Designing a Safer Transitional Electric Vehicle

Center for Environmental Studies Project Proposal for Summer 2009

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Abstract
In effecting a society-wide transition from “heavy” gasoline powered automobiles to lighter, more efficient electric vehicles, we would experience a period during which heavy vehicles would share the road with these lighter vehicles. Collisions between these two types of vehicles during the transition period would be inevitable. The proposed project seeks to identify and characterize design traits for light vehicles which would maximize the safety margins for vehicle occupants during collision with a heavy vehicle. Designs will be tested under simulated collisions using finite element analysis software. The results to be compiled include direct comparisons with parameters from the Department of Transportation (DoT) passenger vehicle collision safety standards, as well as a number of general design recommendations.

Starting date, duration and location of proposed research
The project will run from June 29th, 2009 to August 28th, 2009 (9 weeks total). Research will be conducted on the Harvey Mudd College campus, using on-campus computing resources, and under the guidance of Professor Mary Cardenas.

Proposed research
For the purposes of this project, we define a “light” vehicle as one which lies in the mass regime between a standard passenger sedan and a motorcycle. The definition has been chosen to suggest a different class of vehicle which attempts to combine the efficiency of a motorcycle with safety characteristics of a passenger sedan.

The finite-element solver Abaqus/Explicit will be used to test different vehicle configurations for a variety of light vehicle designs. In the first phase of this project, I hope to quantify the aforementioned safety margins for the different configurations, and to compare them to DoT safety standards for automobiles. I may also be able to identify principal factors influencing the safety of light vehicles.

The electric road vehicles under consideration have four or less wheels. The number of wheels determines the overall chassis layout, and can be used as a convenient first-stage classification of light vehicle types. These classes can be further broken down by frame material (steel, aluminum, plastic, or composite) and overall vehicle mass. Certain simplifying assumptions will have to be made – components not relevant to the large-scale collision resistance will be omitted from the models and other components, such as the engine block, will be modeled as solid material.

Each vehicle configuration will be evaluated during simulation for forces transmitted to the interior of the passenger compartment, and for the degree of crushing of the passenger compartment. Due to the nature of the structural generalizations made, more detailed measurements of the structural damage and passenger damage are not likely to be useful. The DoT front and side impact standards are expressed in terms of force magnitudes and durations over portions of the body, such as the head/neck region, chest, and pelvis area. Measurements made from the simulation may be directly compared to the numbers provided on these DoT impact standards.

The second phase of this project involves indentifying one or two promising vehicle configurations, and attempting to optimize them for energy efficiency. Rolling resistance, aerodynamic drag coefficient, and vehicle mass are often cited as the primary figures-of-merit determining a vehicle's efficiency. Specific structural features may be changed on the vehicle configurations to attempt to minimize the values of these parameters, and the resulting designs will again be tested for impact resistance.

Due to its open-ended nature, this portion of the project will be less experimentally rigorous than the first. Improvements made to the aforementioned parameters due to structural features are speculative at best, and the results of this portion can only be presented as unproven recommendations.

Results from the two phases of the project will be compiled separately. Vehicle configurations and simulation results will constitute the first phase summary. The results of the second phase will be presented along with any general trends identified during the simulations, as well as a small number of general recommendations for light vehicle safety characteristics.

Preparation for this project will include readings on vehicle frame design and chassis configuration. I may also seek advice from Professor Joe King for any mechanical structure concepts I am not clear on. Research on existing electric vehicle designs will be conducted as preparation for creating structural generalizations of the designs. I will also discuss these issues with alumnus Jim Castelaz, who has experience designing electric motorcycles, and their relevant internal components.

Educational value

Computational physical simulations are an important part of the design process for engineers and also for experimental physicists. Proficiency with finite element analysis (FEA), a keystone of physical simulation, is a major advantage in these fields. This project would provide an excellent applied introduction to FEA in general, and to Abaqus – an industry standard FEA package – specifically.

Furthermore, this project will afford me an opportunity to apply conceptual knowledge I have accumulated as a physics major towards an immediate problem affecting the society outside of my college walls. Research in physics can easily become a purely academic pursuit, with both motivations and results circulating endlessly within the confines of academic institutions and esoteric publications. In my opinion, a researcher needs to develop a degree of social insight in order to more efficiently harness conceptual knowledge towards effecting change on a broad scale.

Significance of research for environmental quality

Development of such light vehicles is not a new idea. Canopied motorcycles and “microcars” have been produced since the 1920s by numerous groups as a compromise between the comfort of a car and the efficiency of a motorcycle. Historically, however, there has not been significant public demand for such intermediary vehicles. Vehicle emissions and fuel costs were of little concern to drivers, and motorcycling accidents, however grisly, represented a small enough fraction of automobile accidents to avoid becoming a large public issue.

In my opinion, however, this situation is about to change. Rising fuel costs and continued concerns over vehicle emissions will drive development of more efficient and lighter vehicles. Increased public adoption of these lighter cars will necessitate innovative safety measures for these vehicles. Business-as-usual would suggest an evolutionary progression away from the conventional gasoline automobile, but in light of current market conditions and environmental concerns, this is something I feel we no longer have the luxury of waiting for.

The environmental impact of the millions of gasoline powered vehicles operating today is unquestionable and increasingly severe. We need to effect a transition away from the gasoline automobile at some point in the near future. If an efficient light-vehicle appears on the market with proven collision survivability, I feel this may be accomplished in a much shorter time frame. A sweeping transition away from gasoline powered vehicles, however, is not possible without comparable safety standards for their replacements. This project seeks to explore the possibility for such safety breakthroughs, and in this way, help enable the transition away from gasoline powered vehicles.

Feasibility

I have demonstrated proficiency in performing numerical simulations in Mathematica and MATLAB, and have experience with different computational simulation methods from the Physics 170 (Computational Methods) course. Abaqus, from its product description, shares many similarities to the COMSOL computational multiphysics package, which I explored as part of Physics 170.

By the start of this project, I will also have completed the Engineering Design and Materials course here at Melbourne University. The concepts acquired during this course will be useful in the design of light vehicle prototypes for use in simulation, and will help me frame the results in technically correct form.

Finally, 3D modeling has been a hobby of many years for me. Although I have not applied these skills in a research or experimental setting before, I feel that my experience will be immensely useful for modeling these computational prototypes. The efficiency of FEA simulations on spatial meshes are often heavily dependent on the number of vertices or nodes in the 3D model. Experience with 3D modeling has taught me how to minimize the number of vertices used in the design of a model while preserving important geometric features.

Budget

Abaqus Research Edition (quoted 2/25/09)	$ 2,725
Additional Analysis Tokens (to expedite simulations with multi-threaded processing)	$ 213
Faculty Advisor Stipend	$ 500
Student Research Stipend ($ 400 per week for 9 weeks)	$ 3,600
Total	**$ 7,038**