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# Design of lightweight multi-material automotive bodies using new material performance indices of thin-walled beams for the material selection with crashworthiness consideration

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ABSTRACT

Currently, automotive bodies are constructed usually using a single material, *e.g.* steel or aluminum. Compared to single-material automotive bodies, multi-material automotive bodies allow optimal material selection in each structural component for higher product performance and lower cost. This paper presents novel material performance indices and procedures developed to guide systematic material selection for multi-material automotive bodies. These new indices enable to characterize the crashworthiness performance of complex-shaped thin-walled beams in multi-material automotive bodies according to material types. This paper also illustrates the application of these performance indices and procedures by designing a lightweight multi-material automotive body. These procedures will help to design a lightweight and affordable body favored by the automotive industry, thus to reduce fuel consumption and greenhouse gas emissions.



## 1. Introduction

Vehicle weight reduction has been considered as one of the most important solutions to improve fuel economy and reduce harmful emissions. In recent years, there have been growing concerns over fuel consumption and pollution caused by the increasing number of automobiles, and the automotive industry is under great pressure to reduce fuel consumption and emissions. One solution to these problems is to reduce a vehicle's weight, because 57 kg weight reduction is equivalent to 0.09–0.21 km per liter fuel-economy increase [1]. This reduction is critical especially these days, as the fuel costs are rising and concerns on the climate change are growing.

It is believed that the vehicle body weight can be reduced by the use of multiple materials without cost increase. Various lightweight automotive bodies have been developed using high strength steels [2,3], aluminum alloys [4,5] and composite materials [6]. These special materials can provide lighter weight car bodies. However, the high prices of these special materials have been one of the main barriers to replacing steel with these materials [7]. Therefore, some studies [5,8–10] have argued that the multi-material car bodies are solutions to these problems.

The design of optimized multi-material automotive bodies requires novel material performance indices to effectively evaluate the advantages and disadvantages of using such multiple materials for complex-shape structural components. The concept of the multi-material use is that the right material types are used in the right locations for the desired product functions. Various methods have been developed for such material selection [11–13]. For example, Ashby' method [11] defines a material performance index, and then ranks materials based on the performance index to select the best one for the optimal design of beams, shafts, panels, etc. Many performance indices have been developed for structures with simple geometries. However, the structural beam components of automotive bodies such as A-pillars, B-pillars, cross members, rails and rail extensions do not have such simple structures. Therefore, there is a need to develop performance indices for more geometrically complex structures, which are usually common in automotive bodies.

Furthermore, in spite of their practical importance, material performance indices for automotive body assemblies have been addressed only in limited aspects of body performance. In general, the material selection problems were studied extensively. Several monographs describe general theories and procedures on material selection [11,14]. The role of knowledge-based material selection was described in the context of concurrent engineering [15]. Structural optimization was applied for the choice of materials considering the environmental impact of materials [16] and for

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