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Automation of Finite Element Simulations for the Design Space Exploration and Optimization of Type IV Pressure Vessel

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Abstract : Fuel cell vehicle has become the most competitive solution for the transportation sector in the hydrogen economy. Type IV pressure vessel is currently the most popular and widely developed technology for the on-board storage, based on their high reliability and relatively low cost. Due to the stringent requirement on mechanical performance, the pressure vessel is subject to great amount of composite material, a major cost driver for the hydrogen tanks. Evidently, the optimization of composite layup design shows great potential in reducing the overall material usage, yet requires comprehensive understanding on underlying mechanisms as well as the influence of different design parameters on mechanical performance. Given the type of materials and manufacturing processes by which the type IV pressure vessels are manufactured, the design and optimization are a nuanced subject. The manifold of stacking sequence and fiber orientation variation possibilities have an out-standing effect on vessel strength due to the anisotropic property of carbon fiber composites, which make the design space high dimensional. Each variation of design parameters requires computational resources. Using finite element analysis to evaluate different designs is the most common method, however, the model-ing, setup and simulation process can be very time consuming and result in high computational cost. For this reason, it is necessary to build a reliable automation scheme to set up and analyze the di-verse composite layups. In this research, the simulation process of different tank designs regarding various parameters is conducted and automatized in a commercial finite element analysis framework Abaqus. Worth mentioning, the modeling of the composite overwrap is automatically generated using an Abaqus-Python scripting interface. The prediction of the winding angle of each layer and corresponding thickness variation on dome region is the most crucial step of the modeling, which is calculated and implemented using analytical methods. Subsequently, these different composites layups are simulated as axisymmetric models to facilitate the computational complexity and reduce the calculation time. Finally, the results are evaluated and compared regarding the ultimate tank strength. By automatically modeling, evaluating and comparing various composites layups, this system is applicable for the optimization of the tanks structures. As mentioned above, the mechanical property of the pressure vessel is highly dependent on composites layup, which requires big amount of simulations. Consequently, to automatize the simulation process gains a rapid way to compare the various designs and provide an indication of the optimum one. Moreover, this automation process can also be operated for creating a data bank of layups and corresponding mechanical properties with few preliminary configuration steps for the further case analysis. Subsequently, using e.g. machine learning to gather the optimum by the data pool directly without the simulation process.

Keywords : type IV pressure vessels, carbon composites, finite element analy-sis, automation of simulation process
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