AC 2007-2050: DESIGN-BUILD-TEST---AUTOCROSS-A CAPSTONE DESIGN PROJECT

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.

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.

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

Abstract

Students working toward a 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 design and build an Autocross racing vehicle. This vehicle was built to meet the Sports Car Club of America (SCCA) Autocross specifications, and was tested in the local competition event.

From the concept to the final working vehicle which meets SCCA's specifications, there are many challenges. In the 2005-2006 academic year, a team of four Mechanical Engineering Technology students at the University of Cincinnati built an Autocross racing car as their senior capstone design project. As with all capstone projects, expertise and knowledge acquired from their coursework and co-op were utilized. This project gave them an opportunity to showcase their abilities as well as develop additional skills needed to be successful in a team oriented business world. This team also enjoyed the personal satisfaction of working on a technically complex project from concept-to-tested, and competing against other such projects.

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

Introduction

Completing a senior design project is a graduation requirement for all students in Mechanical Engineering Technology (MET) department at University of Cincinnati (UC). This is a four-course sequence that results in a working product/process. These courses are designed to facilitate students' abilities to synthesize and apply the knowledge and skills they have acquired prior to their senior year. This also enhances their abilities to solve open-ended problems and to prepare them for the transition from an academic to a non-academic environment.

Most projects consist of designing, building, and testing a prototype of a product or process. At the completion of this capstone project, students will have acquired the following necessary skills, which will apply to their professional careers:

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

Senior Capstone Project

The four-course sequence for the senior project consists of Senior Seminar, Senior Design Project I, Senior Design Project II, and Senior Communications. This sequence lasts the full academic year, which allows students to work on complex projects, demands project planning, and the ability to perform in-depth research. Senior communications is taken at the same time as Senior Project II, allowing students to receive individual guidance in writing their final project report. Students are also required 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% of the Baccalaureate Degree requirements. The following is a short description of each course and the required pre-requisites.

Pre-requisites:

In additional to statics, kinematics, dynamics, mechanics of materials, device and system control, and design graphics courses, MET students take three design courses, one each year 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 to expose students to the tools and techniques currently practiced in industry. 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 their senior project in Senior Seminar. These ideas may originate from industry, departmental faculty, national competitions, by themselves, or any other sources. By the end of this course, all students must have a written, detailed project proposal, which includes research, cost estimates, customer surveys, and tentative schedules, etc. Students are assigned a project advisor who works with them to finalize the proposal. The relationship between the advisor and students is like a project engineer and her/his supervisor/manager.

Senior Design I:

Admission to the Senior Design I course is contingent upon the successful completion and approval of the proposal submitted in Senior Seminar. Students use a systemic design methodology to create final technical specifications for their product/process. They generate conceptual designs, and select the best concept using weighted objectives or the Pugh method. They do detailed design and analysis of all of the parts, generate working drawings and create a bill of materials. These analyses may consist of stress, kinematic, kinetic, heat transfer, DFM, etc. The above activities are documented in two different forms: weekly reports and a comprehensive, professionally written design report as well as a short oral report to all MET faculty.

Senior Design II:

During Senior Design II, students are expected to manufacture and/or purchase the necessary parts and build the prototype. Students are expected to machine and/or manufacture most parts, except those requiring sophisticated or precise machining using equipment not available in the department facility. This constraint does not apply to standard commercially approved components. The finished prototype is then tested and debugged to verify that it meets or exceeds the technical specifications promised by the students in Senior Design I.

Senior Communication:

Senior Communication prepares students for oral presentations to both a technical and a non-technical audience. As part of this course, a professional technical report is written as it applies to individual projects.

Tech Expo:

Local industry, employers, parents, families, alumni, and the media are invited to a college sponsored Technology Exposition (Tech Expo) in May. Seniors from all college departments' display, demonstrate and explain their projects to interested parties. Each department invites representatives from industry to judge these projects. All judges invited by the MET department are practicing engineers. Projects are judged on technical complexity, creativity, application of existing technologies in an innovative way, and the students' communication capabilities to explain their projects. The winning project from each department is then judged on a college-wide basis.

2005-2006 Autocross Racing Vehicle Project

As mentioned in the Senior Seminar course description, the Autocross project falls into the category of national/regional/local competitions. The vehicle was designed and built to meet the Sports Car Club of America (SCCA) Autocross specifications and then tested and raced at local/regional events. These monthly events drew dozens of technical and non-technical individuals from across the region and presented excellent opportunities to display the capabilities of the students and amateur car builders. Competing in the SCCA Solo Autocross races also provided an excellent avenue to put engineering designs to the ultimate test.

Autocross racing vehicles are open wheeled racecars with rear-mounted engines powering the rear wheels. Short suspension travel, sticky tires, and a rigid chassis all join together to create a cohesive engineering entity. The 2006 UC Autocross vehicle accommodated a single passenger.

Vehicles that are eligible for registry in the SCCA must adhere to the 2006 Solo General Safety Requirements. The complete specifications can be found at the SCCA website, http://scca.org/_filelibrary/File/2005SoloRules.pdf. Some of the major rules or regulations related to the bodywork and chassis are below:

1. May be of any construction deemed safe.
2. Minimum wheelbase is 72".
3. Minimum track (front & rear) is 42".
4. Minimum wheel diameter is 10".
5. All four wheels will be sprung from the chassis.
6. The brakes shall be a dual system, arranged in a manner to provide braking for at least two wheels in the event of failure in part of the system.

Based on the specifications, the completely new design for an Autocross racing car was broken into four main categories: chassis, drive train, suspension, and controls. Each design category was completed by one team member. They worked individually on research, journal, QFD, design drawings, manufacturing components, and time scheduling. They also worked as a cohesive unit to ensure that the vehicle was fully integrated.

The following describes the design, analysis, manufacturing, and assembly of the suspension system. The same process was used for all major systems/components.

Suspension Design and Analysis:

The objective of a suspension for an Autocross racing car is to provide the ability to produce locomotion, handling and braking. To be successful in this endeavor the suspension must interact with the chassis and drive train to produce acceleration, braking and handling.
The main requirements of the suspension are both competitive and robust handling. Competitive needs in road racing include a tight turning radius and the ability of the suspension to transfer power to the road. This can be affected by load damping, weight and negative camber gain in turns. High strength materials are a must for the suspension to be able to withstand loading from the locomotion and turning. Another design consideration was to use as few parts as possible. Compact design and aerodynamics can give a competitive edge. Finally, in a project of this magnitude, cost is a factor and was taken into account.

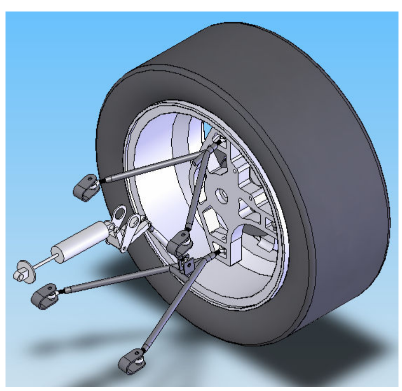
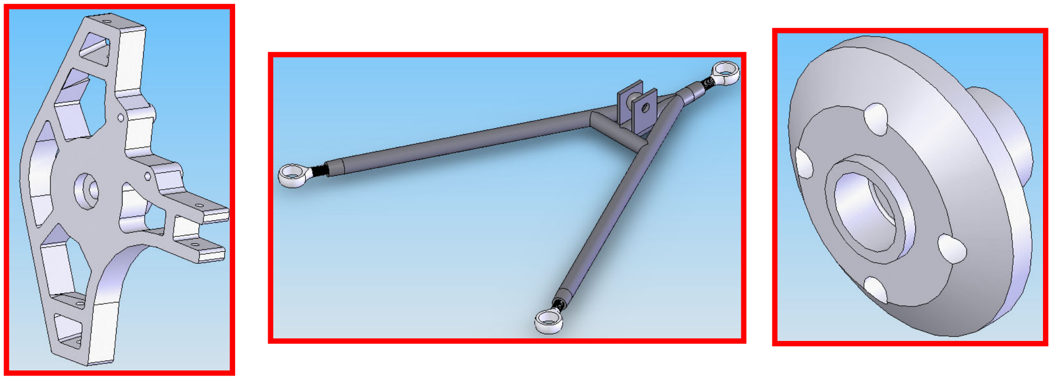


Figure 1. Front Suspension System

There are ten main components that make up the suspension of the Autocross racecar: Wheels and tires, bearings and spindles, wheel and brake rotors, hubs, brake calipers, upper A-arm, lower A-arm, shock bars, shock translator, and shocks. The suspension assembly is shown in Figure 1, with some of the individual components showed in Figure 2.



(a) (b) (c)

Figure 2. Suspension Components Design (a) Hub, (b) Lower A-arm, (c) Rotor

Design integration required incorporation of the sizing, location of parts and material choices for the project to work as a whole. During this phase, some components remained the same as originally designed, while others changed due to location, spacing and safety with concessions being made in handling and weight. The original chassis design had the A-arms attached at an angle to vehicle centerline bar. This would not work, thus requiring the redesign. Figure 3 shows original and redesigned A-arm. Figure 3 (a) shows when force was applied horizontally to the arm, the A-arm would most likely bend. Figure 3 (b) shows the modified design, making it resistance to bend.

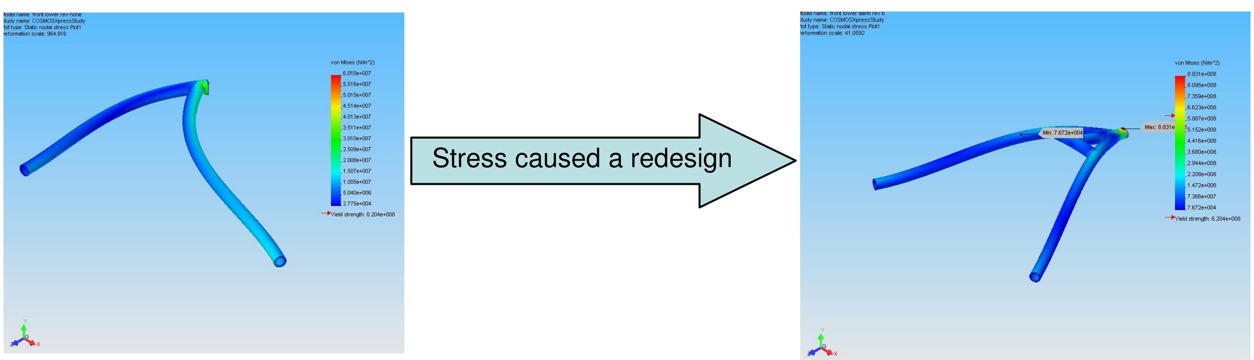


Figure 3. Stress Analysis for Lower A-Arm Design

<u>Fabrication and Assembly:</u>

With all design work completed by the four team members, the fabrication of the Autocross components was started, followed by the assembly of all the components. It took about four-six weeks to have all components manufactured and assembled into a workable vehicle. The four team members worked closely to ensure that all components would fit and were functional. Figure 4 shows the lower A-arm manufacturing steps and subsequent assembly into the chassis. Figure 5 shows the front hub manufacturing steps and assembling into the suspension.

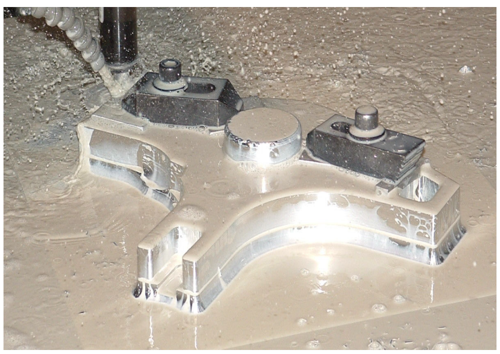
(a

(b)

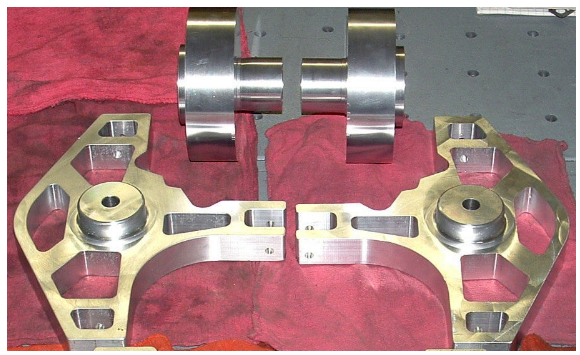
(c

(d)

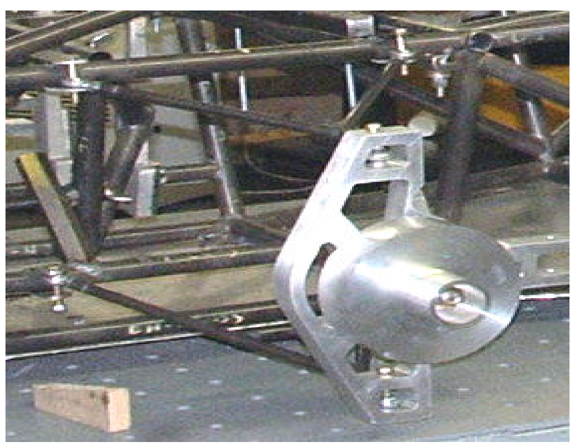
Figure 4. Lower A-arm Machining and Assembling into Chassis, (a) Part stock (b) machined arm cap (c) assembly fixture (d) A-arm in the chassis



(a)



(b)



(c)

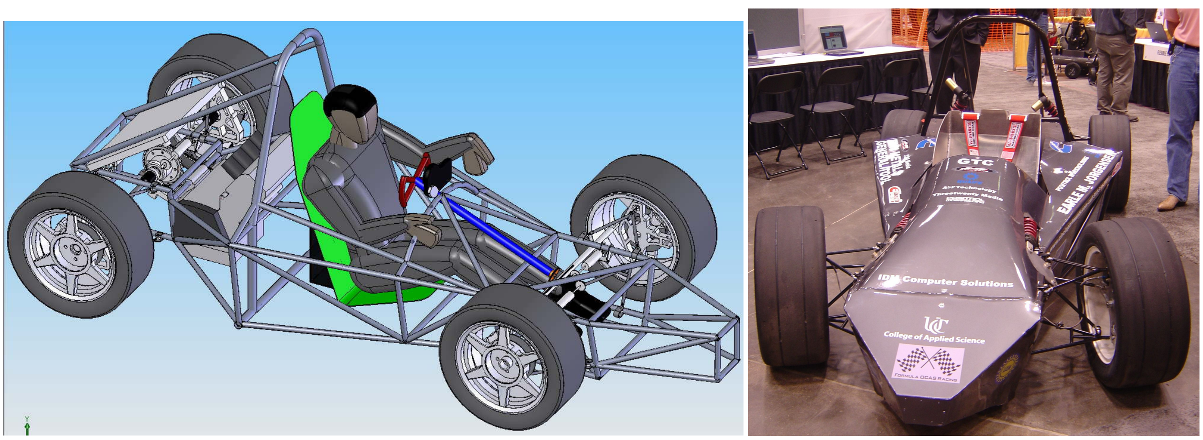
Figure 5. Hub Machining and Assembling into Suspension, (a) Milling Hub (b) Finished Parts (c) Hub in the Suspension

<u>Vehicle Testing:</u>

For the suspension design, the measurable results include both the specifications and desirables for a racecar. The specification necessities are: the wheel base from center to center will be greater than 72”, the track from center to center of the tires will be 47”-49” in front and 48”-50” in the rear. Both track and wheelbase were tested using a tape measure with the steering centered. The wheel base measured 86”, the track of the vehicle was 48” in the front and 52” the rear. Other measurable design parameters are those set by competitive desire. They are: the rebound and jounce will be at least 1”and not more than 2”. Therefore the travel of the suspension will be at least 2” but not more than 4”. The suspension travel was tested using a tape measure with suspension at neutral and moved through its motion. The suspension travel is 1.25” in rebound and 1.625” in jounce for a total of 2.875” [6].

After the car was wired and all team members had their components installed, the vehicle was ready to be tested and tuned. Initial testing showed that under hard acceleration, the engine would bog down and flames were coming from the exhaust under lift throttle. This meant the engine was running very rich. Changing the fuel pressure from 50 psi to 40 psi combined with cleaning the spark plugs solved the issue of engine bogging and improved the throttle response.

The final product for the Autocross racing vehicle is shown in Figure 6, (a) is design model and (b) is real vehicle in the Tech Expo 2006.



(a) (b)

Figure 6. Autocross Racing Vehicle, (a) CAD model (b) Real vehicle

Project Management and Team Experience:

The Autocross racing car project was a team project. Students learned how to perform in a team. They also learned about writing sponsorship letters, fund raising, establishing a budget, dealing with vendors, and time management. They learned to meet deadlines, to work within an organizations rules and regulations. They learned how to communicate and deal with team members, and improve the team’s efficiency. One of the team members also learned to create, maintain and update a website (www.formulaocas.com) for logging the progress of their vehicle.

Students conducted fund raising in two main ways: the first was sourcing free manufacturing by using idle machining centers at local industries; the second source of funding was through material or cash donations from organizations, companies, and individuals. The sponsors were able to monitor the project’s progress on the website.

Conclusions

The Autocross Racing car project was one of more complex senior design project in MET department. During the 2005-2006 academic year, this team learned to design, build, test, and function as a team. Beside the research needed for design, analysis, and building this vehicle, the team obtained invaluable experience in fund raising, teamwork, vendor negotiations , organization compliance, time management, writing technical reports, and product testing. They went through every step-from the concept to a working prototype. It was one of the successful senior design projects in the department with all of the team members winning a departmental/ college awards at the 2006 Tech Expo.

Without extreme dedication and proper planning, teams may encounter frustration and failure. All team members in this particular group were racing enthusiasts and above average students. Project advisors believe that future team members must be selected carefully for any project of this complexity to be successful.

Bibliography

1. BS degree requirements, Department of Mechanical Engineering Technology at the University of Cincinnati, 2005–2006, http://www.uc.edu/met/.
2. "2005 Solo Rules", Sports Car Club of America, August 2005, http://scca.org/_filelibrary/File/2005SoloRules.pdf.
3. SCCA Autocross Senior Report–Drive train and Power train, submitted to University of Cincinnati, Matt Pucke, June 2006.
4. SCCA Autocross Senior Report–Chassis, submitted to University of Cincinnati, Scott Dunsford, June 2006.
5. SCCA Autocross Senior Report–Control Systems, submitted to University of Cincinnati, Josh Pocock, June 2006.
6. SCCA Autocross Senior Report–Suspension, submitted to University of Cincinnati, Geoffry Neundorfer, 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.