Advanced Vehicle Research in a Multidisciplinary Project Laboratory

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Abstract

This paper describes the use of advanced vehicle research projects in a multidisciplinary capstone design laboratory course offered in the Electrical and Mechanical Engineering Departments at Texas Tech University. The course uses projects from industry, research efforts and other faculty initiatives.

A number of research projects involving alternative fuel and hybrid electric vehicles are used in the senior project laboratory. These projects involve essentially all aspects of automobile subsystems design and fabrication including internal combustion engine (ICE) fuel metering and control, hybrid vehicle (ICE/electric motor) control, structures, fluids, heating and air conditioning, vehicle suspension, transmission, brakes, electrical subsystems, advanced system control and electronics. Although the project team is frequently large, the students do an outstanding job of integrating their efforts and coming together as a truly effective working unit.

Introduction

In the fall semester of 1994 the Electrical and Mechanical Engineering Departments at Texas Tech University began a multidisciplinary senior design project laboratory program. Two courses were established by integrating the Electrical Engineering Department's Senior Project Laboratory courses (two 3-semester credit hour courses) with the Mechanical Engineering Department's Design I and II capstone design courses (two 3-semester credit hour courses). The Electrical Engineering Department has a long history of project laboratories.[1-5] The Mechanical Engineering Department has been involved in alternative fueled vehicles for a number of years. Both departments had worked together on a number of special projects and felt the need, as have many others[6-11], for an increased interdisciplinary program for engineering students. The goals of these new courses were:

a) to have the students develop an understanding of engineering design projects from recognition of a need and definition of design objectives through completion of the project
b) to foster student creativity
c) to broaden the students concept of engineering problems to include other engineering disciplines and other non-engineering factors that have an impact on the final problem solution
d) to provide a unique educational experience for students on project teams and]
e) to enhance the students communication skills

The projects for the course come from industry, research efforts and other faculty initiatives. Student groups are required to prepare proposals for the project to which they are assigned. Proposals are due approximately two weeks after the projects are assigned. Specific project deliverables are determined by the responsible project advisor in conjunction with the student group. Project teams meet weekly with their advisor to discuss problems, technical approaches and progress. Students are required to submit a weekly progress report that briefly describes the work accomplished during the previous week and projected activity for the upcoming week. This progress report is signed by the project advisor and submitted to the course instructor. Weekly oral progress reports, including technical details of the project with a question and answer session, are also required.[12]

Example Project

A number of research projects involving alternative fuel and hybrid electric vehicles are used in the senior project laboratory. The Neon HEV project in the 1994-95 terms is a good example. The main objective of the Neon HEV project was to develop a hybrid electric vehicle that is comparable in performance to similar vehicles on the market, while substantially reducing tail-pipe emissions and increasing fuel-economy. What is meant by overall vehicle performance is acceleration, handling, braking, vehicle range, and driveability. The ultimate goal is that the driver have no realization that he/she is driving a hybrid.[13]

Since there is no one best design for a hybrid vehicle, the specific configuration is determined by what traits are deemed desirable by the user. This is illustrated in Figure 1. This figure shows the effect that component selection, in particular the IC engine and electrical drive components, have on the true operation of the vehicle.[14] The sizing of these components basically determines how the vehicle will operate.

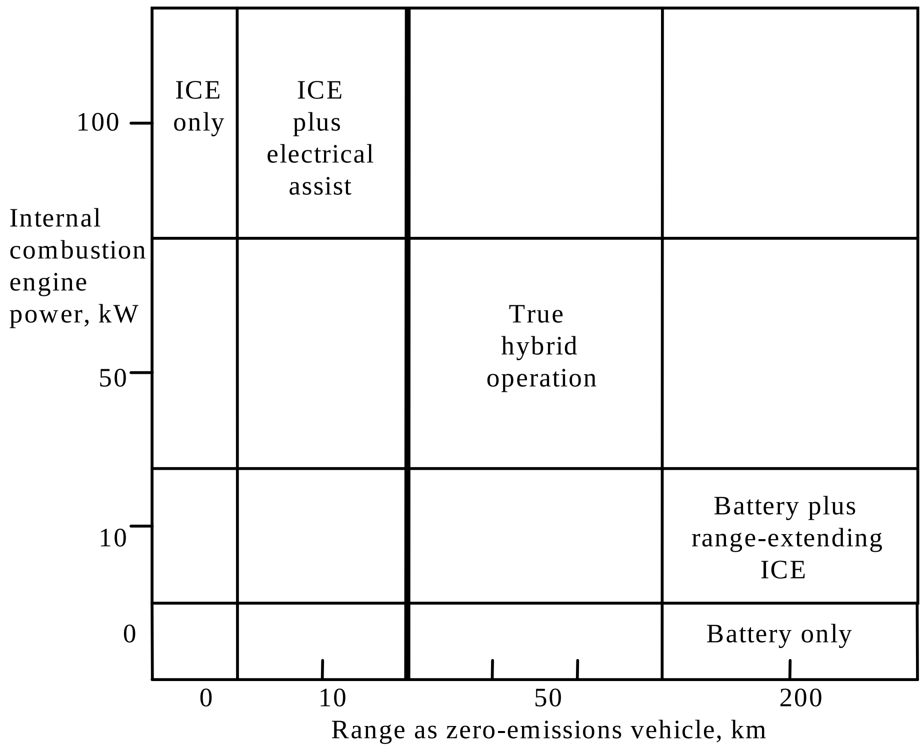

Figure 1 Effect of Mission on Component Sizing [14]

The upper left corner of Figure 1 refers to vehicles that rely more heavily on their ICE power than their electrical system. These vehicles are characterized by higher performance and practical range. They do, however, lose some of the fuel economy and emissions savings of the other groups. Their range on purely electric power is limited, but this is usually not a problem as these systems are rarely asked to perform purely by electrical means.

A parallel structure with an electrical assist was chosen by the group for the Neon HEV. The parallel structure allows more flexibility in vehicle operation. In a parallel HEV, electrical power and/or ICE power can be used to drive the car. This allows the vehicle the flexibility to perform as a ZEV, HEV, or rely solely on its IC engine capability. The parallel structure also incorporates less conversion losses.

The particular vehicle used in this project was a 1995 Dodge Neon. The original project was part of the 1995 Chrysler Hybrid Electric Vehicle Challenge. Aside from making the car into an electrically assisted hybrid vehicle, the Neon engine was converted to run on compressed natural gas (CNG) to help in the reduction of emissions. Figure 2 shows the overall layout of the vehicle.

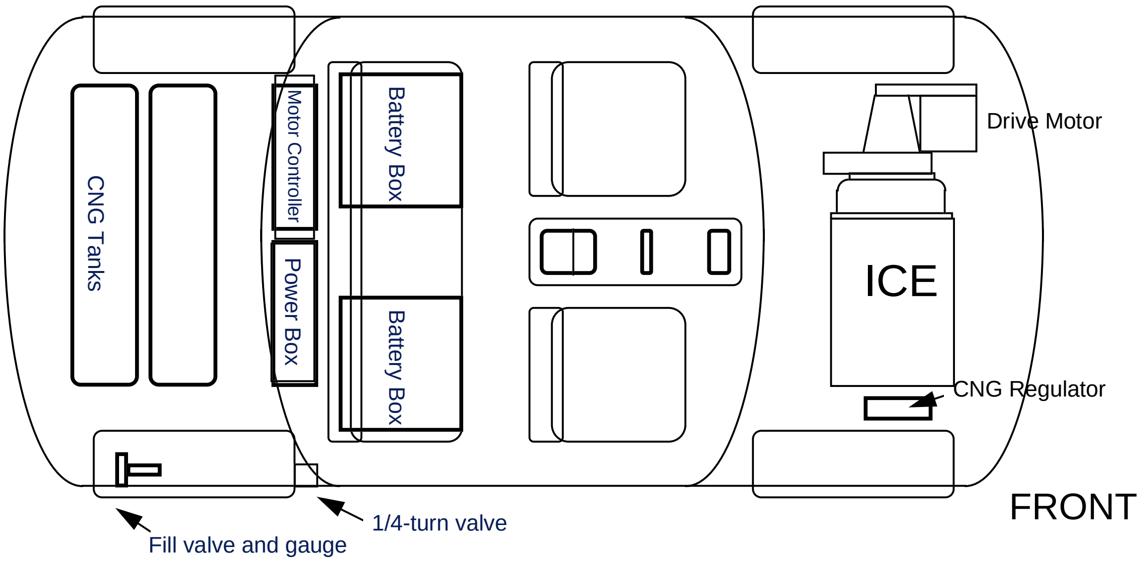

Figure 2 - Vehicle Layout

The project required completion of the following tasks

- conversion of the gasoline engine to CNG
- replacing the gas tank with CNG cyclinders with appropriate mounting and plumbing
- new injectors for CNG
- pressure and temperature transducers to monitor the tanks and fuel level
- gas engine management (GEM) system for the CNG injection
- battery selection and wiring
- battery boxes design and construction
- electric motor and controller selection
- coupling the electric motor through the original transmission to the wheels
- coordinated system control

Figure 3 illustrates the electric motor coupling. A transfer case supports the electric motor and encloses a high-velocity chain drive that connects to an extension from the transmission shaft. This was one of the most critical aspects of the mechanical design.

The power transfer case was constructed of 7075 T6 aluminum with an average yield strength of 85 kpsi (586 Mpa). A solid block of this aluminum was milled to shape using a computerized CNC mill. The cover for the power transfer case was milled from ASTM A-715 10-gauge steel with an average yield strength of 80 kpsi (552 Mpa). The material selection was based upon the event of chain failure during high speed operation. Holes were drilled to match those on the end of the transmission. The shaft and mounting holes for the electric motor were slotted to allow the chain tension to be adjusted. The electric motor was protected from leakage from the oil bath by an oil seal and gasket.

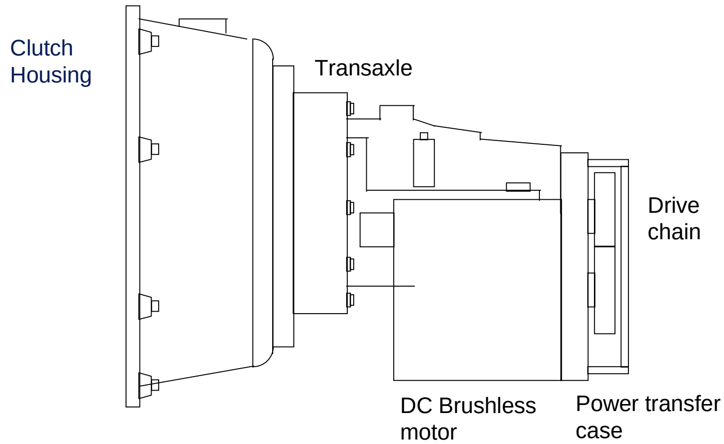

Figure 3 - Powertrain Coupling

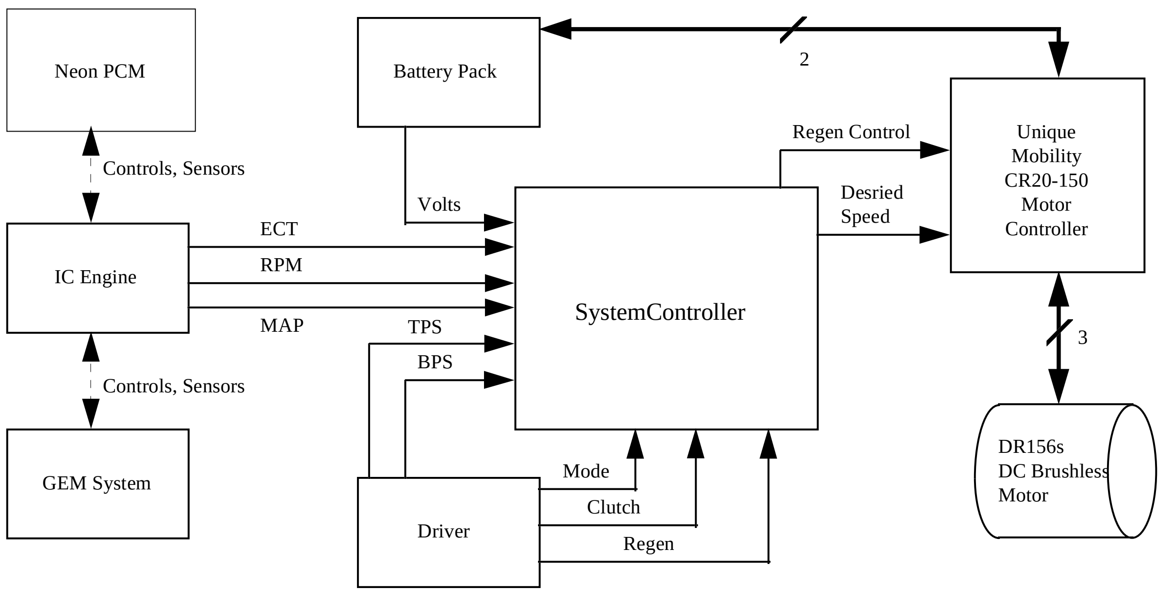

Figure 4 - System Controller and Related Systems

The system controller for the Neon hybrid electric vehicle was a critical item in the electrcal design. The system controller is a microprocessor based system that manages the electric drive system for the vehicle. The objective of the system controller is to incorporate the electric motive power of the vehicle to increase fuel economy and reduce emissions, while being transparent to the operator. A block diagram of the system controller and related systems is shown in Figure 4. The system controller monitors several IC engine signals, the status of the battery pack, and the driver control signals to determine the usage of electric motor power.

For the 1994-95 terms, 15 students worked until mid-June (approximately five weeks after the end of the spring semester) to complete the project. This was probably the most effective multidisciplinary project undertaken in this term. Although the project team was large, the students did an outstanding job of integrating their efforts and coming together as a truly effective working unit. The project involved essentially all aspects of automobile subsystems design and fabrication including internal combustion engine (ICE) fuel metering and control, vehicle (ICE/electric motor) control structures, fluid systems, heating and air conditioning, vehicle suspension, transmission, brakes, electrical systems and electronics. The vehicle participated in the 1995 Hybrid Electric Vehicle Challenge held at the Chrysler Technology Center in Auburn Hills, Michigan. and placed second overall with best dynamometer energy efficiency, best acceleration, best dynamic performance and most efficient zero emission vehicle. This acheivement further attests to the effectiveness and commitment of the project team.[12]

Texas Tech has been involved in 10 international vehicle design competitions over the past 9 years. Since the inception of the multidisciplinary program one project group each term has worked on a competition car. The vehicles from previous competitions are also used as projects. One vehicle, a parallel hybrid electric Escort with equal sized electric and IC engine, is currently on its third complete redesign and construction. The results from the competition vehicles are:

- 1995 Hybrid Electric Vehicle Challenge—conversion of 1995 Neon to a hybrid electric vehicle with compressed natural gas: 1995—2nd overall, 1st acceleration, 1st dynamic performance, 1st fuel economy, 2nd emissions, 2nd range, 2nd consumer acceptance
- 1996/97 Propane Vehicle Challenge—conversion of 1996 minivan to LPG fuel: 1996—5th overall, 1st acceleration, 1st dynamic performance, 1st fuel economy, 2nd emissions; 1997—2nd overall, 2nd acceleration, 1st emissions, 2nd range, 1st presentation

Texas Tech University now has a total of six alternatively fueled vehicles, five of which are involved in senior design projects during the Fall 1997 semester. A new project beginning this fall involves the use of a new fuel (hydrogen) and an all–electric powered vehicle. The team assigned to this project includes eight electrical and nine mechanical undergraduate students, one graduate EE and two graduate ME students. In addition, several additional EE undergraduate and graduate students will be assigned to the development of a control system for this vehicle.

Conclusions

Based on the experiences of the past two academic years, the multidisciplinary senior design course at Texas Tech has been consider a success by the participating faculty and students. Of course, problems do exist and continual changes are being made to improve the program. As to be expected, a number of projects have been outstanding successes and some have been failures. However, the goals of the program are being met and the students are gaining a real appreciation for multidisciplinary nature of real engineering problems.

The advanced vehicle research projects have stimulated significant student interest and involvement. Much of the College of Engineering's success in achieving *real* multidisciplinary education is credited to these projects. As an additional benefit, a number of additional funded research programs have been generated from the senior multidisciplinary vehicle projects.

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Biographical Information

Micheal E. Parten is a Professor of Electrical Engineering at Texas Tech University. Dr. Parten has conducted research and published in the areas of instrumentation, control, modeling and simulation of a variety of systems, including hybrid electric vehicles. Dr. Parten has served for over ten years as the Director of the Undergraduate Laboratories in Electrical Engineering.

Darrell L. Vines is well known in electrical engineering education. His long and distinguished association with the IEEE Education Society led to a Meritorious Service Award in 1990. Dr. Vines has worked extensively and published on the interdisciplinary project laboratory over the last several years. He has also been a researcher on the advanced vehicle research team at Texas Tech University.

Timothy T. Maxwell joined the Mechanical Engineering Department faculty at Texas Tech University in 1984 and has been involved in vehicle research for over 15 years. He is presently involved in several research projects related to vehicles/engines and is co-author of a popular alternative fuels research. Dr. Maxwell has been an advisor for all the TTU teams competing in alternative fuels competitions since 1989.

Jesse C. Jones has been involved in facilities, systems, and component design for over 40 years. He was an engineering manager for NASA for over 20 years before coming to the ME Department at TTU in 1982. He was one of the leaders in establishing the multidisciplinary senior design course presently taught at TTU. He is co-author of a widely used design textbook and a popular fuels reference textbook.