

# Advanced lightweight materials and manufacturing processes for automotive applications

Alan I. Taub and Alan A. Luo

The global automotive industry is facing challenges in several key areas, including energy, emissions, safety, and affordability. Lightweighting is one of the key strategies used to address these challenges. Maximizing the weight reduction (i.e., minimizing vehicle weight) requires a systems-engineering design optimization and iteration process that combines material properties and manufacturing processes to meet product requirements at the lowest mass and/or cost. Advanced high-strength steels, aluminum and magnesium alloys, and carbon-fiber-reinforced polymers have emerged as important materials for automotive lightweighting. This article presents examples of how coupling materials science with innovative manufacturing processes can provide lightweight solutions in automotive engineering.

## Introduction

The machines that move people and goods on land, sea, and air have undergone major changes over the past 50 years, and the key enabler for the improvements has been the development of new materials and their associated manufacturing processes. Covering the broad nature of the materials and subsystems in the various transportation modes is well beyond the scope of this article. Therefore, we concentrate on automobiles, which, on an annual basis, consume the majority of the materials measured in both weight and cost used during the manufacturing of transportation machines.

## Automobile industry challenges

The large economies of scale available to the automotive industry have made vehicles affordable to growing numbers of people. Henry Ford designed the Model T to be “a motor car for the great multitude ... so low in price that no man making a good salary will be unable to own one.”<sup>1</sup> By 1955, the cost of a baseline Chevrolet Bel Air (USD\$1,725<sup>2</sup>) represented about 22 weeks of US wages.<sup>3</sup> Affordability promoted personal mobility, and by the mid-1950s, the North American auto industry was producing almost 10 million units per year (compared to about 17 million units per year today).<sup>4</sup> Global vehicle ownership has grown even more impressively: The industry produced just over

13.5 million units in 1950, but today is approaching 80 million units.<sup>4</sup> In 1950, there were fewer than 60 million vehicles on the planet. Today, the number of vehicles in use around the globe stands at well over 800 million, which corresponds to approximately 12% of the world’s population owning an automobile.

The dramatic growth in vehicles operated around the world has presented societal sustainability challenges, including safety, congestion, tailpipe emissions, and petroleum consumption.<sup>5</sup> Fuel economy has emerged as a particular concern. The focus on fuel economy first surfaced when the Organization of Petroleum Exporting Countries oil crises of 1973 and 1979 drove oil and gasoline prices sharply higher. The continued volatility of oil prices, coupled with concerns surrounding CO<sub>2</sub> emissions from the burning of fossil fuels, has made fuel economy one of the greatest challenges facing the transportation sector.

Since the invention of the powertrain over 100 years ago, the engineering community has innovated to continuously improve the internal-combustion engine. For example, the small-block 4.25-l V8 engine in a 1955 Chevrolet produced up to 195 hp (145 kW) at a volumetric efficiency of 45 hp/l (34 kW/l). Ninety million engines and four generations later, the small-block engine today displaces up to 6.0 l and achieves approximately 400 hp (298 kW), or roughly 70 hp/l (52 kW/l).

Alan I. Taub, Materials Science and Engineering Department and Integrated Systems Engineering Department, University of Michigan, USA, [alantaub@umich.edu](mailto:alantaub@umich.edu)  
Alan A. Luo, Department of Materials Science and Engineering, The Ohio State University, USA, [luo.445@osu.edu](mailto:luo.445@osu.edu)  
DOI: 10.1515/rens.2015.268

# Advances In Lightweight Materials For Automotive Applications

**L Cohen**



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