SAE Mini Baja

By
Chris Bennett, Eric Lockwood, Anthony McClinton,
Robin McRee, and Colin Pemberton
Team 01

Problem Formulation and Project Plan

Document

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design I – Fall 2013

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

Table of Contents

Introduction

The Society of Automotive Engineers International (SAE) has contracted the team to design a Mini Baja vehicle. The stakeholders for the project include Dr. John Tester and the Northern Arizona University student chapter of SAE. SAE is a United States based organization that provides international standards for the automotive, aerospace, and commercial vehicle industries. They sponsor a variety of collegiate competitions that simulate the real-world engineering process and challenge students in their area of study. The SAE Mini Baja competition is designed to challenge each team in the design, planning, and manufacturing process as applied to a small off-road vehicle that could be turned into a consumer product. The competition consists of a variety of different events to test speed and maneuverability, and culminates in a final endurance race. Our sub-team has been assigned the task of designing the frame of the vehicle and ensuring the overall vehicle compliance with the safety regulations.

Project Need Statement

NAU has not won an event at the SAE Mini Baja competition in many years. During the competition, there will be several events that will test the limits of the vehicle. They include the Presentation, Hill Climb, Endurance, and Acceleration tests. The team must make a sales presentation to a panel of judges on the viability of the design as a consumer product. The maneuverability test consists of a variety of tough obstacles and tight turns, and the hill climb event tests the vehicle's low-speed power. The endurance race is a three hour driving test to prove the long-term reliability and average speed of the vehicle. The acceleration event tests the maximum speed of the vehicle. It has been many years since NAU has won an event, and a single event win would satisfy our stakeholders. Therefore, the solution to our need is a single event win at the 2014 SAE Mini Baja competition.

Project Goals

The specific goal for our sub-team is to design the lightest possible frame that satisfies all the criteria specified in the 2014 SAE Mini Baja rulebook. To achieve this goal, the team must use lightweight materials and minimize the size of the frame. At the same time, the frame must be designed to meet all the safety requirements. After the frame is completed, our goal shifts to the overall safety of the vehicle. We will make sure all the sub-teams adhere to the strict safety guidelines throughout the design process, and we will do a final safety inspection before the competition.

Operating Environment

The vehicle will need to traverse rocks, sand jumps, logs, steep inclines, mud, and shallow water. The frame must be able to withstand large impacts and provide a safe environment for the

operator. The vehicle may encounter collisions from other vehicles while competing, and there is significant roll-over risk in the maneuverability events. It will also experience various magnitudes of vibrations over different types of terrain and must maintain the safety of the operator at all times.

Project Goals

The specific goal for our sub-team is to design the lightest possible frame that satisfies all the criteria specified in the 2014 SAE Mini Baja rulebook. To achieve this goal, the team must use lightweight materials and minimize the size of the frame. At the same time, the frame must be designed to meet all the safety requirements. After the frame is completed, our goal shifts to the overall safety of the vehicle. We will make sure all the sub-teams adhere to the strict safety guidelines throughout the design process, and we will do a final safety inspection before the competition.

Objectives

The most important objective for the frame design is safety. The Mini Baja competition focuses heavily on creating a safe environment for the competitors and has very strict safety rules. After safety, our next most important objective is to minimize the frame weight. After consulting with Dr. Tester and thoroughly reading the rulebook, our main objectives were generated and are listed below:

- The frame must be safe.
- The frame weight should be minimized.
- The frame should be easy to manufacture.
- The frame should be inexpensive.
- No damage to the safety cell after an impact.
- No significant damage to the overall chassis after an impact.

Constraints

All of the constraints for this project come directly from the SAE Mini Baja rulebook. While we are limited by the school manufacturing facilities, everything in this project is within the capabilities of the NAU machine shop. The primary design constraints are:

- Must be constructed from steel tubing.
- Tubing must have a bending strength of at least 395 N-m.
- Tubing must have a bending stiffness of at least 2790 $N\text{-}m^2$.
- Tubing must have a minimum wall thickness of 0.062 inches.
- Frame length must be below 108 inches.
- Frame width must be below 40 inches.
- Height must be at least 41 inches above the seat bottom.
- Frame geometry must conform to the specifications.
- Vehicle must satisfy all the safety regulations in the rulebook.

Quality Function Deployment

Our objectives and constraint have been compiled into the QFD chart below. Each customer need has been given a correlation score of 1, 3, or 9 with the corresponding engineering requirement. The relative weight indicates how important a specific requirements is compared to the others. The most important requirements are related to the safety and overall weight of the frame.

Customer Needs	Customer Weights	Length	Width	Height	Weight	Bending Strength	Bending Stiffness	Tubing Wall Thickness	Conform to Safety Regulations	Cost	Man-Hours to Build
Light weight	10	3	3	3	9	3	3	9		3	
Easy to manufacture	6	1	1	1				3	3		9
Inexpensive	5				9	9	9	3		9	
No damage after impact	8	3	3	3		9	9	3	9		
Safe	10					9	9	1	9		1
	Raw score	60	60	60	135	237	237	157	180	75	64
	Relative Weight	5%	5%	5%	11%	19%	19%	12%	14%	6%	5%
	Unit of Measure	in	in	in	lb	N-m	$N\text{-}m^2$	in	T/F	$	hr
	Techical Target	108	40	41	200	395	2789	0.062	TRUE	300	40

Figure 1: Quality Function Deployment

Project Planning

The goal for our sub-team is to have the frame completed by December 16th of this year. We are rapidly generating design concepts and plan to order frame material as soon as possible. The frame material selection has been narrowed down to two possible choices, only dependent upon available funds. Once the frame design has been finalized on October 20th, assembly will begin. We must begin work so early because the rest of the vehicle design depends very heavily on the frame, so the sooner the frame is complete the more time the other teams have to design. Dr. Tester has also requested that the final vehicle be completed at least one month before the competition in April. This makes our overall completion deadline March 15th, 2014. Our preliminary Gantt chart is attached in the appendix.

Conclusion

SAE, along with Dr. John Tester and the Northern Arizona University SAE student chapter has contracted us produce a vehicle capable of competing in the 2014 SAE Mini Baja competition. This team has been assigned to design the frame and guarantee the safety of the

final overall vehicle design. Our goal is to design the lightest possible frame that will win an event at the competition.

References

SAE International, “2014 Collegiate Design Series Baja SAE Rules,” 2014.

Tester, John T., PhD, Associate Professor Northern Arizona University, personal communication, Sept. 2013.

Appendix – Gantt Chart