Introducing Sae Baja in a Sophomore Mechanics and Machines Course

WAEL MOKHTAR
Grand Valley State University, Grand Rapids, MI

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Assistant professor of Mechanical Engineering. Ph.D. in Aerospace Engineering and MS and BS in Mechanical Engineering. Areas of interest include: Thermo-Fluid, Mechanical Engineering Design, Capstone projects and Computational Fluid Dynamics (CFD).

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Abstract

A design project was introduced in a sophomore Mechanics and Machines course. This course was re-modeled by integrating machine elements, basic Mechanics of Material concepts and classical Statics topics. The design project serves as one of the teaching tools that support this integration. In the project, the students were asked to re-design an off-road vehicle for SAE Baja competition. One of the advantages of using SAE Baja was the detailed engineering and safety requirements of the competition. In addition to that, a vehicle was designed and built in the previous year by the school team, which provides an excellent information source for the students during the design process. Another objective from using SAE Baja was to introduce the students to one of the professional organizations and help in activating the local student chapter. The instructor presented the project with a list of technical constraints that served as a starting point. The students have to work in teams and collect more information for the SAE rules and by taking measurements from the vehicle. The project was limited to modifications in the derive train and the suspension system to meet a specified design challenge. The details of the project requirements, and objectives are discussed with samples from the students' work.

Introduction

Design is one of the core engineering skills. Most of the Engineering Schools use capstone projects and senior level course projects to introduce these skills. Recently, small size design projects started to be used as teaching tools to introduce design skills earlier in the engineering programs. A secondary objective of this early introduction was to have 'real life' application for the theoretical topics of the course. In the freshman year, Mokhtar [1] developed a design course where a team of freshman students re-designed and built an off road vehicle for the SAE competition. The team worked for nearly two semesters where they spent the first semester in design and the second semester was for building. The team was successful to complete the vehicle and compete in the SAE race. All the design was done on CAD which is the only design skill that students have at this level. The feedback from the students was positive. In a sophomore Mechanics and Machine course, Chaphalkar et al.[2] and Mokhtar[3] introduced reverse engineering and open-ended design project to introduce Engineering Problem Solving (EPS) and design skills. In the reverse engineering, the students were asked to reverse engineer a mountain bicycle. The project included technical and cost contestants. In the open-ended project the students were asked to design an overhead mobile crane. With the experience of the first project, the students performed even better in this second project. The challenge also included both technical and budget constraints. Both projects showed success.

Projects, as a teaching tool, were used by Duesing et al.[4] in a freshman CAD course. The students were asked to complete a series of projects where each project focused on a certain tool in the CAD package. Mokhtar[5] used a similar Project-Based-Learning (BPL) in teaching a CFD undergraduate course.

For a Heat Transfer course, Newell et al. [6] and Fleischmann et al. [7] used design projects to support the material of the course for upper level engineering students. Leifer [8] also used projects

in junior level Kinematics and Dynamics courses. Crone [9] used projects in three courses in the Mechanics sequence. Mokhtar et al. [10] presented several approaches of using projects in a Machine Design course. In Thermo-Fluid, Mokhtar et al.[11] discussed the integration of design projects in several level of the engineering program. Mokhtar [12] and Hadim [13] expanded the using of Project-Based-Learning (PBL) in several levels of the engineering program starting from the freshman year to the completion of the capstone senior project.

Present approach

In the present approach, a design project was assigned to the students at the end of a sophomore Mechanics and Machines course. The project was to redesign and address a list of technical concerns in a Mini Baja vehicle and to meet the SAE competition requirements. The main objective of the project was to provide the student with a real application for the topics covered in the course and challenge their skills beyond the course limits. Working in teams with a team captain was among the tools that were used to develop team work skills. Engineering problem solving (EPS) was the main tool that the students used to address the technical concerns in the vehicle. The vehicle was built by the Baja team in the previous year. The technical concerns were some of the defects that team noticed during the SAE race.
An over view of the SAE Mini Baja competition, is presented in the following section. The details of the project and samples from the students' work are discussed. Finally further discussion and conclusions are presented.

SAE Mini Baja competition

Mini Baja is one the design competition that SAE (Society of Automotive Engineers) organize every year. Each team designs and builds an off-road vehicle to meet a set of rules. All teams are given the same engine and the challenge is to design a light strong car that can survive and sequence of testing during the race. Before the race each team has to submit a design and budget report. In the competition day, all vehicles have to pass a detailed inspection. The points of the race include several events such as, acceleration, braking, maneuverability, and fours hours of endurance race. Figure 1 shows three of the cars during the endurace race.

Figure 1: A photo of the Mini Baja vehicles during one of the SAE competitions

Mini-Baja is a good engineering project where the students design and build a product with realistic constraints. It is usually used as a capstone senior project by many engineering schools. It was successfully used before as a project for freshman and sophomore course, Mokhtar [1,12]

Project overview

Figure 2 shows the vehicle that was built by the team during the previous year. The students was asked to re-design several sub-systems of the vehicle. Below is the list that was given to the students:

- **Speed reducing train:**
  Currently, the speed reduction train includes a CVT and a set of timing belts. Your task is to first evaluate the current system and then develop improvements for better efficiency and reliability. Train devising method has to be used for this part of the project. The final design should include all specifications and stress analysis of the components used such as shafts, bearings, keys, belts, chains, gears, lubrication system, etc.
- **Front and rear suspension:**
  The Baja team decided last year to use independent suspension system (double A-arms). It is required to evaluate the current design, perform loads and stress analysis of the components and develop improvements for better vehicle stability.
- **Steering system:**
  It is required to explore and proposed the recommended components to develop a four-wheel steering system.
- **Knuckle stress analysis:**
  The Baja team has designed and manufactured (CNC) a knuckle. During the last year race, the knuckle failed several times. It is required to evaluate the problem and propose a solution.

Figure 2: The Mini Baja vehicle that was built in the previous year.

The design challenge was to minimize the overall weight and meet the required SAE specifications. It was also required that all parts of the project should include expected cost of the components used. The students worked in teams of 5 to 6 students. A final report and presentation was the product of the project.

Students' samples

In this section, samples from the students' work are discussed. Figure 3 shows some of the photos that one of the teams presented in their report to show some of the defects in the current design. The right hand side photo shows the interference between the upper A-arm and the spring. Each team spent a lot of time in inspecting the current design and identifying the main defects. This phase of the project is "problem definition" which is one of the major skills for practicing engineer.

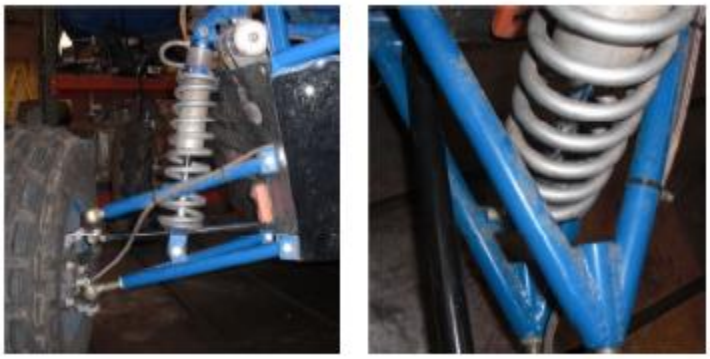

Figure 3: Photos for the front suspension.

After the inspection phase, each team developed a list of concerns that need to be addressed in the new design. Figure 4 shows part of the design process for the front suspension. The figure shows the performance and the new dimensions of the A-arms. Further force analysis was performed on the new design, Figure 5.

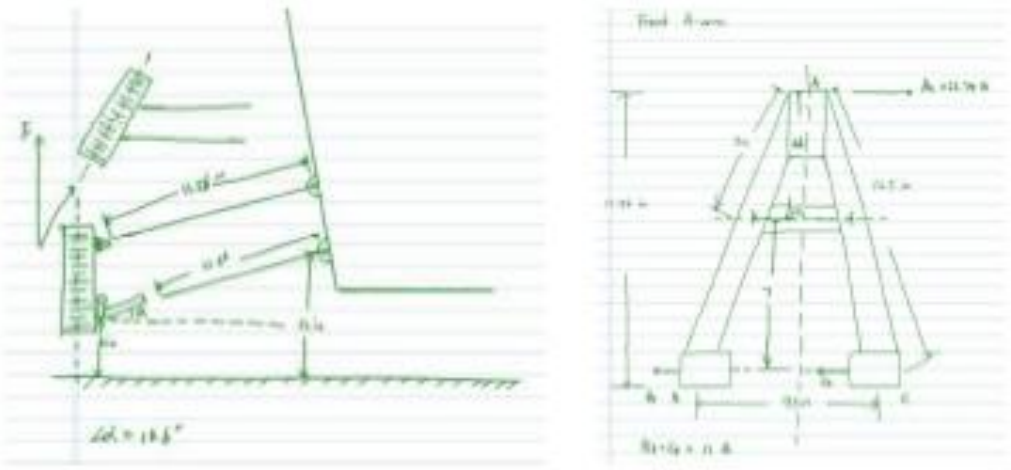

Figure 4 Sketches for the re-designed front suspension.

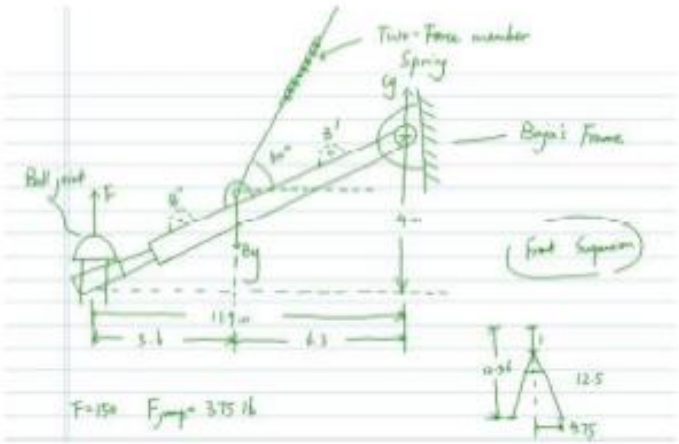

Figure 5: Free Body Diagram (FBD) for the new front suspension.

Figure 6 shows the broken knuckle. This part failed several times during the SAE race. The weld near to the left hand side was done during the race. This is another challenge where loading of the knuckle includes dynamic forces which were beyond the limits of the course. The students had to learn the dynamic loading and added its effect to the force analysis. Figure 7 shows the force analysis. One of the students in this team got more interested in this part of the project and performed a Finite Element Analysis (FEA), Figure 8. FEA is a senior level topic and this student put a lot of time to learn it on his own and performed a reasonable analyses to evaluate the problem.

Figure 6: A photo of the broken front knuckle.

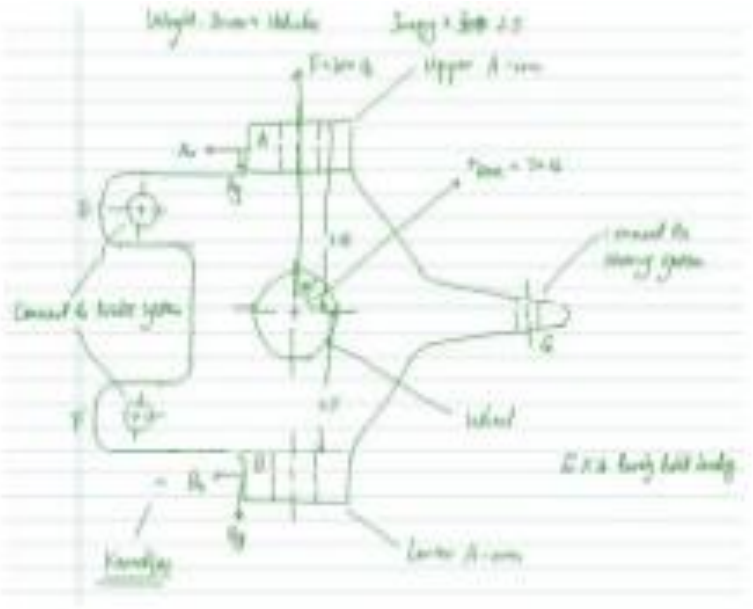

Figure 7: Free Body Diagram (FBD) for the front knuckle.

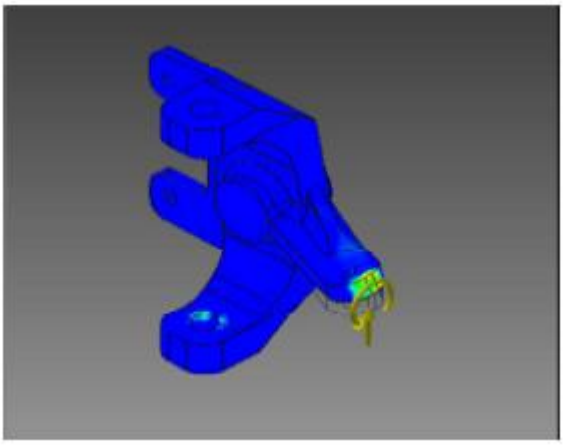

Figure 8: Finite Element Analysis (FEA) for the front knuckle.

Another task for the project was to explore the use of an alternative gear train instead of the CVT. This topic is a new part of the course where the students learn the basics of gears and use simple design software to select the suitable gear. Figure 9 shows the multi-stage gearbox the students selected for the gear train. A 3D CAD view is presented in Figure 10. Based on the limited area inside the car the students decided to use helical gear. The course was limited to spur gear. This team expanded their knowledge to learn how to select helical gears.

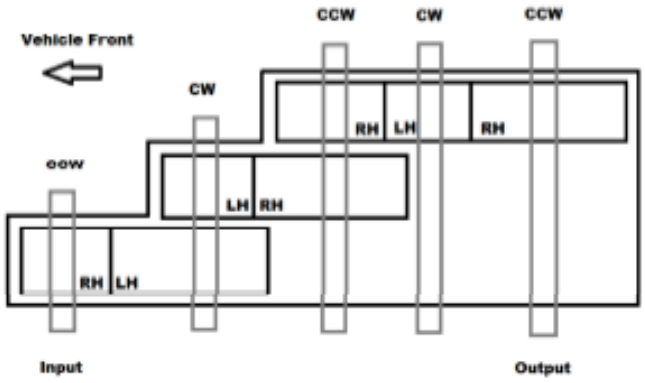

Figure 9: Layout of the designed gear train

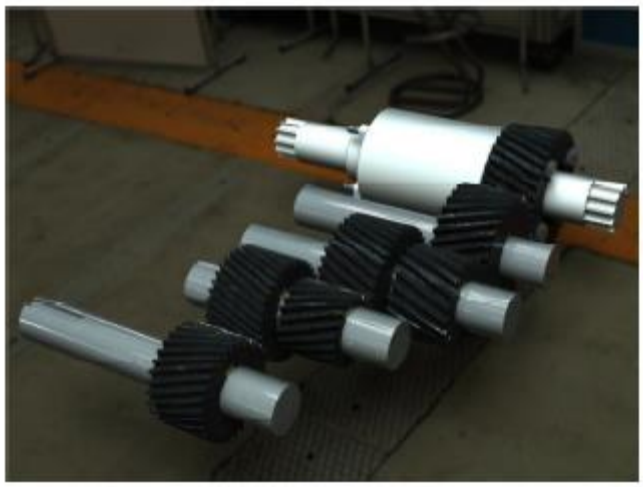

Figure 10: 3D CAD view of the designed gear train.

Further discussion

The main objective of the project was to get the students to apply the knowledge they learn in the course to solve a real engineering problem. The process started with problem definition where team formulated the problem in hand. The full analysis of the current design was the first step in the solution. The teams then proposed solutions for each problem and supported their discussion with calculations.

One of the major benefits of this project was that the students learned a lot of skills beyond the course to complete some of the tasks. This is a very important skill for a professional engineer (life-long learning). Other tasks needed a direct application for the topics covered in the course. This part increased the students' confidence in the subject. Team work was another benefit of the project where the students worked as sub-teams and integrated their work to complete the project. The author used this project before in several courses, being automotive related makes it close to the students.

Another objective of the project was to increase the student interest to join the SAE chapter. Toward the end of the project, several students approached the author to join the team.

Conclusions

SAE Min Baja was used as a re-design project in a Mechanics and Machines course. The students were introduced to several engineering problem solving (EPS) tools. The project showed success and many of the students went beyond the required tasks and learned advanced topics to solve some of the problems.

The project was a design only with no building. It offered a good semi-open-ended problem for a sophomore course. It helped to increase the students' interest in the subject and teach them further skills. The size of the project and the requirements were set to match the time available of the course as a supporting tool.

The author used this project for several courses and with right choice of the requirements, it showed success.

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