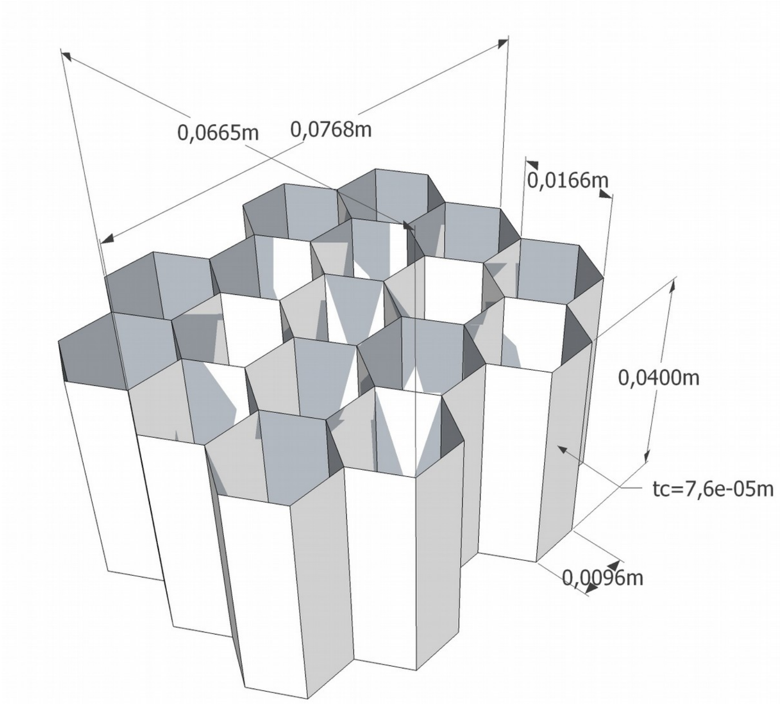
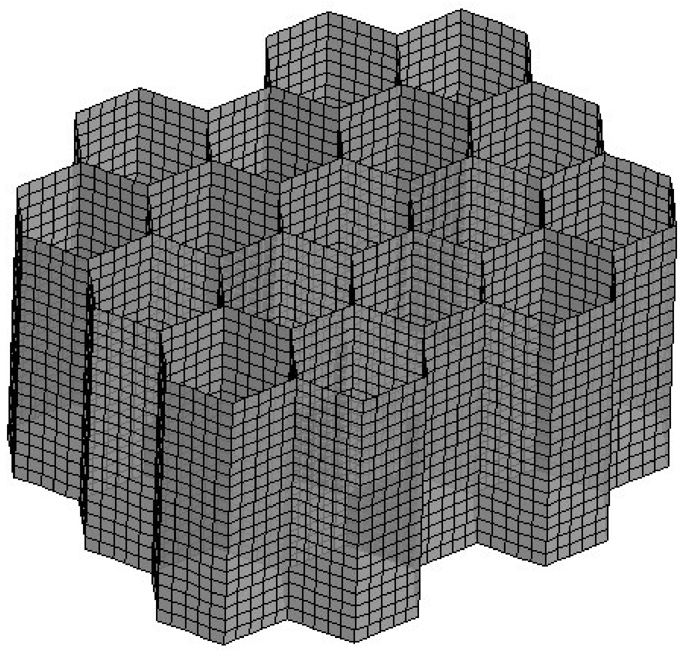
1. Introduction

In this report I will compare the mean and ultimate crushing forces for a honeycomb structure subjected to crushing using analytical methods and results from FEA using LS-DYNA. All units are based around the SI set m; kg; s.

1.1. Model information



1.1.1. Geometry of the honeycomb structure



1.1.2. Mesh of the honeycomb structure generated using HyperMesh; it consists of 10200 square shell elements with the dimension of 1,92E-03m

The impactor is modelled as a rigid shell consisting of 1443 shell elements 39 elements in length and 37 in width. As for the material properties there were taken from [http://asm.matweb.com] for Aluminum 5052-O. The material model used in LS-DYNA was Shell 003-PLASTIC_KINEMATIC for the honeycomb and 020-RIGID for the impactor.

As for the kinematics setup the bottom nodes of the honeycomb were fixed in all directions of both translations and rotations also the top nodes of the honeycomb were fixed for translation in x, y direction in order to simulate the contains that a top plate would impose on the honeycomb. The velocity of the impactor was set to $2^{0,5}$ m/s and it's density to 8,725E+06 kg/m^3. Having it's thickness set to 0,001m, length 0,0783m and width 0,0732m it all added up to 50kg of mass and 50J of kinetic energy. I decided to ramp up the energy by means of mass, because when I tried to do it with the velocity ramping my laptop crashed.

The contact is established via AUTOMATIC_GENERAL option having all objects attributed to a single part set and running it as a slave segment. The simulation was run using the explicit default solver for 0,005s with the initial time step set to 0,001s. The output data was gathered using NOTOUT and NOTFOR with the resolution of10E+05Hz.

In general I based the dimensioning of my model on the "PREDICTION OF CRUSHING BEHAVIOUR OF HONEYCOMB STRUCTURES" [2] paper, wanting to compare my results with theirs. However that plan backfired because as it turned out there was no meaningful data which could be extracted from that paper in my humble opinion.

2. Analytical results

The analytical results were calculated based on the formulas found in "The strength characteristics of aluminum honeycomb sandwich panels" [1] paper.

2.1. Initial calculations

$$d = 0.0096$$

Dominating dimension of a single cell [m]

$$S = 0.0166$$

Distance between two edges of honeycomb core hexagon [m]

$$\sigma = 8.96 \cdot 10^{7}$$

Yield stress of honeycomb core material [Pa]

$$\alpha = \frac{2\pi}{3}$$

Angle of honeycomb core hexagon [rad]

$$t_c = 7.6 \cdot 10^{-5}$$

Wall thickness of honeycomb core cell [m]

$$n = 17$$

Number of honeycomb cells modelled in my structure

$$L = 2d \cdot \left(1 + \cos\left(\frac{\alpha}{2}\right)\right) = 0.029$$

Virtual length of the a unit honeycomb [m]

$$W = 2 \cdot \left(t_c + d \cdot \sin\left(\frac{\alpha}{2}\right) \right) = 0.017$$

Virtual width of the a unit honeycomb [m]

$$A = L \cdot W = 483.255 \times 10^{-6}$$

Virtual area of a unit honeycomb core at the cross section parallel to the facing skin plane [m^2]

$$E = 7.03 \cdot 10^{10}$$

Elastic (Young's)modulus of the core material [Pa]

$$v = 0.33$$

Poisson's ration of honeycomb core material

2.2. Mean crushing force

$$P_m = 16.54 \cdot A \cdot \sigma \cdot \left(\frac{t_c}{S}\right)^{\frac{5}{3}} = 90.406$$

Mean crushing force for a single cell of the honeycomb of given dimensions [N]

$$Pm = n \cdot P_m = 1536.897$$

Result for a structure comprised of 17 hexagonal cells [N]

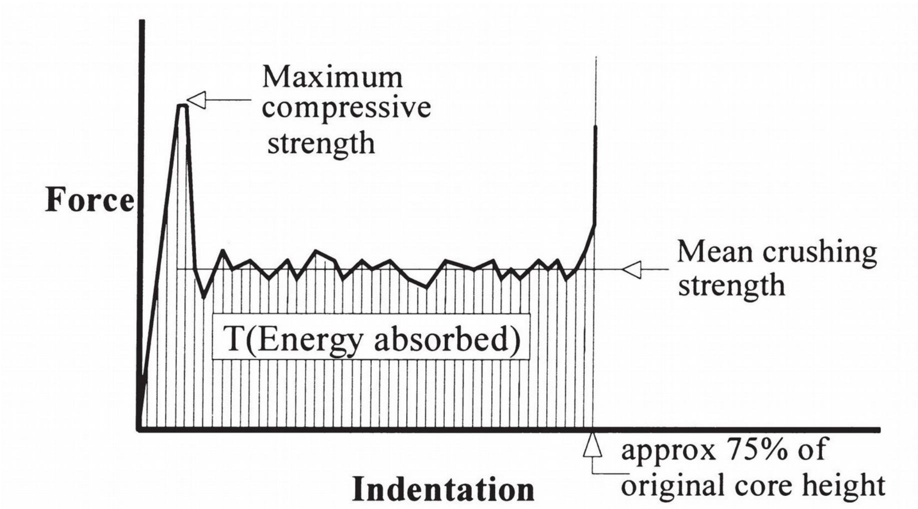
2.3. Ultimate crushing force

$$P_u = 8d \cdot t_c \cdot \left[\frac{\pi^2 \cdot E \cdot \sigma^2}{3 \cdot \left(1 - v^2\right)} \cdot \left(\frac{t_c}{d}\right)^2 \right]^{\frac{1}{3}} = 296.127$$

Ultimate crushing force for a single cell of the honeycomb of given dimensions [N]

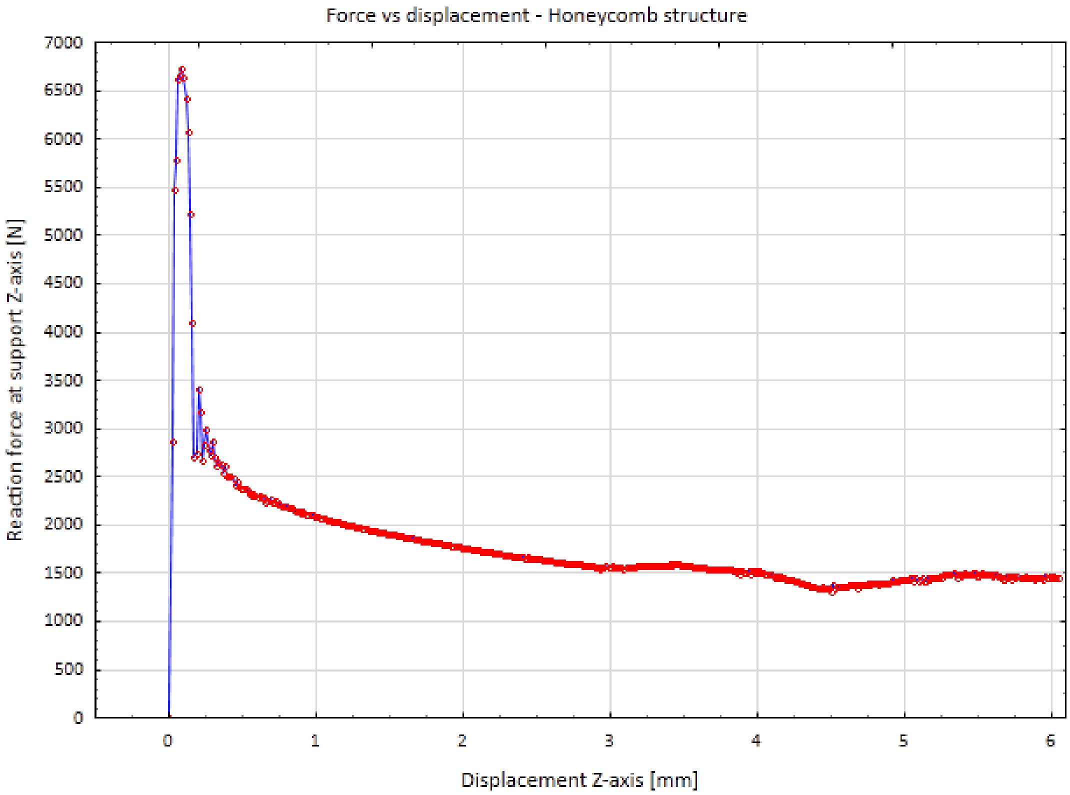
$$Pu = n \cdot P_u = 5034.153$$

Result for a structure comprised of 17 hexagonal cells [N]

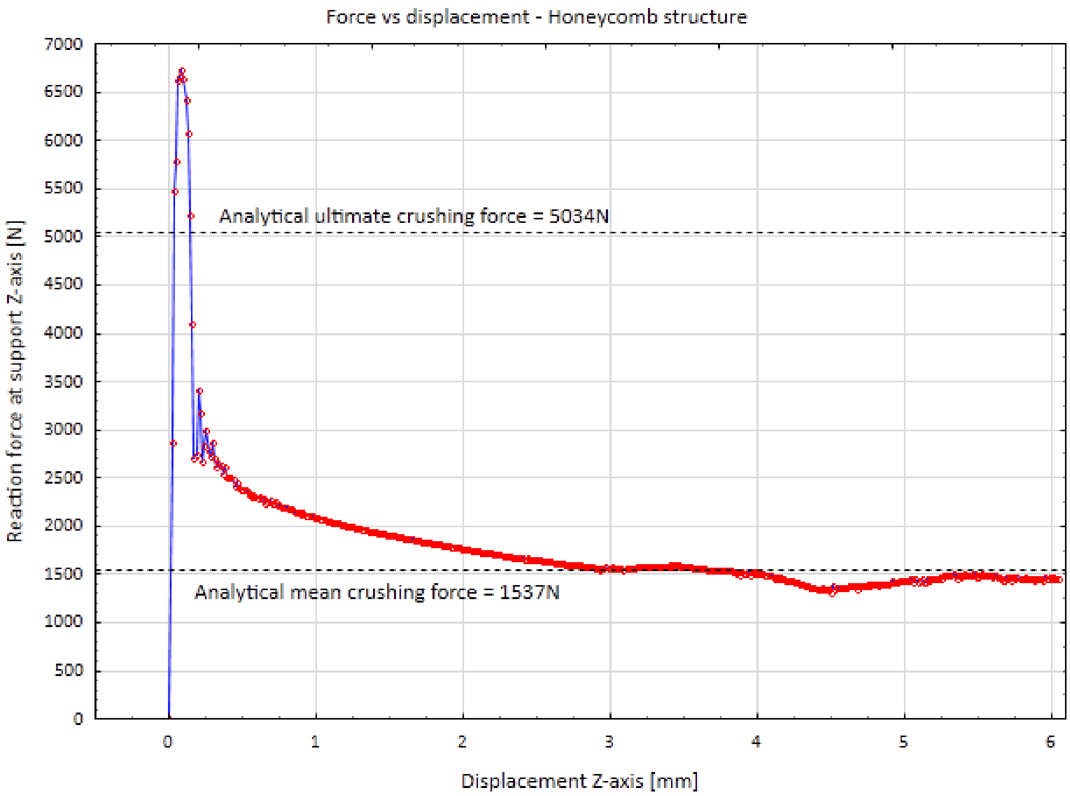


2.3.1. Schematic representation of a typical force versus indentation curve for a thin-walled structure subject to crushing loads

3. FEA results



3.1.1. Force vs displacement of the modelled honeycomb structure diagram plotted from the NODFOR and NODOUT outputs of LS-DYNA; output resolution 10E+05Hz



3.1.2. Force vs displacement of the modelled honeycomb structure diagram with results taken acquired from the analytical analysis; output resolution 10E+05Hz

The analysis was run only for the deformation reaching 15% of the total structures height because as the honeycomb folded more and more the calculations connected with the contact between all the elements got more complex and my laptop just couldn't handle it in a reasonable time.

4. Conclusions

Theoretical knowledge is as important as pure point and click skills when it comes to solving finite element analysis problems. Due to the limited processing power of desktop laptops the idea of “Make everything as simple as possible, but not simpler” is really useful. As for the results acquired via means of FEA and analytical methods they seem to converge to the same values, it would be useful to validate those results with real life experiments. The height of the honeycomb has no impact on the ultimate and mean crushing forces that I may withstand; the largest effect on those parameters may be ascribed to the thickness of the cell's wall in case of the honeycomb geometry.

5. References

[1] The strength characteristics of aluminum honeycomb sandwich panels J Kee Paik, AK Thayamballi, G Sung Kim - Thin-walled structures, 1999 – Elsevier

[2] Prediction of crushing behaviour of honeycomb structures A Chawla, S Mukherjee, D Kumar, T Nakatani... - International Journal of ..., 2003 - Springer