Master's Thesis Engineering Technology

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Simulating and testing the effect of layer build-up on impact resistance of the backsheet for lightweight PV-applications

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Master of Electromechanical Engineering Technology

Introduction

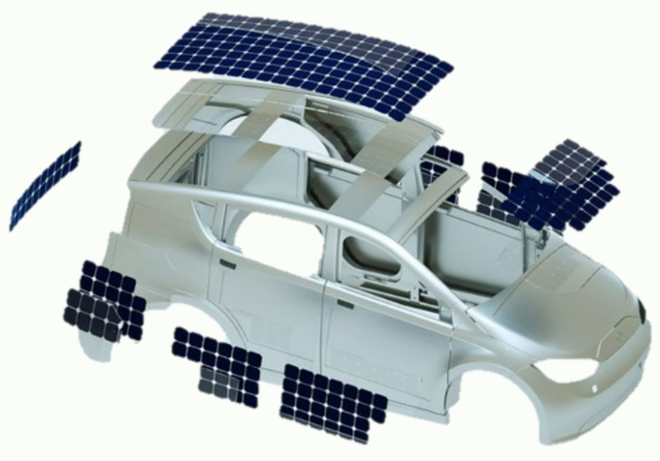

Figure 1: Example of a VIPV-application [1]

Due to the rapid implementation of electric vehicles, the possibility of integrating photovoltaics (PV) onto the body of these cars, as shown in figure 1, becomes interesting. Materials used for **vehicle-integrated photovoltaics** (VIPV) must be **lightweight** to keep the weight of a car to a minimum. Due to the absence of a glass plate, the **impact resistance** of lightweight PV modules is almost fully defined by the backsheet [2]. A backsheet is highlighted in figure 2. In this master's thesis the use of carbon fibre-reinforced polypropylene (CFPP) and glass fibre-reinforced polypropylene (GFPP) as a backsheet material in lightweight PV applications is tested and simulated in Ansys Workbench.

The main goal of this thesis is to **accurately simulate** these composite materials as **computationally light** as possible to later be integrated into more extensive FEM-analyses. To achieve this, the materials first have to be **characterised**. Lastly, **impact behaviour** is **simulated and validated** via impact testing.

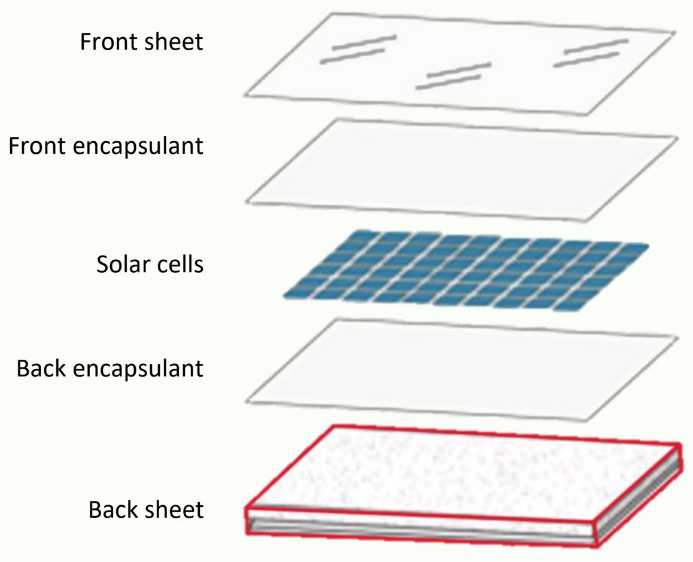

Figure 2: Build-up of a lightweight PV stack with backsheet indicated in red [3]

Materials and Methods

Experiments

The laminates are **produced** using unidirectional tapes provided by Misumi Chemicals and BüFA for CFPP and GFPP, respectively. Figure 4 shows a finished 8-ply CFPP-laminate.

To obtain the material properties **three-point bending tests** according to the ISO-14125 standard were conducted. Specimens of different thickness were tested for CFPP and GFPP using symmetric and asymmetric layups.

An **impact setup** dropping a 200g steel ball from adjustable heights was designed and constructed, as shown in figure 3. The ball was dropped onto 350mm x 350mm sheets of CFPP and GFPP with different thicknesses. The effect of the addition of encapsulant material and a PET sheet were also tested. The deflection of the test sheet was measured using a laser triangulation sensor.

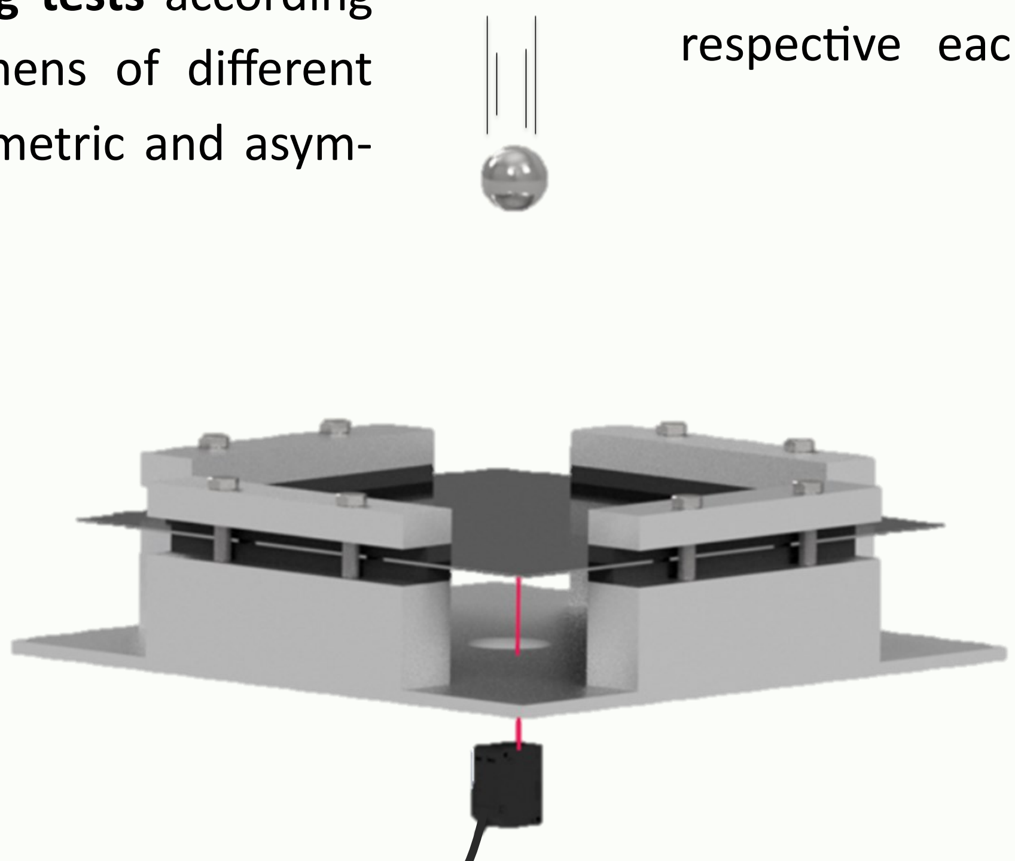

Figure 3: Used clamping setup with laser displacement sensor

FEM simulation

The **three-point bend test** was simulated using Ansys Composite Preprocessor (ACP), shown in figure 5. This module models each layer of the laminate as a layer of solid-shell elements. The material properties for respective each layer were assigned using element orientation.

The **impact test** was simulated in Ansys Explicit Dynamics. The laminate was modelled as a single layer of laminate with equivalent properties of the stackup or **Equivalent Single Layer (ESL)**. A linear elastic model was used with values from the bending test for the elastic modulus and values from literature for the shear modulus. Figure 6 shows the result of an impact test simulation.

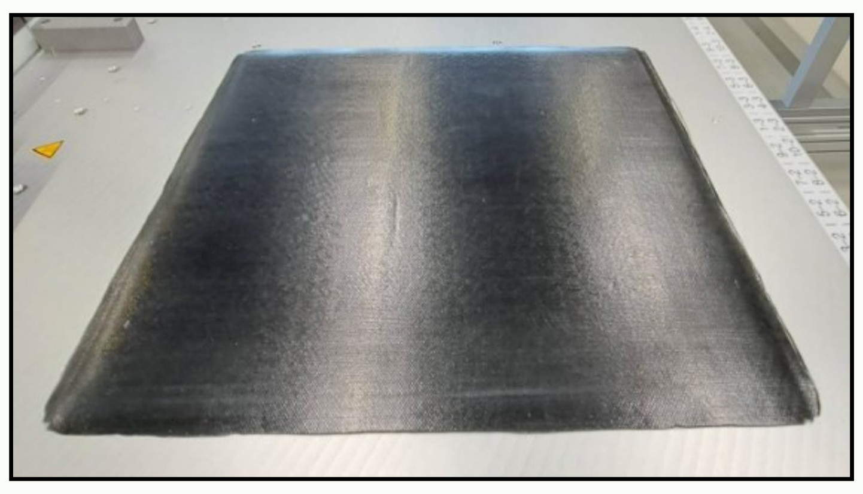

Figure 4: Finished 8-ply CFPP-laminate

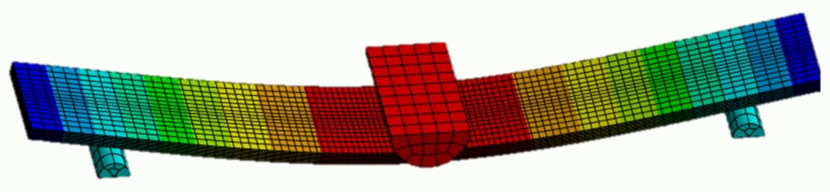

Figure 5: Result of an 8-ply CFPP stack with lateral first and last layer under three-point bending

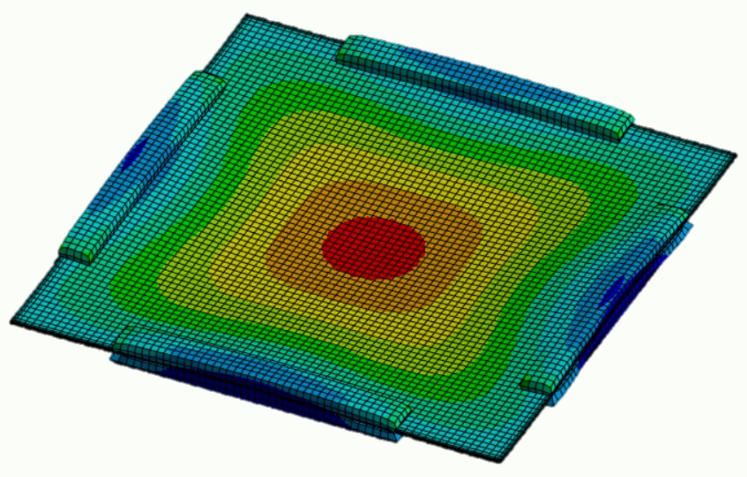

Figure 6: Results of an 8-ply CFPP stack at maximum displacement after impact

Results

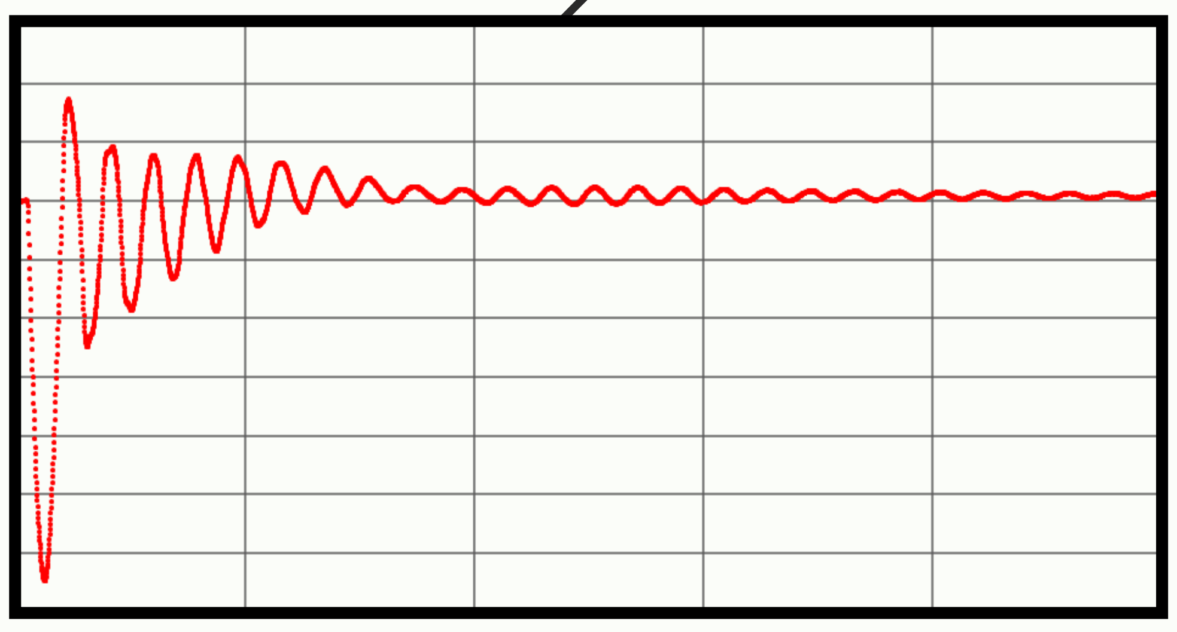

Figure 7: Impact measurement of an 8-ply CFPP stack

Figure 7 shows a typical impact response of a laminate. Table 1 shows the maximal displacements in both simulation and experimentally obtained.

The simulations of the bending tests were all within an error of 10%. Using the maximal deflection given in the model, a flexural modulus can be obtained for every specimen that can be made in ACP, which can then be implemented in the impact model as an equivalent single layer (ESL).

For the impact test, on average, the model was able to predict the deflection 97% accurately for CFPP and 87% accurately for GFPP for drop heights of 2 m, 2.5 m, and 3 m for the test laminates shown in Table 1 using an ESL model. The deflection of the laminate with encapsulants and PET was marginally different from the deflection measured without.

Table 1: Maximum displacements measured and simulated after impact on symmetric configurations

Stackup	Experimental [mm]	Simulation [mm]	Error [%]
8L CFPP	13.31	12.28	8.1
12L CFPP	9.94	10.50	5.5
16L CFPP	7.11	8.27	14.8
8L GFPP	18.68	18.52	0.9
12L GFPP	16.24	15.12	7.1
16L GFPP	13.99	12.89	8.2

Conclusion

Despite the use of a linear elastic material model, the simulations were able to accurately predict the behavior upon impact of CFPP and GFPP using an equivalent single layer model.

Although the available computing power was low, the findings suggest that a composite backsheet can be simulated using an equivalent single layer model regarding impact. The importance of the backsheet was experimentally verified by testing configurations with and without multiple layers of encapsulation and a frontsheet.

References

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[2] J. P. Martins, J. Garćıa-Ramos, F. Belo, A. P. Tavares, A. F. Fernandes, R. P. Pinto, and A. Mateus, "Robust glass-free lightweight photovoltaic modules with improved resistance to mechanical loads and impact," Materials Today Energy, vol. 11, pp. 63–71, 2019.
[3] C. Schinke, "Lightweight pv module approach-field test study and yield evaluation," Solar Energy Materials and Solar Cells, vol. 141, pp. 244–249, 2015.

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