NUMERICAL AND EXPERIMENTAL STUDY OF AN AL-PLA SANDWICH BEAM LOADED IN BENDING

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SUMMARY: The purpose of this paper was to highlight the difference between the results obtained experimentally and those numerically obtained with FEM for a sandwich beam loaded in bending. The beam was supported at its ends, a force being applied in the middle spam. Sandwich beams are strength components for larger structures, so it is very important to know their behavior when subjected to various loadings, in this paper being study its behavior in bending.

KEY WORDS: Sandwich beams, experimental results, three-point bending, FEM.

1. Introduction

Sandwich beams are used to strengthen a structure. Some models can also be used in aviation due to their low weight. As they are elements of resistance, it is very important to know how they behave when subjected to bending. The figure below shows the components of such a beam.

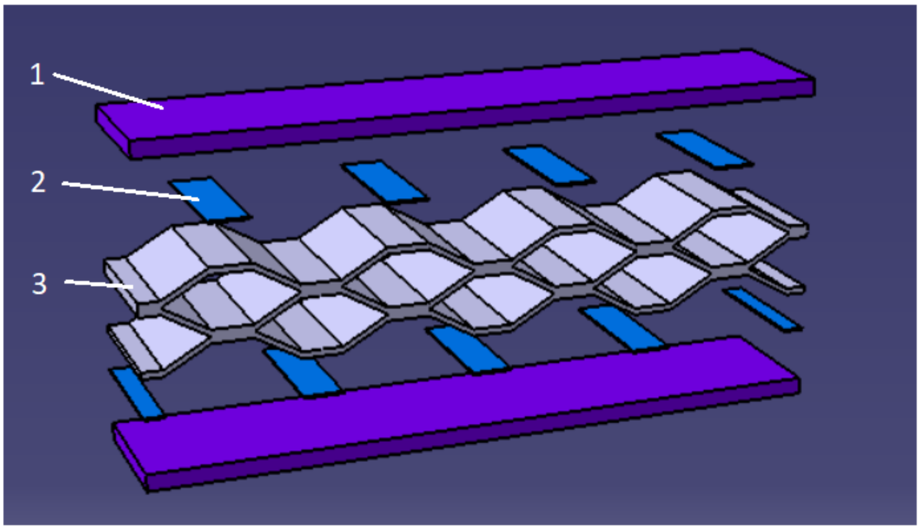

Fig. 1. Beam components

2. Analysis of a sandwich beam in Ansys Workbench

In order to perform the analysis, the material characteristics for each surface must be defined. In figure one it can be seen that three different materials have been defined. The standard aluminum, the adhesive, and the PLA for which Young's modulus, Poisson's ratio, and density were selected.

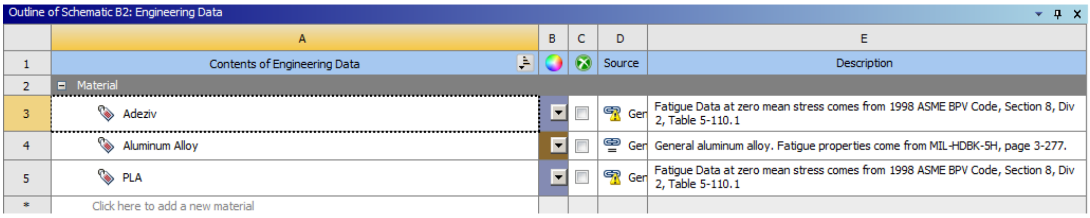

Fig. 2. Defined materials

Table 1. Material characteristics of the sandwich beam

No.	Material	Density [kg/m^3]	Young modulus [MPa]	Poisson's ratio
1.	Aluminum	2770	71000	0.33
2.	Adhesive	1380	3050	0,34
3.	PLA	1400	3200	0,35

Once the materials were defined, the geometry was modeled. It was performed in CATIA V5 and later imported into Ansys. The variant to be used can be seen in Fig.3.

Three planes have been created in Space Claim to apply the supports and movements. These planes are highlighted with indices one, two and three.

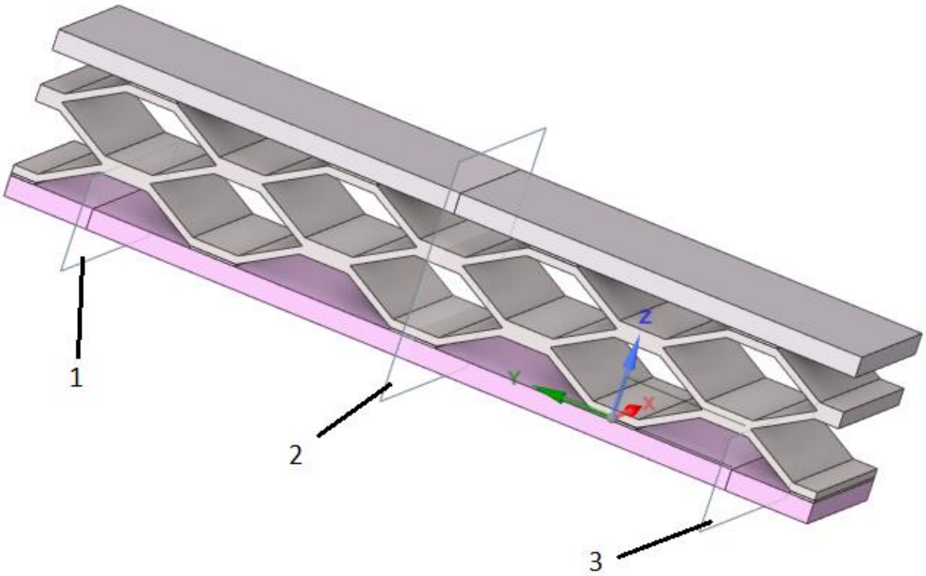

Fig. 3. Geometry and highlighting of the three planes

A controlled discretization was used so that the elements were predominantly quadrilateral and had a size of 1 mm. Due to the appearance of a single element on the thickness of the structure it has been necessary to use the function "Element Order" → "Quadratic". The use of a single element on the thickness of a structure should be avoided as this may influence the results. In Fig. 4 it has been represented the structural mesh.

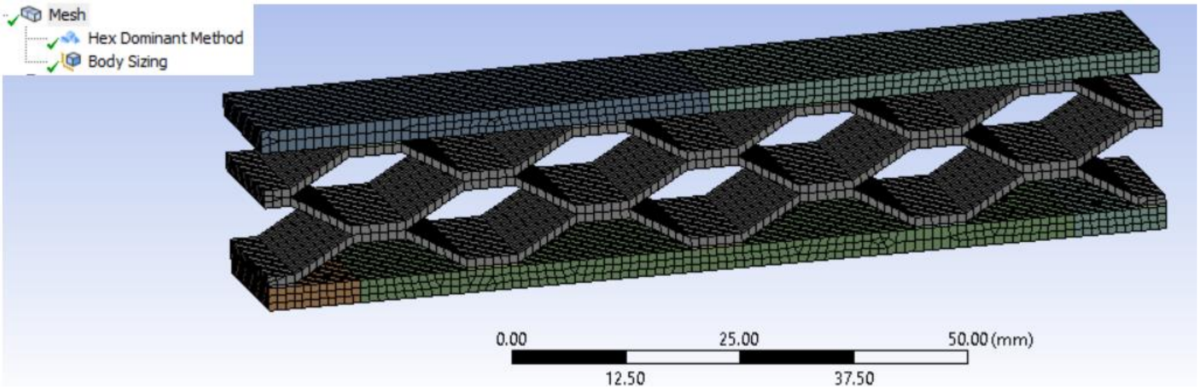

Fig. 4. Structure mesh

The boundary conditions were applied as it can be seen in Fig.5. A 1.88 mm "Displacement" was applied at the top, and a "Displacement" was also applied at the bottom so it will allow the structure to move only along the z axis.

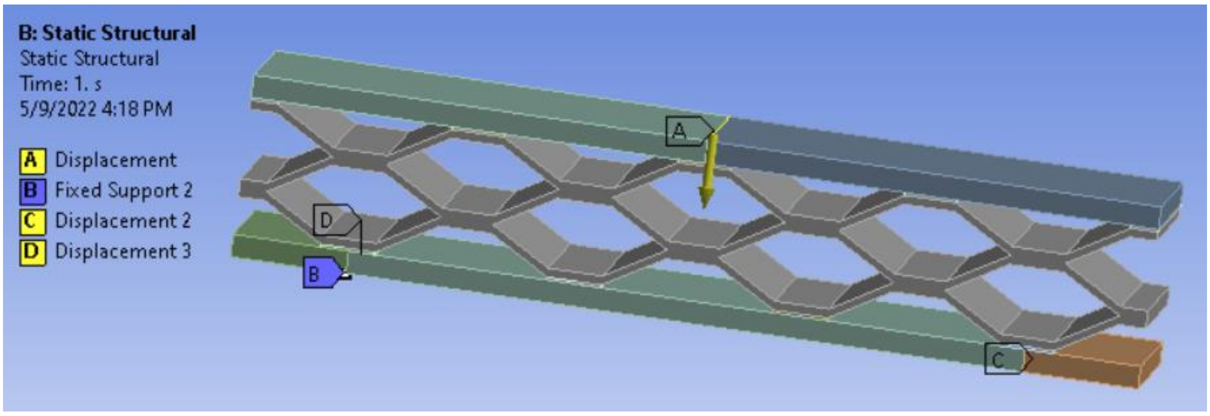

Fig. 5. The boundary conditions

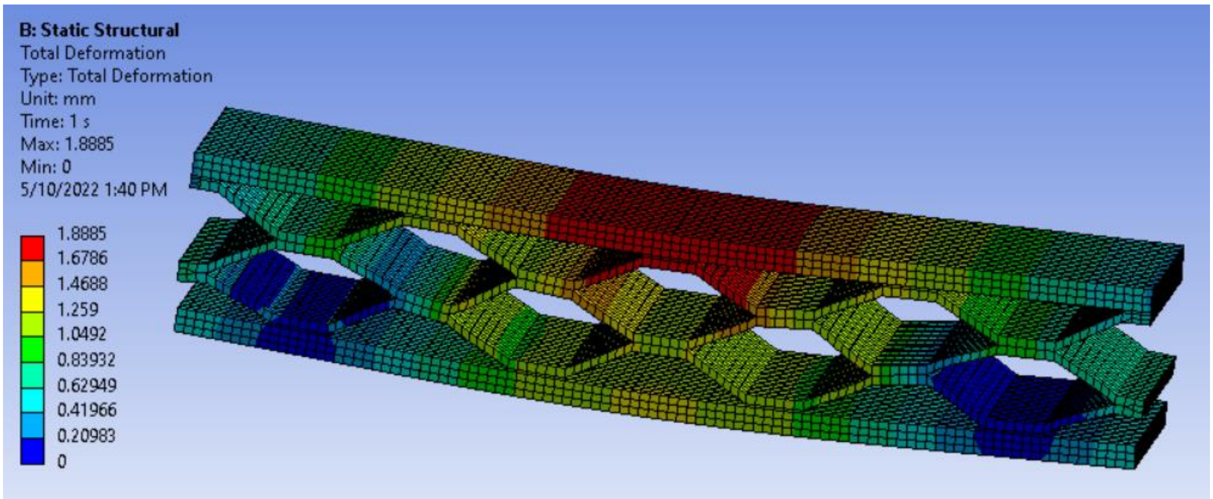

Fig. 6. Total displacement [mm]

3. The experimental part

3D printing is a process of forming a solid three-dimensional object of any shape. 3D printing is also distinct from traditional processing techniques, which are mainly based on the removal of materials by methods such as cutting.

The Fig.6 depicts the Vertex 3D printer that was used to print the PLA core.

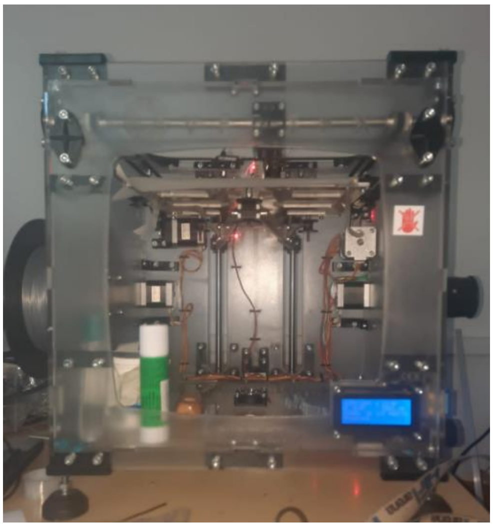

Fig. 8. Vertex 3D printer

CURA is an open-source application for 3D printers. It was created by David Braam, who was later hired by ULTIMAKER, a 3D printer company, to maintain the software. The CURA was originally released under version three of the Affero General Public License with open source, but on September 28, 2017 the license was changed to LGPLv3. This change has allowed for better integration with third-party CAD applications.

In Fig. 9 is the 3D printer that was used is marked with index one. The second index marks the two print heads of the printer. It can be seen that one head is inactive and the second one is assigned the material, PLA.

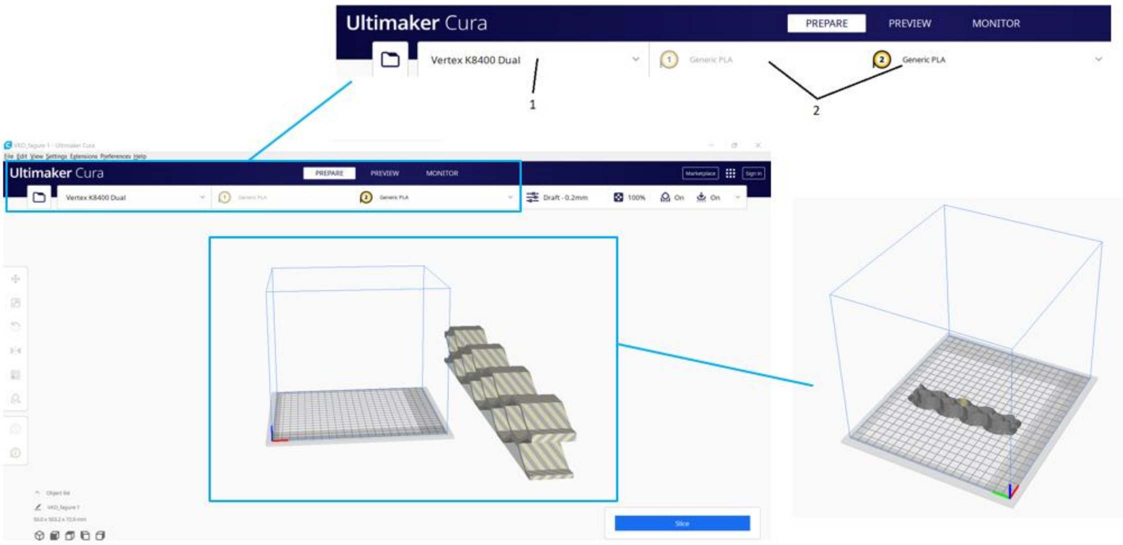

Fig. 9. Soft interface ULTIMAKER CURA

A virtual version of the 3D printer is generated on the right side of the new figure, so that the operator can estimate the maximum dimensions that he can use for a structure.

Once the structure has been dimensioned and positioned inside the virtual printer, a preview can be given to make sure everything is compliant.

The transfer of data from the program to the 3D printer was performed using an SD card. In order to access the geometry, the printer is equipped with a digital display like the one in the figure 10.

Fig. 10. 3D printer digital display

This screen shows us more information about printing. 190/200 ° meaning the temperature at which the printhead is located and 22/0 ° the ambient temperature. SD means that the structure being printed is on an SD card. It is not necessary for the geometry to be on the card, the printer can also print directly from the computer, however there is the possibility of a time delay, which could affect the structure leaving gaps.

That percentage of 22% refers to the percentage that the piece reached during printing, and below the word "Printing ..." suggests that printing is in progress.

This printer can use one or two printheads. If two printheads are used, the structure can have two colors. In our case it has been used a single printhead.

Fig. 11 shows the print head on the right side, the red LED indicating that the printing of the structure is in progress and on the left side you can see the roll of PLA filament that has been used.

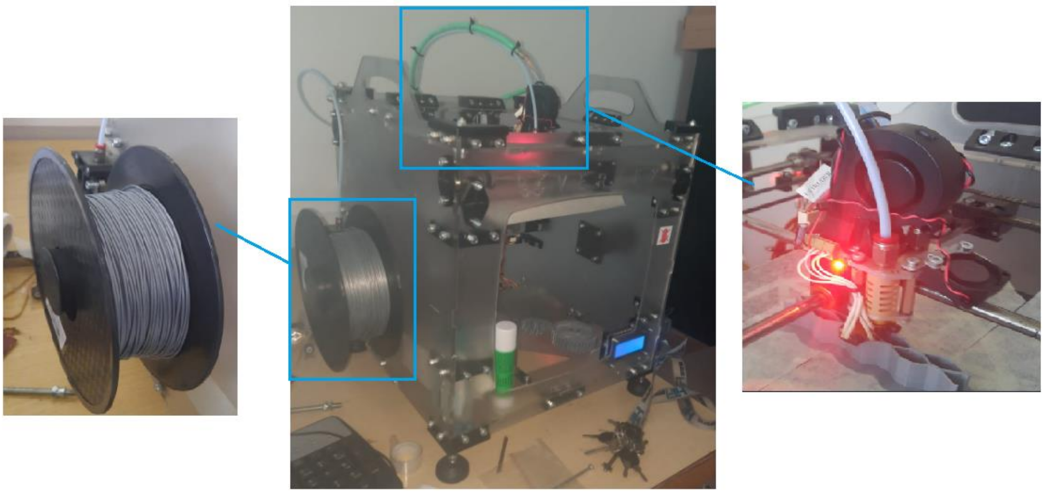

Fig. 11. 3D printer and they component

Polylactic acid (PLA) is a thermoplastic aliphatic polyester produced from renewable resources, such as corn starch (in the United States) or sugar cane in the rest of the world. It is biodegradable under certain conditions, such as the presence of oxygen, and is difficult to recycle.

The 3D printing filament is the thermoplastic raw material for 3D melt molding printers. There are many types of filaments with different properties that require different printing temperatures. The filament is commonly available in the two standard diameters of 1.75 mm and 2.85 mm.

PLA polymers range from amorphous glassy to semi-crystalline and highly crystalline polymer, with a glass transition of 60–65 ° C, a melting point of 130–180 ° C, and a Young modulus of 2.7–16 GPa. PLA is heat resistant, up to 110 ° C.

After the tiles were cut to the desired size, they were sanded at a 45° angle for better adhesion of the adhesive. They were degreased with industrial acetone and avoided touching them so as not to leave a layer of grease on them, as the adhesion of the adhesive would have been negatively affected

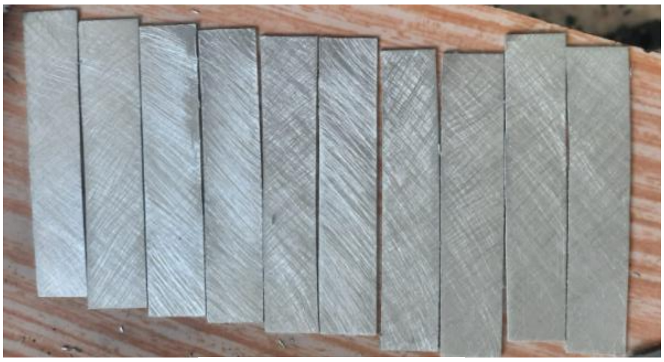

Fig. 12 Aluminum plates

Fig. 13 shows the adhesive that was used, which is a metal adhesive. It can be seen that it consists of two tubes, inside one of them being the base, and inside the second one being the hardener. I tried to put an equal amount of both in the plastic holder and mix them until a homogeneous substance was formed.

Fig. 13 Adhesive

The sandwich beam was subjected to a -point bending test as can be seen in Fig. 14. In order not to stress only the aluminum plates, the structure was supported in the area where the aluminum comes in contact with the PLA, and the displacement of was placed in the middle of the beam following the same principle. The required displacement was considered to be 1 mm/ min.

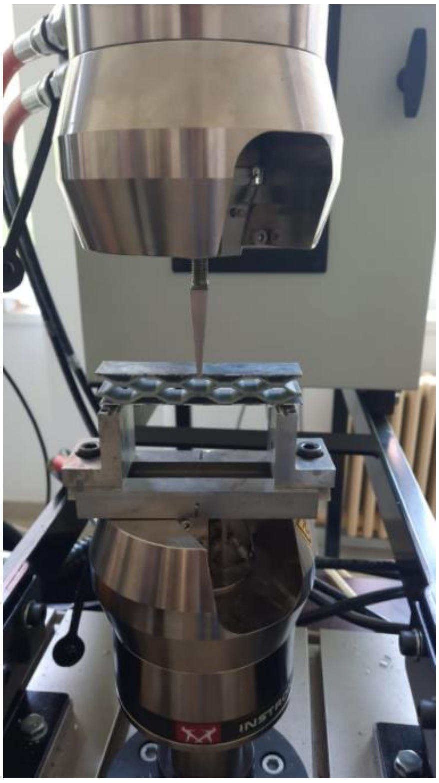
Fig. 14. Equipment used to perform three-points bending

3. Comparison of results

Table 2 shows the experimentally obtained data for the five samples. Sample one and sample two are the tests that failed due to incorrect application of the adhesive, and test four and five are the tests in which the core of the PLA failed. Sample three is a mixture of the previous ones, in this case it was observed that both the PLA core and the adhesive gave way.

Table 2. Experimental data

	Maximum Force [kN]	Maximum Displacement [mm]
1	0.48	1.6
2	0.34	1.21
3	0.54	2.22
4	0.56	2.26
5	0.5	2.13
Arithmetic average	0.484	1.88

From Table 3 it can be seen that the maximum displacement is the same because for the finite element analysis no force was used but an imposed displacement. To observe the difference between the results obtained experimentally and those obtained with F.E.M. we must look at the reaction of the forces. The difference of 0.126kN is an acceptable error.

Table 3. Comparison between experimental and numerical results

Results	Maximum Force [kN]	Maximum Displacement [mm]
Experimental	0.484	1.88
F.E.M	0.610	1.88

4. Conclusions

Following this test, it can be seen that samples one and two failed due to the way the adhesive was applied, while samples four and five failed due to rupture of the core of the PLA. Instead, sample three is a mix between the two failure modes. Due to the small size of the beam, buckling was avoided.

In order to allow the sample to move only vertically, "Fixed Support" was applied at one point, which is not possible in reality. Although there is only one element on the thickness of the core, this does not affect because we used "Qadratic" elements.

The loading was done gradually with a mm / minute to avoid obtaining unrealistic results. We made sure that the movement and the constraints were on one of the edges of the core, not in the empty spaces.

A very small difference can be seen by comparing the results. Experimentally the obtained force was 0.484 kN and through FEM a value of 0.610 kN was obtained.

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