THE UNIVERSITY of TENNESSEE at CHATTANOOGA

COLLEGE of ENGINEERING and COMPUTER SCIENCE

2006 Midwest Mini Baja Team

Design Report

Vehicle #134

Our Sponsors:

Vehicle Number 134

University of Tennessee at Chattanooga 2006 Mini Baja Design Report

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ABSTRACT

Each year, the Society of Automotive Engineers (SAE) sponsors an intercollegiate Mini Baja® Series competition. Teams consisting of engineering students from universities around the world are tasked with designing, building and testing a vehicle to compete in one of six regional competitions. The University of Tennessee at Chattanooga (UTC) has elected to participate in the Midwest Mini Baja® Series. As part of this competition each team is required to submit, for review by the SAE judging body, a technical report documenting the design of their vehicle. The following is an analysis of the process the UTC team used in designing their vehicle.

INTRODUCTION

This report describes the processes undertaken by the UTC team in designing, constructing and testing a vehicle that will compete in the Midwest division of the SAE Mini Baja® Competition scheduled to be held in Milwaukee, Wisconsin on May 24-27, 2006. The purpose of this competition is to simulate a "real world" engineering design project in which collegiate teams design and manufacture a prototype of a "rugged, single seat off-road recreational vehicle intended for sale to the non-professional week-end off-road enthusiast"[1]. The design should be durable, safe and easy to maintain and must be able to negotiate rough terrain in all weather conditions.

In addition to the design of the vehicle, a detailed cost analysis associated with development of the prototype was performed and submitted for review by the SAE judging body. The team maintained detailed records of the actual cost to produce the prototype. A cost report was submitted separately per the guidelines of the competition rules. The scope of this report therefore considers cost only when it pertains to making a design decision.

The twelve member UTC team consisted of eight mechanical, one civil, one electrical, one chemical and one industrial engineering students. Drawing upon multidisciplinary engineering knowledge, adherence to strict design parameters prescribed by SAE competition rules and varying levels of experience with recreational off-road vehicles, the UTC design team sought to develop a prototype that balanced the primary objectives (safety, durability, manufacturability and maintainability) with performance in an attempt to maximize competitiveness in each of the judged events of the SAE Midwest competition.

FRAME DESIGN

OBJECTIVE

The functions of the chassis are to protect the driver and support all operator control systems, front and rear suspension systems, and engine and drive train. The objective of the frame design was to satisfy these functions while meeting the SAE regulations with special considerations given to safety of the occupants, ease of manufacturing, cost, quality, weight, and overall attractiveness. Other design factors included durability and maintainability of the frame.

DESIGN

The UTC Mini Baja team designed and fabricated a vehicle frame with primary emphasis given to factors of safety, durability, performance, and manufacturability while abiding by requirements established by SAE.

Safety

The components of the frame are the RRH, LDB, RHO, FBM, LC, LFS, SIM, FAB, and FLC (See Figure A-1 and the Acronym list for member clarification). Per SAE Competition Rules, the RRH, LDB, RHO, FBM, and LC material properties were required to have a bending stiffness and a bending strength equal to or greater than that of 1018 steel with an O.D. of 1 in. and a thickness of 0.12 in. Members LFS, SIM, FAB, and FLC were required to have a minimum wall thickness of .035 in and a minimum O.D. of 1 in. All frame members with a bend radius greater than 6 in. may be no longer than 28 in. unsupported. Clearance guidelines dictate a minimum of 6 in. vertical distance from the driver's head to the bottom of the RHO and 3 in. clearance between the rest of the body and the vehicle envelope.

The SIM was designed to give the occupant extra security during a side impact on the vehicle and to reduce the possibility of the driver leaving the cockpit. The SIM is bent outward from the car at 20 degrees and curved ribs vertically attach the SIM to the LFS which gives a strong and spacious enclosure for the driver (See Figure 1).

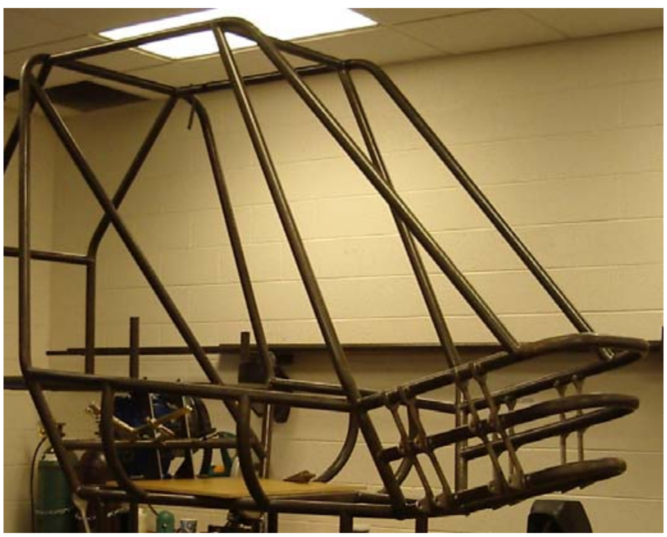
Figure 1. Side View of Frame.

The harness attachment points are designed to accommodate a 5 point harness. All harness mounts are made from 3/16 inch 4130 steel plate. The shoulder mount points are attached to the LDB with an additional cross bracing that connects both shoulder mount points to ensure the driver is always properly restrained. The lap belt mounts are securely attached to the LFS and angled such that all force acts through the center of the mount point reducing the possibility of the lap belt mount failure due to fatigue.

Performance

Two materials were considered for the construction of the chassis: AISI 4130 and 1018 seamless tubing. 4130 steel with an O.D. of 1.25 in. and a minimum wall thickness of 0.065 in. was chosen because it exceeds the bending stiffness and strength requirements of SAE, which gives increased protection to the driver (See Table 1).

Table 1. Tubing Alternatives Comparison

Material	1018 Steel	4130 Steel
O.D.	1	1.25
Wall Thickness (in.)	.12	.065
Weight (lb/ft)	1.13	.82
Ultimate Strength (ksi)	60.2	161
Bending Stiffness (kip-in^2)	981	1,280
Bending Strength (lb-in)	3140	4311

After comparing the bending stiffness and strength, it was determined that a minimum wall thickness of .065 in. was needed using 4130, compared to 0.120 in. wall thickness using 1018, reducing the overall weight of the car by 0.31 lb per linear foot of material used for fabrication.

Manufacturability

The UTC Mini Baja team elected to use SolidWorks® to design a three dimensional model of the chassis. Using this design software allowed the team to convert part files to CAD/CAM programs and use the in house CNC mill to cut some of the chassis parts. This lowered manufacturing costs by avoiding excessive out-sourcing while obtaining the highest quality parts for fabrication. Using SolidWorks® also allowed the team to plot full scale prints of each individual part which provided a quality control check of each part that had to be out-sourced. The utilization of CAD/CAM software, CNC manufacturing and full scale prints reduced complication during the fabrication process, permitted the team to easily replicate duplicate parts and provided a quality control check during fabrication.

The frame design incorporated bends instead of miters in many of the structural members, believing that this allowed for faster construction, and increased material strength from cold working resulting in an overall increase in product quality. Although there was added cost associated with out-sourcing tube bending, this cost was offset by a reduction in fabrication man hours through decreasing the amount of mitered and welded joints and eliminating man hours and material needed to fabricate fixtures for fit-up.

The front of the car (See Figure 2) features three concentric rounded tubes that miter into the FAB and angle 15 degrees up from the LFS giving the car extra front end clearance.

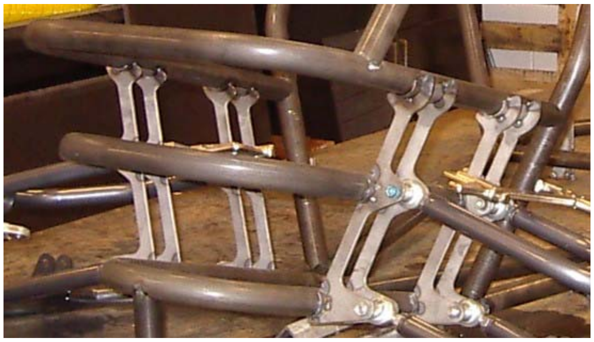

Figure 2. Front View of Frame

The front lower and mid concentric tubes are positioned such that the mounting points of the upper and lower A-arms are directly attached to those tubes with a doubling plate. This arrangement gives extra support to the front suspension A-arm mount points in a one wheel front impact as well as side impact. The A-arm mount plates were CNC milled from 3/16 inch 4130 steel plate and attached to all three front concentric tubes. This design also adds strength to the car in the event that the front end of the car bottoms out. The arrangement also simplified the manufacturing processes because no fit-up fixtures were needed.

Durability

A GTAW process with an ER 80S-D2 filler material and a pure argon shielding gas was used to weld all components of the vehicle. The GTAW process was chosen because of its ability to control the interpass temperature of the weld, minimizing the weld effected zone and ensuring the material retains its toughness and strength. ER 80S-D2 filler material was chosen because it provides the greatest tensile strength of all available filler materials used to weld 4130 steel. During the fabrication of the chassis, holes were drilled at every point where tubes connected to each other. This was done to allow argon to purge the inside of the chassis during welding. This process eliminates scaling and oxidation on the inner surface of the tube and decreases the possibility of defective welds. To reduce distortion of the vehicle during welding a wandering sequence procedure was used. This process applies equal amounts of heat on opposite sides of the vehicle. Acetone and sandblasting were used to ensure that every weld joint was clean before welding.

DESIGN ANALYSIS

Objective

Frame analysis was performed to ensure expected loadings do not exceed material specifications and ensure the safety and durability of the frame.

Analysis

The UTC student team's skill set included some familiarity with static, linear, elastic FEA using ANSYS®. The analysis concentrated on estimating the linear von Mises equivalent stresses in the 0°, 90°, 180°, and 270° planes of the pipe elements from which the model was constructed. In the load scenarios described below, the chassis structure was constrained at convenient locations opposite to or adjacent to the load location(s). The magnitude of the applied load was 1800 lb which is equivalent to a 3g impact acceleration of the estimated vehicle weight and driver mass.

The analysis was performed for several impact scenarios including: Nose impact (See Figure 3), Side (at driver's location), Side (at nose), Top rear, and Top corner. Analysis indicated stresses below the yield strength of 4130 steel (138 ksi) for all scenarios except the nose impact study which showed a maximum stress of 162 ksi. Based on these results, reinforcements were added to the nose at the intersection of the FBM and SIM down to the LFS.

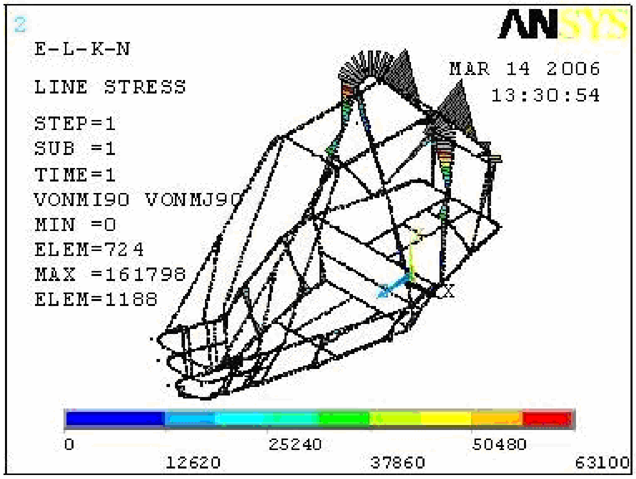

Figure 3. Stress Analysis of Nose Impact at 3g.

To verify the strength properties of the tubing, a tensile test was also conducted to determine the weld strength. A welded specimen of 4130 steel 1.25 in. x 0.065 in. tubing was tested. The weld resisted a load of 14.7 kips at which point the test was stopped due to failure of the specimen mounting point to the Tinius Olsen testing device (See Figure 4).

Figure 4. Weld Test Specimen

The 14.7 kips is equivalent to an average tensile stress across the section of tubing of 59.1 ksi. A plot of test load versus time can be seen in Figure 5.

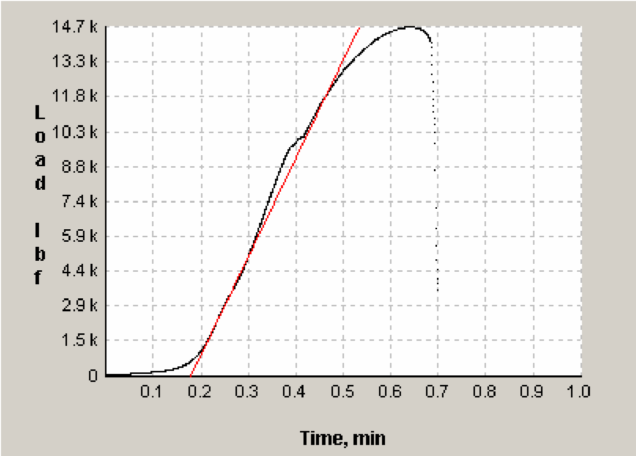

Figure 5. Results of weld test of 4130 1.25 in. x 0.065 in. frame tubing.

SUSPENSION DESIGN

OBJECTIVES

The purpose of the suspension is to reduce shock loads that act on the car while providing optimal wheel contact when operating under dynamic conditions. The suspension must provide enough wheel travel to dampen the impacts imposed on the vehicle.

DESIGN

Front Suspension

The front suspension is a short-and-long control arm/A-arm wishbone arrangement (See Figure A-2). The upper control arm is 13 in. long and the lower length is 15 in. The length of the front control arms allows for a positive travel in the front of the car to be 10 in. In order to compensate for dive-effects during aggressive cornering, the camber angle for the front suspension has been set at 0˚ at ride height. The camber angle goes slightly positive as wheel travel increases to assist the driver in steering (See Figure 6).

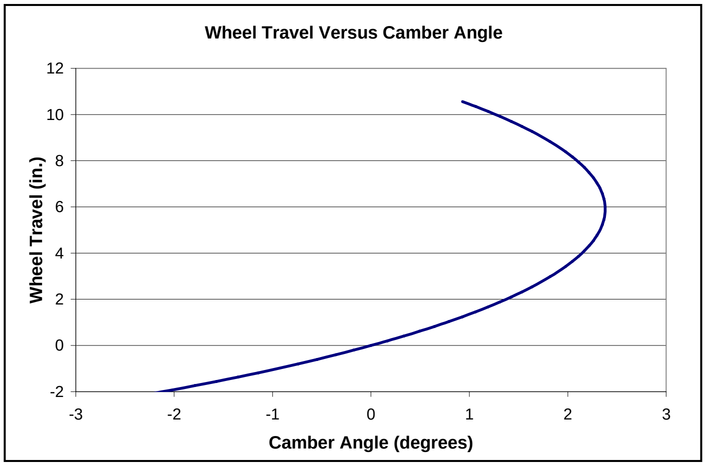

Figure 6. Wheel Travel versus Camber Angle

The front wheel angle of the car is 37°. The minimum radius of curvature for the car was determined to be 125.2 in.

Analysis

Assuming a coefficient of friction of 70% of the estimated car weight with driver, the “break away” speed of the car before sliding was determined to be 16 mph at maximum turning conditions. The car and driver should experience 0.73 radial g’s before sliding in a turn.

Rear Suspension

A swing arm design was chosen over a fully independent rear suspension because of its simplicity. This was important because the final approval for this project was not received until the third week of the fall semester of 2005 which limited the amount of design time. The pivot point of the swing arm is mounted concentrically with the center of the output shaft of the transmission. This mounting configuration allows for the transmission to be mounted as low as possible. The path of the chain travels directly down the length of the arm, minimizing chain slack during articulation. Threaded Heim joint fasteners are used to connect the swing arm to the chassis. These joints also allow for minor chain tensioning adjustments by permitting the lengthening or shortening of the swing arm. The removable axle is mounted inside custom bearing housings at the end of the swing arm, and is made of solid 4130 steel with 1 3/8 in. O.D. to accommodate stock aluminum pinned wheel hubs (See Figure A-3). Positive rear travel is limited to 8 in. to avoid interference of the rear brake rotor and the rear housing.

Shocks

Gas shocks and coil-over shocks were both considered for use on the vehicle. Gas shocks were found to be significantly lighter than coil shocks; however, coil-over shocks were selected because of their superior ability to respond after impact.

In order to determine the correct valving and spring rate for the shocks, availability and constraining parameters were considered. The weight of the vehicle and driver was estimated to be 600 lb. The weight distribution for the car was estimated to be approximately 60/40 from the rear to the front. Using the total weight of the car and the weight distribution, the weight on each of the front tires was determined to be 115 lb. The weight on each of the rear tires was evaluated to be 190 lb. The desired static ride height is 10 in. This allows for a wheel travel of 10 in. for the front tires and 8 in. for the rear tires. The rating for the selected front springs is 175 lb/in. and 225 lb/in. for the rear.

DESIGN ANALYSIS

Objectives

Analysis of the swing arm was performed to ensure the durability of the chosen material and proper configuration of the design.

Analysis

The chosen swing arm design was modeled in SolidWorks® and FEA was performed using COSMOSWorks®. The pivot points of the arm were constrained to allow for no translation while the bearing houses were subjected to 1000 lb in opposing directions to simulate racking. A maximum von Mises stress of 85,500 psi was seen at the pivot point location on each swing arm extension (See Figure 7). This extreme value is due to rotational constraints that will not exist due to use of Hein connectors and is not expected to be seen under vehicle driving conditions. Therefore, it is concluded that the chosen swing arm is a satisfactory structural design.

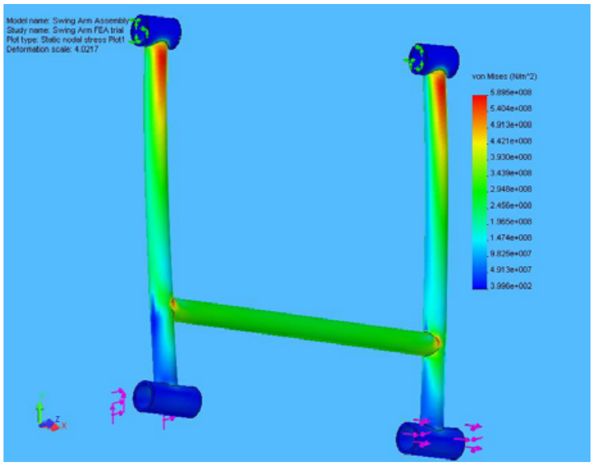

Figure 7. FEA of Swing Arm performed in COSMOSWorks®.

STEERING SYSTEM DESIGN

Objectives

The purpose of the steering system is to provide directional control of the vehicle.

Design

A rack and pinion steering system was chosen over a recirculating-ball system because of low cost, light weight and simplicity in design. The advantages of a rack and pinion system are positive feedback and responsiveness to driver inputs[2]. The selected 14 in. rack and pinion with a 12:1 gear ratio incorporating OEM Honda 400EX spindles satisfies these requirements.

DRIVE TRAIN DESIGN

OBJECTIVES

The purpose of the drive train is to transmit shaft power and torque of the Briggs and Stratton engine to the rear wheels of the car. The 10 HP engine produces 14 ft-lb of torque at 3800 rpm. The objective for the Mini Baja competition is to optimize the power delivered to the wheels regardless of the vehicle speed for the various competition conditions. High speed was desired for the acceleration and speed trials while high torque was preferred for towing and hill climbing events.

DESIGN

The drive train design consists of a 10 HP engine, CVT, 2-speed gearbox with reverse and a chain driven solid steel axle. The Comet 790 Series CVT (See Figure 8) was selected because of its large range of gear ratios. As the engine reaches its governed rpm limit, 3750 rpm, the gear reduction across the CVT has been determined to be 0.82:1 thus serving as an “overdrive” for the car. At low engine speeds the CVT produces a reduction of 3.38:1 providing necessary torque.

Figure 8. Comet 790 Series CVT.

The CVT is assisted by a Polaris model number ME25P8 two-speed gearbox (See Figure 9). The gearbox is not a “shift on the fly” unit so the car will have to come to a complete stop before the gears can be changed. The reduction across the gearbox in high gear will be 3.34:1 and 6.72:1 in low gear. These gear ratios make it possible to change the torque transmitted to the axle from the engine.

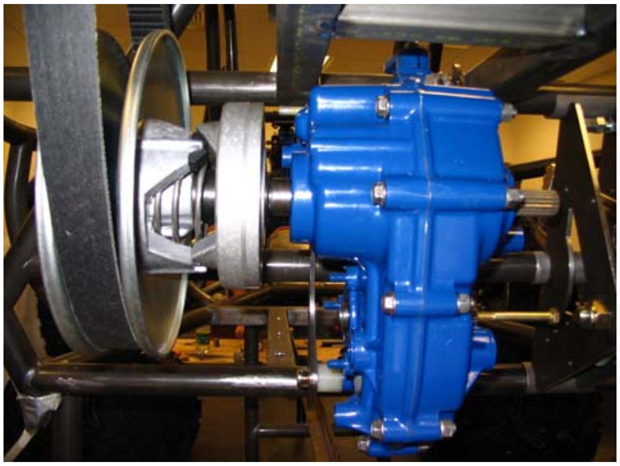

Figure 9. Polaris two-speed gearbox attached to CVT.

The final gear reduction for the drive train comes from the sprocket sizes on the gearbox output shaft and the driven sprocket located on the axle. Several combinations of drive and driven sprockets were analyzed. The analysis was performed with the goal of maximizing the relationship between vehicle top speed and torque output. It was determined that the drive sprocket should have 12 teeth and the driven sprocket should have 38, providing a reduction of 3.17. A low friction O-ring 520 series motorcycle chain will be used to power the axle from the output shaft of the transmission. The yield strength of the chain is listed from the manufacturer to be 8100 lb. Estimated forces on the chain will not exceed forces greater than 3800 lb, providing a 2.1 factor of safety for the chain.

The axle is made of 4130 steel. The axle diameter and length is 1.375 in. and 38 in. respectively. Brake rotor and sprocket mounting hubs were machined out of 6061 aluminum in an effort to reduce weight and utilize readily available material.

It was assumed that the engine develops 10 hp at the governed rotational speed of 3750 rpm. At this speed and power rating the engine generates 14.01 ft-lb of torque. Assuming a 17% power loss due to friction across the drive train, the torque transmitted to the axle was determined to be 101 ft-lb in high gear and 203 ft-lb in low gear. The top speed of the car in high and low gears was evaluated to be 29 mph and 15 mph respectively based on a rear tire diameter of 22 in.

To align the lateral center of gravity of the vehicle, two 500 lb capacity Interface® force transducers were placed equidistance from the centerline of the frame. The drive train assembly was positioned such that the force on each load cell was within plus or minus 1 lb (See Figure A-8).

BRAKING DESIGN

OBJECTIVES

The purpose of the braking system is to increase the safety and maneuverability of the vehicle by locking all four wheels in a time of less than 1/3 of a second.

DESIGN

The braking system locks all four wheels by using a brake for each wheel on the front and a single brake for the rear axle. The front and rear components of the vehicle were modeled after those used on an OEM Honda 400EX four-wheeler. This ATV was chosen because it is a performance model, replacement parts are readily available and multiple team members have had prior experience with its performance characteristics.

The calipers are powered by dual master cylinders. Both master cylinders are standard 3/4 in. bore direct mounted Wilwood Master Cylinders with 4 oz. reservoirs. Wilwood has proven to be a reliable brand in Mini Baja racing based on discussions with established Mini Baja race teams. Two master cylinders are used to increase safety by incorporating dual redundancy as well as for SAE rules compliance. Using this system a failure to one component does not mean the entire system fails. Another reason for choosing this design was its compact arrangement. The master cylinders mount directly to the custom made brake pedal and are located above the driver’s feet, allowing the driver to easily enter and exit the car (See Figure 10).

Figure 10. Brake System mounted on Chassis.

DESIGN ANALYSIS

Objectives

The objective of the brake system analysis is to ensure selected components satisfy the design objective of locking all four wheels in less than 1/3 of a second and determine the required force for this accomplishment.

Analysis

Engineering statics were applied to determine that a 145 ft-lb force must be applied to the brake pedal in order to lock all 4 wheels simultaneously. The parameters and assigned values used in the analysis are shown in Table 2.

Table 2. Braking Analysis Parameters

Parameter	Value
Front Disk O.D. (in.)	6.183
Rear Disk O.D. (in.)	8.500
Front/Rear Radial Pad Width (in.)	1.500
Front/Rear Piston Diameter (in.)	1.170
Front/Rear Master Cylinder Diameter (in.)	0.750
Pedal Ratio	4.250
Front/Rear No. Pistons per Pad	1
Weight of Vehicle (lb)	608
Front Weight Bias Percentage (%)	40
Height of CG (in.)	14
Coefficient of Friction	0.45

CONSUMER INTEREST

The UTC Mini Baja team designed its 2006 vehicle with seven categories in mind. They were weighted in order of importance to the driver with a typical "weekend warrior" in mind as the ideal customer. The seven categories, in order of significance, were: safety, performance, durability, comfort, cost and serviceability.

Through analysis, 4130 steel was selected for its high yield stress. It was found to be three times higher than that of 1018 steel, which correlates directly to increased safety for the driver. The SAE competition rules defined a minimum requirement of a 4-point restraint safety harness, but the team decided to use a 5-point harness in the interest of occupant safety. The remaining standard safety equipment, including arm restraints, fire extinguisher, and two kill switches were all placed for easy access and use, as well as maximum optimization of their functions during an emergency.

Increasing the performance of the vehicle is in the interest of the race team and is something that is much appreciated by our target customer. For this reason, the entire vehicle was designed to be built from high-grade 4130 steel. This lowered the overall weight of the vehicle by nearly a third of a pound per linear foot of steel.

Further performance enhancements included using a two speed transmission, low range for towing or steep inclines and high range for speed and reverse. In addition, rack and pinion steering and custom built Bilstein coil-over shocks were selected with performance in mind. Although features such as reverse were not required by SAE Rules, they will help the vehicle handle more like the customer would expect and provide the performance aspects that they desire.

Durability is of vast importance to off-road vehicles, since navigating rough conditions in remote locations is part of their typical use. This has been addressed in all aspects of the vehicle design. Initially this was considered in frame construction ensuring that the vehicle would have the sufficient structural integrity for typical ATV conditions it is expected to navigate. Secondly, the dimensioning and locations of high maintenance parts was taken into account. This vehicle is constructed using high grade, readily available, aftermarket ATV parts, preserving the option of further customization of the suspension, drive train, steering and braking system components for those customers with a more aggressive use in mind.

Although comfort is not the first thing that all consumers think of in an off-road vehicle, after hours of driving the designers understand that it becomes an important aspect of the overall design scheme. The cockpit is designed using a male driver profile of 5'11" and medium build as the typical driver. The vehicle is designed for optimal comfort in the areas of mirror, steering wheel and rack and pinion placement. The positioning of the foot pedals are pushed as far forward as possible with the assemblies tilted downward so that the pedals travel in the same line of the foot's natural travel, reducing the stress on the driver's legs. This vehicle is designed to feel quite roomy for the typical driver because it is built to accommodate the largest member of the team who was 6'6" tall. All of these considerations contribute to providing the most comfortable driving experience possible.

While designing and fabricating the vehicle, the cost aspect was approached in an unconventional method. Instead of selecting lowest cost parts and materials, the team decided to focus on making the vehicle maintenance and modification friendly in the interest of the owner. For instance, using various aftermarket parts lowers the cost of having to purchase expensive custom parts. Efforts were also made in the design process to decrease the manufacturing costs of the vehicle. To do this, the team increased the amount of bends in the vehicle to increase its strength and also to lower the amount of welds required in fabrication. These considerations ensure a safe, high performance, durable but also inexpensive vehicle.

CONCLUSION

The Mini Baja prototype that the UTC team intends to submit for entrance in the SAE Midwest competition was a collaborative design effort among students from several engineering disciplines. The team's goal was to produce a design that met or exceeded the SAE criteria for safety, durability and maintainability as well as provide features that would have mass market appeal to the general off-road enthusiast such as performance, comfort and aesthetics. Design decisions were made with each of these parameters in mind.

The team relied on individual member's knowledge and experience with off-road vehicles as a tool for developing many of the initial subassembly designs for the prototype. Several team members attended the 2005 SAE competition to gather ideas and information about what design choices were successful and how they could be incorporated into the UTC prototype design.

Where applicable, selection of components for each subassembly of the prototype was based on engineering knowledge gained through undergraduate level course work. Reliance upon "engineering intuition" governed the selection of the remaining components. Computational design and analysis software were used to verify that each part of a subassembly design met or exceeded its stated objective. Use of these design tools also allowed the team to address and rectify conflicts between interfacing subassemblies before fabrication, saving both time and cost. Additionally, a digitally cataloged inventory of parts was created so that parts could be readily duplicated if necessary.

When possible, subassembly component parts were machined in-house using CNC and manual machining equipment. This process reduced cost, saved time and ensured precision. Parts not machined in-house were out sourced to qualified professionals. In some cases after market parts common to certain off-road vehicles currently on the market were incorporated into the design for both convenience and because they were readily accessible.

The use of a high strength 4130 alloy steel allowed the frame to be both light weight and resilient. Using bends in the frame geometry provided strength and allowed for a faster fabrication process. Employing a swing arm rear suspension provided a durable, less complicated system over other proposed alternatives. A rack and pinion steering system provided both positive response and feedback characteristics. The use of a gearbox in conjunction with a CVT allowed for a broader range of gearing ratios. The dual braking system provided redundancy which enhances safety. Coil-over shocks provided a superior response after impact. Each of these designs was incorporated into UTC's prototype in an attempt to produce a superior off-road recreational vehicle.

VEHICLE SPECIFICATIONS

ENGINE	
Type	4-stroke, OHV, Briggs & Stratton
Displacement	305 cc
Compression Ratio	8:1
Power	10 hp
Torque	14 ft-lb
DRIVE TRAIN	
Transmission	2-Speed Polaris Gearbox, Comet 790 Series CVT
CVT Reduction	3.38:1 to 0.52:1
Gearbox Reduction	6.67:1 and 3.34:1
Final Drive Reduction	3.17:1
CHASSIS/SUSPENSION	
Chassis Type	4130 steel, tubular frame
Overall Length	91 ½ in.
Wheel Base	68 in.
Overall Width	54 in.
Front Suspension	Double Wishbone
Rear Suspension	18 in. Swing Arm
Ground Clearance	10 in.
Shocks	Bilstein coil-over
Front Travel	10 in.
Rear Travel	8 in.
Vehicle Weight	430 lb
WHEELS/TIRES	
Front Tires	23 in. x 5 in. ITP Holeshots
Front Wheels	10 in.
Rear Tires	22 in. x 11 in. ITP MudLites
Rear Wheels	10 in.
PERFORMANCE	
Approach Angle	90 degrees
Departure Angle	90 degrees
Top Speed (est)	30 mph high gear 16 mph low gear
Rear Wheel Torque	107 ft-lb high gear 203 ft-lb low gear

ACKNOWLEDGMENTS

The UTC Mini Baja team would like to thank Dr. Ron Goulet, Karl Fletcher, Ryan Johnson, and the rest of the UTC Engineering and Computer Science department for their assistance and encouragement on this project. Appreciation is expressed to our sponsors: SAE, ASME, Briggs & Stratton, Shaw, Master Machine, Inc., and Miller Industries. We are also grateful for support from the following companies: Metro Boiler Tube Company Inc., Fastenal, PowerSport and Hudlow Axle Company.

REFERENCES

1. *Consolidated Rules for Mini Baja SAE East, Midwest and West – 2006 SAE MINI BAJA SAE® SERIES,* <http://students.sae.org/competitions/minibaja/rules/.>
2. Stone, Richard and Jeffrey K. Ball. Automotive Engineering Fundamentals. Warrendale, PA: SAE 2004.

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ACRONYMS

SAE: Society of Automotive Engineers

UTC: University of Tennessee at Chattanooga

CAD: Computer Aided Drafting

CNC: Computer Numerical Control

CAM: Computer Aided Manufacturing

CVT: Continuously Variable Transmission

SIM: Side Impact Member

LFS: Lower Frame Support

LDB: Lateral Diagonal Bracing Member

FBM: Front Bracing Member

LC: Lateral Cross Member

FAB: Fore / Aft Bracing

FLC: Front Lateral Crossmember

RRH: Rear Roll Hoop

RHO: Roll Hoop Overhead Member

FEA: Finite Element Analysis

AISI: American Iron and Steel Institute

GTAW: Gas Tungsten Arc Welding

OEM: Original Equipment Manufacturer

CG: Center of Gravity

APPENDIX

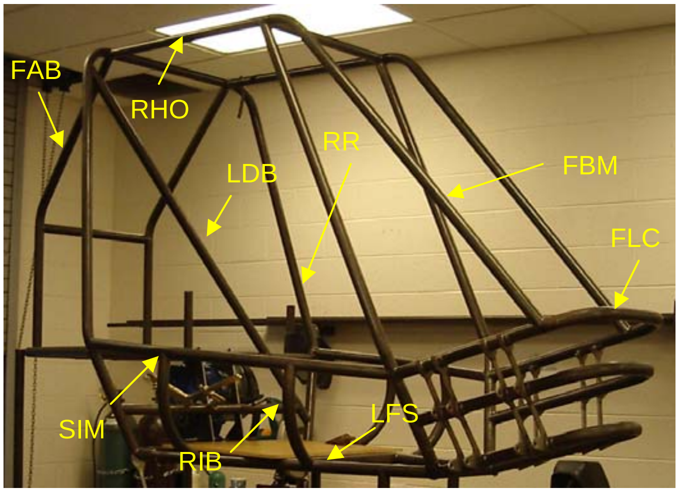

Figure A1. Vehicle Frame with Labeled Members


Figure A-3. Rear Axle Hubs


Figure A-2. A-Arms

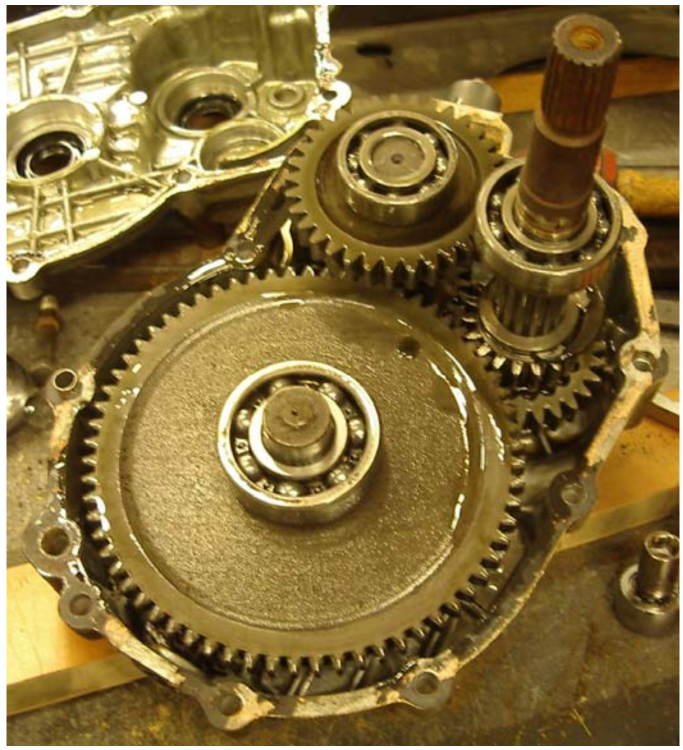
Figure A-4. Transmission

Figure A-5. Drive Train Arrangement

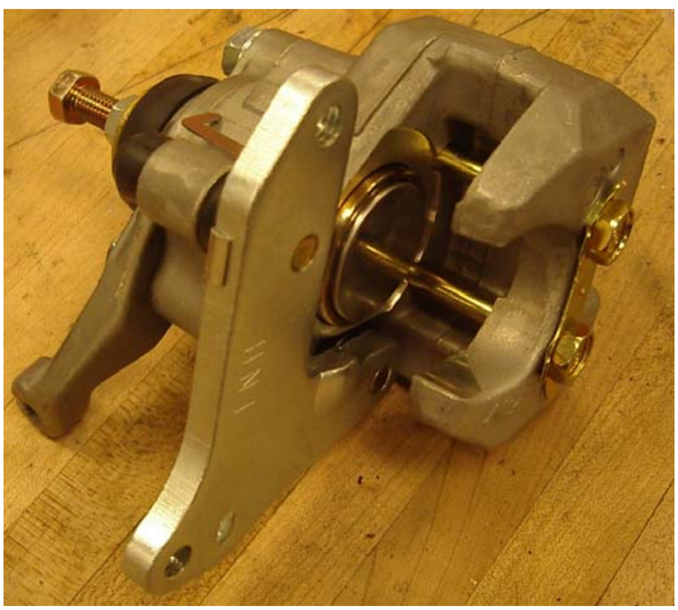

Figure A-6. Brake

Figure A-7. Tires

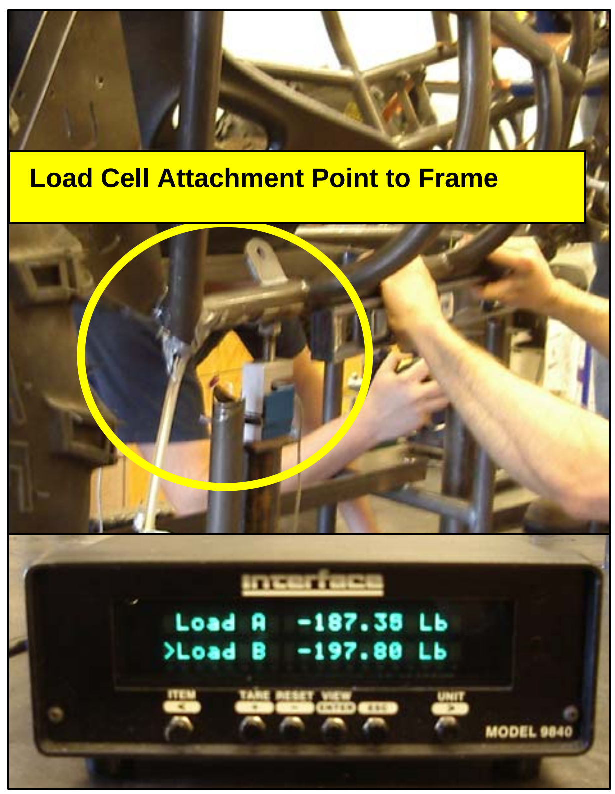

Figure A-8. Load Cell Drive Train Alignment Test