

Comparison of integrated functions in a multifunctional sandwich composite rail car body

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EXTENDED ABSTRACT

Sandwich composite panels offer significant weight-saving potential for rail vehicle car bodies (walls, roofs, floors), thereby improving energy efficiency and reducing environmental impact compared to traditional steel and aluminium structures. Conventional car bodies made of metal structures offer high stiffness and strength, but additional materials are needed to fulfil acoustic and thermal requirements. Smart sandwich structure designs can meet these requirements, while also maintaining the fire safety standards. Traditionally, car body materials are evaluated solely based on structural requirements; however, excluding additional materials needed for acoustic and thermal performance can lead to an incomplete or misleading comparison when identifying the most suitable material. For the material selection process Granta Edupack's material database was used. Core materials were evaluated based on yield strength, compressive modulus, compressive strength, shear modulus, shear strength, thermal conductivity, and acoustic velocity, meanwhile face materials were evaluated based on elastic modulus, yield strength, tensile strength, and compressive strength. Due to limited information on flammability in the material data base, that performance indicator was omitted from the current scope, but could be an indicator of interest. The effects of the material properties were also tested on the density and the price per unit volume of the materials. Sensitivity analyses were conducted by systematically varying critical property thresholds and observing their impact on the number of

suitable materials available, as well as on the other performance properties. The base values for the interdependency comparison were chosen based on the rail vehicle standards. These values are good indicators for the eligibility of the materials, but it is important that the structure and the load cases can modify the final requirements. The sensitivity analysis (Figure 1) revealed that thermal conductivity had the most significant impact on core material selection, substantially affecting structural property requirements. Specifically, tightening thermal conductivity criteria dramatically reduced the number of available core materials and restricted feasible structural properties such as yield strength and shear modulus. Conversely, relaxing thermal conductivity constraints significantly broadened material options without negatively impacting other performance criteria. For face materials, the elastic modulus was found to have the strongest influence on tensile strength. Stringent elastic modulus requirements excluded aluminium alloys, narrowing choices to steel and fibre composites. Fibre composites consistently met or exceeded structural requirements while also demonstrating lower densities and potentially lower costs per unit volume compared to steel and aluminium alloys. The results emphasize the critical importance of carefully selecting appropriate performance criteria in sandwich composite material design for rail vehicles. Excessively stringent criteria, particularly related to thermal conductivity and elastic modulus, can severely limit material options without providing proportional performance benefits. Hence, it is essential to critically evaluate which criteria are genuinely necessary and achievable. A multifunctional and integrated design approach, considering interactions and trade-offs between structural, thermal, acoustic, and economic aspects, is crucial for optimizing material and structural selections. This strategy enables designers to identify either suitable materials with the desired properties or to adapt structural designs to compensate effectively for certain material property limitations.

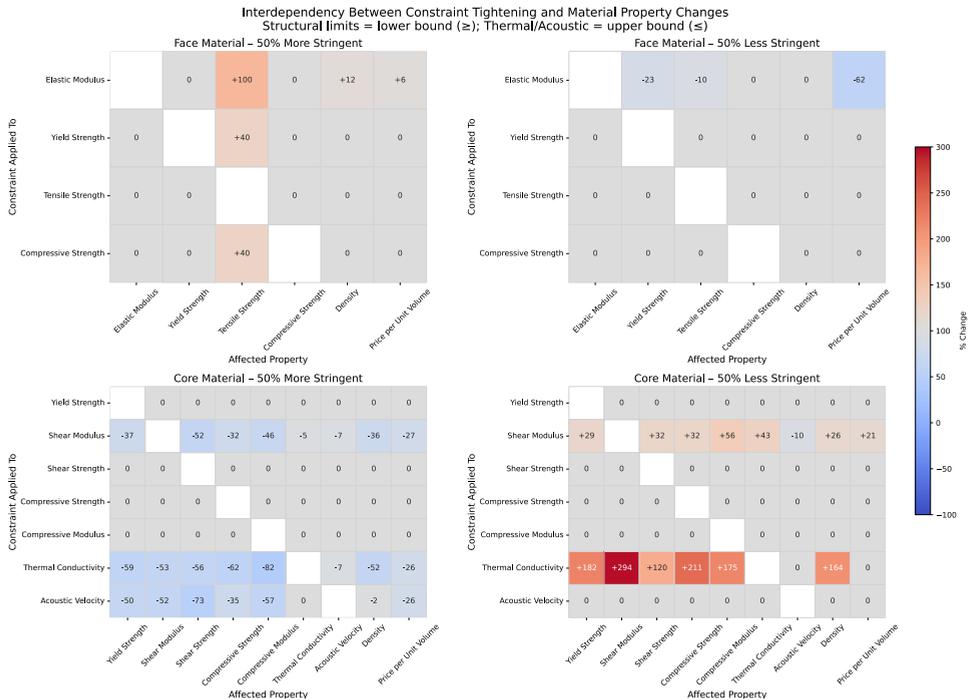


Figure 1: Heatmap visualization of interdependencies between property constraints and resulting material property changes.

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