Experience from a First-Time Offering of a Motorsports Technology Course

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Abstract

As part of a continuing effort to enforce the multidisciplinary and applied character of the courses offered, the department of Mechanical Engineering Technology (MET) has instituted a class on motorsports. It is intended to combine the different subjects taught in the undergraduate curriculum into a continuum as they are applied to open-wheel vehicles with a focus on Indy Racing League (IRL) cars.

There are a number of annual student competitions structured around motorsports. In two of them, teams develop small, but sophisticated cars to compete on prescribed tasks. These competitions along with natural interests among the students combine to make motorsports an attractive venue for an interdisciplinary senior level class. The course within the Purdue MET department is currently being presented as a special studies course. In this sense, it serves as a prototype for a permanently offered course.

Motivation

This course was offered in response to requests by both students and outside organizations. Our students tend to be very interested in cars and often come us with a background in modifying, racing and even building them. The potential for outside support offered the possibility of creating an appealing course that would link a variety of subjects in a rigorous way. The student response was enthusiastic, so we think this is a good venue for highlighting how working with a complex system integrates subject matter from the entire curriculum[1].

Basic Structure of Course

The course was developed with 12 distinct modules:

1. The Role of Automotive Motorsports in the Undergraduate Curriculum
2. History of Automotive Motorsports
3. Automotive Motorsports Classifications: Styles and Racecourses
4. Vehicle Materials

5. Racing Engines
6. Drivetrain: Engine Output Shaft to Wheels
7. Suspension Systems
8. Vehicle Aerodynamics
9. Vehicle Dynamics
10. Data Acquisition and Analysis
11. Racing Theories and Strategies: Calculations
12. Factory Involvement in Motorsports

The course was taught cooperatively by several members of the MET faculty with guest lectures by other faculty members and by outside experts. Several members of the faculty have professional experience in the auto industry and Purdue is close enough to Indianapolis that a close connection with the entire IRL infrastructure was possible.

Core Learning Objectives and Their Implementation

The course contained 12 Core Learning Objectives (CLO). These are presented here along with brief comments on how they were implemented.

1. Understand the history of high performance racing and related benefits to development and improvement of automobile industry.

Visit to Indianapolis Speedway Museum – This trip provided a good appreciation of the history of the race vehicle and its development. Some improvements in automotive technology were easily linked to racing technology. These include radial tires, fuel injectors and seat belts. A strong link with OEM engineers would help in identifying technology transfer paths between racing and production vehicles.

2. Perform comparisons of various racecourse geometries and technical challenges these present to the design and performance of racing vehicles.

3. Conduct a study of key Indy-Car Series rules and their impact on design and development of racing vehicles and how these vehicles differ from so-called street engines.

There were no sessions dedicated to the exclusive study of the rule book. However, each instructor used the book to formulate assignments involving the vehicle, the engine, the tires, the shock absorbers, airfoils, etc.

4. Perform in-depth analysis leading to the preparation of a vehicle for qualification and race-day operation.

Only cursory treatment of this item was made in the course. That was done by outside speakers. This item is linked to the rules and deals with vehicle ‘set-up’ – a term widely used to describe the preparation of a vehicle for the track. This can be problematic since it can involve information that is closely held by the teams.

5. Develop an understanding in the use of advanced materials by the racing industry, including carbon fiber.

No activity in initial course offering. Future offerings will include class time on the nature of composite materials and examples of their implementation on IRL cars. A lab may be included to perform a basic material test on composite specimens.

6. Compare design, performance, and manufacturing methodology between racing and street engines. Emphasis shall be placed on internal engine components such valving, fuel injectors, piston, and crankshaft.

One lecture was devoted to air-fuel systems. This included an overview of manifold design for racing applications versus street applications and the calculation of volumetric efficiency. A lab activity characterized production variation in fuel injectors.

7. Conduct a study of the selection and use of gears on a race vehicle. Topics such as gear-shift selection points and power transmitted to meet demands of the straightway and cornering shall be examined.

Although nothing on gears and shifting was done, future plans include an in-depth study of the gearbox. Specifically, we will cover selection of gears to match track geometry and related parameters.

8. Understand basic elements of race vehicle suspension system including tires, shocks, and springs, in both static and dynamic applications. Emphasis shall be placed on static distribution of forces on each wheel in order to satisfy the dynamics of a vehicle in motion.

Significant course time was allotted to basic concepts in vehicle dynamics and suspension components. These were reinforced with a lab activity in which the weight distribution of several cars were determined experimentally. We did cover the basics of weight shifts and resultant forces on springs, dampers, etc.

9. Understand the role of aerodynamics in high-speed racing. Measure and perform calculations that involve lift and drag force acting on an airfoil section.

The fundamental concepts of aerodynamics were introduced. These included the generation of aerodynamic forces, behavior of finite and infinite lifting surfaces and non-dimensional coefficients. These concepts were reinforced with a wind tunnel lab activity.

10. Perform basic calculations using data collected during an actual race. Such calculations shall include predicting lap times, speeds, fuel consumption, power requirements, etc.

We used IRL data and related engine information to do analyses in the Racing Engine module. Examples include fuel consumption and estimating how many laps a driver can go at one of the tracks before running out of fuel.

11. Develop a strong technical perspective involving racing theories and strategies including the effects of ambient conditions, racing vehicle adjustments such as tire pressure, airfoil wing angles, weight/corner jacking, etc.

An outside speaker – an engineer from a racing team – discussed his duties and responsibilities on an actual team, both in preparation for and during a race. He briefly touched on tire pressure, recording, adjusting wing angles, ambient conditions and their effects on the car.

12. Develop an understanding of the role of the "factory" in the manufacture of the engine, chassis, tires, etc.

No activity in initial course offering. We are seeking a guest lecturer for the next course offering.

Dynamics Module

It is not possible to present details on from all the modules in this paper, so we will use the vehicle dynamics module and the engine module, as representative examples.

Approximately three weeks of lecture and four weeks in the laboratory were devoted to vehicle dynamics and data acquisition/analysis. Table 1 outlines the material covered in each module. In the vehicle dynamics module, simple models of acceleration performance, handling, and tires were covered. Students learned to apply the basic equations of acceleration and weight distribution for side view and rear view vehicle models, worked with steady-state cornering and concepts such as understeer/oversteer, and became familiar with simple tire concepts and models. In the data acquisition and analysis portion, students were introduced to sensors, basic signal processing, measurement systems, and simple analyses used in racing. Industry-standard software was used in lecture as a demonstration tool and in the laboratory to support student analysis work.

Table 1 - Outline of vehicle dynamics and data acquisition course modules

	Vehicle Dynamics	**Data Acquisition/Analysis**
Goals	• Introduce major vehicle dynamics concepts and models • Provide understanding of vehicle behavior through theory and applications • Relate basic vehicle design factors to vehicle dynamic behavior	• Demonstrate the need for data acquisition in motor sports • Introduce sample data sets and analysis • Relate data acquisition to vehicle dynamics and other principles
Lecture Topics	• Background and history • Basic models and analysis o Performance o Handling/Cornering o Tires	• Background, history, & rules • Data acquisition basics o Signals o Measurement systems • Sample data analysis
Laboratory Exercises	• Performance simulation: effect of vehicle parameters and external loads on performance • Weight distribution: measurements on two vehicles under various load conditions	• Familiarization with data acquisition software • Race data analysis with sample data sets

Informal student feedback to the vehicle dynamics and data acquisition modules was generally positive. One of the more interesting lab activities was the weight distribution lab, in which vehicle scales were used to determine front/rear and corner weight distributions on two vehicles. A passenger car and a pickup truck were used for the measurements, and various loading conditions were tested, as shown in Figures 1 and 2. Students performed calculations to determine corner balance characteristics and center of gravity locations, and made related conclusions about vehicle performance and handling for these two vehicles.

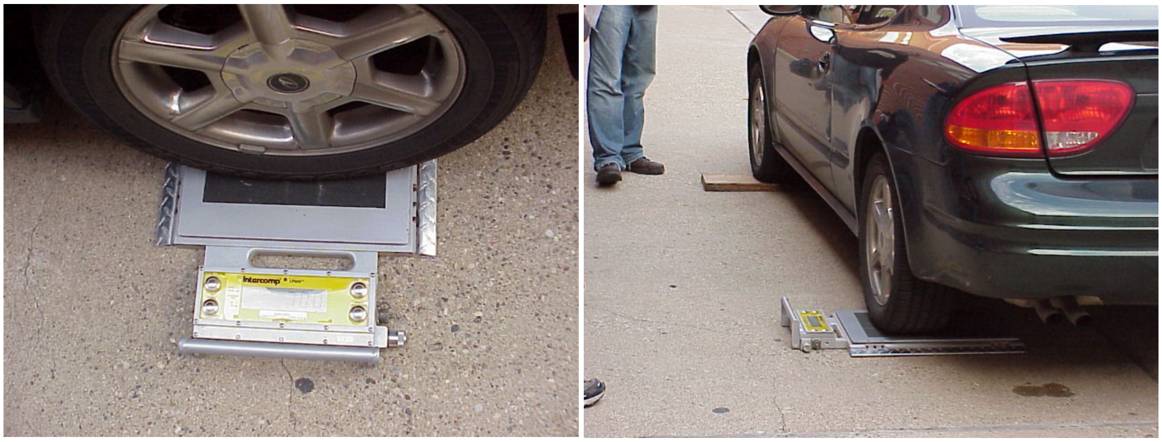

Figure 1 – Determining Vehicle Weight Distribution

Figure 2 - Weight distribution laboratory experiment

Much was learned during this first course offering about how the vehicle dynamics and data acquisition modules might be improved for the future. Students also provided significant input on what they would like to have seen and analyzed during this portion of the course. Some of the key changes expected in the future are:

- More interaction with racing industry to help focus the vehicle dynamics topics covered
- Improved coverage of tires and handling principles
- Larger sample data sets (data from more sensors) for use in the laboratory
- Real-time data acquisition using typical hardware used in racing

Engine Module

Three weeks of the Motorsports course were dedicated to this module. Consideration was made for the fact that student familiarity with engines at the nuts and bolts level varied extensively. The principal goal of the module was to develop an understanding of similarities and differences between street and racing engines. Some of the topics covered in lectures and labs included:

- Otto cycle analyses involving fuels, air-fuel ratios, compression ratios, valve timing events, engine speeds, etc.
- Size and weight measurements of numerous engine components including pistons, connecting rods, camshafts, etc. This activity was invaluable in helping students discern between the relatively robust design of a street engine and its high-speed, lighter-weight counterpart.
- Performance analyses involving parameters such as fuel consumption, volumetric efficiency, power output, etc.
- Witnessing a dynamometer test of a 2004 Indy racing engine at speeds ranging from 7000 to 10,300 RPM. This activity was followed up with analyses of partial test data shared by the testing organization with the students. Figure 3 shows an engine similar to the one tested.

External Support

The course benefited from the active support of organizations associated with IRL and contributions of hardware and software. Figure 3 shows a partially disassembled IRL engine. Technology students are, by nature, very interested in direct applications of course material. Working with actual racing hardware was valuable both for its direct relevance to the course and in maintaining student interest.

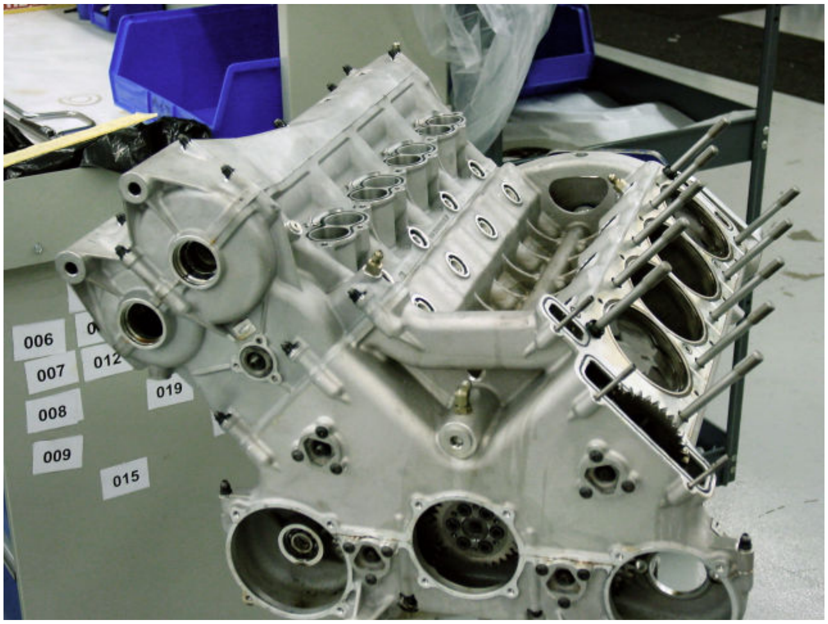

Figure 3 – IRL Engine

Suggestions for Similar Classes

We benefited greatly from being so near Indianapolis. However, we feel that a similar course could be developed at other schools using the local racing infrastructure. Many racing classes exist for the expressed purpose of being inexpensive and easily accessible. Drag racing, SCCA autocross, Motocross and Kart racing exist all over the country and all of these can be used as the basis for a valuable motorsports class.

Acknowledgements

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References

1. *Howard, Joseph P. and Kmec, Joseph F., "Motorsports 1: Introduction to Motorsports", Proceedings, 2003 ASEE IL/IN Sectional Conference, Valparaiso, IN.*

Biography

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Joseph Kmec is an Associate Professor of Mechanical Engineering Technology at Purdue University. He teaches courses in applied thermodynamics, internal combustion engines and powerplant technology. He actively continues to develop lectures and lab materials for use in the Motorsports course.

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