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Mechanical Testing of Composite Materials for Monocoque Design in Formula Student Car

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Abstract : Inspired by the Formula-1 competition, IMechE (Institute of Mechanical Engineers) and Formula SAE (Society of Mechanical Engineers) organize annual competitions for University and College students worldwide to compete with a single-seat race car they have designed and built. The design of the chassis or the frame is a key component of the competition because the weight and stiffness properties are directly related with the performance of the car and the safety of the driver. In addition, a reduced weight of the chassis has a direct influence on the design of other components in the car. Among others, it improves the power to weight ratio and the aerodynamic performance. As the power output of the engine or the battery installed in the car is limited to 80 kW, increasing the power to weight ratio demands reduction of the weight of the chassis, which represents the major part of the weight of the car. In order to reduce the weight of the car, ION Racing team from the University of Stavanger, Norway, opted for a monocoque design. To ensure fulfilment of the above-mentioned requirements of the chassis, the monocoque design should provide sufficient torsional stiffness and absorb the impact energy in case of a possible collision. The study reported in this article is based on the requirements for Formula Student competition. As part of this study, diverse mechanical tests were conducted to determine the mechanical properties and performances of the monocoque design. Upon a comprehensive theoretical study of the mechanical properties of sandwich composite materials and the requirements of monocoque design in the competition rules, diverse tests were conducted including 3-point bending test, perimeter shear test and test for absorbed energy. The test panels were homemade and prepared with an equivalent size of the side impact zone of the monocoque, i.e. 275 mm x 500 mm so that the obtained results from the tests can be representative. Different layups of the test panels with identical core material and the same number of layers of carbon fibre were tested and compared. Influence of the core material thickness was also studied. Furthermore, analytical calculations and numerical analysis were conducted to check compliance to the stated rules for Structural Equivalency with steel grade SAE/AISI 1010. The test results were also compared with calculated results with respect to bending and torsional stiffness, energy absorption, buckling, etc. The obtained results demonstrate that the material composition and strength of the composite material selected for the monocoque design has equivalent structural properties as a welded frame and thus comply with the competition requirements. The developed analytical calculation algorithms and relations will be useful for future monocoque designs with different lay-ups and compositions.

Keywords : composite material, Formula student, ION racing, monocoque design, structural equivalence
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