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Using Quality Function Deployment and Analytical Hierarchy Process for material selection of Body-In-White

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ABSTRACT

Presented manuscript discusses the usage of multi-attribute decision making tools to assist in the material selection for vehicular structures; mainly the automotive Body-In-White (BiW) panels at the conceptual design stage using Quality Function Deployment (QFD) and Analytical Hierarchy Process (AHP). The main advantage of using QFD and AHP is their abilities to rank choices in the order of their effectiveness in meeting the functional objective. AHP discriminates between competing options where interrelated objectives need to be met; AHP is based on straightforward mathematical formulations. QFD on the other side is a customer focused method that usually starts by collecting customer needs and tries to integrate these needs into the product. In this study, following classes of engineering materials are analyzed; forming grade Bake Harden-able steel (BH), Dual Phase steel (DP), High Strength Low Alloy Steel (HSLA), Martenistic steel, Aluminum 5xxx, 6xxx sheets, Magnesium sheets, Titanium sheets, Carbon Fiber Reinforced Plastic (CFRP) and High Density Polyethylene (HDPE). The presented study showed that the different grades of steel gained the first ranks in the selection process for almost most of the BiW panels; however other alternatives could work in trade-off with cost and manufacturability.

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1. Introduction

New trends in vehicle light-weighting not only aim at enhancing the vehicle fuel efficiency, but also at improving its driving performance in addition to lowering its emissions [1]. Weight saving might be achieved through replacing current high density materials such as steel, in chassis and suspension, and other power-train and driveline vehicular sub-systems with lightweight to achieve small weight savings. However, significant improvements in vehicle efficiency in terms of the mile per gallon will require larger reductions in the vehicle weight. To quantitatively describe the relationship between the vehicle weight and its fuel efficiency, several correlations have been proposed and are listed through

$$MPG = 895.24\ (mass^{-0.463}) \quad (1)$$

$$MPG = 8627.4\ (mass^{-0.74584}) \quad (2)$$

$$mass = 2.015 \times FE^2 - 194.85 \times FE + 6375.54 \quad (3)$$

where the *MPG* is the mile per gallon and the *mass* is the curb weight in Lbs, while the *FE* is the fuel economy.

Inspecting these equations one can conclude that in average a weight reduction of 10% of the total vehicle curb weight can only lead to about 5% improvement in the fuel efficiency. That means that major weight reductions (>10%) are required to have any tangible effects on the vehicle fuel consumption. Automotive designers typically target the vehicle main structure or Body-In-White BiW for weight reduction activities because; any weight savings from the vehicle interior trim affects its comfort options (e.g. motorized seats, etc.), while any weight savings from the power-train imparts the vehicle mobility function, both of these effects hinder the vehicle marketability. Fig. 1 displays the weight distribution of a typical sedan, with the BiW weight comprises around 20–25% of the total vehicle curb weight.

The direct replacement of steel structures with other less dense materials has been the usual route for earlier light weight engineering efforts, especially using more Aluminum in the BiW. However this trend is challenged by the following: (a) the complexity associated in forming aluminum using the standard press based stamping, which limits the minimum bending radius to panel thickness ratio hence limiting the geometries, and design features which in turn affect the vehicle styling and limiting the use of

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