AC 2000-246: The Formula SAE Racecar Project at WPI

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Session 3268

The Formula SAE® Racecar Project at WPI

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Abstract

The Formula SAE (Society of Automotive Engineers) is a design-based competition that is attended by universities throughout the world. The competition is for engineering students to conceive, design, fabricate, construct, test, and market a prototype formula-style racecar. The objective of this paper is to discuss some of the aspects of entering and competing effectively in the competition. At the end of this paper some aspects of engineering mechanics carried out by students in the suspension group are discussed. The model of the Worcester Polytechnic Institute (WPI) is featured.

1. Introduction

The Formula SAE Competition is provides an opportunity for students to apply their theoretical knowledge to practical situations, gain hands-on experience, and at the same time get credit for their work. This project prepares a student to solve a real-world problem that is ill defined, interdisciplinary, and open-ended. Most of the students have never had to face the issue of solving an open-ended problem with no single correct answer. The students at first are uncomfortable with the situation and were troubled that the answers were not found in books. It is very important that the advisors play an active role by structuring the project for the team, each technical group and each student. Constant sharing of ideas and coaching reduces tensions.

This paper will first discuss the concept of the competition and the events. The paper will then address the team composition, grading, team and group structure, team and group meetings, team schedules and deadlines, and fielding a competitive team, The paper will also discuss some engineering mechanics applications that are associated with the suspension system.

2. Formula SAE Competition and Events

The Society of Automotive Engineers (SAE) sponsors a Series of Collegiate Design Competitions [1] that include Aero Design®, Formula SAE®, Formula Student, Mini Baja®,

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Supermileage®, Walking Machine Decathlon™, and the Micro Truck Baja. As stated by SAE, SAE Collegiate Design Competitions put classroom training into action by challenging students to design, build, and test the performance of a real vehicle in a competitive environment.

The first Formula SAE [2] competition was held in 1981 at the University of Texas at Austin with four cars competing. The Formula SAE competition today involves approximately 100 engineering schools throughout the U.S., Canada, South America, United Kingdom and Japan. The competition is held in mid-May outside of the Pontiac Silver Dome in Auburn Hills, Michigan. Daimler-Chrysler, Ford, and General Motors are the major sponsors of the competition.

The Formula SAE competition is for engineering students to conceive, design, fabricate, construct, test and market a prototype formula-style racecar. The restrictions on the vehicle chassis and engines are limited so that the knowledge, creativity, and imagination of the students are challenged. Each design is compared and judged with other competing designs to determine the best overall car. Each team must design their car following the premise that a manufacturing corporation has hired them to design and manufacture a limited production racecar (1000 units per year) aimed at the non-professional weekend autocrosser. The car must demonstrate superior performance along with ease of maintenance/repair and reliability at the lowest manufacturing cost possible. The car should be aesthetically pleasing, innovative and provide comfort as well as sound ergonomics. The team must combine all these design aspects into a well-balanced package that will sell for $9000 at a dealership.

Each team is required to follow rules and they can be found in electronic form at [2]. Safety is a key issue at the competition and they are strictly enforced. These rules cover the design of the vehicle, the staging of events and the behavior of participants on the FSAE site.

Over three days the cars are evaluated in three different categories: static design and safety inspection, solo performance trials, and high output track performance. The entire competition is worth 1000 points and the team with the greatest number of points at the end wins the competition. The static events are held on the first day of the competition (Thursday) and include Engineering Design (150 points), Cost (100 points), and Presentation (75 points). The second day of the competition (Friday) includes such dynamic events as Skid-pad (50 points), Acceleration (75 points), and Autocross (150 points). The final day of the competition (Saturday) consists of the Endurance/Fuel Economy event (400 points). Prior to the dynamic events all vehicles undergo a rigorous set of safety inspections. During this phase the judges can require modifications before a car is allowed to enter the dynamic events.

3. Role of the Advisors

The role of the faculty advisor is explicitly stated in the competition rules [2]. The rules state that the design aspects of the project should remain completely with the students. The advisor should keep in mind that this is a student design experience. At no time should the faculty advisor be making design decisions unless it is to veto a design, which would, in the advisor's opinion, compromise student safety.

The advisors must play an active role in the project so that it is successful. The advisors need to structure the project both managerially and technically since most of the students have little experience in these areas. The advisors must make sure that they are available to the students on a regular basis for advice and questions. The advisors should attend the weekly team and group meetings so that feedback can be given on a continuous basis. The students need to hand in weekly technical reports that discuss design and analysis aspects of their group. The advisor needs to inquire on why a particular design was selected and how it compares to other design options the students considered. For example, if the drivetrain is using a rear wheel drive then the group must be able to justify technically why that design was selected over front and all-wheel drive. Even though the advisor may feel that the choice is inappropriate, the selection is up to the students. The author feels that a design is appropriate if it is justified.

4. Team Composition

The WPI FSAE team the last three years has consisted of approximately 14 to 22 students. Almost all students on the project receive some form of academic credit. Typically there are two students per year who do not receive academic credit. Almost the entire team consists of seniors. This is a big problem since there is no continuity from one year to the next. Due to the academic demands of WPI very few students are willing to spend free time on the project unless there is some sort of academic credit. Since very few students are willing to participate without credit, this has resulted in very little continuity from one year to the next. Continuity is very important in having a competitive team each year. Continuity provides a knowledge base from one year to the next.

The team composition consists mainly of mechanical engineers and two or three electrical engineers. The electrical engineers are very critical in assuring that the car will start. Also, they can enter the optional Delco Electronics Innovation event at the FSAE competition. Each year there is at least one manufacturing engineer to deal with the manufacturing aspects that arise in the FSAE cost, presentation, and design events. It is a good idea to have at least one management major to address the marketing/sales aspects in the presentation event. Over the years the author has essentially been the only faculty advisor overseeing the project. This past year a few faculty members have been recruited to help with the drivetrain, engine, manufacturing and electrical.

5. Academic Year, Academic Load and Grading System

The WPI academic year runs from late August to early May. WPI is on a non-conventional half semester system called a term and each term is seven weeks long. The academic year consists of four terms where the first two are held from late August to mid-December and the final two terms from mid-January to the beginning of May. The major advantage of this system is that it provides the students intermediate deadlines besides the ones specified by SAE toward the end of the academic year. A student is considered full-time if he/she is enrolled in three course and/or project activities. Each activity is equivalent to three semester hours. The students usually enroll in the FSAE project for one course per term totaling four courses per academic year.   This is equivalent to working on the project one-third of the academic year full-time. WPI expects that each student spend approximately twenty hours per week on such an activity.

As discussed in Section 4, almost all the students receive academic credit. The project grading system at WPI consists of A, B, C, NR and NA. Everyone in the academic community is familiar with A, B, and C, however, the non-conventional grades of NR and NA stand for No Record and Not Acceptable, respectively.   The NR is used for courses and projects, while the NA is only applicable to project activities. The NR means that the activity will not show up on the student's transcript.   The main reason for this type of grade at WPI is that it allows students to experiment without being penalized, i.e., it provides life-long learning skills. However, the faculty advisors do not give out a grade of NR since it allows the student to walk away without any type of penalty. On a project like FSAE it is very important for everyone on the team to complete his/her assignment on time. If a student was assigned an activity and does not deliver the whole team if affected. If a student receives a NA in any given term, then he/she must find another senior project.

The assignment of individual grades is very similar to reviewing an employee for a raise and/or promotion. You must award the individuals who have contributed the most to a project by awarding those individuals the highest grade. Record keeping becomes a problem. To solve this problem each group is required to keep a three-ring notebook. The notebook is handed in at the middle and end of each quarter for the faculty advisors to review. The notebook includes FSAE rules, current and marked up copies of the technical report, manufacturer/supplier information, bibliography, reference material, group presentation slides, weekly group assignment sheets, weekly team meeting minutes, weekly group reports and weekly individual activity sheets. Such items as meeting attendance, completing tasks on time, and submitting professional technical reports is also considered in the term grade. The weekly activity form summarizes the activities assigned, activities completed, days of the week the activity was performed, the number of hours per activity, and any comments about activity, e.g., why the activity was not completed. This has been very helpful for the faculty advisors in seeing if there is consistency between the number of hours worked and the actual activity stated in the report. At WPI the students are graded each quarter and given an overall project grade at the end of the academic year. There are many factors that affect the grade and the weight you place on each one is personable and not quantifiable.

The faculty advisors require each student to evaluate their group members and other groups they closely interact with. This is usually done once a quarter and sometimes twice a quarter depending on how group and team activities are progressing. The evaluations are used in determining a student's term grade.   The evaluation asks the following questions:

1. Estimate the % effort by each group member, including yourself. Total must equal 100%.
2. What is the most valuable contribution to the project made by each group member, including yourself? Include technical, analytical, organizational, documentation, creativity, research, leadership, construction, etc.
3. Rate your opinion of yourself and each of your groupmate understands of the concepts involved in this project, on a scale of 1 (poor) to 5 (excellent).

4. Comment on your interaction with other group(s) that your group heavily relies on.

This peer evaluation has been a very successful way for faculty advisors to identify any teamwork problems within a particular group and with other groups.

6. Team and Group Structure

At the beginning of the academic year the team was divided into the following eleven groups: frame, suspension, engine, drivetrain, steering, brakes, tires and wheels, body, ergonomics/interior and safety, manufacturing, and electrical. In January the cost group (for FSAE Cost Event) and presentation group (for FSAE Presentation Event) are established and at the end of March the dynamic testing group begins. The number of groups will depend on the size of your team. When the team is small then you have a group of generalists and when the tem is large then you have specialists that can carry out some excellent in-depth technical analysis studies. Each student is given the opportunity to select their area of interest; however, at times this is not possible since there may be too many people interested in a particular group. Individuals who were not able to have their first choice at the beginning of the project have propriety when reassigned to another group. No individual remains on one group throughout the entire academic year. Individuals are placed based on the needs of the team at a given time. Also the capabilities of each student is considered in the best interest of the team at the time of reassignment.

The faculty advisors assign group leaders at approximately one-quarter of the academic year. The faculty advisors feel that the group leader is a position of leadership and carries such responsibility as seen in a low-level management position. The team co-captains are selected by the faculty advisors approximately half-way through the academic year. The advisors find it difficult to select one captain so two or three are usually selected. The captains are usually very capable technically and have very good hands-on skills. These individuals have worked significantly more hours in comparison to the other team members. The co-captains are responsible for managing the overall weekly team efforts and plan and lead the weekly team meeting.

7. Team and Group Meetings

Throughout the academic year a weekly team meeting is held for one hour. The weekly team meetings are very structured in accordance to a meeting agenda that is handed out before the meeting begins. Individuals attending the meeting are required to sign an attendance sheet. At the beginning of the academic year, all students receiving academic credit must sign an attendance sheet and they are informed that attendance affects their grade. Attendance is extremely important so that the team is able to work together to accomplish short term goals and the overall goal of attending the FSAE competition. The advisor's policy is that if you are on time you are late. And this means that the door is locked when the meeting starts. From past experience the author has found that when you are informal with students they treat it just like a class since attendance does not affect the class grade. At the end of the term if a student missed one meeting and was on the border of a C/B then a term grade of C is given. If a student missed two meetings and had a solid B, then a term grade of C is awarded. A typical class at WPI has four lectures per week. This project requires that the student attend two meetings per week, once for the team meeting and the other for the group meeting. As discussed in Section 5, all students receiving academic credit must submit a weekly activity form at the team meeting.

At the team meeting each group orally updates team members of their weekly activities. Each group also hands out a brief summary of items completed and incomplete for the week and new items to be addressed the upcoming week. Each week one to two groups gives a formal presentation of their technical activities on overheads. These presentations are used to educate and inform other teams members on various technical aspects of the car. The presentations also serve as preparation for the FSAE competition. Many of the team members ask very thoughtful questions during each presentation. The team meeting is also used to review the purchasing and construction schedules. Other team business is addressed and any team assignments are discussed. The advisors try to make sure that the meeting promptly begins and ends on time. During the first half of the academic year the meeting is lead by the author, after which the co-captains plan and lead the meeting with, input from the advisors. The author has found it very important that a meeting be held on the first and last day of quarter for planning purposes. The first day lets the team begin where they left off the last quarter and allows them to modify their time schedule for the quarter. Furthermore, since classes are just beginning, the students are able to allocate more time and focus on the project. If a meeting is not held at the beginning of the term, many students will wait a week before doing anything. A meeting on the last day of class is extremely important so that the team plans ahead for next quarter. The time of the weekly meeting is selected so that minimal academic conflicts occur between team members.

Each group meets with their faculty advisor once a week for one hour. Each student is required to sign in at the beginning of the meeting. A meeting agenda prepared by the faculty advisor is given during the first quarter of the project. The agenda includes items that have not been completed, items assigned for next week and future items that must be planned. The agenda is very important since most of the students have not had any experience on such a large-scale project and have no formal academic exposure to engineering a racecar. There are some students who are familiar with repairing cars and being a spectator. Each group is required weekly to hand in sections of the final project report. By reviewing the report weekly, the faculty advisors are able identify any technical problems and provide continual feedback to the students. After one-quarter of the academic year is completed, the students determine the weekly group meeting agenda. At this time most students are very familiar with their group activities and know to some degree what needs to be done. The academic advisors provide input to assure that group activities are progressing in a reasonable manner.

8. Team Schedule and Deadlines

The team establishes a schedule for each academic quarter (seven-week). The schedule is very important since the team must adhere to deadlines so that the project is continuously progressing. The schedule keeps all team members informed on who is working and who is not. A schedule is something that the team does not want to do since it involves a large commitment on their part.

Students are typically use to deadlines that can be changed a majority of the time. A typical example is that if you give a student one month to complete an activity it will proceed very slowly until about a week before the deadline more activity will occur. The author has found that most of the time the project will not be completed. However, this does not occur if you have very good or excellent students. In general the students will tell you how much work has been done, but you will see very little activity until the deadline nears. This is very apparent when most of the work is on the construction phase and you can see the daily progress in the shop. A successful FSAE car requires that the advisor's stress that deadlines must be meet. The author tells the students that SAE has deadlines and if the team does not meet then they are penalized. For example, SAE requires that a design report be postmarked by April 1st. If the report is not received by SAE on that date, then the team is not allowed to participate in the FSAE Design event. The Design event is worth 150 points out of the 1000 possible points at the competition. Another deadline is that the cost report must be received by April 1st or the team loses 10 points per day late with a maximum penalty of 75 points and the event is worth 100 points. Other deadlines include the competition being held over a three-day period in mid-May and that the team must be at each FSAE event on time or lose all points for the event or they are penalized for arriving late.

Numerous mechanisms have been employed in the past for enforcing deadlines, however, success has been mixed. What has been found to work well is that all team deadlines are associated with the reason why all the students are part of the project, and that is the car. All students on the project want to complete the car and go to the FSAE competition. This is the way the author has been successful in assuring that the team deadlines are met. The faculty advisors deadline policy says that if the team deadline is not meet then all purchasing cease and the car will be placed in permanent storage. The remainder of the academic year will consist of the team making a virtual car. This still allows all team members to complete the project so that they can satisfy their degree requirements. Each student can still obtain a grade of A for the project. This is an option that the team does not like. Some of you may feel that this policy is rather strict but it does make the team work together. I would like to point out that if a deadline is not met then it can be extended (within reason) if the team is showing continuous progress in completing the assignment. This policy eliminates any last minute activity and ensures a higher quality car. The author clearly explains to the team that continuous progress is a requirement, but do not tell them about the extension. By having this type of requirement, the author has found that many team members ensure that their teammates are working on their assignments.

The advisors need to establish an overall time schedule for the students since they have never done a project of this magnitude or complexity before. The academic year at WPI is divided into quarters. The following is a list of major activities that are scheduled during the four quarters of the academic year:

- August - October
    1. *Planning, Design and Analysis* - Planning, design and analysis of the car is the major activity during this quarter. The team is broken up into groups, e.g., frame, suspension, drivetrain, engine, etc. and each group is required to interact at the team meeting and outside this meeting. Each week the groups hand in sections of their technical report. At

the end of the term a final report is submitted. The report is reviewed weekly by the faculty advisors.

2. *CAD Model* - A CAD model (in our case we use Pro/E) of the car is made and each technical group is involved in its development. The groups primarily responsible for the CAD model are the frame, ergonomics and suspension. The CAD model is very important in regard to packaging, ergonomics and structural issues. The CAD model contains the following major components: ergonomic human, frame, drivetrain, steering wheel and rack, shifter, pedals, suspension, tires, engine, intake, exhaust, turbo, gas tank, and seat. This model can be used the next year and improved.
3. *Team Schedule for Next Quarter* - At the end of this quarter, construction and purchasing schedules are developed by the team and approved by the faculty advisors. The group responsible for a particular activity is also identified.

- October - December
  1. *Design and Analysis* - During this period each group will continue to write the technical report and hand in sections weekly. This activity accounts for approximately three-quarters of the student's effort during this quarter. Technical report activities are essentially completed at this time and resume in the forth quarter.
  2. *Construction* - This activity accounts for one-quarter of the teams effort during this period. The following items are completed at the end of the quarter: frame, suspension, uprights, engine (w/o intake), exhaust, fuel tank, basic electrical, firewall/closeout panels, and tires/wheels. This means that the car must be on four wheels and rolling. During this period construction activities only occur during the daytime on weekdays. This allows the technicians to carefully monitor the student's activities and ensure they are using equipment properly and safely. It is extremely important for the students to gain experience so that can left on their own in the next quarter.
  3. *Team Schedule for Next Quarter* - A construction schedule for next quarter is established at the end of the quarter. Parts and materials are ordered so that when the students return from break, they can begin construction activities immediately.
- January - March
  1. *Construction* - This is the major activity that occurs during this time period. Most seniors are working on the construction of the car. The deadline for completing the car is mid-February and the car is considered complete if it is driveable (this includes a painted body) and passes the FSAE technical inspection (see rules). The technical inspection certifies whether the car can compete in the dynamics events at the competition. During this period the team is given access to the lab during the daytime and nighttime every day of the week. Through experience, the author has found that if a student is doing construction during this quarter, then that student cannot be assigned any type of in-depth technical report activities since construction is very time consuming.
  2. *Strip Down Car and Reassemble* - The last two weeks of the quarter are used to strip down the car and reassemble it. When the car is stripped down the cost group reviews each part with the technical groups. The frame is then painted and the car is then reassembled with the proper fasteners. When the students return next quarter, the car will be ready for testing.
  3. *First Draft of FSAE Cost Event Report* - This is the second major activity that occurs during this quarter. Three seniors are working on the cost report full-time so that a first

draft is completed at the beginning of March. Each technical group is required to work with the cost group during this period. A first draft can be done very accurately since the car is completed in mid-February. SAE requires the final report be submitted April 1st.

4. *Two Drafts of FSAE Pre-Event Design Review Report* - All groups write a first draft of the pre-event design review. The design review contains a brief description of the vehicle with a discussion of any important design features and vehicle concepts. The first draft of the four-page report is due the end of January and the second draft at beginning of March.
5. *Preliminary FSAE Presentation Event Activities* - Two to three juniors are working on the marketing/sales and manufacturing activities for the presentation event. A rough draft of the presentation is done during this period along with support activities.
6. *Design and Analysis* - The engine group usually cannot complete all its technical activities during the first two quarters. They will typically work for approximately the first three weeks on design and analysis. This activity depends on the group size and sometimes involves more that one technical group.
7. *Team Schedule for Next Quarter* - At the end of the quarter the team schedules the activities for next quarter.

- March - May
  1. *Testing and Drive Identification* - A formal documented testing program is carried out during this time period. This is a major activity that is done during this quarter. The testing sessions consist of skid-pad, acceleration, braking and autocross/endurance trials. Testing allows each group to optimize vehicle performance and most importantly identify and redesign any failures. During testing the advisors can identify individuals who can be used as drivers at the FSAE competition. Times are recorded so that the advisors can make an appropriate decision regarding drivers. Drivers are selected so that the best drivers can maximize team placement at the competition.
  2. *Component Redesign* - All components of the car are reviewed when the students return from spring break. Components are identified and prioritized for redesign at this time. The components are the manufactured for inclusion on the car.
  3. *Car Failures* - During testing there will always be some type of failure that occurs. A failure must be repaired as soon as possible. Repairing the car as soon as possible is very important so the testing time is maximized. New England weather typically interferes with testing until mid-April.
  4. *Submit FSAE Cost Event Report* - This is a major activity that is done at the beginning of the quarter. The report is reviewed and completed by three to four students. Groups are also responsible for reviewing their area of expertise. SAE usually requires the final report be submitted the beginning of April.
  5. *Submit FSAE Pre-Event Design Review Report* - This activity is done at the beginning of this quarter. The team iterates on the report at least three times. The final four-page report is due at SAE the beginning of April.
  6. *Final FSAE Presentation Event Activities* - Since the car is completed, the presentation group can finalize FSAE presentation event activities. This includes overheads, commercial, brochure, etc. Every two weeks the group gives a formal presentation to the team in preparation for the competition.

7. *Other Team and Group Activities* - The seniors must complete a formal report that is submitted to the registrar as part of their WPI degree requirements. In mid-April WPI has a project presentation day for all senior projects. At this time each group must prepare a poster for presentation to industrial judges.
8. *Team Schedule for Pre-FSAE Activities* - At the end of the term the team schedules activities to be completed after school ends.

- Pre-FSAE Activities: These activities usually occur over a one week between the end of school and the FSAE competition (held in mid-May). All team members that received academic credit are required to be at WPI during this period.
  1. *Team Meeting* - Each weekday mourning a team meeting is held at 8:00 AM so that the remainder of the day can be used to prepare drivers for the competition.
  2. *Practice FSAE Presentation Event Presentation* - At the mourning meeting the presentation group does a formal presentation in front of all team members. Team and faculty members provide input on the presentation.
  3. *Practice FSAE Design Event Presentation* - Done in the same manner as the presentation event.
  4. *Practice Optional Event Presentations* - At the FSAE competition there are a number of optional competitions that any team can enter. Each group practices in front of the team during the team meeting.
  5. *Driver Preparation and Identification* - During the previous quarter preliminary driver identification was done. During this period the drivers and alternates for the competition are preparing for the competition.
  6. *Car Failures* - Any failure that occurs must be corrected as soon as possible. If a failure occurs, the car comes right back to the shop and is fixed so that testing can occur the next day.
  7. *Other* - There will always be some activity that was overlooked and they must be addressed. The individuals who are not driving and/or making a presentation at the competition do these tasks.

The author would like to point out that each academic year the schedule above is modified and these modifications have resulted in the project running more smoothly the next academic year.

9. Fielding a Competitive Team

If your school has never done the FSAE before, it is a good idea to send a number of students along with the faculty advisor to the competition before you begin. You really have no idea what goes on at the competition unless the faculty advisor and students are there. This is an excellent learning opportunity for the advisor and students. The author feels that most faculty advisors will need at least two to three years to get familiar with the competition. Each year the author makes improvements in every aspect of the project. A major way to improve your placement at the competition is to have student carry over from one year to the next. Students who have just attended the FSAE competition is very valuable. This is one thing at WPI that has not been able to do as discussed in Section 4. If your current team has access to past team members, then they will also be a valuable resource.

Another way to become more competitive is to save all technical and cost event reports. A knowledge trail is very important since many valuable students will leave your institution after the competition. When the students complete the project, they are required to hand all reports in hard copy and disk before a project grade is submitted to the registrar. The presentation event overheads should also be saved and the event videotaped. Books should be purchased yearly on theoretical and practical aspects of automotive/racecar design since they are a valuable resource for the students throughout the project. A policy for checking out books should be implemented so that all team members have access to the team library. If some type of policy is not implemented, the students tend to let the books sit at home.

At the Formula SAE competition it is very beneficial for the students to take photos of other teams so that your team can develop a library (archive). The photo library is an excellent way for the students to get good, also bad, ideas to design a future vehicle. At the competition the author requires each group examine other competitors cars. The students must take pictures and document important design features. At the competition there are various seminars that are held by the judges to inform the competitors on what they expect in each event. The seminars include the cost event (Friday), presentation event (Friday) and design event (Sunday mourning). Each year the author attends the three seminars and video tapes each one so that all points addressed by the judges are documented. It is very valuable to have some of the students attend the seminars. You will find that most students would rather watch the dynamic events that run simultaneously with the seminars on Friday and sleep in during the Sunday seminar. If you have students that will be on the team next year, strongly encourage them to attend all the seminars.

Keeping old cars has it advantages and disadvantages. The old cars allow the students to study a real racecar up close and select its positive and negative attributes. The old cars allow the students to test each car and decide what types of changes are necessary. The major disadvantage I find with old cars is that the students will typically copy things. This is something that needs to be discouraged since the judges want to see changes in the design from one year to the next.

Testing the car after it is completed is one of the most important things that a team can do to be competitive at the FSAE competition. If construction is completed by at least by mid-March (I require mid-February) it has many advantages. The first thing is that the team can test out the car and identify failures and/or minor problems. Having thoroughly tested the car, you have a greater chance of completing all dynamic events at the FSAE competition. The dynamic events account for 675 of the possible 1000 available points at the competition. In particular, the endurance/fuel economy event is worth 400 points (50 points fuel). Secondly, having a team with very good drivers will maximize points at the competition. The third advantage is that the cost event requires that a cost report be submitted on April 1st. Completing the car early allows the team to submit an accurate cost report. Furthermore, the cost event is worth 100 points at the competition. The forth advantage of having the car completed early is that the team can have a lot of testing time. This is very important for WPI due to the New England weather. A snowstorm in early April can lead to one or two weeks without testing. The author cannot emphasize how important it is to have the car completed early so that testing can occur as soon a possible.

The faculty advisors must play an active role as discussed in Section 3. The author has found it difficult to provide technical expertise in all aspects of the car and has recently been able to recruit other faculty members. If you have a small team, i.e., four to six students, then you will find that you do not have the time to cover all theoretical aspects of the car, however, if you have a large team then they can really go into technical depth. Having faculty whose expertise fills your void will provide a better learning experience for the students. It is also important to have at least one technician to train students in construction aspects. Students today have little if any hands on experience and they need to learn how, for example, to weld and machine correctly and safely.

10. Engineering Aspects of the Suspension

The suspension of the Formula SAE racecar contains many examples of where engineering mechanics can be used. Only three examples are discussed in this section. Determining the suspension geometry involves a kinematic analysis. The kinematic analysis is verified by making a paper model of the suspension and comparing it to the TK results. A commercial suspension program is also used to verify the TK model.

Once the suspension geometry is determined, the next step is to carry out a strength, stiffness and buckling analyses of the suspension members. A *TKSolver* [3] program was developed by the students to determine the optimal member sizes for the suspension. All equations are derived symbolically for input to *TKSolver* so that any geometric configuration and loading case can be considered. Once the suspension has been sized the students must ensure that TK has carried out the analysis correctly. The strength component of TK is verified on an control arm through strain gauge analysis and the displacements are measured during this test.

The initial size of the uprights are determined using conventional mechanics of materials techniques and a solid model is then created in Pro/ENGINEER [4]. Pro/MECHANICA [5] is used to carry a stress analysis of the preliminary uprights and hand calculations are used to verify the results. The upright is then optimized using the optimization capability of Pro/MECHANICA. The students must be sure that the mass and center of mass of the solid and finite element model are verified through hand calculations. The optimized upright is verified through mechanics of materials calculations and when the upright is finally constructed a strain gauge analysis is carried out. All seniors on this project must submit a professional project report in a format similar to a thesis.

11. Conclusion

The SAE sponsors an annual formula racecar competition. This competition involves the design and construction of a prototype formula style racecar. Being involved in this competition the author has found it to be an effective way of teaching automotive design to students. Engineering students are typically intellectually curious and competitive by nature. Adding a competition results in greater student motivation and an atmosphere of realism. The motivation to produce the best design is an important element of the engineering design process. The project promotes teamwork, a sense of loyalty and brings the student to a level where he/she can be a productive engineer in industry faster than traditional methods. The successful completion of this project requires students to work as a team to develop ideas and then apply engineering principles and analysis to develop a detailed design. The project can provide effective simulation of the planning, design and development phases of a large-scale product design. It is less effective in simulating the production and manufacturing phases since the car is a prototype and involves production methods not appropriate for mass production. The author personally believes that the Formula SAE competition provides an engineering student with one of the most realistic design experiences available within an academic setting.

This paper presented guidance for advisors who wish to mentor a student team. The author personally feels that the key ingredients in being competitive is that the advisor(s) must play an active role, the project must be structured, deadlines must be established and firmly held to, and the car must completed in early March. The reader may contact the author at jjrencis@wpi.edu or (508) 831-5132 if you would like to discuss the project.

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