AC 2007-2038: DESIGN-BUILD-TEST---BUV, A CAPSTONE DESIGN PROJECT

Janak Dave, University of Cincinnati

Janak Dave, PhD, PE is a professor in the Mechanical Engineering Technology department at the University of Cincinnati. He obtained his MS and PhD in Mechanical Engineering from the University of Missouri, Rolla. He has presented papers at ASEE Annual Conferences, ASME International Congress, and several international conferences and conducted CAD/CAM/CAE workshops nationally and internationally. He has held various positions in the EDG and DEED divisions of ASEE, as well as local and national committees of ASME.

Janet Dong, University of Cincinnati

Janet Dong, PhD is an Assistant Professor in the Mechanical Engineering Technology department at the University of Cincinnati. She received her PhD and MS degrees in Mechanical Engineering from Columbia University, and her MS and BS in Manufacturing Engineering from China. Her academic interests include manufacturing technology, CAD/CAM, computer aided process planning and optimization, control and automation, robotics, and mechanical engineering application to dental endodontic treatment. She had published journal papers and conferences papers nationally and internationally. She is the member of ASEE, ASME, and SME.

Design–Build–Test
BUV–A Senior Capstone Design Project

Abstract

Students working toward baccalaureate degree in Mechanical Engineering Technology at the University of Cincinnati are required to complete a “Design, Build, and Test” Senior Capstone Design Project. One of these capstone design projects was to build a Basic Utility Vehicle (BUV). It was geared to meet the needs of developing countries for an affordable transportation. BUV competition is sponsored by IAT–Institute for Affordable Transportation, a non-profit organization in Indianapolis, IN. IAT's mission is to improve the living standards and enable economic growth in the developing world by creating a simple vehicle that can be assembled almost anywhere, by almost anyone. They donate the vehicles to needy countries in South America and Africa.

A team of students in the Mechanical Engineering Technology Department at the University of Cincinnati built a BUV as their senior capstone design project during the 2005-2006 academic year. By doing this project, they developed the additional skills needed to be successful in a team oriented business world. They realized transportation needs in the developing countries. They also enjoyed the personal satisfaction of working on a technically complex project from concept to a final working vehicle, and competing against other university teams.

This paper will give the short description of the senior capstone design course sequence at University of Cincinnati, the list of pre-requisites of its sequence, and describes the 2005-2006 BUV project and the team experiences of the project from start to finish.

Introduction

Completing a senior design project is the graduation requirement for all of the students in Mechanical Engineering Technology (MET) department at University of Cincinnati (UC). The project consists of a four-course sequence resulting in a working product. These courses are designed to help student synthesis and apply the knowledge and skills they have required prior to their senior year. This also makes them use their abilities to solve open-ended problems and prepare them for the transition from academic to non-academic environments.

The project consists of designing, building, and testing a prototype of a product or process. At the completion of their senior capstone project, students will have acquired the following necessary skills, which will apply to their professional careers.

1. Synthesizing knowledge from early courses
2. Starting from concept to making a working prototype
3. Project management
4. Time management
5. Dealing with vendors
6. Oral communication to a technical and non-technical audience
7. Writing a formal project report

Senior Capstone Project

The four-course sequence for senior project consists of Senior Seminar, Senior Design Project I, Senior Design Project II, and Senior Communications. It is also required for students to present their project at the annual Technical Exposition (Tech Expo). The first three courses are offered by the MET department, and the fourth one is offered by Humanities, Media and Cultural Studies (HMCS) department. The sequence constitutes 6.75 percent of Baccalaureate Degree requirements. The following is a short description of each course and required pre-requisites.

Pre-requisites:

In additional to statics, kinematics, dynamics, mechanics of materials, and design graphics courses. MET students take three design courses. They take one course each quarter during their sophomore, junior, and senior years. This sequence consists of: Design of Machine Elements, Mechanical Design, and Product Development. The main emphasis of the Product Development course is to teach systematic design methodology, and expose to students the tools and techniques currently practiced in industries. Topics in these courses include Quality Function Deployment (QFD), Concurrent Engineering, Design for Assembly (DFA), Design for Manufacturing (DFM), and Project Management. This prepares students to apply some of the above tools and techniques to their senior project.

Senior Seminar:

Students are required to propose ideas for the senior project in Senior Seminar. These ideas may originate from industry, departmental faculty, national competitions, by the students themselves, or any other sources. By the end of this course, all students must have a written detail project proposal, which includes research, cost estimate, customer surveys, and tentative schedules, etc. Students are assigned a project advisor who works with them in finalizing the proposal. The relationship between the advisor and students is like a project engineer and her/his supervisor/manager.

Senior Design I:

Admission to Senior Design I course is contingent upon the successful completion and approval of proposal submitted in Senior Seminar. Students use systemic design methodology to come up with final technical specifications for their product. They generate conceptual designs, and select the best concept using a weighed objective or the Pugh method. They also do a detail design and analysis of all the parts, including generating working drawings and a bill of materials. The analyses may consist of stress, kinematic, heat transfer, and DFM, etc. The above activities are documented in two different forms: weekly reports and a comprehensive professionally written design report at the end of the quarter.

Senior Project II:

During Senior Project II, students are expected to manufacture the necessary parts and make the prototype. The exception to this requirement is parts needing sophisticated or precise machining using equipment not available in the department facility or commercially approved components. The finished prototype is tested and debugged to verify that it meets or exceeds the technical specifications promised by the students in Senior Design I.

<u>Senior Communications:</u>

Senior Communications prepares students for oral communications to all audiences. It also prepares them for oral presentations to a technical audience. They produce a professional technical report, with individual guidance from technical writing faculty.

<u>Tech Expo:</u>

Local industries, employers, parents, families, alumni, and presses are invited to a college sponsored Technical Exposition (Tech Expo) in May. Seniors from every department display, demonstrate and explain their project to interested parties. The best project from each department and the best in the whole college will be judged and awarded during the Tech Expo. One of the winning senior projects in the year of 2005-2006 was the Basic Utility Vehicle (BUV) project.

2005-2006 BUV Project

As mentioned in Senior Seminar course description, BUV project falls into the category of national competitions. In developing countries there is need for an affordable means of transportation that will help fulfill the basic transportation need of the people living in that area. The Institute for Affordable Transportation (IAT) hosts a competition of designing and building BUV each year. IAT is a not-for-profit public charity devoted to developing high-quality, low-cost transportation for the working poor in the developing world. The competition tests and judges all of the entries to identify best design and suitable vehicles for developing countries. The goal is to assemble these vehicles in small factories in developing countries. IAT has donated several vehicles to Honduras and in Africa.

2005-2006 BUV challenge given by IAT was to design a 3-wheel vehicle based on the rear-end (i.e. the bed, axle, suspension, wheels, frame, etc) of a small pick-up truck (Chevy S-10, Ford Ranger, etc) cut near the cab/bed interface. It was also required to design a rear ambulance unit to be attached to the rolling chassis. In addition to cost, design emphasis was on drive train, ease of assembly, durability, serviceability, and the ambulance unit itself. Design for small-scale assembly operations in the developing worlds that can each produce one vehicle per day. The goal is to minimize the investment needed for "micro-factory" to do assembly.

The BUV was designed to meet all of the IAT specifications, and to be successful in all of the different performance tests in the competition. The complete 2006 BUV specifications can be found at IAT website, <u>www.drivebuv.org</u> [2]. Some of the major 2006 BUV specification rolling/drivable chassis are:

- The pre-welded cost should be less than $1,350
- Provide a powered reverse
- Front frame to weight less than 120 lbs
- Payload including passengers or cargo more than 1200 lbs

- Must have regular and emergency brakes
- Primary engine must be 8.5 -10 hp internal combustion engine
- Front suspension must have minimum of 3" wheel travel

Based on the specifications, BUV project was separated into four different areas by the project team: Steering, suspension and braking, see Figure 1, Chassis and frame, power drive train, and ambulance attachment. Each area was completed by one team member. Each member had a schedule in which their section was to be completed.

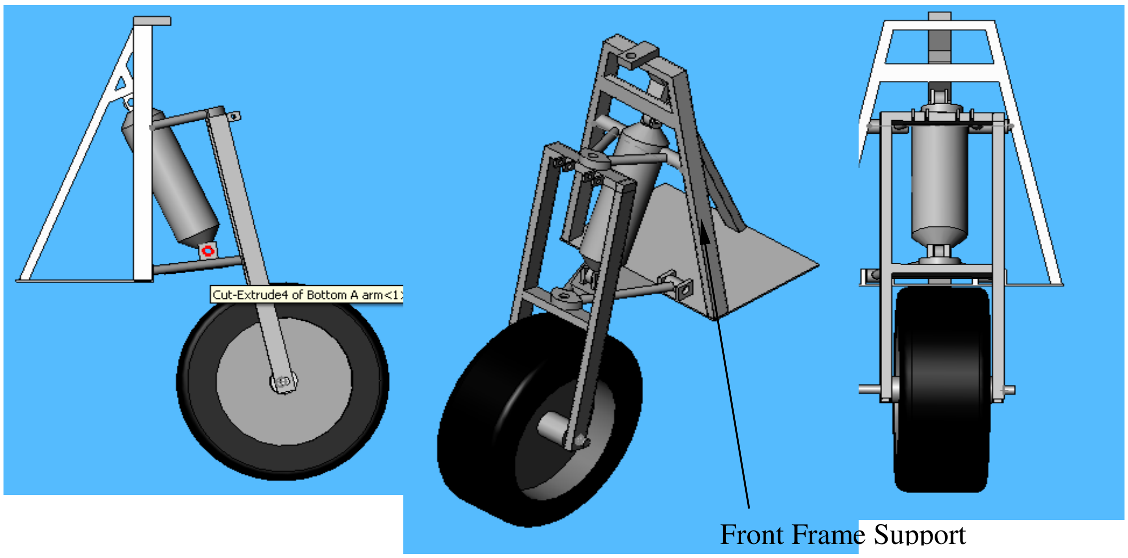

Figure 1. Steering, Suspension and Braking System (Different views)

<u>Front Support Frame Design and Analysis:</u>

All the major components were designed/selected and analyzed by the team members. The next paragraphs describe the principle support frame details.

Figure 1 also showed a component design example of Front Framing Support in the steering system. The front framing support was designed in an effort to create maximum rigidity for the forces incurred by spring and turning functions. There were three areas of concern that could potentially affect the integrity of the member. The first one was the compressive force of the spring acting upwards on the center of the support. The second area of concern was due to lateral forces that may be put on the support due to turning or any shift from side to side that is may encounter. The last area of concern was stresses that may be formed from impacts caused by the wheel assembly hitting an obstacle pushing the front support back. The Cosmos Static analysis program shows the stresses and deformations due to load on front framing member in Figure 2 (a) and (b). After running these three major scenarios the design of the front support was considered to be capable of handling all the different scenarios that it may encounter. Similarly, the other components were designed using above processes for designing Front Framing Support.

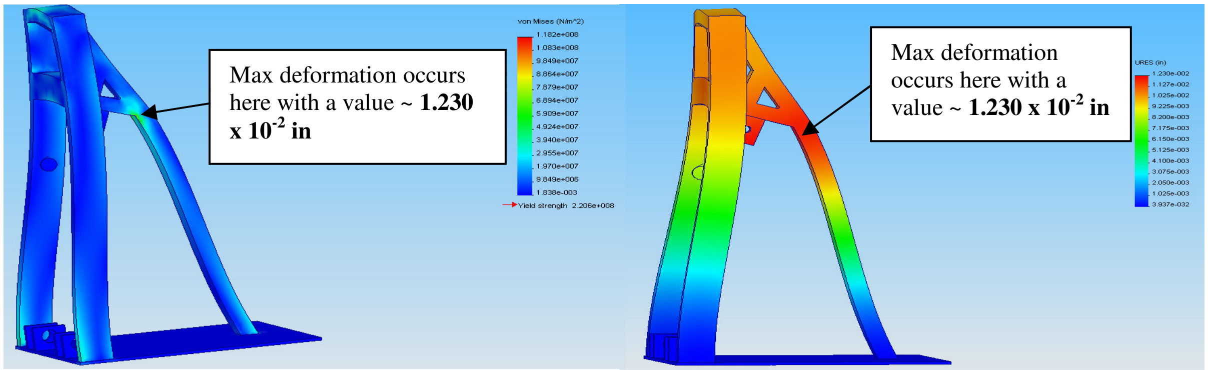

Figure 2. Front Support Frame Design (a) Stress of Front Framing Support due to frontal force, (b) Deformation of Front Framing Support due to frontal force

Fabrication and Assembly:

With all design work completed by four team members, the fabrication of the BUV components had to be undertaken, followed by the assembly of all the components. It took about four weeks to get all components manufactured and assembly into a workable vehicle. Since the BUV project was separated into four different areas, and each member had a schedule in which their section was to be completed. The four group member kept in close contact to ensure that all components would fit together right when it was time for assembly. To begin the fabrication some preliminary processes had to be completed before the newly designed members could be incorporated. Those included the stripping of the totally rusted Chevy S-10 frame so that parts could be welded and attached easily to it, and the drum brake wheel cylinders had to be replaced due to the fact the old cylinders were froze into place. Then the assembly process began with chassis, sub-floor, bed, and front framing support were assemble and welded on the truck frame. The rear suspension along with wheels and tires were place back on the truck frame chassis. With a completely rolling vehicle the next step was to install the drive train components. Assembled vehicle is shown in Figure 3 (b), (c), (d), and (e).

Vehicle Testing:

Initial testing of the vehicle took place in the college parking lot. The real tests of the vehicle occurred at the annual IAT competition that was held on April 29th and 30th, 2006, in Indianapolis, IN. The vehicle and the team was required to go through

- obstacle course,
- swamp crossings,
- mud pits,
- weighted hill climbs
- judges drive experience
- maneuver course
- oral presentation
- written report

Figure 3 shows some terrains and obstacles the vehicle had to endure. The vehicle performed very well. The ride on the vehicle was very comfortable, and rode over obstacle with ease, and rode crossing the swamp finished best. Although some problems occurred during the test, they found the right way to fixed them, and all the way to the end with finishing each test. In addition to the real test, the group had to present their technical report. The cost of the BUV without the ambulance attachment was $2,500. Overall the team achieved second place among all participating teams.

(a)

(b)

(c)

(d)

(e)

Figure 3. 2006 UC BUV in the Competition Site
(a) Welcome (b) Mud Pit (c) Swamp Crossing, (d) the Maneuver Course, (e) Obstacle course

__Project Management and Team Experience:__

The BUV was a team project. Students learned how to perform in a team and as a team. They learned about writing sponsorship letters, fund raising, estimating a budget, dealing with vendors, and time management. They learned to meet deadlines, and how to work with an organization's rules and regulations on purchasing parts, scheduling before and after competition. They learned how to communicate and deal with team members. They were acquaintances at the beginning of the project, but three of the four became very good friends and good at working with each other.

__Aware of International Issues:__

The most common BUV applications are general purpose work vehicle, medical vehicle, farm vehicle carrying farm inputs / outputs, material carrier at construction projects, water distribution, and school bus for children. By doing BUV project students learned about the lack of infrastructures in developing countries and basic transportation needs to move cargo or sick people from one place to the other. They realized the issues how the people would make, maintain, and use donated vehicle in the developing countries, such as in Africa. They also experienced research activities and procedures on developing countries when planning for this project. Some team members improved their knowledge of geography as well.

By building this vehicle, students learned to help meet peoples' needs in other parts of the world. More than the cars, they learned about helping people, provide opportunities to get sick people needed medical attention, and farmers moving their products to the markets.

Conclusions

The BUV project was one of the more complex senior design projects in the MET department. During the year of 2005-2006, participants learned how to meet transportation needs of developing countries at a reasonable cost. Beside the research needed for design, analysis, and building the vehicle, the team obtained invaluable experience in meeting transportation needs of different countries, fund raising, working in a team, time management, oral presentations to the competition judges and non-technical audience, writing individual reports and a team project report, as well as real testing of their product. They went through every step from a concept to a working vehicle. The 2006 UC BUV was one of the most successful project in the department.

Bibliography

[1] B.S. degree requirements, Department of Mechanical Engineering Technology at University of Cincinnati, 2005–2006, http://www.uc.edu/met/.
[2] Institute for Affordable Transportation, "Basic Utility Vehicle", August 2005 http://www.drivebuv.org/.
[3] The 2006 BUV Design Report–Drive train, submitted to University of Cincinnati, Brian Farno, June 2006.
[4] The 2006 BUV Design Report–Chassis, submitted to University of Cincinnati, Chris Mayleben, June 2006.
[5] The 2006 BUV Design Report–Suspension and Steering System, submitted to University of Cincinnati, Daniel Lingrosso, June 2006.

[6] The 2006 BUV Design Report–Ambulance Attachment, submitted to University of Cincinnati, John Duncan, June 2006.
[7] Creation, Development and Approval of Design, Build, and Test Senior Design project, Janak Dave, Thomas Boronkay, ASME International Mechanical Engineering Congress and Exposition (IMECE), 2001.
[8] Senior Capstone Design Project in the Mechanical Engineering Technology Curriculum, Thomas Boronkay, Janak Dave, ASME International Mechanical Engineering Congress and Exposition (IMECE), 2001.
[9] Improving Student Team Experiences, Janak Dave, Thomas Boronkay, Interamerican Conference on Engineering and Technology Education (INTERTECH) 2004.