Session 2208

Introducing Engineering Design Concepts with a Micro Steam Car Project

Alan C. Hansen[1], Prasanta K. Kalita[1], Peter W.L. Lyne[2], Loren E. Bode[1]

[1]Department of Agricultural Engineering, University of Illinois at Urbana-Champaign/ [2]School of Bioresources Engineering and Environmental Hydrology, University of Natal, South Africa

Abstract

A micro steam car construction project was introduced for the first time in Fall 2000 as part of an introduction to agricultural engineering course for freshmen. Its purpose was to provide students with a hands-on engineering design experience constructing and testing a micro steam car. Most of the materials for building the car were supplied as a kit and comprised raw materials in the form of sheet metal, soda can, rubber tubes, wire, string and tin lids. Students built a car approximately 30 cm long powered by an ethanol heated tin can boiler, a pin sized nozzle and a turbine, which drives the front wheel. The project culminates with a competition in which the objective is to achieve maximum distance traveled on 20 mL of ethanol fuel. Apart from learning some metal working and soldering skills, the nature of the project allowed students to wrestle with a number of basic engineering and science concepts such as energy conservation, heat transfer and efficiency. While engineers in their first year of study may not yet have covered these topics in any detail in their classes, the need to try and identify factors contributing to the performance of the car provided a long-lasting learning experience. They are also able to practice problem-solving skills and learn to work in teams. Feedback from students on the project was positive with most students concluding that it had been a worthwhile activity in terms of learning problem-solving skills, working in a team and getting to know other students.

Introduction

ABET accredited undergraduate engineering programs, including Agricultural Engineering at the University of Illinois at Urbana-Champaign have begun to introduce design concepts at the freshman level with the objective of maintaining a common design thread through the entire program. In addition, by introducing design as early as possible there is an opportunity to promote early interaction between students and faculty and generate excitement about engineering at a time when the curriculum is heavily loaded with basic math and science courses and relatively little perceived engineering.

As a first step in introducing design at the freshman level in Agricultural Engineering at the University of Illinois, the Introduction to Agricultural Engineering course was modified in 2000 to include a micro steam car project. This hands-on project was originally developed and implemented very successfully at the University of Natal in South Africa over ten years ago[1,2]. There are many examples of other hands-on projects that have been implemented with varying degrees of success in the early years of the undergraduate degree.[3,4,5] Key factors of these various projects are the level of technology and complexity, funding, and time requirements. The micro steam car project does not require sophisticated instrumentation and relies on basic engineering principles of energy conversion. Inexpensive raw materials are used in its construction and a kit is provided with most of the components needed to construct the car. This greatly reduces construction time. The purpose of this paper is to provide some details about the micro stream car project and to report results of its implementation in a freshman agricultural engineering curriculum.

Objectives of the Micro Steam Car Project

The overall objective of the project was to provide students with a hands-on engineering design experience constructing and testing a micro steam car. Specific goals included the following:

(a) Develop communication skills through team interaction,
(b) Promote early interaction among students and faculty,
(c) Exercise both creative and critical thinking skills,
(d) Apply strategies for problem-solving,
(e) Demonstrate basic engineering principles of energy conversion efficiency,
(f) Develop skills in metalworking and soldering,
(g) Stage a competition in which the objective is to travel as far as possible on a smooth floor on 20 ml of ethanol, and
(h) Generate enthusiasm about engineering.

Modification of Course Curriculum

Introduction to Agricultural Engineering is a one-credit hour course and is specified as a "Discovery" course at the University of Illinois. Discovery courses have the common goal of helping freshmen in the transition to the intellectual life of the campus. Apart from introducing the agricultural engineering discipline and career opportunities, class activities have included familiarization with laboratories, computer facilities and network software. Taking into account the student learning outcomes specified by ABET, key topics that are now covered include time management and study skills, habits of highly effective people[6], communication skills, creativity and problem solving techniques, and ethical situations in engineering practice. The micro steam car project is introduced early in the semester so that students have most of the semester to build their cars. In addition, students are assigned to work in teams from the outset.

Problem solving is a fundamental skill that engineers are expected to have and is listed by ABET as a necessary attribute for an engineering graduate. However, relatively few engineering courses are taught at Universities that focus primarily on a generic approach to effectively solving problems. Fogler and LeBlanc[7] emphasize the benefit of applying a problem-solving heuristic in defining the real problem. Their heuristic comprises five steps: defining the real problem, generating solutions, deciding the course of action, implementing the selected solution, and evaluating the solution. This heuristic was presented for the first time in the introduction to agricultural engineering course in 2000 and the micro steam car project has provided a very useful topic for applying the heuristic. For example, in one class exercise the project teams are required to brainstorm ways to increase the performance of their cars and to document their ideas with the aid of a fishbone diagram.

Description of the Car

The micro steam car is a toy sized vehicle approximately 30 cm long, powered by an ethanol flame. The flame boils water in a tin can creating steam, which blows out of a pin sized nozzle to drive a turbine as shown in Figure 1. The turbine in turn is connected to the front wheel by a rubber band.

Figure 2 illustrates the layout for a micro steam car constructed from a basic kit obtained from the University of Natal. The fuel tank into which the ethanol is injected is shown. The fuel tank is secured under the chassis with each wick protruding through the base. Apart from the steam nozzle attached to the boiler, there is a second copper tube that has a small hole drilled in its side with a small piece of plastic tubing covering it. This acts as a relief valve to prevent the pressure becoming excessive in the boiler and it also allows the boiler to be filled with water.

In terms of expected performance and maximum distances that could be attained with the car, Bindon[1] indicated that the basic car design used in this project could achieve about 1000m. In South Africa, distances achieved increased from the pioneering 175m to as much as 6000m for specially designed and constructed cars.

Materials and Tools for Car Construction

The car design in Figure 2 has evolved over ten years at the University of Natal, South Africa where Bindon[8] has been largely responsible for developing and promoting the whole concept of a micro steam car project. The kits assembled by Bindon[8] contain most of the materials required to construct the car shown in Figure 2. The raw materials consist primarily of sheet metal, a 240 ml steel beverage can, rubber tubes, wire, string, tin lids and a round ointment tin for the fuel tank. Nails and an awl for making holes of the correct size in the sheet metal and tins are included. A comprehensive set of instructions and templates are also supplied with the kit.

Both hand tools and self-made tools are needed to complete the project[2]. For the introduction to agricultural engineering class, a pair of pliers and heavy-duty scissors were provided to each team to allow them to cut the sheet metal and bend it, and also to hold components while soldering. A 400 mm long PVC pipe of 50 mm diameter was used to bend the chassis plate into a circular shape. The self-made tools included an alignment jig created from a rolled piece of sheet metal and two tin lids placed at each end to provide a cylindrical shape. An axle rod was inserted into centralized holes in each lid and used to align the wheel and turbine spoke plates when soldering them to the respective tin lids. Soldering was done with an alcohol flame burner made from the round ointment tin and a wick identical to that used for the car. Some student teams elected to use a soldering iron.

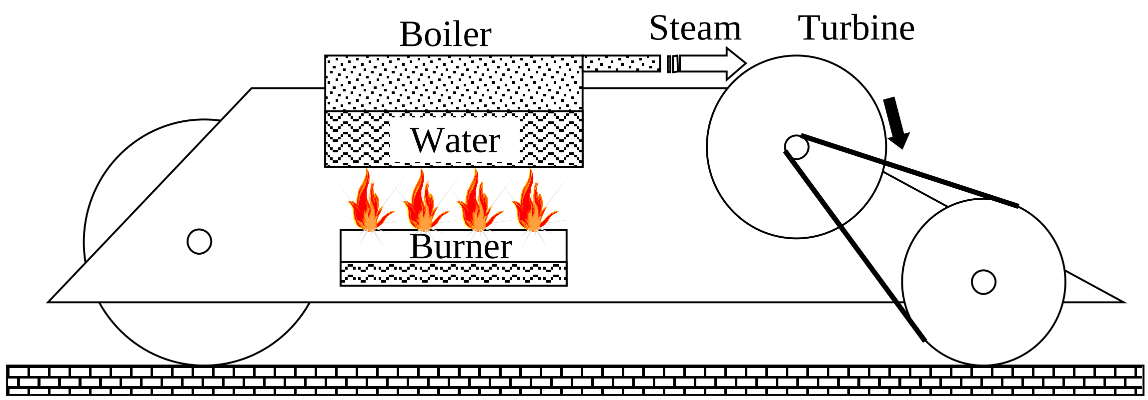


Figure 1. Schematic of micro steam car showing sequence of energy transfer from fuel to front wheel.

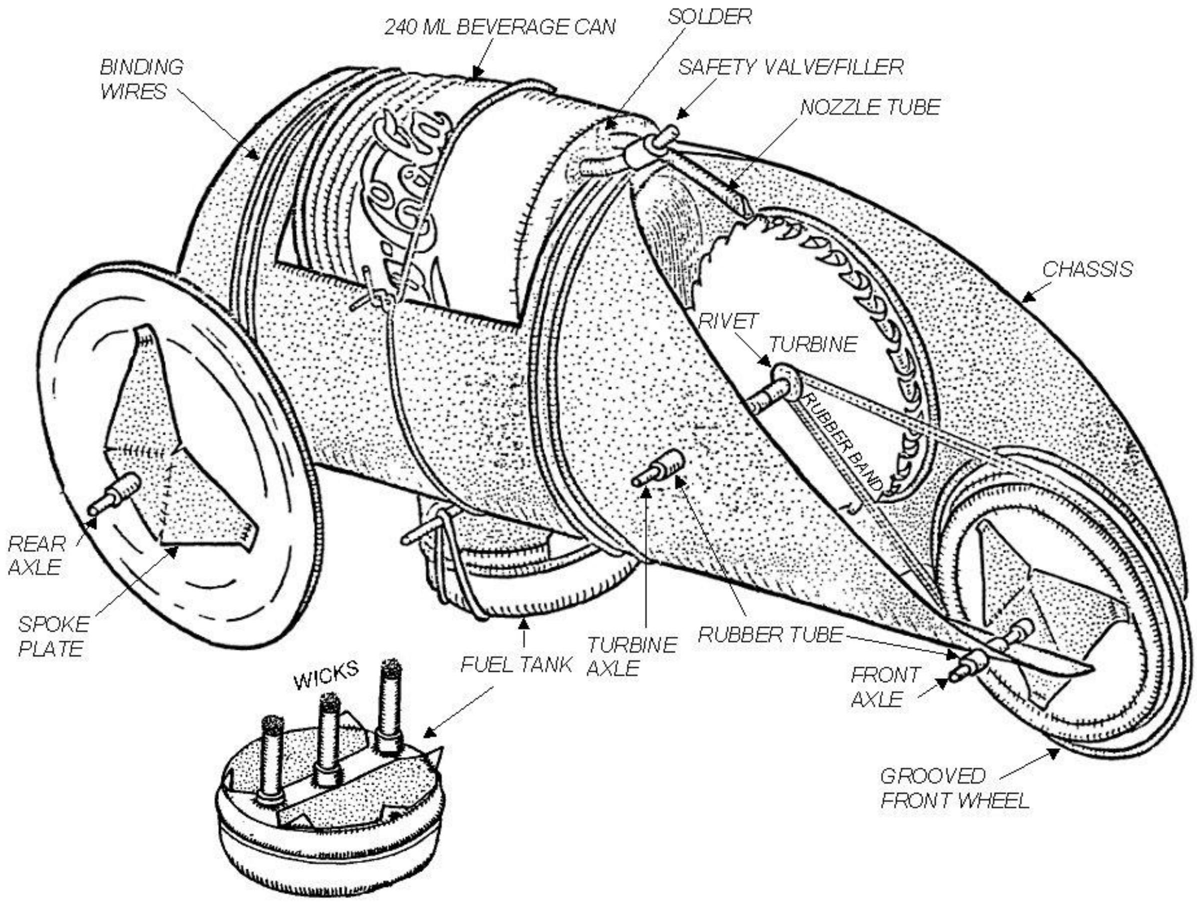


Figure 2. Basic micro steam car designed from kit[8]

Project Execution

Early in the semester, teams were formed and each team was supplied with a car kit and tools. Each team comprised three students and each member of the team was assigned responsibilities. One member was the convenor and was responsible for arranging for the team to meet at regular intervals, organizing the agenda for the meetings, and monitoring progress on the project to make sure it remained on schedule. A second member was responsible for construction and was required to assemble and look after all the materials and tools needed for the project, keep track of what needed to be done in the construction sequence of the steam car, and to assign particular construction tasks. The third member was responsible for the performance of the car and needed to think about and implement innovative ways to increase car performance. This member ensured that care was taken in constructing those elements of the car that significantly affected performance. Finally this third member was responsible for testing the car.

During the course of the semester, times were arranged both in class and outside of class for demonstrations by faculty on the construction of the car with special reference to the more difficult and relatively important components. Demonstrations of both cutting with the heavy-duty scissors and soldering with the ethanol flame burner were performed. Special emphasis was placed on safety with students being warned and reminded regularly of the need to be careful in cutting the sheet metal and also using the burner for soldering. Faculty acted as facilitators with each team when assistance was requested. Figure 3 shows students working on their cars in the classroom. Time was also spent discussing the transition from fuel energy to mechanical energy and the efficiencies associated with each step change. Ways of improving the performance of the car were debated in class and those parts of the car such as the turbine that needed to be constructed with extra care were highlighted.

Figure 3. Student teams working on their micro steam cars in the classroom

A date was chosen near the end of the semester in consultation with the students on which to stage the competition. The competition took place on the smooth floor of a building in a relatively long passageway as shown in Figure 4. Lanes of approximately 20 m length were marked out with tape. Exactly 20 ml of ethanol was provided for each run and students determined how much water to put into the boiler of their respective cars. Sufficient water was needed to provide steam until the fuel ran out; however, too much water meant that the car was carrying unproductive additional weight. It took approximately 4 to 5 minutes for the water to heat up sufficiently to begin generating steam. Once the car was moving, a long wooden ruler or dowel rod was used to keep the car running in the lane by tapping it on the side. At the end of the lane the front of the car was picked up by hand and the car was rotated and set down to continue back along the track. The number of laps and the final stopping point of the car measured from the one end were recorded and used to determine the overall distance traveled. Prizes were awarded for first, second, and third placed teams.

Assessment of Project Effectiveness

The project has been implemented for two semesters (2000 and 2001). An informal assessment in the form of a questionnaire in 2000 at the end of the semester indicated that a large number of the students found the project to be worthwhile. In 2000, the kits were supplied to the students one month into the semester and many of the students recommended that it be introduced as early as possible. In 2001, the kits were supplied almost immediately at the beginning of the semester. Also more time was spent during the semester demonstrating the construction processes as it was felt that students in 2000 had not grasped the finer details needed to ensure success in the operation of the car.

Figure 4. Students with their micro steam cars at the starting line for the distance competition

At the end of the semester in 2001, students were supplied with a more detailed survey to assess the overall effectiveness of the project and identify what improvements could be made (Table 1). The first seven questions in the survey requested a rating on a five-level scale: Strongly Agree,

Agree, No Opinion, Disagree, and Strongly Disagree. An additional four questions requested a written response. The survey forms were completed by a total of 36 students out of a total of 42 that were enrolled for the course.

Table 1. List of questions in student survey

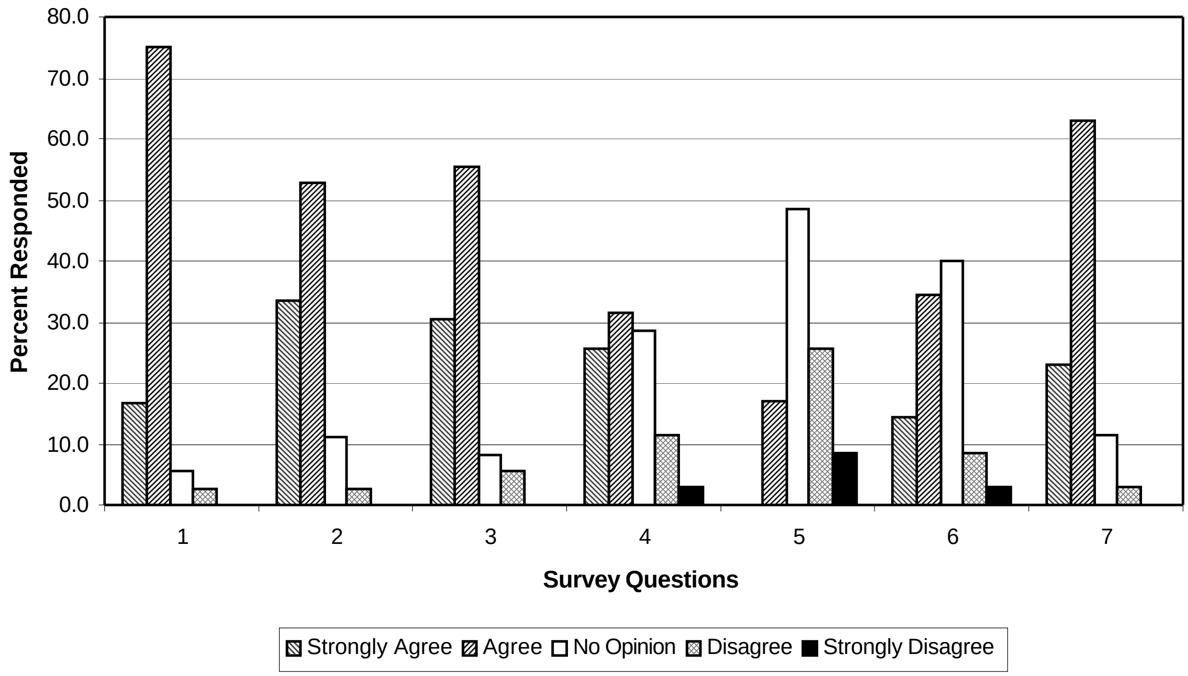
1. The micro steam car project was effective in helping me understand and apply problem-solving techniques
2. I thought that building a steam car was an effective way to learn to work in a team
3. As a result of this project, I was able to meet and get to know other students
4. I was able to develop skills such as soldering and metal working that I did not have before the project
5. I spent more time on this project than I could really afford (time estimate in hours =)
6. My enthusiasm to study engineering has increased as a result of the steam car project
7. I found the steam car project to be satisfying and challenging
8. Describe briefly any factors that inhibited you from working effectively with your team
9. If you had the opportunity to start over with this project, what would you do differently?
10. Comment on your level of satisfaction with the project. Were you pleased with the outcome?
11. What recommendations do you have to help us improve the project

Results and Discussion

The results from the first seven questions in the survey are presented in Figure 5. Over 90% of the class agreed that the micro steam car project helped them to understand and apply problem-solving techniques, one of the learning outcomes specified by ABET. Approximately 85% of the students thought that project was an effective way to learn to work in a team and the same percentage indicated that the project helped them meet and get to know other students. Again these were key objectives of the project.

Approximately 60% of the class indicated that they developed skills in soldering and metalwork, which they did not have before the project. However, 28% had no opinion and the remaining 14% disagreed. This result could be attributed to the fact that some of the students had already learned to solder through working with electronics. Observations in the classroom also suggested that in some teams one of the students was assigned the responsibility of doing all the soldering tasks and another the metalwork. Having at least half the class gain these skills during the project was regarded as a positive outcome.

The in-class and additional contact time allocated for students to work on the project was regarded as very important to the ultimate success in the competition. The survey showed that only 17% of students felt that they spent more time on the project than they could really afford. Estimates of time given by students varied from as little as three hours up to a maximum of 15 hours with an average of 7.7 hours. Bindon et al.[2] indicated that a complete car could be made in 10 hours by an individual under the guidance of a tutor, however, this time could be reduced to a 3-hour session if a group shared in the construction. Hence the average time of 7.7 hours, which falls between these two limits, appears to be sufficient to complete the project during this particular course.



1. The micro steam car project was effective in helping me understand and apply problem-solving techniques
2. I thought that building a steam car was an effective way to learn to work in a team
3. As a result of this project, I was able to meet and get to know other students
4. I was able to develop skills such as soldering and metalworking that I did not have before the project
5. I spent more time on this project than I could really afford
6. My enthusiasm to study engineering has increased as a result of the steam car project
7. I found the steam car project to be satisfying and challenging

Figure 5. Students' evaluation of micro steam car project

Question 6 in the survey regarding enthusiasm for engineering was particularly relevant in terms of the objective of increasing student retention. Approximately half the respondents in the class felt that their enthusiasm had increased with the project, while 40% expressed no opinion and the remaining 11% did not agree. This response could be interpreted to mean that some students felt that they were already enthusiastic about engineering and this project helped to sustain that same level of enthusiasm.

The last question requiring a rating was included to gauge the overall satisfaction of students with the project. Approximately 85% of students agreed that that the project was satisfying and challenging, while only one student disagreed with this statement. This was an important result in determining the overall effectiveness of the project in engaging the students.

Answers to the question of factors inhibiting teamwork tended to focus mainly on conflicting schedules, which made working outside of class difficult and in some cases impossible. Future formation of teams could take into account conflicting schedules and also residence location, although these factors would add complexity to the management of the project.

Comments as to what students would do differently if they were able to start over centered mainly on starting the project earlier in the semester. Our observations of the relative progress made by students during the semester support this realization. Arrangements were made for faculty to be available on three evenings after class during the semester to help students with the building of their cars and to provide encouragement. Some teams took advantage of all three evenings and their progress was evident, while other teams only attended one of the work sessions and their lack of progress impacted on their success in the competition and hence on the overall quality of their car construction. Other notable individual comments included giving each person their own car to build, planning better, paying closer attention to detail and working together more.

Comments on the level of satisfaction with the project corresponded to the ratings of question 7. Notable individual comments included "I was pleased. We put some work into it and it went well", "I was pleased with the outcome, but had to do most on my own", "I would have liked to do more modifications", "We barely got the car done, let alone make improvements", and "Yes, it was a good deal of learning and fun".

Recommendations from the students to help improve the project were mainly to provide more in-class time with supervision to work on the car. Specific comments were to add one more group work night and provide better tools with particular reference to a soldering iron.

Notable general comments included the following:
"Building the car wasn't very difficult but it took a while to complete. The hardest thing was getting everyone together to work. Most of the time we traded it off individually and worked on it by ourselves",
"I always went when we met to work on it, but I did not feel I had that much to offer the group"
"I enjoyed it. I like to build things so putting it together and then having it work pretty well-- I was pleased", and
"It was fun and difficult at the same time".
As could be expected, students derived different levels of benefit from the project and this was reflected in the range of comments that were received.

The results of the competition were also an important assessment of the success of the project. The winning car in 2000 achieved approximately 850m with an average of 225m for nine teams, excluding cars that did not run because of mechanical failures. This maximum distance was close to the expected design distance achievable according to Bindon[1]. In 2001, the maximum distance was 585m with an average of 135m for nine cars that achieved more than 3m minimum distance. Five cars did not run due to malfunctions at the start line. These malfunctions varied from boilers leaking because of improper soldering, to fuel tanks catching fire because of fuel leakage from the tank. It was difficult to find a definite reason for the difference in average performance achieved in the two years apart from expected variation in student interest and motivation.

Conclusions

The micro steam car project was introduced for the first time in 2000 as part of an introduction to agricultural engineering freshman course with the overall objective of providing students with a hands-on engineering design experience constructing and testing a micro steam car. Student responses indicate that the project was successful in helping them apply problem-solving techniques and learn to work in teams and get to know other students. Half the students learnt additional skills in soldering and metalwork that they did not have before the project. Most students were able to afford the time they spent on the project. Most of the students found the project to be satisfying and challenging. The main recommendation from the students to help improve the project was to provide more in-class time with supervision to work on the car. We concluded that the project overall had been successful and was worth continuing.

References

1. Bindon, J. P., 1999. The micro steam car, an all embracing practical and theoretical design Project. The International Journal of Mechanical Engineering Education 27(3): 181-194.
2. Bindon, J. P., Kaiser, I. and Powell, N., 1996. The micro steam car, technology education by participation. Proc. Third International Conference of the Third World Science, Technology and Development Forum, University of Natal, Pietermaritzburg.
3. Ambrose, S. A. and Amon, C. H., 1997. Systematic design of a first year mechanical engineering course at Carnegie Mellon University. Journal of Engineering Education 86(2): 173-181.
4. Butterfield, R., 1997. Benefit without cost in a mechanics laboratory. Journal of Engineering Education 86(4): 315-320.
5. Wicker, R. B. and Quintana, R., 2000. An innovation-based fluid mechanics design and fabrication laboratory. Journal of Engineering Education 89(3): 361-367.
6. Covey, S. R., 1989. Seven habits of highly effective people. Publ. Simon and Schuster Inc., New York, USA.
7. Fogler, H. S. and LeBlanc S. E., 1995. Strategies for creative problem solving. Publ. Prentice-Hall PTR, New Jersey, USA.
8. Bindon, J. P., 2000. Personal communication. School of Mechanical Engineering, University of Natal, Durban, South Africa, bindon@nu.ac.za.

Biographical Information

ALAN C. HANSEN
Alan Hansen is an Associate Professor in the Department of Agricultural Engineering at the University of Illinois in Urbana-Champaign. He received his B.Sc.Eng. (Mech), M.Sc.Eng. and Ph.D. degrees from the University of Natal in South Africa. After twenty years of teaching and research at the University of Natal, He moved to University of Illinois where he teaches courses in engine and tractor design and performance. His research areas are in biofuels and simulation modeling of agricultural materials handling systems.

PRASANTA K. KALITA
Prasanta Kalita is an Assistant Professor in the Department of Agricultural Engineering at the University of Illinois in Urbana-Champaign. He received his B.S. in Agricultural Engineering from the Punjab Agricultural University in India, his M.S. in Agricultural Engineering from the Asian Institute of Technology in Thailand, and his Ph. D. in Agricultural Engineering from Iowa State University. Initially he was an Assistant Professor at Kansas State

University before moving to University of Illinois, where he teaches courses in soil and water conservation engineering. His research areas are in water quality, bioremediation of contaminated soils, and biofiltration.

PETER W. L. LYNE
Peter Lyne is a Professor and Head of the School of Bioresources Engineering and Environmental Hydrology at the University of Natal, Pietermaritzburg in South Africa. He received his B.Sc.Eng. (Agric), M.Sc.Eng. and Ph.D. degrees from the University of Natal in South Africa. He has been involved in research and teaching at the University of Natal for twenty five years in the area of power and machinery. Apart from many other courses that he has taught, he has been responsible for teaching an Introduction to Engineering Design class that incorporates a micro steam car project. Currently his research activities are focused on the simulation of over-the-road vehicle performance.

LOREN E. BODE
Loren Bode is a Professor and Head of the Department of Agricultural Engineering at the University of Illinois in Urbana-Champaign. He received his B.S., M.S. and Ph.D. degrees in Agricultural Engineering from the University of Missouri. During almost thirty years of service at the University of Illinois, he has been involved in research and extension related to spray chemical application systems. He has also taught courses in agricultural chemical application systems. Since becoming Head of Department he has been responsible for teaching the freshman Introduction to Agricultural Engineering course.