

AC 2008-2611: UTILIZING ADVANCED SOFTWARE TOOLS IN ENGINEERING TECHNOLOGY CURRICULUM AS A BRIDGE BETWEEN ACADEMIA AND INDUSTRY

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Utilizing Advanced Software Tools in Engineering Technology Curriculum as a Bridge between Academia and Industry

Abstract

The engineering and technology software tools are used by professionals and companies worldwide, and thus the students are given the opportunity to familiarize themselves with the operation of software packages that most likely they will use after they join the workforce. A substantial portion of the classroom projects in engineering technology curriculum that require the use of advanced software tools has been increased in many higher institutions for both undergraduate and graduate levels.

Emerging virtual applications may enhance understanding both theoretical and applied experiences of engineering technology students by supporting laboratory experiments. AMESim, SolidWorks, ProE, MultiSim and LabView™ are some of the well known system modeling, simulation and monitoring software tools that offer solutions to many problems in mechanical, thermal, hydraulics, pneumatics, electrical, electronics, controls, instrumentation and data acquisition areas. These virtual tools also help to improve learning pace and knowledge level of students in many applied subjects. This paper presents a number of case studies used in applied class projects, laboratory activities, and capstone senior design projects for a B.S. degree program in electrical and manufacturing engineering technology. Many students have found the software tools helpful and user friendly in understanding fundamentals of physical phenomena in engineering and technology areas.

1. Introduction

The development of educational and industrial software and simulation tools has been considerably increased. Industrial applications started to concentrate replacing expensive equipments by software and simulations tools while a number of educational institutions are preferring simulations tools instead of purchasing expensive test equipments for their laboratories. The universities especially engineering education departments increasingly incorporates such industry standard programming environment tools mostly in laboratory practices but more frequently also in the research and the classroom education. In engineering education, the demonstration is the most common utilization and operation. Taking engineering education into account, demonstration mostly engages process modeling, testing and simulation, imitated data acquisition and process control. For the demonstration purposes high level graphical user interface is required for providing efficient communication. The virtual applications may enhance both theoretical and hands-on experience of engineering technology students by supporting laboratory experiments as well. Most well-known industrial and educational software packages such as AMESim, SolidWorks, ProE, Matlab, MultiSim and LabView™ are powerful physical system simulation and monitoring software tools that offer solutions to many problems in mechanical, thermal, hydraulics, pneumatics, electrical, electronics, instrumentation and data acquisition areas. For example, one of the well-known industrial software packages used in engineering and technology education is the LabView™ developed by National Instruments (NI)¹. The NI LabView™ is a user friendly graphical

based programming environment mainly developed for data acquisition, instrumentation, and monitoring in addition to process control and modeling. These virtual tools also help to develop learning and knowledge level of students in many applied subjects.

There are variety of research attempts to add simulations tools into laboratory experiments in engineering education courses. Virtual Control Workstation Design using Simulink, SimMechanism, and the Virtual Reality Toolbox was conducted in education to teach control theory principles as well as a test station for control algorithm development². Authors used two workstations from Quanser Consulting for their electrical and computer engineering program student projects. Their claim was that incorporating a laboratory support into the engineering courses would enhance learning skills of the students. The discussion of the design and using a low-cost virtual control workstation has been done in the first undergraduate control theory course. Then the virtual workstation model from the physical, electrical, and mechanical parameters of a Quanser Consulting electromechanical system was built during the course period. The system has been used in over a dozen student projects and faculty research in the Electrical and Computer Engineering department at Bradley University. A capstone project advising was distributed to all faculty members. Also the learning curve of Simulink in senior capstone project was tested by designing a six-week design project for a course that required system modeling using Simulink.

Another research incorporating the use of multimedia tools into a reverse engineering course has been presented by Madara Ogot³. The main goal of this study was to use multimedia initiative for the students to learn how to use main tools, and use them in other academic activities beyond the reverse engineering class. Since, a classic mechanical engineering curriculum may not offer instructions of the use of multimedia tools in the areas of computer illustration, animation, and image manipulation, this experience increased interest of the major students. Besides, instruction on the use of these tools was incorporated into a mechanical engineering course at Ruther University where it was planned to send out follow-up surveys at the end of the each semester to students who have taken the class. It is expected that, the results of the surveys should provide an indication as to whether providing formal instruction in the use of multimedia tools actually translates into their common use during their technical, oral and written communications.

Another study has been conducted to increase use of software tools such as PSCAD/EMTDC⁴, an electrical power and power electronics transient studies software tool for majors in the Electrical Engineering area. The aim of this study was to make students to be familiar with the electrical power systems due to cost and safety issues in actual power system simulators. Introduction of the PSCAD is usually introduced in the second week of an undergraduate power systems class and training starts with two basic sessions. For this purpose two case studies were presented on PSCAD that included the simulation of a three-phase system that allowed for independent control of voltage on each bus in a way that clearly illustrates the principles of power flow control⁵. Author's objective on using digital simulation software tools in power systems is that "modern teaching facilities supported with digital simulation tools and well equipped laboratories

have great impact in the development of engineering programs in power systems and energy technologies”.

2. Suggested Digital Software Tools in Engineering Technology

Authors of this paper introduce a number of case studies based on the following digital simulation and modeling tools in both mechanical and electrical engineering technology areas.

AMESim simulation package that comes with very helpful demo models for a convenient initial start of modeling⁶. This digital software tool offers extensive set of application specific solutions which comprise a dedicated set of application libraries and focus on delivering simulation capabilities to assess the behavior of specific subsystems.

Pro/ENGINEER (ProE) Wildfire 2.0 and its “Mechanism” simulation application used to demonstrate an interference problem between parts in the engineering assemblies by simulating the individual parts⁷. ProE is another standard in 3D product design, featuring industry-leading productivity tools that promote practices in design while ensuring compliance with industry standards.

Another 3D design software is SolidWorks Education Edition that brings the latest technologies in 3D CAD software, COSMOS Design Analysis software, and comprehensive courseware to the modern design-engineering curriculum⁸.

National Instruments (NI) MultiSim⁹ formerly Electronics Workbench software integrates powerful SPICE simulation and schematic entry into a highly intuitive user friendly graphical based electronics labs in digital environments.

LabViewTM is another NI graphical development environment to help create flexible and scalable design, control, and test applications¹. With LabViewTM, engineering and technology students can interface with real-world signals from variety of physical systems in all engineering areas; analyze data for meaningful information; and share results through intuitive displays, reports, and the Web. Although not covered in this paper due to the length of work, Matlab has been one of the strongest mathematical tools in analog and digital signal and control systems design and simulation studies in the Electrical and Information Engineering Technology program at the University of Northern Iowa.

3. Case Studies

Six case studies are presented in this section of the paper. The first two case studies have been applied to a sophomore/junior level “Power Technology” course with 18 student enrolments. The course was supported with at least six different laboratory sections that students were asked to apply the theory into analysis using AMESim advanced simulation tool. In the first case study the students were expected to determine the angle of inclination of plane after the object starts moving when it is located on a flat inclined surface with a given static friction of coefficient. In the second case study, the students

determined the stopping distance and time of a vehicle model on inclined surfaces. The third case study was applied to an “Advanced Computer Aided Design” course as an independent study. The main objective of the assignment was to solve interference problems between engineering models created by ProE Wildfire based on Mechanism simulation application. The fourth case study was implemented in both “Senior Design I” and “Senior Design II” courses with 14 students. It describes implementation of Solid Works in a capstone design project to model and simulate floating calculations for a solar electric powered fiberglass boat developed at the University of Northern Iowa. Besides, Solid Works supported these projects by providing free copies of Solid Works software CDs. The fifth case is demonstrating the implementation of MultiSim that is used in almost all electronics courses such as “Circuits and Systems”, “Electrical Circuits”, “Analog Digital Electronics”, “Electronics Communication”, “Linear Control Systems”, and “Power Electronics”. In this case study, as a lab support to “Circuits and Systems” course with 16 students and “Power Electronics” course with 12 students, simple RLC circuits, a low pass filter, Bode Plot for stability, and full-wave bridge rectifier simulation studies were simulated respectively in MultiSim and reported for measurement purposes. The last digital tool covered in this paper is LabView™ for data acquisition and instrumentation of a 1.5 kW wind-solar power system where AC and DC voltage, current, power, wind speed values are monitored and recorded precisely. This case study was implemented in a graduate level independent study course titled “Data Acquisition in Wind-Solar Power System Design”.

3.1. Angle of Inclination Study

Figure 1 depicts a schematic of the simulated system. An object with mass, m , is located on a flat surface. One edge of the surface is lifted up to form an angle, α , with the ground. The static friction coefficient, μ_s , is given. The purpose of this test is to determine the angle of inclination when the object starts the motion by using a digital simulation tool.

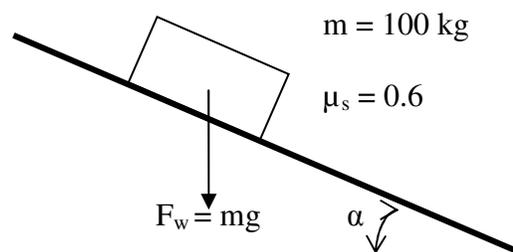


Figure 1. Object on inclined surface

LMS.Imagine.Lab 7b is used to simulate the system⁶. In the mechanical library there exists a component called “linear mass with 2 ports and friction”. The user can apply external forces through the ports, for our purpose the external forces are set to zero. Figure 2 illustrates the simulation model where attachments from both sides of the mass represent the zero external forces. Parameters of the mass component are populated as demonstrated in Figure 3. First two parameters are state variables that are calculated internally, the user is supposed to provide only the initial conditions. Initial velocity and displacements are set to zero. As a selected mass of 100 kg starts the motion, initial

velocity and displacement values are set to calculated values by the model. Since stiction force is good enough for calculations selected, the other three friction inputs, coefficient of viscous friction, coefficient of windage, and Coulomb friction force are all set to zero values.

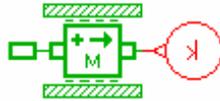


Figure 2. Simulation model of the object on inclined surface

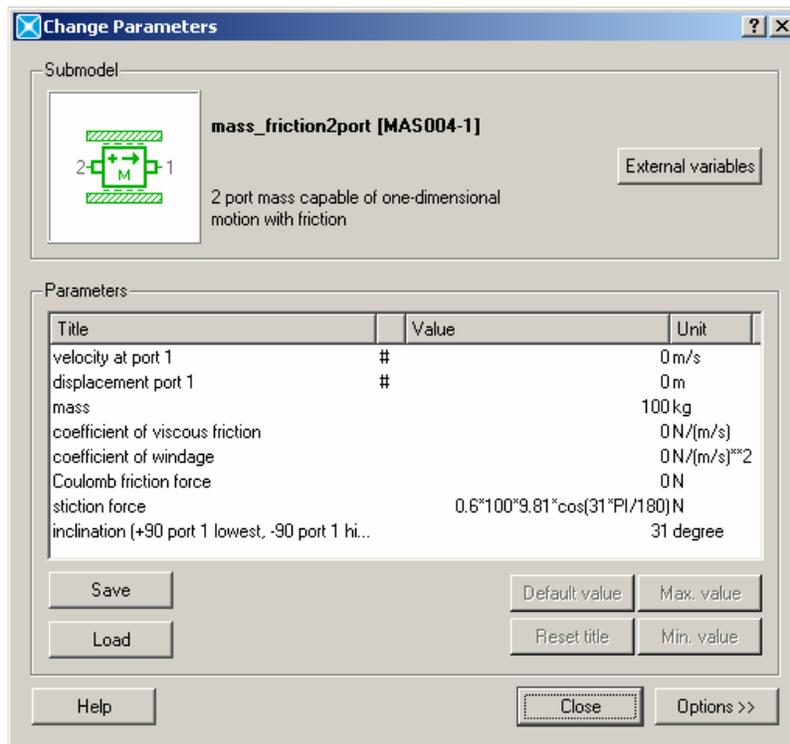


Figure 3. Parameters input to mass component

The formula for the stiction force is given as:

$$F_{fs} = \mu_s mg \cos\left(\frac{\alpha\pi}{180}\right)$$

where,

$\mu_s = 0.6$	coefficient of friction
$m = 100 \text{ kg}$	mass
$g = 9.81 \text{ kgm/s}^2$	gravitational coefficient
α (degree)	angle of inclination

The angle of inclination in the stiction force formula and the inclination in the following line must be identical. Several runs are conducted with different inclinations for 10 s and

velocity of the mass has been observed to determine a motion. The results are given in Table 1. According to this study the angle of inclination is determined as 31 degree.

Table 1. Results of the simulation model for angle of inclination

The angle of inclination(degree)	Mass Velocity(m/s)
0	0
15	0
30	0
31	5.1
40	6.3

An analytical formula to calculate the angle of inclination is given as follows¹⁰:

$$\mu_s = \tan \alpha \quad \text{or} \quad \alpha = \arctan \mu_s$$

where μ_s coefficient of friction
 α (degree) angle of inclination

Since $\mu_s = 0.6$, the angle of inclination can be calculated as $\alpha = \arctan(0.6) = 30.96^\circ$.

This results validates our simulation model. This simple case and several other cases that are introduced in lectures and labs have alleviated instructing a complicated engineering software tool (such as AMESim) to students who are taking beginning level of engineering or engineering technology courses. It is observed that the modeling approach has contributed students to the grasp of more advanced engineering subjects.

3.2 Vehicle Traveling Distance Study

As it is an introductory level engineering technology course, subject of Power Technology class includes basic level of mechanical power transmissions calculations such as gears, pulleys, inclined plane, etc. Vehicle level design and analysis are generally covered in higher level courses at junior or senior levels. Moreover testing such vehicles in labs or fields is always hard to conduct for even an experienced technician and it is expensive to maintain such facilities for a teaching institute. Using software tools may improve instruction of harder subjects at lower level courses.

One of the problems presented as a computer lab assignment was determining stopping distance and time of a vehicle model on an inclined ground profile. Schematic of the problem is shown in Figure 4. An initial torque profile, as depicted in Figure 5, is applied to vehicle first 22 s of the test, and the travel distance and the elapsed time until the vehicle comes to complete stop are asked to be determined at the given ground slopes of 5% , 10%, 15% and 20%. The vehicle model consisted of engine, vehicle, transmission, differential and tire components. AMESim simulation package offers an extensive set of application specific solutions which comprise a dedicated set of application libraries and focus on delivering simulation capabilities to assess the behavior of specific subsystems. The current portfolio includes solutions for internal combustion engines, transmissions, thermal management systems, vehicle systems dynamics, fluid systems, aircraft ground loads, flight controls, and electrical systems. AMESim comes with very helpful demo models for a convenient initial start of modeling. "VehicleTire.ame" is a demo model in

their power train library which consisted of differential, vehicle and tire models. While the engine has been represented by a simple torque curve, transmission model has been completely ignored. For the part of the lab work, the students were expected to integrate a transmission model to the demo vehicle model. They are instructed to use the variable gear ratio component from AMESim mechanical library for a simplified transmission model. The component allows the user to specify any gear ratio externally. A snapshot of the modified vehicle model is demonstrated in Figure 6.

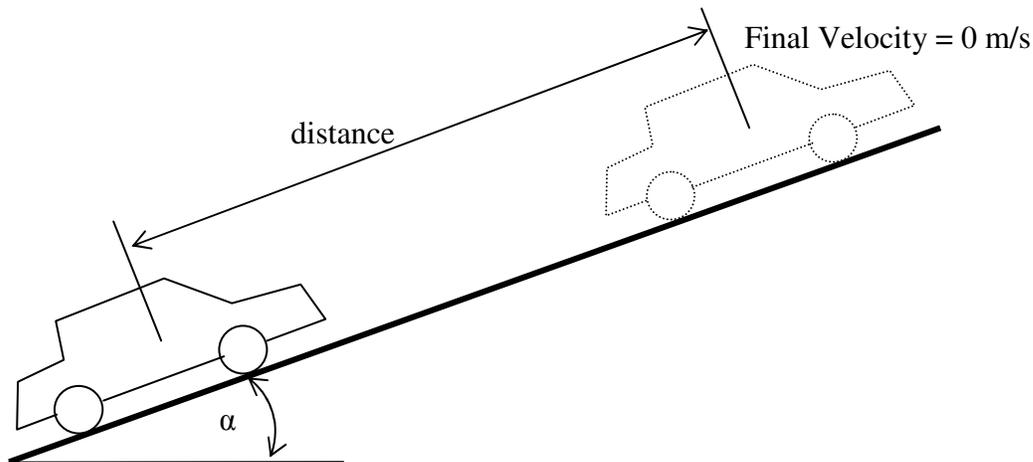


Figure 4. Schematic of vehicle and ground profile

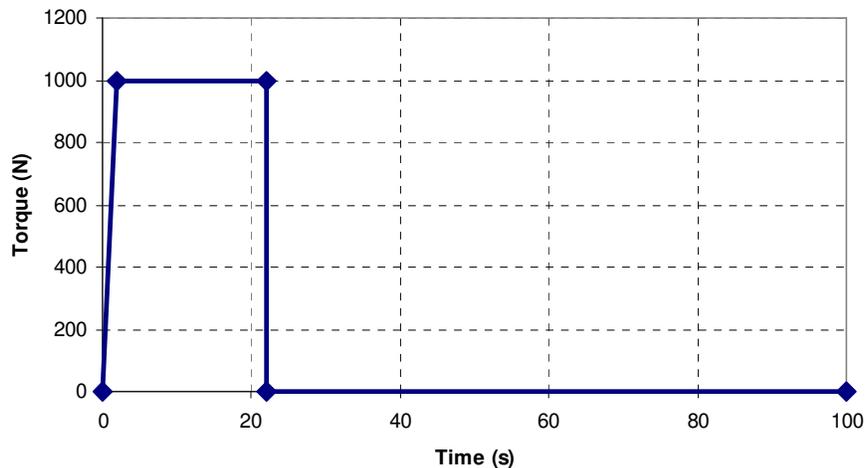


Figure 5. Engine torque profile

Breaking torque is set to zero for the purpose of this study. Gear ratio of the transmission has been increased from 0 to 1 by 0.25 increment for each 5 s as depicted in Figure 7. The other parameters except the slope input have been left the default parameters from demo model. The model has been run twice for 5% , 10%, 15% and 20% of ground slopes. The results are shown in Table 2. It is obvious that as the slope increases, the vehicle stops earlier. Interestingly at 20% slope the vehicle did not even move towards up to hill, instead it start moving back after the engine torque released at a time of 22 s of the simulation. This has given the student an opportunity of investigating the system

capabilities. The model can be used further detailed discussion and analysis of the vehicle behavior. For example, the car body longitudinal velocity and acceleration for 5% ground slope are shown in Figure 8.

The vehicle is accelerating and reaches to maximum velocity until time 22 second when the engine torque is set to zero as seen in Figure 8.a. The accelerating scheme as seen in Figure 8.b during this period looks like a step function since gear ratios are suddenly increased at times of 5, 10, and 15 s of simulation. The slight decrease in acceleration through the end of each step is because of the drag losses that were set to nonzero by default.

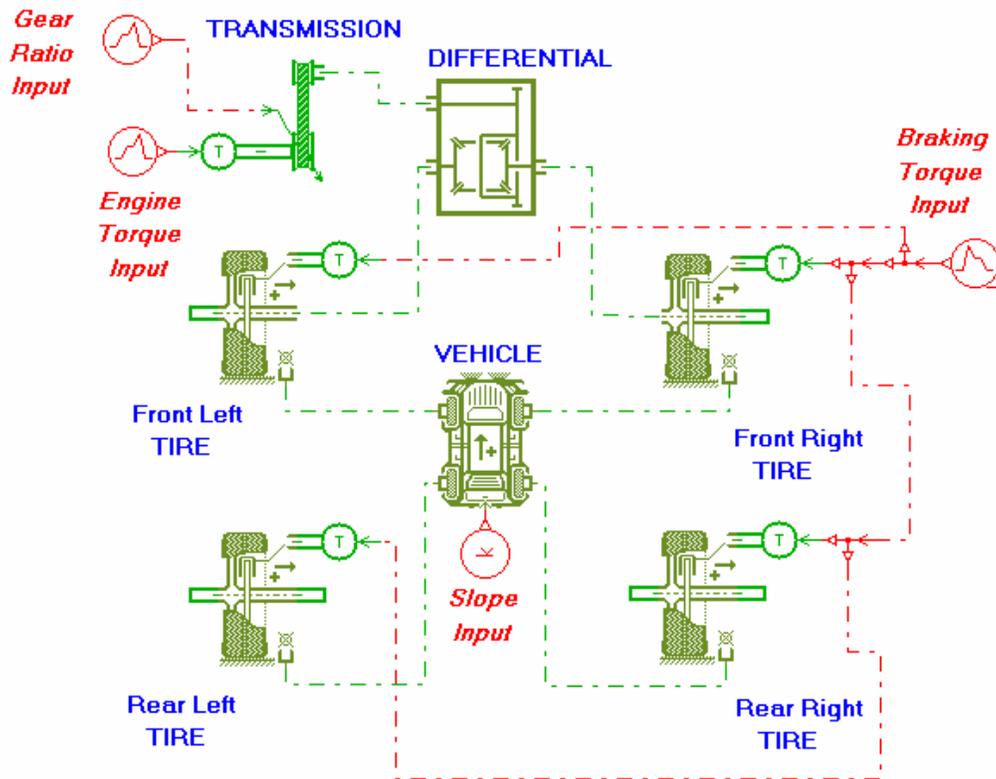


Figure 6. Vehicle simulation model

Table 2. Results of the vehicle simulation model

Ground Slope (%)	Stopping Distance (m)	Stopping Time(s)
5	1304	85.96
10	454	47.38
15	111	32.4
20	n/a	n/a

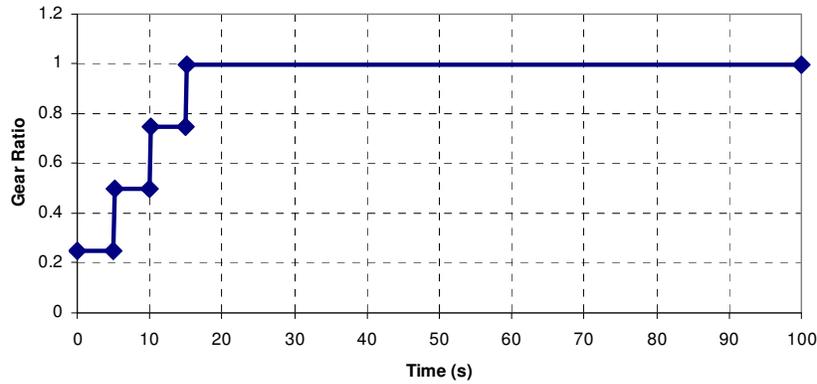
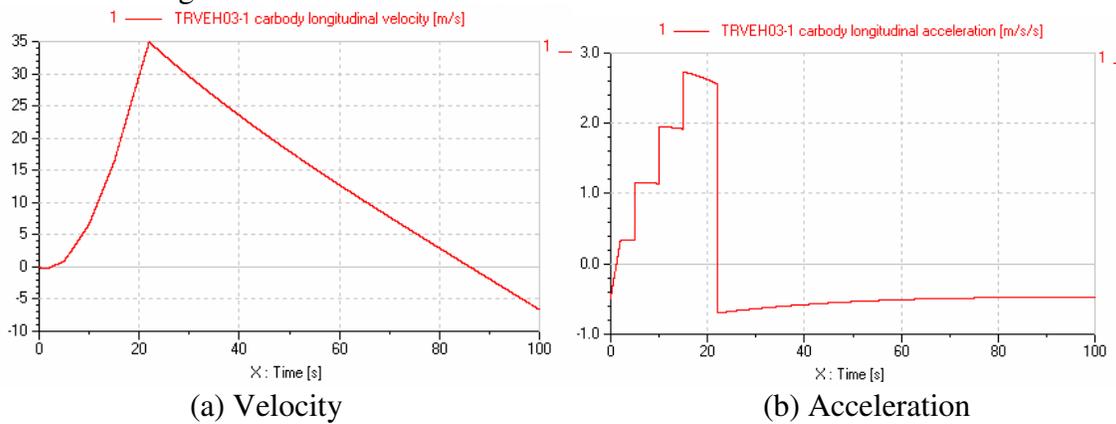


Figure 7. Gear ratio of transmission in a vehicle simulation model



(a) Velocity (b) Acceleration
Figure 8. Car body longitudinal velocity and acceleration

3.3 Solving an interference problem with Pro Engineer Wildfire 2.0

Pro/Engineer (ProE) Wildfire 2.0 is an engineering modeling and design program capable of creating engineering models, drawings, and assemblies. Besides, ProE comes with different application program packages to help design and modeling process. These application programs aid to engineers to test parts, models, and assemblies from early to advanced development stages. These applications included cabling, piping, welding, sheet metal, mechanism, animations, plastic advisor, finite element analysis etc. Student groups who is familiar with ProE can be divided into small groups to make projects using application packages depends on their interest points. For instance cabling application can attract an electrical engineering major student to learn and design electrical cabling of the system. Piping application package can be interesting part of modeling for students who want to model air, gas, fuel pipes or hoses for the automotive industry. In fact learning fundamentals of how to use ProE applications will enhance students' knowledge. Fundamentals of each application help students to understand the basic terminology, tasks, and procedures so they can build their own models efficiently and share information, ideas, and processes with other students.

In this case study a small group of engineering students was required to solve an interference problem between two parts by providing new design solution. For this purpose ProE "Mechanism" application was suggested to use to find out where the

interference occurs. ProE Mechanism is used to define a mechanism, make it move, and analyze its motion. In Mechanism application, engineering student can create connections between parts to build an assembly with the desired degrees of freedom, then apply motors to generate the type of motion student wants to study. Mechanism design allows designer to extend the design with cams, slot-followers, and gears. When the movement of the assembly is ready to analyze student can analyze the movement, observe and record the analysis, or measure quantities such as position, velocity, acceleration, or force, and graph the measurement. Mechanism is also capable to create trace curves and motion envelopes that represent the motion physically. When movement becomes ready, then mechanisms can be brought into “Design Animation” to create an animation sequence. Actual physical systems such as joint connections, cam-follower connections, slot-follower connections, gear pairs, connection limits, servo motors, and joint axis zeros are all supported in “Design Animation”.

Initially four different parts and their dimensions were provided to the students to model them in ProE. The parts were named with appropriate explanations to alleviate the modeling for students. Intentionally, the dimensions of ball adapter and main structure plate were changed to cause interference between these two parts when operating in the assembly. When these parts are modeled and assembled together it will be obvious that ball adapter and main plate are interfering each other when moving the mechanism. In this case, students used mechanism application by changing assembly type and using joint connection to move the parts in the assembly. Figure 9 depicts ProE assembly of four different parts; ball adapter, connection pin, tightening pin, and main structure plate.

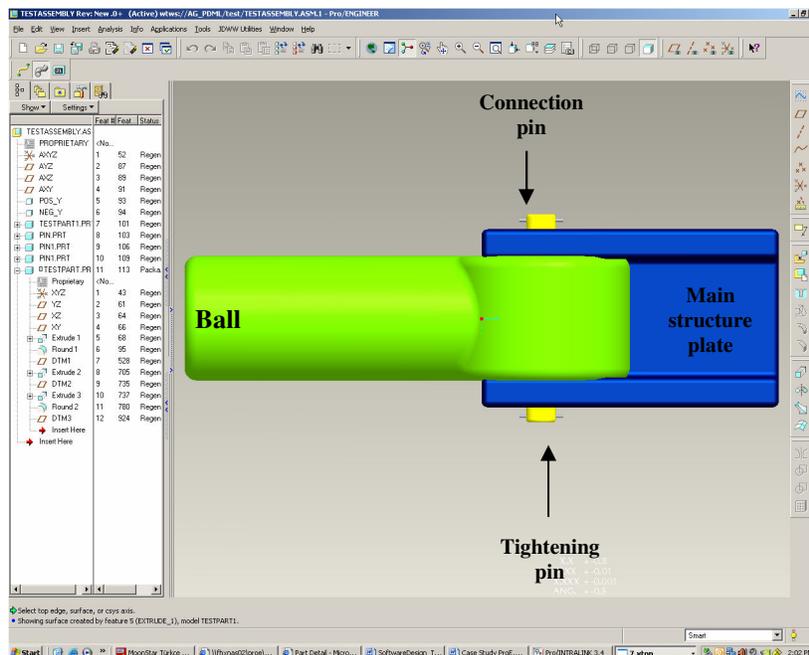


Figure 9. Pro Engineer assembly to test assembly for interference control

As a result of modeling and assembling the aforementioned parts together, students realized that there was interference between internal sides of the main plate and the ball adapter. The interference amount was found by making model clearance analysis with

ProE and depicted in Figure 10 with red lines. Second interference was occurred when testing the ball adapter using mechanism application. When the ball adapter moved 65 degree angle down, there was interference between narrow edge of the main structure plate and round shape of the ball adapter. This was obvious when testing with mechanism otherwise this interference is not visible without moving the ball adapter. Second interference diagnosed by mechanism application is shown in Figure 11 with red lines and 65 degree angle. In this example, 65 degree angle was given initially to indicate that the ball adapter is supposed to move maximum 65 degree angle to avoid interference of other parts in the assembly. As a result of diagnosing interferences problems the design change of the parts have been conducted by changing dimensions. This case study motivated students to involve more model analysis with other applications of ProE. Students gained skills on how to model, assemble, and analyze their designs with ProE and its applications.

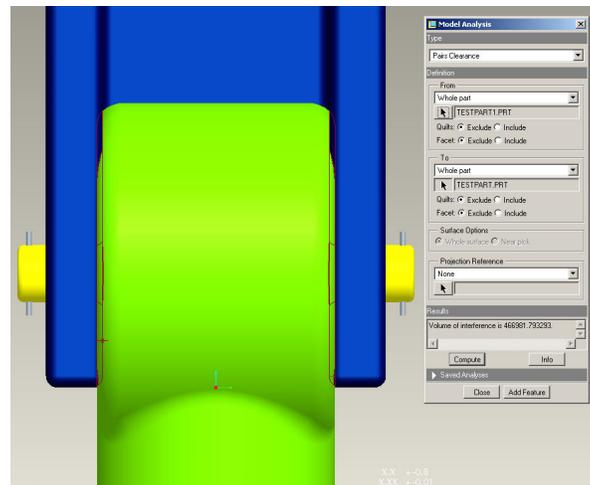


Figure 10. Interference between main plate and ball adapter without moving the parts

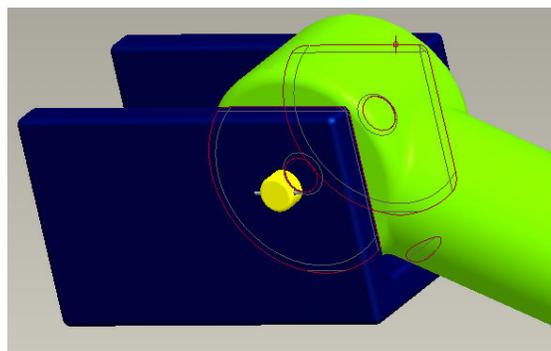


Figure 11. Interference between main plate and ball adapter when moved 65 degrees

3.4 Using Solid Works in a Solar Electric Boat Design and Floating Calculations

The University of Northern Iowa (UNI) solar electric boat team used both Solid Works and ProE to model the new fiberglass solar electric boat in 2007. With the team's extensive use of CAD, it was easiest to change the material of the hull to water and have

Solid Works calculate the new mass as shown in Figure 12. Buoyancy is created by the displacement of water. As modeled, the boat displaces 288 pounds of water when submerged. Calculations by Solid Works indicate that the weight of the hull with the actual foam material to be only 40 pounds. With all other components taken into account, the boat weighs approximately 230 pounds in race trim. This yields a safety factor (SF) as follows:

$$SF = (288 - 230) / 288 = 0.2014 \text{ or } 20.1 \%$$

These calculations together with SolidWorks modeling show that the UNI solar electric boat, in the event of capsizing, will not sink and has a safety margin of 20.1 %.

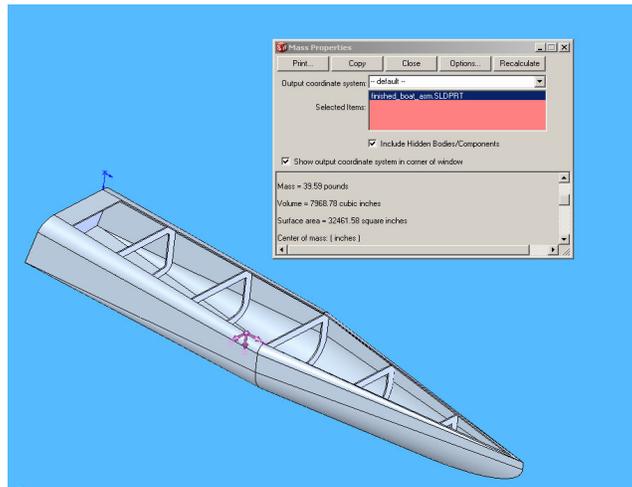


Figure 12. Solid Works model of UNI solar electric boat using actual material.

3.5. Using MultiSim in a variety of EET Applications

Although actual analog electronics labs must be part of any electrical engineering technology (EET) curriculum, students in these programs may also gain valuable skills and depth in knowledge safely in their home computers before the lab day. Figure 13 depicts a simple RLC circuit and how to connect appropriate meters to measure voltage, current, and power values.

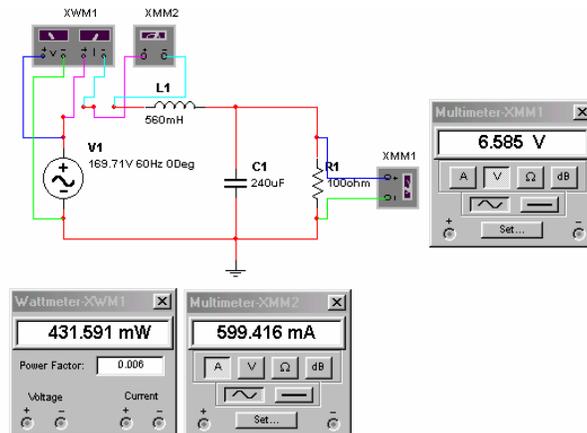


Figure 13. Voltage, current, and power measurements in MultiSim for a simple RLC Circuit.

Figure 14 shows a simple passive low pass filter circuit and its frequency response in MultiSim using a cut off frequency of $f_c = 2,192$ Hz.

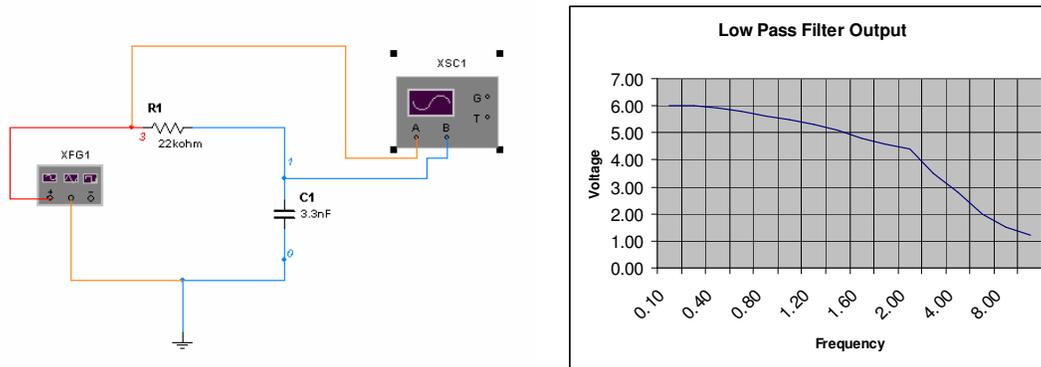


Figure 14. A simple passive low pass filter and its frequency response using MultiSim.

Similarly Figure 15 depicts a Notch filter design, its frequency response, and Bode Plots respectively in MultiSim.

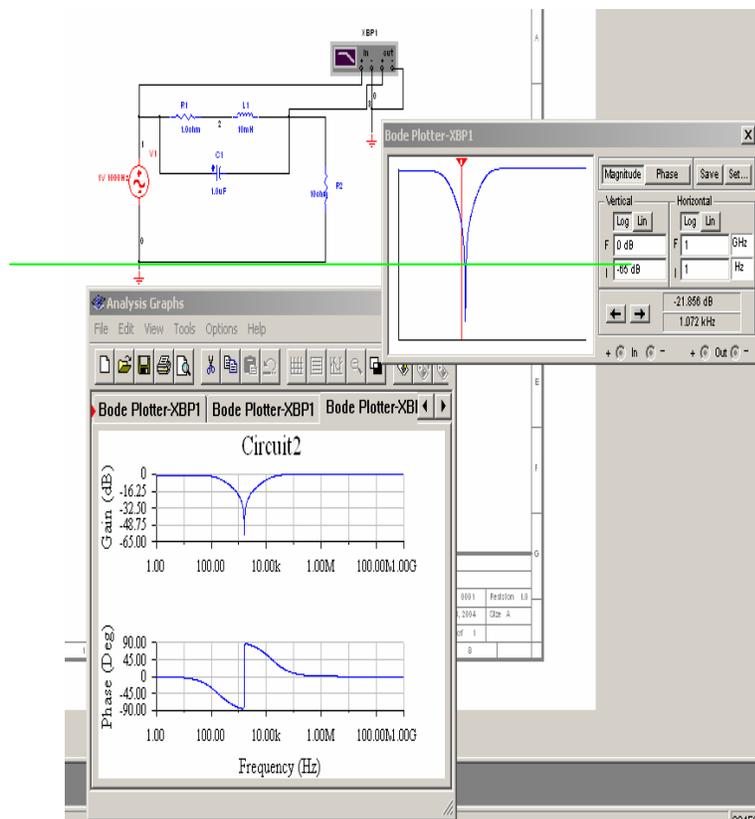


Figure 15. A Notch filter design and its Bode Plots in MultiSim.

Figure 16 indicates another example of MultiSim applied to simulation of a full-wave bridge rectifier in a power electronics class. Students safely gain depth-in knowledge of a high power AC/DC converter before the lab day in their home computers. This also includes instrumentation connections in a virtual environment, waveforms monitoring

and overall circuit operation in steady-state. Figure 17 depicts a DC waveform output and numerical readings from the same bridge rectifier circuit shown in Figure 16.

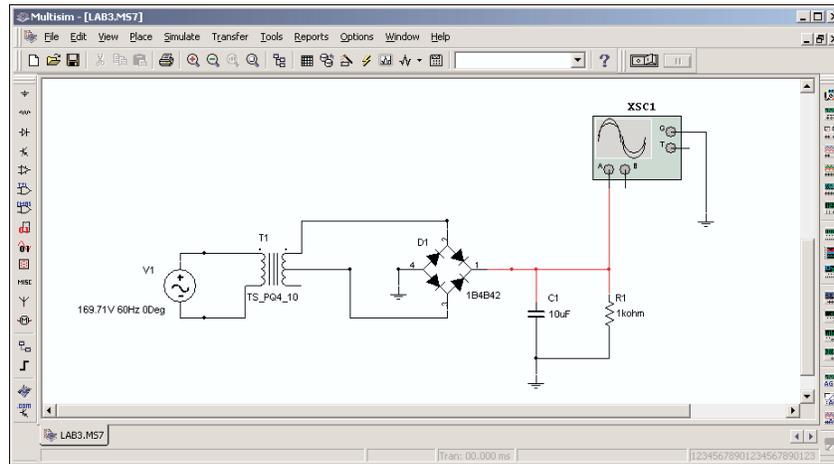


Figure 16. A full-wave bridge rectifier in MultiSim.

3.6. Using LabView™ in Computer Based Data Acquisition and Instrumentation Classes and Capstone Design Projects

Figure 18 and 19 show a LabView™ based data acquisition virtual instrument diagram and graphical outputs respectively for a 1.5 kW hybrid wind-solar power system where wind direction, wind speed, AC/DC voltage, current, and power values are measured and monitored precisely.

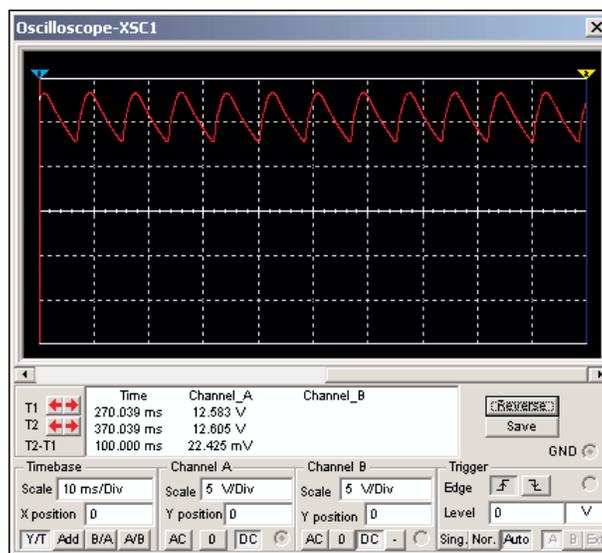


Figure 17. DC Output waveform of the bridge rectifier circuit shown.

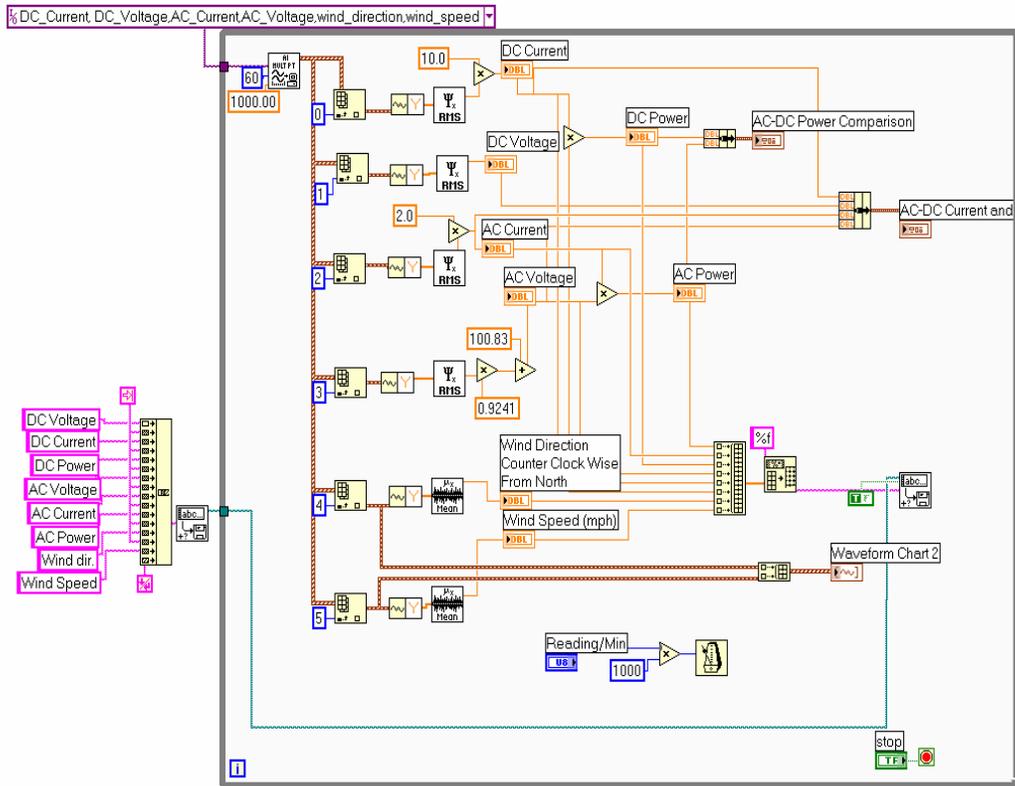


Figure 18. Overall diagram of the LabView™ data acquisition virtual instrument (VI).

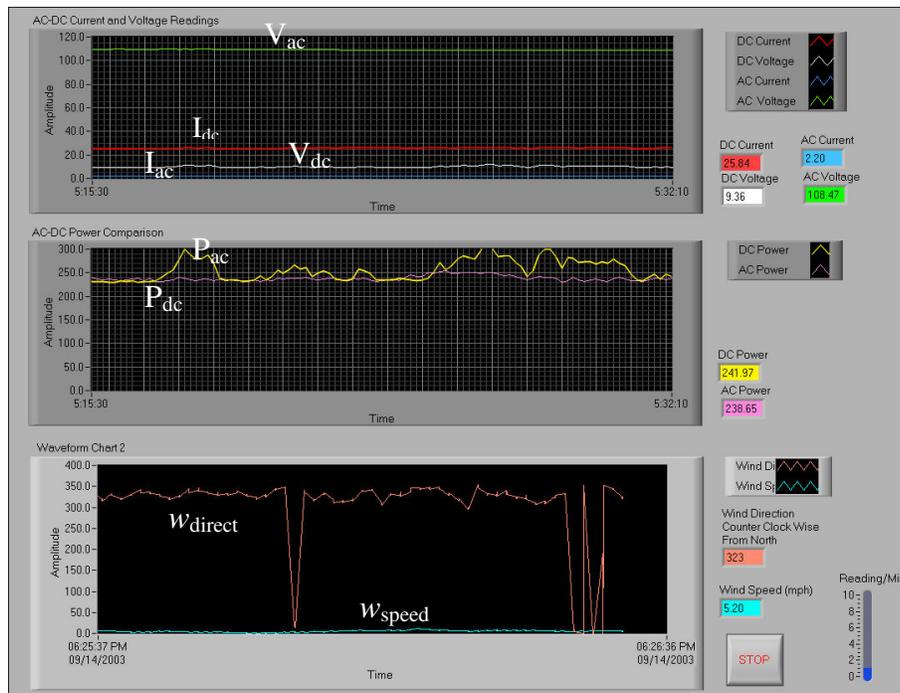


Figure 19. Front panel of the data acquisition VI for a 1.5 kW wind-solar power system.

4. Conclusion and Recommendations

Computer aided engineering and technology education offers a valuable and cost effective solution to increase the quality of laboratory environments in the educational institutions. The physical environment may be further visualized and demonstrated in the classroom education by introducing more advanced simulation tools. Several case studies have been demonstrated using LMS Imagine.Lab AMESim; a professional grade, integrated platform for 1D multi-domain system simulation, Pro Engineer Wildfire; well-known three dimensional CAD/CAE software tool, SolidWorks; another 3D digital simulation tool, NI MultiSim; formerly Electronics Workbench software integrating powerful SPICE simulation and schematic entry into a highly intuitive user friendly graphical based electronics labs in digital environments, and finally LabView™; another NI graphical development environment to help create flexible and scalable design, control, and test applications in electronics and electromechanical systems.

According to the end of year student evaluations in different courses, many students have found the software tools very helpful and user friendly in understanding fundamentals of physical phenomena in engineering technology areas. Depending upon one-on-one interactions with students one can easily conclude that freshmen were more motivated using the software tools than the non-traditional students. A number of students have used their knowledge and experience with the aforementioned software tools as a valuable bridge to many internship and part-time student positions in local electronics and manufacturing industries. Our industrial advisory board members have repeatedly mentioned their satisfaction with our students and their valuable experience on digital modeling and simulation tools.

The authors agree that, as a future work, each of the software tools presented in this paper can be separately and thoroughly investigated as an up-to-date support to engineering and technology education curriculum.

References

- [1] National Instruments, 2008, <http://www.ni.com/labview/>
- [2] Kain Osterholt, et al., “Virtual Control Workstation Design Using Simulink, Simmechanics, and The Virtual Reality Toolbox”, *Proceedings of American Society for Engineering Education*, 2006-567.
- [3] Madara Ogot, “Integration of Instruction on the use of Multimedia Tools into a Mechanical Engineering Curriculum”, *Proceedings of the 2003 American Society of Engineering Education Annual Conference & Exposition*, 2003-1566.
- [4] <http://pscad.com/> Professional Power System Design and Simulation
- [5] F. Chalkiadakis, “Classroom Studies in Power Flow and Transmission Lines by Means of PSCAD/EMTDC”, *Proceedings of the 2003 American Society of Engineering Education Annual Conference & Exposition*, 2007-321.
- [6] <http://www.lmsintl.com/Imagine> AMESim
- [7] <http://www.ptc.com/> Pro/ Engineer WildFire 4.0
- [8] <http://www.solidworks.com/>
- [9] <http://www.ni.com/academic/multisim.htm>
- [10] J. Harter, “*Electromechanics: Principles, Concepts, and Devices*”, Prentice Hall Publishing, 1995.