Process development of integrated photovoltaic cells in a double-curved composite structure for Vehicle-Integrated PhotoVoltaics (VIPV) application

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Topics and investigations

The automotive industry is changing to lightweight materials and more energy-efficient vehicles. PV modules have a potential market in this transition. Rigid PV panels integrating silicon cells built directly into the car body outperform thin flexible solar films in terms of efficiency and reliability. To increase the integration of PV modules into the car, the use of composite materials is an interesting option, as they offer an efficient combination of mechanical performances and lightweight. However, the high heterogeneity of the components, the impermeability of the cells and the necessary achievement of certain optical characteristics make it necessary to adapt the usual manufacturing processes of composite panels. Thus, this study focuses on the adaptation of manufacturing processes for the production of composite double-curved PV modules. Moreover, it treats with a coupled numerical and experimental approach the aspect of thermomechanical stresses resulting from these processes.

Methods

Two processes are being developed, that use composite materials and not only polymers or glass, like most VIPV actors do. These processes - thermocompression and Resin Transfer Molding (RTM) – are more adapted to the automotive industry constraints than lamination.

As a first step towards the development of the RTM process, the early prototypes were produced using vacuum bagging process, which facilitates the selection of materials and stacks for injection processes.

A new numerical model is developed with a Finite Element Analysis to optimize the process parameters and the layup for a one-cell composite PV module.

Results

A double curved composite PV module was manufactured using vacuum bagging process. This step enabled to select the most appropriate materials and process parameters for the RTM process, in terms of transparency, adhesion between the encapsulant and plies, diffusion of the resin, ageing behavior …

A first numerical model (Figure 2) was developed. This model is validated by 3-point bending tests. The correlation between tests and numerical simulation is very good, with a relative error of around 5%.

The thermocompression process is under development. It still represents a challenge in terms of residual stresses resulting from thermomechanical loading. The ongoing developments on the numerical model aim at optimizing the stack and thermocompression parameters to minimize these stresses.

Conclusions and perspectives

Two processes are developed. This work enabled to size a double-curved PV module with composite front and back sheets. It is applicable to either the automotive industry or any application needing lightweight and curved PV modules. The experimental tests validate the mechanical model and provide other properties like the photoelectric performance and the ageing behaviour of these curved panels with respect to IEC61215 standard. Further researches include the optimization of the composite layout and processes parameters to minimize weight while keeping high mechanical strength, as well as the optimization of the reliability and performance of the module.

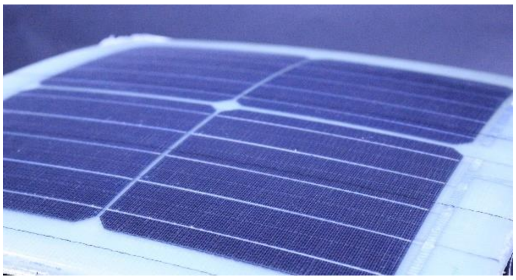

Figure 1 - Double-curved composite module produced by vacuum bagging process

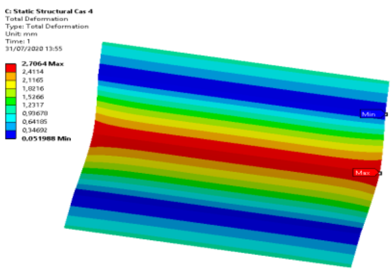

Figure 2 - Validation of the numerical model: simulation of the 3-point bending test