Missouri S&T

Center for Transportation Infrastructure and Safety

Development of Teaching Material to Integrate GT-POWER into Combustion Courses for IC Engine Simulations

by

Umit Koylu, Ph.D.
Associate Professor

A National University Transportation Center at Missouri University of Science and Technology

Disclaimer

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NUTC R200		

4. Title and Subtitle	5. Report Date
Development of Teaching Material to Integrate GT-POWER into Combustion Courses for IC Engine Simulations	February 2009
	6. Performing Organization Code
7. Author/s Umit O. Koylu	8. Performing Organization Report No. 00017656
9. Performing Organization Name and Address Center for Transportation Infrastructure and Safety/NUTC program Missouri University of Science and Technology 220 Engineering Research Lab Rolla, MO 65409	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTRT06-G-0014
12. Sponsoring Organization Name and Address U.S. Department of Transportation Research and Innovative Technology Administration 1200 New Jersey Avenue, SE Washington, DC 20590	13. Type of Report and Period Covered Final 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The main objective of this project was to develop instructional engineering projects that utilize the newly-offered PACE software GT-POWER for engine simulations in combustion-related courses at the Missouri University of Science and Technology. Students teamed up to perform modeling of engine performance and emission characteristics so that they could learn state-of-the art engine technology and explore innovative design procedures routinely employed by the leading automotive companies. This helped to bridge the gap between the theoretical and simple concepts learned by students in the classroom and the practical and advanced skills desired by industry. The project allowed various tools for studying engine combustion fueled by alternative fuels such hydrogen.

17. Key Words	18. Distribution Statement
Education, engine simulations, alternative fuels	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. Of Pages	22. Price
unclassified	unclassified	5	

Form DOT F 1700.7 (8-72)

Background

Advanced simulations are commonly utilized in the automotive industry because they can provide engineers cost-effective technical tools that considerably shorten the development time from conceptual ideas to actual products. Simulation methods also allow real-time system modeling with access to essential information that may be nearly impossible to obtain during experimental observations. Furthermore, they open the door for new technologies with the ability to conveniently change various parameters for achieving optimal solutions that satisfy design constraints. While internal combustion engines have been powering transportation vehicles for more than a century, complying with the demanding pollutant emission regulations without compromising the engine efficiency is currently the main challenge for the vehicle manufacturers. With the above-mentioned features, state-of-the-art simulations such as GT-POWER are crucial to achieve this ultimate goal. However, engineering students are rarely exposed to such modeling software that will transfer their theoretical knowledge to real applications and help them acquire essential qualifications sought by companies.

Objectives

To enhance student learning relevant to the needs of automotive industry, the main objective of this project was to develop course material for the integration of PACE software into Mechanical Engineering curriculum at Missouri S&T. Specifically, combustion processes within engines were simulated by students in course projects using the GT-POWER software, which is used by General Motors and other leading vehicle manufacturers for internal combustion engine modeling. The NUTC matching was mostly for extending the utilization of simulation software to alternative fuels, including hydrogen and ethanol, so that hydrogen engine combustion could be explored and demonstrated. This was essential to address safety issues and help develop the necessary codes and standards for hydrogen technologies. This is also consistent with the objectives of the NUTC, especially with the campus research on hydrogen energy, as well as our current departmental efforts to establish a strong relationship with General Motors for addressing their needs in thermal/fluid engineering.

Project Activities

The advanced software, GT-POWER, was offered to the PACE Institutions for the first time in 2007, and it was adopted at an academic institution and used by students here at Missouri S&T for the first time in 2008. To accomplish the project objectives, two dedicated HP work stations as well as the educational license for this advanced software were acquired from Gamma Technologies, Inc. for a period of 2 years. A Ph.D. student, Shravan Vudumu, was involved to prepare the educational materials. The software manuals were first studied to learn the basics. An official training was also obtained by attending the Gamma Technologies Conference and Training in Birmingham, MI, November 12-14, 2007. This allowed an advanced training for the complicated features of the GT-POWER software for internal combustion engine (ICE) simulations.

Following the educational objectives, two tutorials for two semester projects were developed for students in the courses "Applied Thermodynamics (ME 221)" and "Combustion Processes (ME/AE 327). There were a total of 44 students in ME 221 and 13 students in ME/AE 327. Students in these courses formed teams to utilize the GT-POWER software to perform advanced modeling engine performance and engine characteristics of ICE's so that they could learn state-of-the art engine technology and explore innovative design procedures routinely employed by the leading automotive companies.

The assigned project in ME 221 was somewhat simpler compared to the one in ME/AE 327 because the former is an undergraduate required course and the latter is an elective undergraduate/graduate course. The use of GT-POWER in ME 221 involved computations of the thermal efficiencies and pollutant emissions of a gasoline engine and a diesel engine and comparisons to the ideal thermodynamic cycles (Otto and Diesel cycles) discussed in class. The more advanced project/tutorial for ME/AE 327 included building the model of a gasoline engine cylinder. Students then computed various engine parameters, compared the results to simple equilibrium calculations learned in class, and extended the simulations to an alternative fuel mixture, E85. Engine conditions were varied so that students could observe the variations in important engine parameters such as thermal efficiency and pollutant emissions such as NO. For students to engage, explore, and receive hands-on skill on the GT-POWER software, two separate training sessions were held in the PACE Computer Laboratory located in Toomey Hall. To organize these sessions, 30 temporary licenses from Gamma Technologies, Inc. were acquired and installed on the lab computers. Students in both classes were very enthusiastic about such a state-of-the-art software used by many automotive companies and felt that this would help bridge the gap between the theoretical and simple concepts they learn in class and the practical skills desired by the industry. Additional and detailed information can be found in the project descriptions and the associated tutorials posted on the PACE Course Depository webpage: http://www.pacepartners.org.

In addition to continuing to use of the GT-POWER in these two courses in the next semesters, we intend to extend its use in another course "Internal Combustion Engines/ME 333". This implies that we should be preparing another tutorial and project. We also plan to explore the feasibility of using it for more complex simulations in our senior design course and Formula SAE student design team. Another interesting application is its adaptation for our new student design team, GM's EcoCar Next Challenge. For these extended activities, which strongly support NUTC's mission on transportation vehicles, engineers from GM have been contacted to seek practical design problems of technological interest.

In addition to the above educational activities, there are many research opportunities that can be explored with the GT-POWER software. Currently, the utilization and emission characteristics of alternative fuels, especially hydrogen, are being investigated. GT-POWER has been commonly employed for studying traditional-fueled reciprocating internal combustion engines. Its adaptation for hydrogen-fueled gasoline or diesel engines first requires benchmarking against well-documented data. Two recent studies have already been identified for successful comparisons of the software to experimental data in a gasoline engine. Several topics are planned to be investigated in the near future, e.g., performance of fuel mixtures (diesel and hydrogen, gasoline and ethanol, natural gas and hydrogen), and second-law analysis of hydrogen-fueled engines for improving thermal efficiency.

Technology Transfer Activities

The results from this project were presented at the PACE annual meeting:

S. K. Vudumu and U. O. Koylu, "GT-POWER for the Simulations of IC Engines in Combustion Courses at Missouri S&T," 2008 PACE Global Annual Forum, Detroit, MI, July 28-August 2, 2008.

It is also planned to report the final implementation and suggestions in a paper at the next ASME IMECE conference in Florida in November 2009. Moreover, the developed instructional tutorials have been posted on the PACE Course Depository webpage: http://www.pacepartners.org so that the experiences gained and the lessons learned during the project could be disseminated to other universities.

Benefits

Advanced simulations are increasingly employed in the automotive sector in order to accelerate the pace of engine development. Engineering students are to keep up with this trend and use sophisticated thermodynamic models for the analysis of combustion processes and pollutant emissions. By modeling engine performance and carrying out integrated cross-disciplinary simulations in a team, students can enhance their abilities to explore innovative engine concepts and stay at the frontier of engine technology. Demonstration and visualization of complex engine combustion can further stimulate interests of potential students to pursue engineering careers.

Relationship to other Research/Projects

The project is directly related to the recent efforts at Missouri S&T to establish a Hydrogen Center in order to pursue a broad research, training, and education agenda for the development of a rural hydrogen transportation test bed that can demonstrate, evaluate and promote alternative fuel technologies in a real-world environment. Additionally, it paves the way to other research projects on the effective and clean utilization of non-traditional fuels in transportation vehicles.