

Aerodynamic Development of the 2011 Chevrolet Volt

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ABSTRACT

This paper presents some of the challenges and successful outcomes in developing the aerodynamic characteristics of the Chevrolet Volt, an electric vehicle with an extended-range capability. While the Volt's propulsion system doesn't directly affect its shape efficiency, it does make aerodynamics much more important than in traditional vehicles. Aerodynamic performance is the second largest contributor to electric range, behind vehicle mass. Therefore, it was critical to reduce aerodynamic drag as much as possible while maintaining the key styling cues from the original concept car. This presented a number of challenges during the development, such as evaluating drag due to underbody features, balancing aerodynamics with wind noise and cooling flow, and interfacing with other engineering requirements. These issues were resolved by spending hundreds of hours in the wind tunnel and running numerous Computational Fluid Dynamics (CFD) analyses. The end result is a unique electric vehicle that, at start of production, has the lowest coefficient of drag, C_D , of any Chevrolet sedan.

INTRODUCTION

The Chevrolet Volt (Fig. 1) is an electric vehicle with extended-range capability powered by the Voltec electric propulsion system (Fig. 2). It consists of a 16 kWh lithium-ion battery, an electric drive unit, a 1.4-liter internal combustion engine generator, and a vehicle charge port. Able to re-charge the battery from a standard wall outlet, many drivers will consume no gasoline and utilize only battery power that provides the first 25-50 miles of range. Afterwards, the engine generator can deliver electric power for 300 more miles if needed. Extending the life of the battery to achieve the initial electric range and making the Volt as

fuel efficient as possible for the total extended mileage were key goals during its development. Aerodynamics played a crucial role in that quest. Engineers spent over 500 hours in the wind tunnel and thousands of cpu hours on the computer to refine the air flow around the vehicle.



Figure 1. The 2011 Chevrolet Volt.

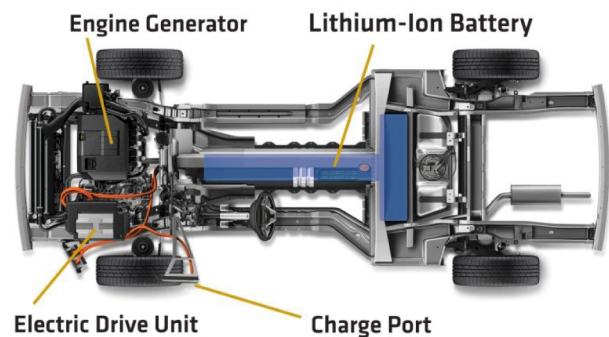


Figure 2. The Voltec electric propulsion system.

VOLT AERODYNAMICS

Drag Requirements for Fuel Economy

Aerodynamic requirements on any given vehicle are determined by top speed, handling, and fuel economy needs. For efficiency cars, aerodynamic drag is to be minimized for vehicle energy conservation. Once the electric and extended range objectives were determined on the Volt, the required drag coefficient was backed out. On conventional vehicles, aerodynamic drag is usually the third largest energy loss, behind powertrain friction and vehicle mass. On the Volt system, losses from the electric drive unit are less significant, leaving mass and aero drag as the main fuel economy enablers. However, in an electric vehicle where much of the weight is fixed due to battery capacity, efficiency is much more sensitive to percentage changes in C_D , rather than mass. This fact put aero development to the forefront of the Volt engineering process.

Figure 3 shows aerodynamic drag performance of a number of production vehicles in the North American small car market since the 2001 model year. GM and competitor data were consistently gathered in the General Motors Aerodynamic Laboratory (GMAL). Clearly, minimizing drag area (C_DA) is key to all hybrid and electric cars in this segment. A saleable Volt was tested per the new SAE Recommended Best Practice J2881, "Measurement of Aerodynamic Performance for Mass-Produced Cars and Light-Duty Trucks" [1], and achieved a C_D of 0.28 in GMAL.

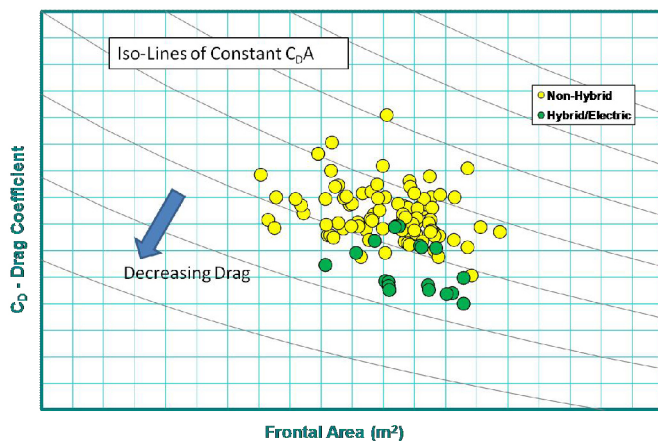


Figure 3. Aerodynamic Drag of North American Small Car Market, 2001-2011

Development Process

The development process began shortly after the Volt concept car debuted at the North American International Auto Show in January 2007 (Figure 4). Engineering efforts started in earnest as the concept design was proportioned to fit on to

GM's small car platform. This provided the first aerodynamic evaluation as shown in the scale model of Figure 5.



Figure 4. Volt concept vehicle



Figure 5. First reduced scale wind tunnel test.

GM's aero methodology relies on several complementary tools. Drag reduction is developed mainly in the wind tunnel starting with reduced scale clay models and then full scale clay models, where design studies can be quickly sculpted and tested to a high degree of accuracy. Computational Fluid Dynamics (CFD) is the primary method to analyze and optimize front end airflow, with its faithful representation of