

AC 2007-2967: SAE COLLEGIATE DESIGN PROJECTS AS PART OF THE ENGINEERING CURRICULUM

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ABSTRACT- *The SAE Collegiate Design Series is a set of design competitions held throughout the world where undergraduate and graduate engineering students conceive, design, fabricate, and compete with student developed project vehicles. The restrictions on these vehicles are limited so that the knowledge, creativity, and imagination of the students are challenged. The projects are built with a team effort over a period of about one-year and are taken to annual competitions for judging and comparison with a number of other vehicles from colleges and universities throughout the world. The result of these yearlong projects is a real world engineering experience for all students involved. Working within an interdisciplinary team environment from conception to completion gives our students a distinct advantage over others who have not been involved in extra curricular engineering project teams.*

The program benefits students in ways standard curricula cannot. The ability to work in a team environment, the ability to generate funding and support, and the hands on skills developed over the course of completing one of these projects has helped students both in their engineering abilities as well as their marketability after graduation. At our institution, students will come into the project at the freshman or sophomore level helping the team to complete some of the simpler tasks such as generating funding or physically wrenching on the projects. During their first few years, our SAE Project students are required to complete both a manufacturing engineering course as well as a machine tool applications class in order to be permitted to build and fabricate parts designed by upper division team members. Once our students reach the junior level, they apply for and are generally granted class credit for upper division technical elective credit for design and analysis work on their respective projects. The student's senior year involvement in the project is used as senior project or senior design credit in which they generally take on a more managerial role as lead engineers. In the course of their engineering education, our most involved students learn basic fabrication techniques, team and group project management, solid modeling and analysis techniques, and finish by producing, testing, and competing in a project that accurately reflects what they will come up against in real world engineering. This paper gives a general idea of how we have incorporated the SAE Collegiate Design Series competitions into our Mechanical Engineering Curriculum.

Introduction

Standard curriculum within the college of engineering at many universities seems to lack the strong hands on and project emphasis so valuable to many graduating engineers. Whether it is a collegiate competition, group project, or multidisciplinary design group, engineering students benefit greatly by being involved in a program of study that creates the need to manage a project from conception to completion. Not only do engineering students apply what they have learned in the classroom to a viable project, they also benefit greatly from actively working in a team environment much like they may experience upon graduation in an industry or “real world” setting.

The Mechanical Engineering Department allows and encourages undergraduate students to seek a path through their curriculum that employs project work as part of their studies. One group of projects in which students have worked with are some of the SAE Collegiate Design Series projects including Formula SAE, SAE Baja, and SAE Supermileage competitions. As with the majority of projects, these competitions are primarily design events, placing emphasis on project management, engineering analysis, marketing skills, and presentation ability. This transition from initial conception of the project to the final completion encompasses an enormous amount of information an engineering student will be exposed to within their field of study. The engineering skills required alone to complete an SAE project will touch on almost every aspect of an undergraduate student’s course of study through our Mechanical Engineering curriculum.

Of the major hurdles facing student design teams, one paramount concern is support from the Department, College and University. It is imperative the student group is well organized and acts in a professional manner in order to obtain and maintain this support. These teams are representatives of the University and it is important they maintain a professional attitude toward both their academic performance as well as the project in question. This involves comprehensive time management monitoring by both the student and either the team as a whole or a faculty member who is involved.

Creating and maintaining an academic engineering design team typically involves the following key elements:

- Student commitment
- Academic credit for project work
- Faculty support
- Organization
- Workspace and availability
- Ability to generate financial support, Budget

Student Commitment

Student interest in the SAE project is generally a non-issue. Most mechanical engineering students who have the time and aspirations will flock to a project that encompasses their coursework and studies as well as a competition where they can showcase their abilities and skills. The SAE Design projects our students have shown the greatest interest in are the SAE

Formula Competition and the SAE Baja Competition. Generating interest in these projects has not been a problem, the problems lie in retaining students who have the commitment to see the project through to completion. During orientation meetings at the beginning of the academic year, there may be 50 students who sign up and join one of these teams. These numbers historically diminish by one half as the workload and commitment becomes apparent. The remaining students are the individuals that are willing to put in the time and effort to immerse themselves in these projects.

Academic Credit for Project Work

For the freshman and sophomore level students, there is little opportunity to receive academic credit for working on an engineering project. However, in order to be allowed to work in the engineering project facility on the larger machine tools, these lower division students are required to take a basic machine tool class which earns them a few units of lower division elective credit. The skills and knowledge gained by working with other students who are fulfilling their academic credit requirements give the lower division student an advantage in finding their course of study toward elective and senior design project selection. To receive upper division technical elective class credit for project work, our Mechanical Engineering Department requires students to meet the following criteria:

Prior to requesting ME400 technical elective credit, all 300 or Junior level ME courses applicable to the proposed ME400 work need to be complete. For proposed work on any SAE project, the student's core GPA must be 2.2 or above.

To receive ME 400 credit, the student's tech elective package needs to be completed and signed by their academic advisor, and a proposal needs to be submitted to the ME dept. curriculum committee for approval. The proposal must include a timeline as well as a description of specific tasks and/or research work which qualify as upper division engineering work. The following is a guideline that is to be followed for ME400 tech elective proposal and subsequent work.

A preliminary proposal must be prepared. This proposal is generally one to two pages in length and includes the following:

- An executive summary defining the concentration area and describing its relevance to the mechanical engineering curriculum
- A list of primary and alternate courses which constitute a program of study in this concentration area.
- A brief description of the student's educational objectives and career plans and how these are related to the concentration area proposed. Indicate any special background or preparation that may motivate this choice.

The preliminary proposal is then discussed with the student's tech elective faculty advisor as well as their academic advisor. If the student's academic advisor approves of the concentration area, the student's tech elective package will then be signed and returned.

The final proposal is now generated by consulting with the student's tech elective faculty advisor. Once the final proposal is completed, it is returned to the student's tech elective faculty advisor who will in turn present it to the Curriculum Committee for approval. The petition for tech elective credit is reviewed by the department Curriculum Committee and the student is informed of the decision by the tech elective faculty advisor.

In making its decision, the Curriculum Committee will address the following points:

- The appropriateness of the concentration area as a plan of professional study and its relevance to the student's individual educational goals and career objectives.
- The design, technical, and analytical content as well as the merit and rigor of the concentration area as a whole.
- The maturity, motivation, and academic ability of the individual student.

Faculty Support

Faculty Support is extremely important. Whether it be as academic advisor, senior project advisor, or simply an interested faculty member who will show up during club meetings or at their workspace to offer constructive criticism and personal support. A show of interest by the students' mentors will positively stimulate a team of young engineers. These projects encompass a wide variety of engineering skills from management techniques to solid modeling and analysis techniques. A single advisor is most likely not equipped to help in all aspects of a particular SAE project. Given the complexity of a particular project, the student group will benefit greatly from a number of different advisors or mentors. There should be open discussion between the student groups to encompass management techniques, solid modeling and analysis problems, basic component design and manufacture, heat transfer and fluid dynamic issues, engine development and drivetrain analysis, vehicle geometry and dynamics, as well as public relations and marketing issues. In all, the various tasks which compose the whole project relate extremely well to real world manufacturing and engineering issues.

Organization

Taking into consideration the complexity of an SAE project, the student group must be required to submit and discuss progress throughout the course of the given project. Gantt charts and timelines are a must. It is also very helpful both to students as well as faculty and other supporters of the project to clearly display a timeline and indicate a critical path. This provides up to date information to everyone as to which student sub-groups are expected to complete their respective tasks. This alone will ensure progress stays on a forward path and will also indicate where the time issues may lie. Historically, students from one task group will see where the time is critical and jump in to help other task groups to ensure the project stays on schedule. The stages that a project must go through start with the conception, where the student ideas of what the finished product should include are all open for discussion within the group. A basic set of groups and related tasks within the team has traditionally been as follows:

Marketing - P.R.	Contacting potential sponsors / donors Generation and distribution of newsletter
Chassis Team	Frame, Suspension, Uprights, Steering, and Braking design and fabrication
Power Plant Team	Engine- Intake, exhaust, supercharger/turbocharger, engine management electronics
Aero Package Team	Downforce devices (wings), body
Drive Train Team	Shifting mechanism, differential, axles and/or half shafts, wheels & tires
Controls Team	Shifter controls, cockpit design, seat, pedal rack, cables and hydraulic lines, data acquisition system, gages and cockpit systems
Packaging Team	Fuel cell (fuel lines), wiring harness, brake lines and plumbing, cooling system and plumbing, cable and control line (shifter mechanism) plumbing
Testing Team	Scaling, chassis setup, alignment and torsion bar specifications
Logistics	Vehicle transport, SCCA event coordination, student transport, reservations and deadlines

By assuming a 1 year project timeline, the following is a representative snapshot from year to year. Start of project time is typically at the beginning of June following spring competitions. End of Project is 1 week prior to the spring competition (late May).

	Task Name	Duration	Predecessor
1	Start of project	0 days	
2	Officer / team selection	7 days	1
3	Progress mtg / task group selection	0 days	
4	Chassis selection / initial design	21 days	3
5	Power plant selection	28 days	3
6	Drive train selection / initial design	21 days	3
7	Design finalization meeting	0 days	
8	Suspension component selection	21 days	4

9	Drive train component selection	21 days	6
10	Engine component selection	21 days	5
11	Component incorporation meeting	0 days	
12	PR list / newsletter generation	14 days	11
13	Aero pkg. design initialization	14 days	11
14	Chassis design finalized - aero pkg design review	0 days	
15	Cockpit / controls/ steering grp	28 days	14
16	Aero material requirements list generation	7 days	14
17	Chassis material requirements list generation	14 days	14
18	Overall design review	0 days	
19	Cockpit / controls / gages ordered	7 days	18
20	Packaging material requirements list list generation	14 days	18
21	Aero/controls/packaging/cockpit design finalized	0 days	
22	Order package components	3 days	21
23	Order aero materials	3 days	21
24	Cut tubing / tack weld chassis	21 days	18
25	Machine suspension / uprights/ drive line components	21 days	18
26	Progress mtg	0 days	
27	Weld alltabs (body/ wings/packaging)	14 days	24
28	Finish welding all components	14 days	27
29	Finish machining all drive line components	21 days	25
30	Progress report	0 days	
31	Assemble rolling chassis	14 days	28,29
32	Mount all components	14 days	28,29
33	Dyno (tune, map fuel injection/ check components)	1 day	32
34	Progress mtg	0 days	
35	Testing	1 day	33
36	Debug entire system	7 days	35
37	Generate cost and design report	14 days	36
38	Mount aero package	7 days	36
39	Fabricate body	7 days	36
40	Test all components	7 days	38,39
41	Progress mtg	0 days	
42	Testing	1 day	40
43	Debug entire system	14 days	42
44	Mount body	7 days	43
45	Progress mtg	0 days	
46	Final scca testing	1 day	44
47	Disassemble vehicle / paint.	14 days	46
48	Progress meeting - final testing/ fabrication	0 days	
49	Assemble, debug all components	21 days	46
50	Apply sponsor decals, load car in trailer	2 days	49
51	Final meeting before competition	0 days	50
52	End of project	0 days	51

Workspace and availability

Workspace and availability is without doubt the most deciding factor as to whether or not a project can be completed within the given time frame. Students will need a space to hold meetings and discuss design and deadlines. They will need computer and software access to manage, design, analyze, and generate documentation. They will need a shop equipped with the tools necessary to fabricate the given project with basic hand tools, machine shop equipment including engine lathes, vertical milling machines, grinders, sheet metal equipment, drill presses, and welding equipment along with associated tooling and fixtures to go with these machines. A huge concern with availability of the workspace is that an open lab can be a dangerous situation, both physically and academically. Though most students involved in these projects exhibit a good amount of professionalism, time management needs to be stressed and an open shop with lax limitations invites poor time management skills. In our facility, the machine tools are only available 4 days per week, during the day. The shop is open late and on weekends to those students enrolled in senior design project or fulfilling technical elective credits, but the larger machine tools are off limits and locked out during off hours. The later hours and weekends are used basically for assembly, brainstorming, welding, and non-machining intensive tasks. These limitations have worked well as the students who are adept at machine tool usage schedule hours within the open shop schedule to accomplish their tasks.

Ability to Generate Financial Support, Budget

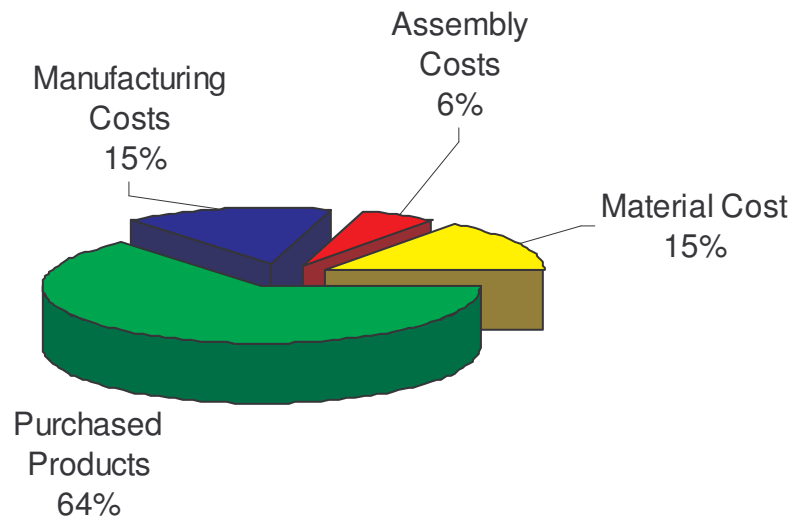
The ability to generate financial support is a problem with many solutions depending on need and student involvement in a particular project. Schools with supportive and wealthy alumni obviously have much less financial problems within the project teams. A good PR person within the team is worth their weight in gold. Donations of materials and fabrication help are generally the easiest to come by. Hard cash on the other hand is more difficult. Parents contribute much of the time but a professional eye catching proposal sent out to prospective sponsors can be the biggest generator of cash. At our University, student groups have enlisted the help of the College of Business and some of their students to assist in the marketing and support aspect of the project. The students from Business have in the past worked with their advisors to receive class credit within their major, but do not actively work on the project within the engineering facility. Another way students can generate financial support is by working in the community directly within the field their project relates. Racetracks and automotive events usually are very willing to encompass a group of engineering students into their schedule to assist in financing their project. By working at events or competitions, the students also have an excellent opportunity to showcase their project and generate financial support from the organizers as well as participants in a given event. Our Formula SAE team has been actively involved in local SCCA (Sports Car Club of America) events actually setting up and running local Solo II time trial events. Freshman and newer students are expected to spend one Saturday per month helping set up these events which entails placing cones and ensuring the track is clear and clean for vehicles. These events are a major part of our team's financial support. Not only does SCCA pay our student club for their work, the students have been very successful in generating monetary support from attendees at these events due to the similar interests in sports cars and engineering.

Budgeting problems associated with some of these more expensive projects need to be addressed by the student team at the outset of the design process. The financial goals that must be overcome create an environment where simply designing and engineering parts depends on whether the overhead is manageable. Depending on the particular project students wish to complete, the cost can range from a few thousand dollars to near one hundred thousand for a Formula SAE team attempting multiple competitions with state of the art components and manufacturing techniques.

The following vehicle specification sheet and cost summary chart depicts a typical SAE off road competition vehicle. The cost summary is for a total of \$8000.00 to manufacture the vehicle.

Baja Vehicle Specification Sheet	
Engine	Briggs & Stratton 10 hp OHV Intek Model 205432 Type 0036-e1
Driveline	Comet 790 CVT
Transmission	Comet Transaxle 214109C 12.5:1 ratio
Fuel Capacity	4 quarts
Length	92.6 in.
Wheelbase	70.8 in.
Trackwidth	54.6 in.
Estimated Weight (dry)	450 lbs.
height	62.5 in.
Ground Clearance	13.6 in.
Front Suspension	Independent double A-arm with Fox shocks with 12-inch travel
Front Brakes	2003 Polaris Predator 500HO calipers and discs
Front Tires	23 x 7-10 knobby radial
Rear Suspension	Independent Double A-arm with Fox shock with 12-inch travel
Rear Brakes	2003 Polaris Predator 500HO calipers and discs
Rear Tires	25 x 7-10 knobby radial

Cost Summary



SAE Off-Road Collegiate Design Vehicle

Upper Division Technical Elective Example

Focusing on a task group involved in attempting to complete a Formula SAE vehicle, some of the major hurdles involving engineering skills include Fluid dynamic analysis both for cooling systems as well as the Air intake. These subsets of the larger goal are projects within themselves. As an example of an upper division student receiving technical elective credit for their work on a particular project, last year's team had one student member in charge of the air intake design, analysis, and manufacture. This student received upper division technical elective credit for the design, analysis, manufacture, and implementation of the intake for the 2006 Formula SAE vehicles. The Mechanical Engineering department has recently purchased a 3D prototype printer, which this student utilized not only to model the prototype intake system, but also to manufacture the final product. Following is a quick summary of the tasks performed for this project.

Design Goals:

- Improve airflow
- More power with better delivery
- Equal distribution of air to each cylinder
- Light weight
- Resist heat soak
- Precision manufacturing to maximize restrictor envelope

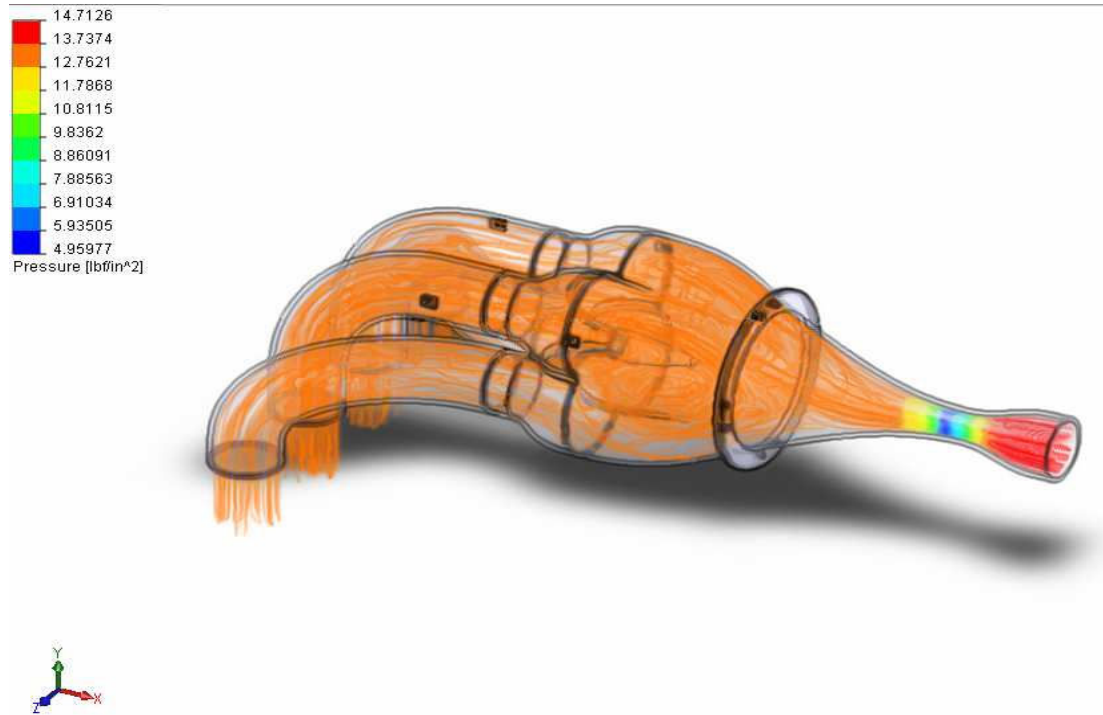
Assumptions:

- No heat transfer through the walls of the intake
- Engine speed is 10,000 rpm
- Surface finish is approximately 150 micro inches
- Steady state flow simulation used to approximate high frequency transient system

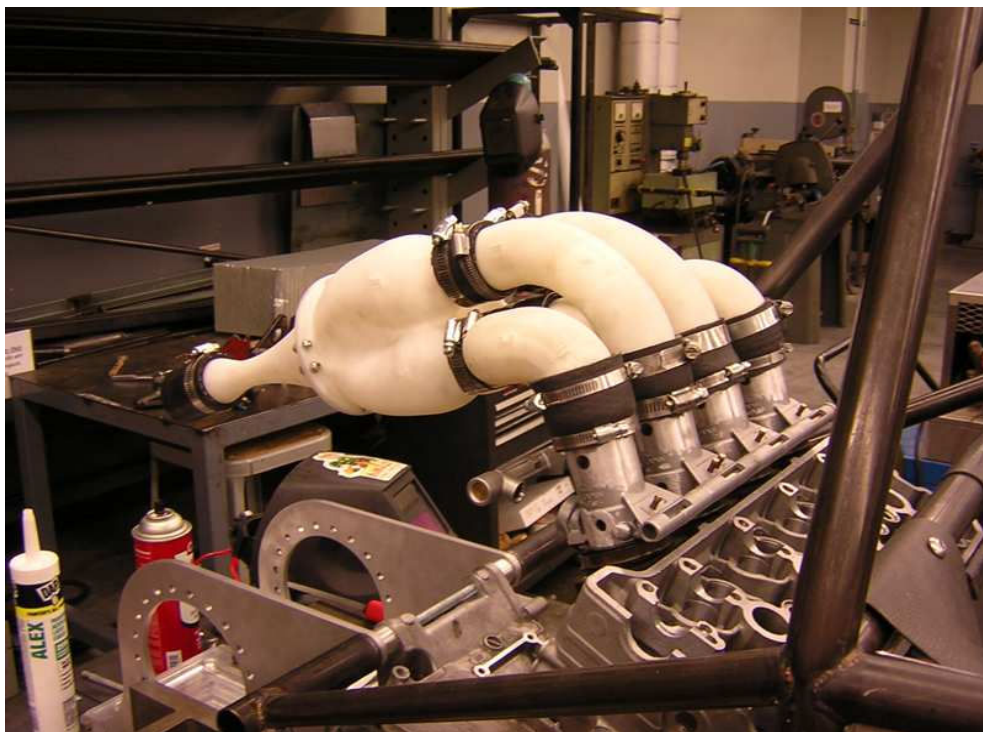
Conclusions:

- Rapid prototyped ABS plastic resists heat soak, is light weight, and critical dimensions are accurately reproduced
- Using CFD to reduce turbulence in transitional regions improves engine output at every speed
- Using acoustical models to predict torque peak can be very close approximations and have been confirmed by dynamometer testing.

Flowworks Snapshot of 3D Intake Model



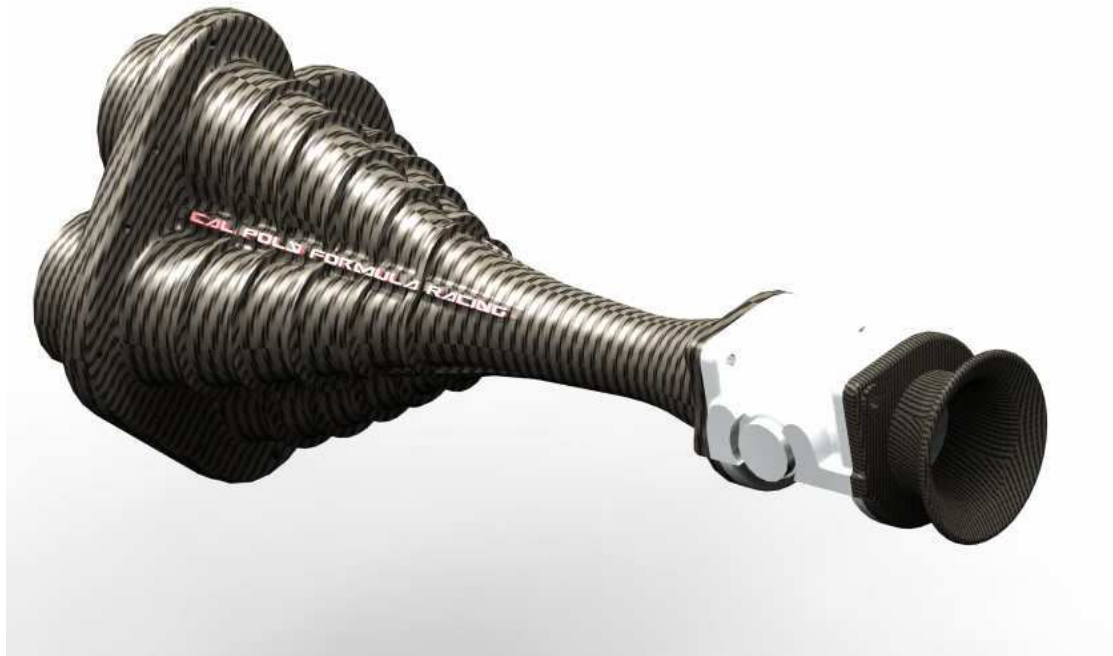
Finished Rapid Prototyped ABS Plastic Intake



The intake system designed and implemented by this student functioned well, but exhibited a “flat spot” during tuning and testing likely due to the exhaust primaries not being properly matched to the intake system. This student feels the unit can be designed to perform much better given time to redesign these components. As a senior this year, this student is currently acting as a mentor and advisor to a group of upper division students interested in intake design. This student is fulfilling his senior project requirements by not only acting as a senior engineer on this project, but also by taking on an extensive management role on the team. Pictured is the conceptual design of the new intake for our student’s 2007 SAE Formula entry. Our current Collegiate Design Formula SAE Team is registered for the following 2007 events:

- Formula SAE, Romeo Michigan
- Formula SAE West, Fontana California
- Formula SAE Italy

Solid Model of 2007 Formula SAE Intake



Conclusion

Putting coursework into practice and applying academic knowledge to a verifiable project recognized internationally as a complete engineering package is a huge undertaking. Our students with the help of the College, Faculty, and Alumni have done very well over the years both in their academic advancement as well as at the actual design events. These individuals must have the time, energy, drive, motivation, backing, and ability both within the facility in which they operate as well as within their own mindset to successfully get through an intensive project as presented. Other important key elements to success is having student commitment, academic credit for project work, faculty as a support web, setting up an organization that will keep groups accountable within a given timeframe, having workspace and availability to complete their project as well as the ability to generate financial support

SAE Collegiate Design competitions are great motivators of future engineers as well as a comprehensive platform for students to apply themselves during their course of study. The engineering competencies as well as ability to immediately apply engineering knowledge in the workplace upon graduation is clearly apparent with our project students. The key reasoning behind this statement is the annual graduating class's interaction with on and off campus recruiters. A good portion of recruiters looking into recent Mechanical Engineering graduates request to interview students who have been involved in an SAE project. Observations at this University have shown that the students who apply themselves to extracurricular engineering design projects are more marketable upon their separation from the University.

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