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A material and gauge thickness sensitivity analysis on the NVH and crashworthiness of automotive instrument panel support

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Abstract

This paper provides a finite element analysis of the effects of using alternative materials and gauge thickness on the weight and structural performance of the VN127 instrument panel support. Two types of analyses were performed, NVH and crashworthiness. The NVH analysis was used to determine the structure's natural frequencies, whereas the crashworthiness analysis was used to examine the structure's crash behavior under two different impact conditions. The materials used in this study included mild steel, aluminum and magnesium alloys. The thickness of the structure was varied from 0% to 40%, in increments of 10%. The results of different models were compared with the baseline model, i.e., the mild steel model with nominal thickness. It was found that by replacing mild steel with aluminum alloys, and increasing the gauge thickness of the structure by 40%, the NVH and crashworthiness performance of the structure was equivalent to the baseline model.

Keywords: NVH; Crashworthiness; Instrument panel support; Cross-car-beam

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1. Introduction

A major challenge in today's automotive industry is to reduce the weight of conventional steel vehicles without compromising their structural performance and safety. The major driving forces behind this weight reduction arise mainly from today's customers who are always demanding highly fuel-efficient vehicles and those tougher environmental legislations set by the government. Based on extensive practical experience and studies, the most promising way to reduce vehicle weight is to use alternative vehicle designs and manufacturing materials. Weight savings from alternative vehicle designs can be achieved by downsizing the vehicle or re-designing vehicle components. Other manufacturing materials, such as high strength steels, aluminum, magnesium and titanium, allow engineers to use less material in a component or reduce its density, thereby saving the vehicle weight. Although weight saving can be achieved by these design and material alterations, they must also maintain or improve the vehicle performance compared with that achieved by the conventional steel vehicle. These performance requirements basically include the noise, vibration and harshness (NVH) performance, the crashworthiness performance according to the Federal Motor Vehicle Safety Standard (FMVSS) as well as the durability performance of the vehicle.

In the last two decades, several non-ferrous materials have been investigated and many of them have been successfully integrated into various vehicles at the component level. Many engine blocks, cylinder heads, oil pans, hoods, outer panels and rail structures in vehicles are nowadays manufactured with aluminum alloys, whereas many steering wheels, steering column support brackets and seat base structures are made of magnesium alloys. With the successful use of non-ferrous alloys to manufacture some of the vehicle components, many automotive companies and original equipment manufactures (OEMs) are cooperating to improve the weight and structural performance for every vehicle component. However, building a new prototype of the steel counterpart for physical testing may be very costly and time consuming. Even for a simple component, it may be required to build many different prototypes for testing in order to achieve the final design. Therefore, actual physical testing is not recommended in the preliminarily design stage unless the final or near-final design has been reached. To cope with this problem, many engineers utilize finite element (FE) simulations to test the structural performance of components. These FE simulations always include static analysis for stress distribution and component deformation, modal analysis for NVH performance and impact analysis for crashworthiness performance. Usually, the prototype will not be built until a satisfactory result is obtained from those analyses.

Besides the aforementioned non-ferrous components, the instrument panel (I/P) support is another vehicle component that is worthy of investigation for its feasibility to be manufactured with lightweight alloys. In this paper, an existing I/P support, which is called the VN127 I/P support, was examined via FE simulations in order to investigate the effects of utilizing different materials and gauge thickness on the NVH and crashworthiness performance of the structure. One of the main goals of