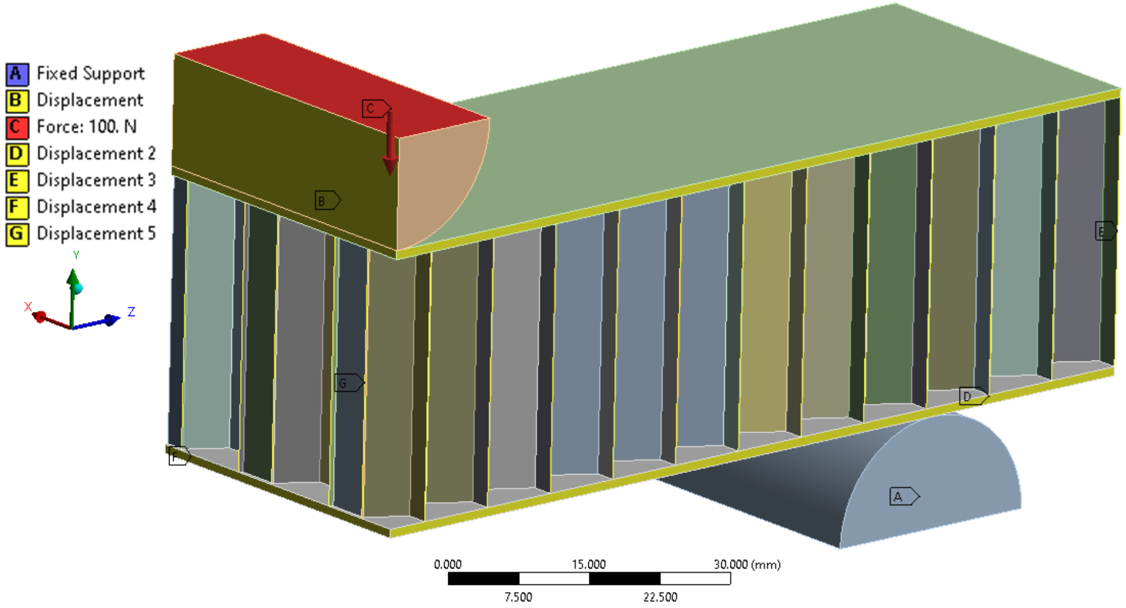
Hexagon cell displacement FEM vs. Analytic



Square cell structure equivalent flexular modulus curves

THREE POINT BENDING TESTS

- The geometry of the model was created according to the ASTM C393 standard.
- I used a linear solver for my simulations, because the required equations for the material properties belong to the linear zone.
- The applied material was ANSYS's built-in 'strucutral steel'.
- I took advantage of the double symmetry and used a quarter model for my simulations.
- I used quadratic solid elements for the face sheets and loading cylinders (SOLID187), shell elements for the honeycomb core (SHELL281). The core and the sheets are bonded together. The sheets and the cylinders are using a frictionless condition.
- The load and the boundary conditions can be seen in the picture:
  - A: fixed support on the supporting cylinder's flat surface
  - B: 0 displacement in the 'X' and 'Z' direction applied to the flat surface of the loading cylinder
  - C: The quarter of the total load applied on the upper flat surface of the loading cylinder
  - E,D: 0 displacement in the 'X' direction, applied to the surfaces of the face sheets and core edges
  - F,G: 0 displacement in the 'Z' direction, applied to the surfaces of the face sheets and core edges

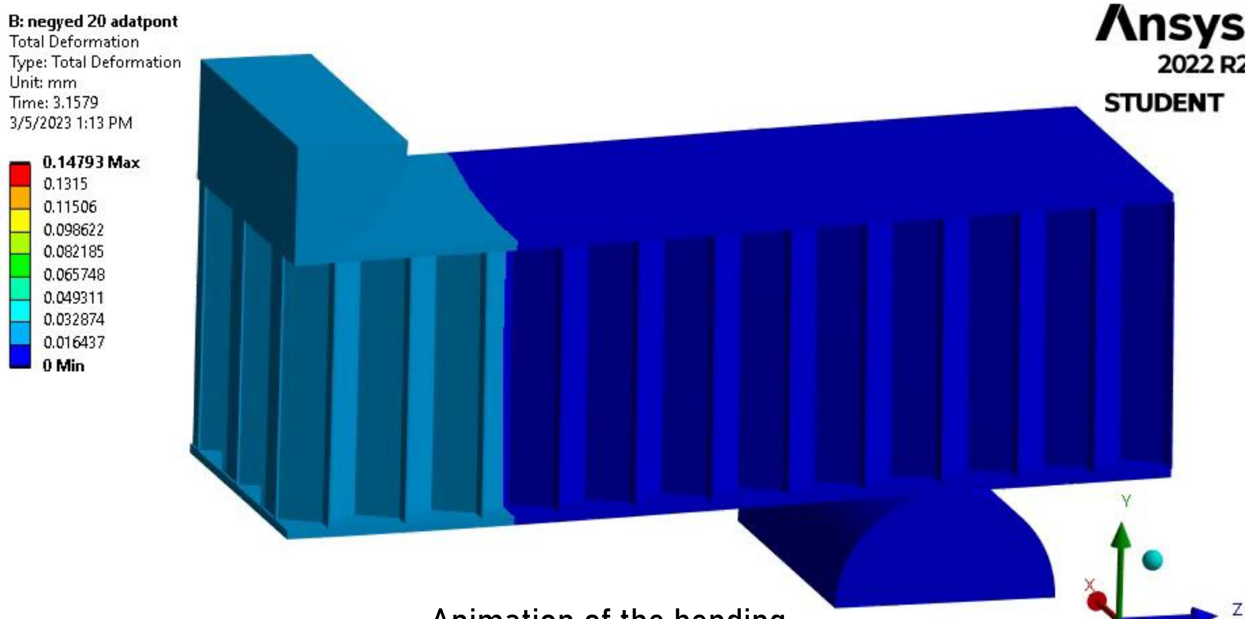


Load and boundary conditions

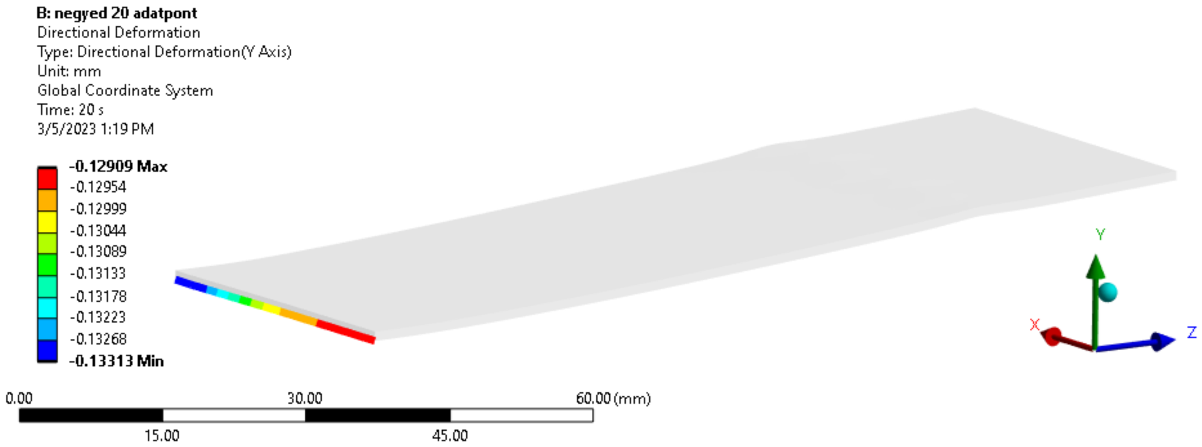
Name	Symbols	Value	[ ]
Sandwich height	d	32	mm
Face sheet thickness	tf	1	mm
Core height	c	30	mm
Sandwich width	b	75	mm
Sandwich length	L	200	mm
Loading span	l	150	mm
Cylinder diameter	D	25	mm
Cell size	a	5	mm
Cellwall thickness	t	0,25	mm
Element size	e	1,5	mm
Number of elements	Ne	38336	-
Number of nodes	Nn	100058	-

Geometry and discretion data (hexagonal cell)

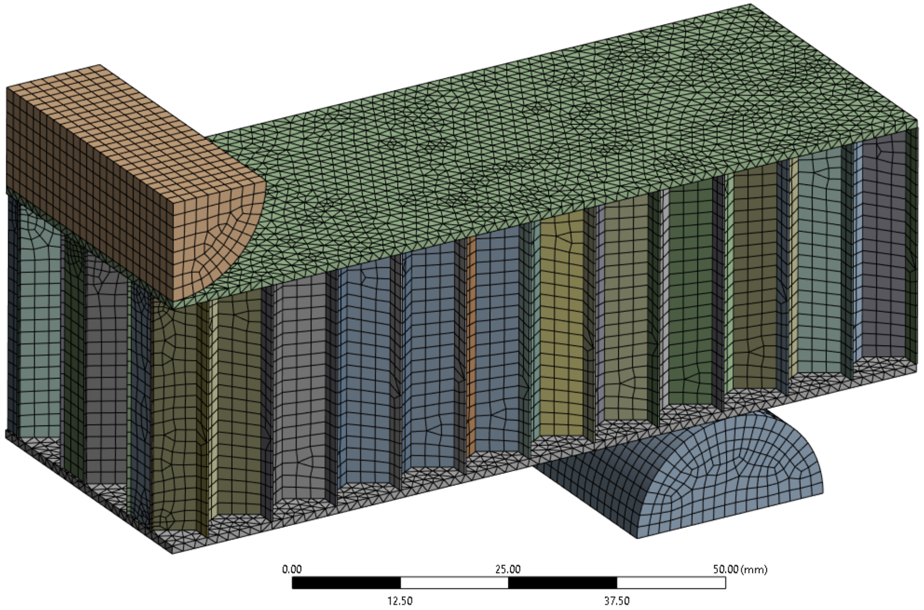
THREE POINT BENDING TESTS



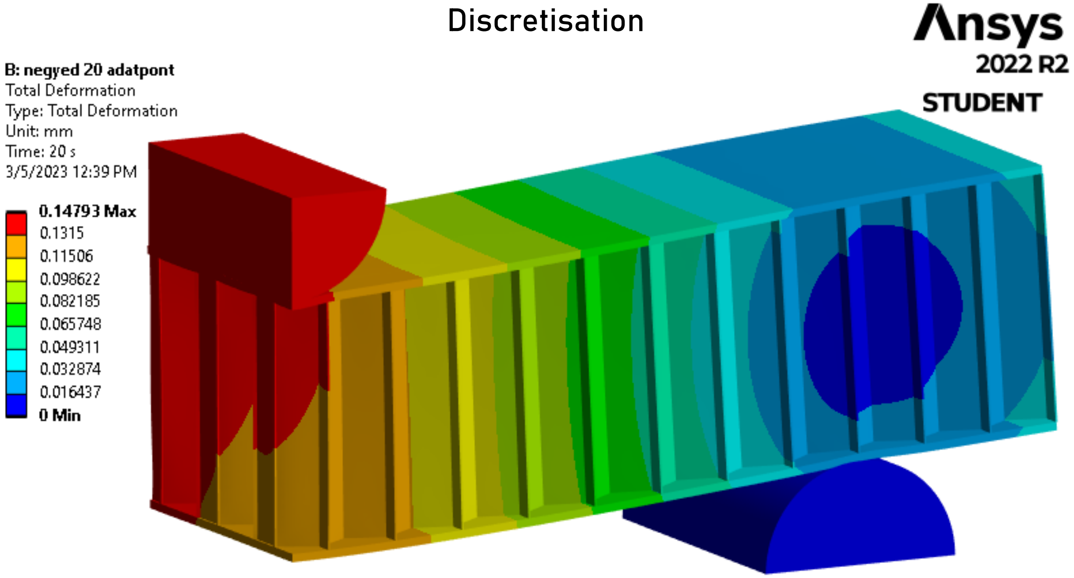
Animation of the bending



Deflection in the Y direction of the lower edge of the lower face sheet



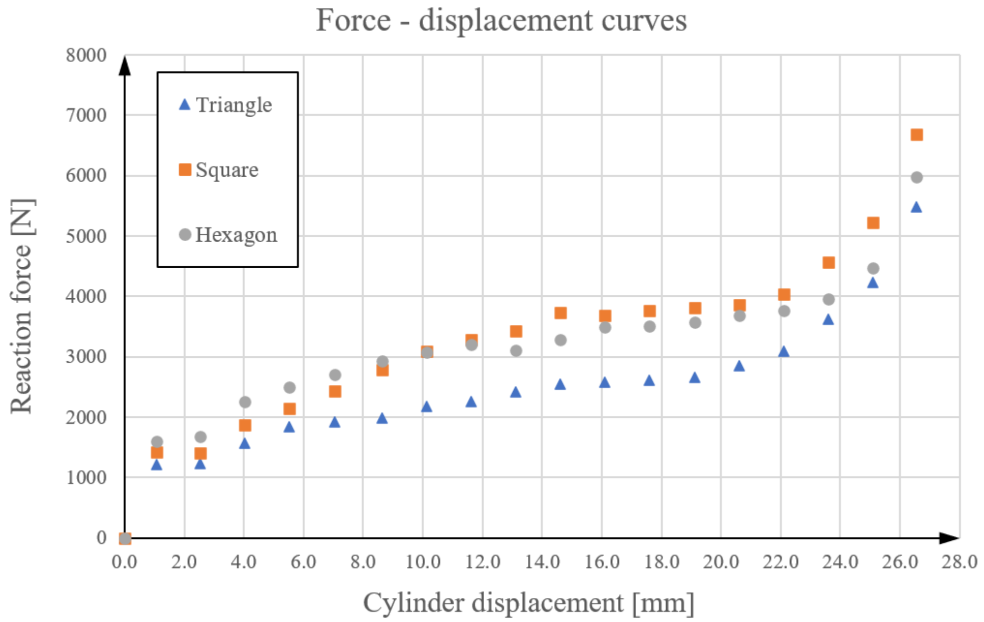
Discretisation



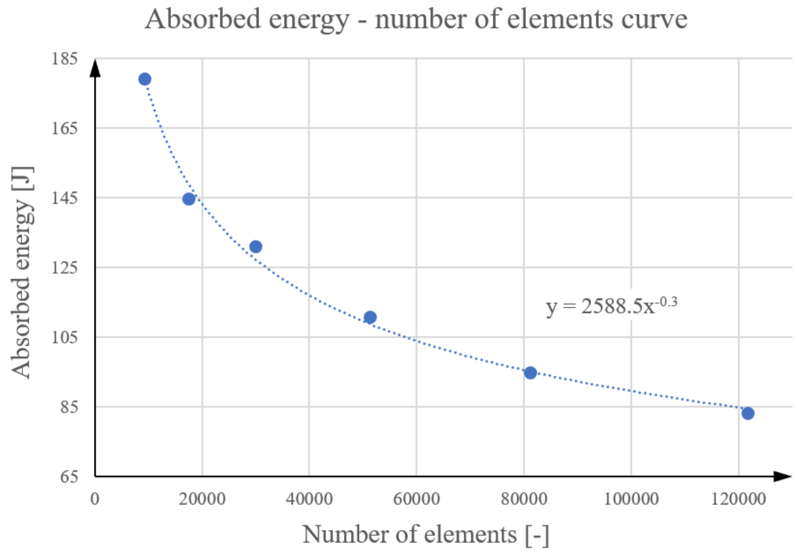
Deflection at 8000 [N] total load
40x scale

CRUSHING TESTS

- The objective of the project was to determine the energy absorbed by the sandiwch panel.
- During the simulations, I measured the reaction force at the supporting end, and the diplacement of the cylinder. The area below the force-displacement graph is equal to the absorbed energy.
- I used explicit solver for my simulations, because the impact is highly nonlinear and significant deformation occurs in a short period of time.
- I assumed that the cylinder is part of a rigid body, with high inertia, so the impact's decelerating effect is not significant.
- During my thesis, I compared three different cellastructures: hexagon, triangle and square. The relative densities of the panels were the same, meaning that the weight of the three panels was equal.
- The scientific literature does not provide analytical formulas for this type of research. For proper validation of the model, further tests and experiments with real specimens are required.
- I performed a sensitivity examination of my mesh, resulting in the lower graph.



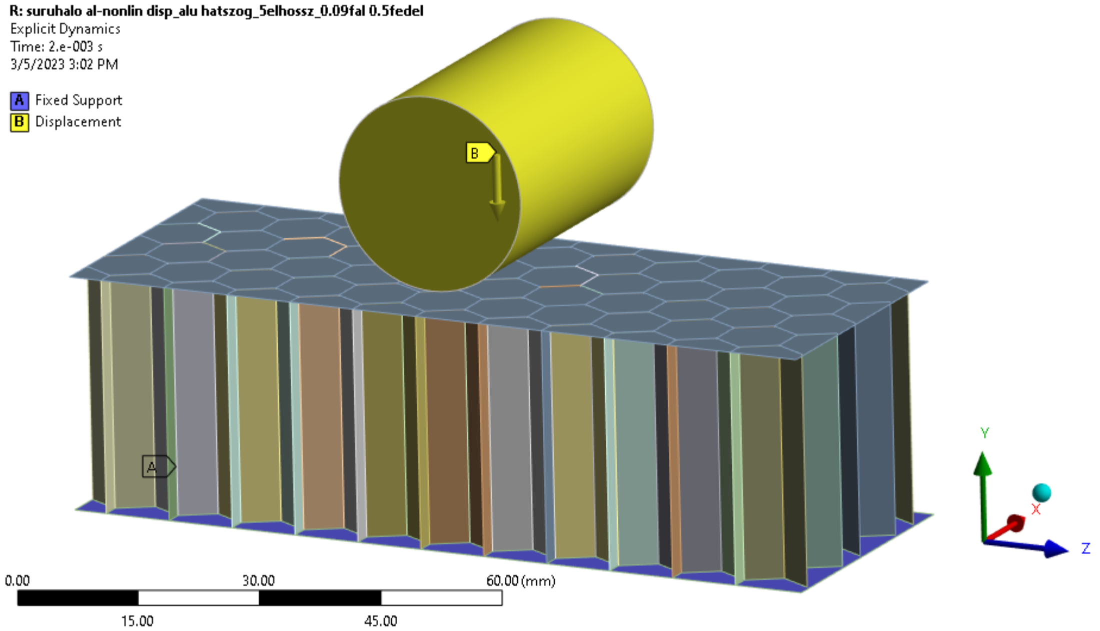
Force – displacement curves for different cell structures



Mesh sensitivity

CRUSHING TESTS

- The applied material was ANSYS's built-in 'Aluminium Alloy' with an added bilinear isotropic hardening factor (100 [MPa] tangent modulus)
- The total time of the impact was t = 0,002 [s].
- Cylinder speed: 15 [m/s] = constant. Applied by cylinder displacement.
- Boundary condition: A: fixed support on the lower face sheet.
- Both face sheets and core were modelled using surfaces, and bonded together. Linear shell elements were used, with a size of 0,8-0,9 [mm] (to achieve similar number of elements with all three models).



Boundaryconditions

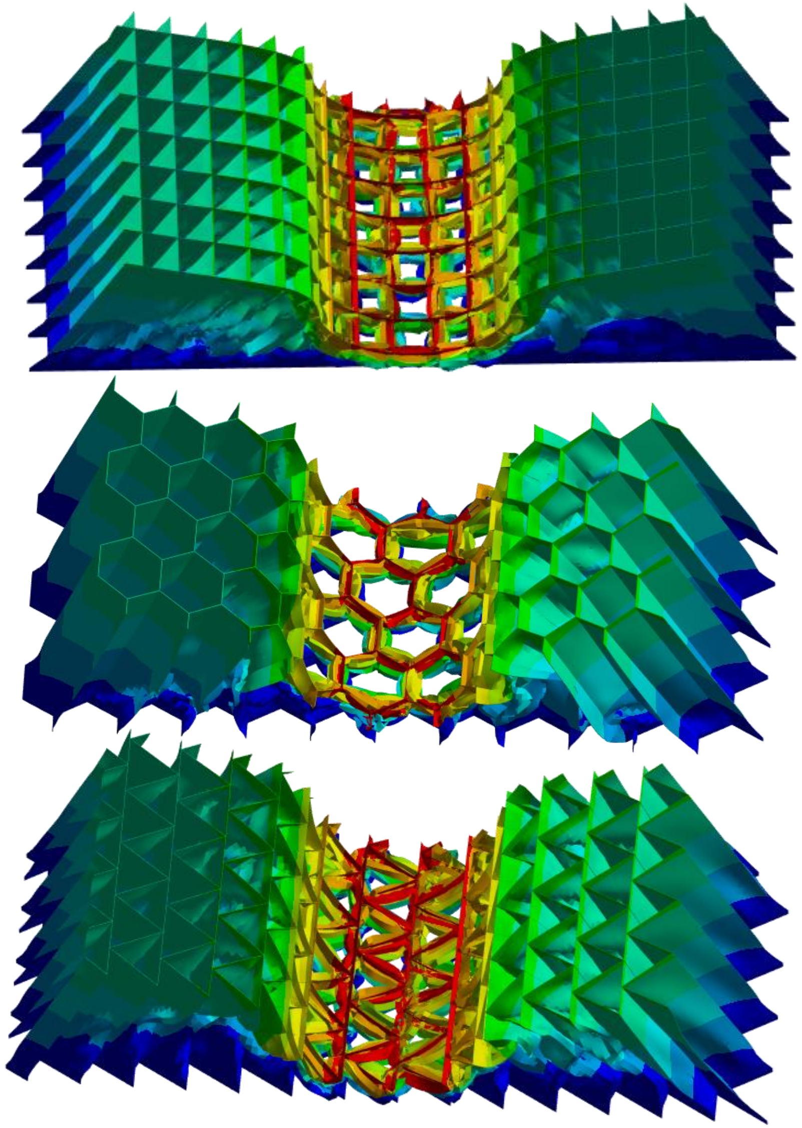
Element size [mm]	Number of elements	Number of nodes	Run time [min]	Absorbed energy[J]
0.8	121693	122489	162	83.1
1	81182	81806	88	94.8
1.2	51307	51404	47	110.9
1.5	29903	29821	31	131.1
2	17472	17238	20	144.7
2.5	9288	9017	4	179.2

Mesh sensitivity

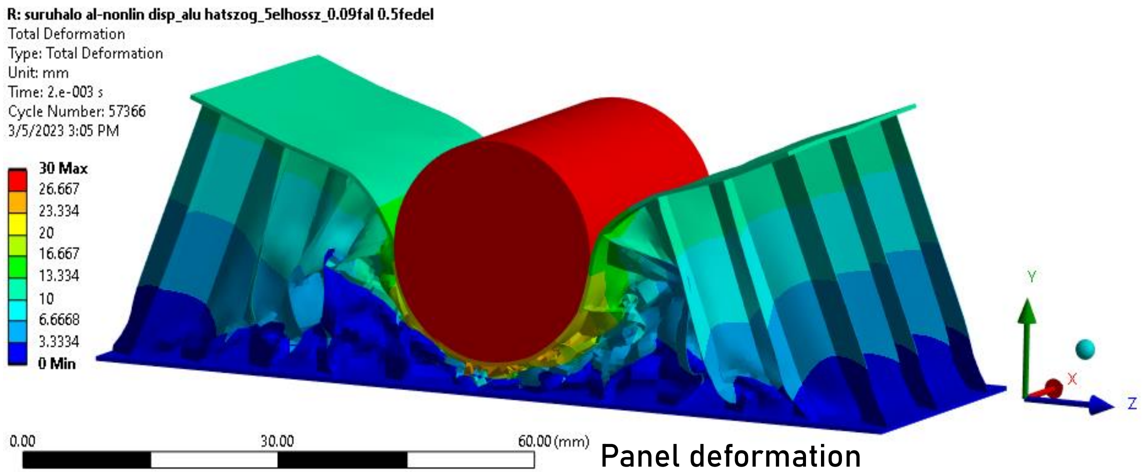
Cell shape	Square	Triangle	Hexagon
Cell wall length [mm]	5	8	5
Wall thickness [mm]	0,05	0,045	0,09
Element size [mm]	0,85	0,9	0,8
Number of elements	114972	119710	121693
Number of nodes	111599	116361	122489
Run time [min]	211	192	162
Absorbed energy [J]	86,2	64,8	83,1

Geometry, discretion data, results

CRUSHING TESTS

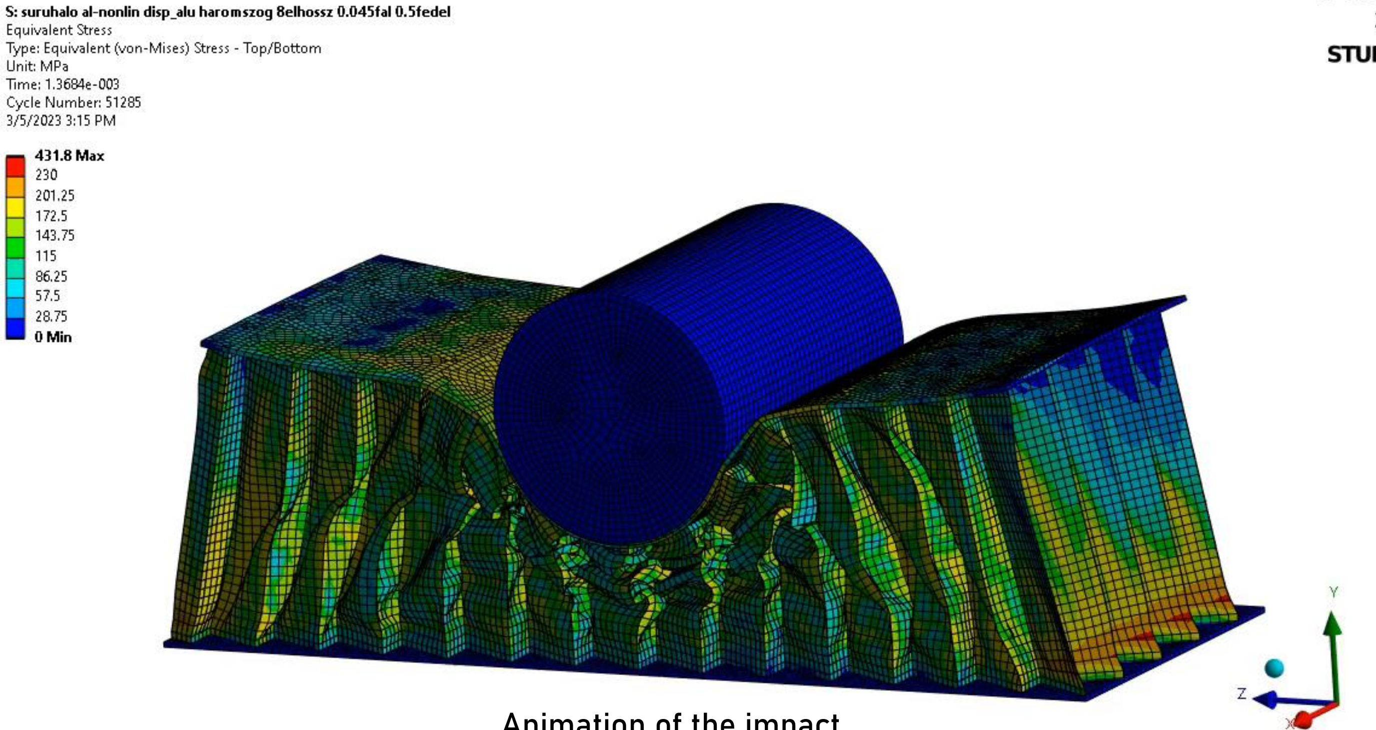


Core deformations



Panel deformation

Ansys
2022 R2
STUDENT



Animation of the impact