Design and Fabrication of

An All Terrain Vehicle (Mini Baja)

A Project Report

Submitted by

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in partial fulfillment of the requirement in the subject of
(ME1357) Design and Fabrication Project

Under the guidance of
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BONAFIDE CERTIFICATE

Certified that this project report entitled "**Design and Fabrication of a Gang Drill Holder**" is the bonafide work of

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CERTIFICATE OF EVALUATION

College : Kumaraguru College of Technology

Branch : Mechanical Engineering

Semester : Sixth Semester

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The Report of the project work submitted by the above students in partial fulfillment of the award of Bachelor of Engineering degree in Mechanical Engineering of Anna University were evaluated and confirmed to be report of the work done by them

(INTERNAL EXAMINER) (EXTERNAL EXAMINER)

SYNOPSIS

The goal is to design, build and race off-road vehicles that can withstand the harshest elements of rough terrain. The vehicles used in Baja racing are often similar to dune buggies.This report describes the processes undertaken by the team in designing, constructing and testing an all terrain vehicle .The purpose of this project is to 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". 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. The team maintained detailed records of the actual cost to produce the prototype. The scope of this report therefore considers cost only when it pertains to making a design decision.

The six member split into two teams consisted of mechanical engineering students from third year. Drawing upon multidisciplinary engineering knowledge, adherence to workshop etiquette and varying levels of experience with recreational off-road vehicles, the 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 of the vehicle.

ACKNOWLEDGEMENT

First and foremost, we pay our sincere and humble salutations to the almighty for equipping us with all the strength and courage throughout our venture in our project work.

We express our profound gratitude to Dr.C.Sivanandam H.O.D., Mechanical Engineering Department, KCT for his benevolence and valuable advice throughout our project work.

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We thank **Mr.Balasundaram, Proprietor, Hari Machine tools ltd**. for the valuable help rendered to us towards the completion of this project work. He provided us the right ambience for this project work. We would be failing in our part if we do not thank the lab technicians of our department without whom our project would not have been a success.

Last but not the least our sincere most thanks are due to our beloved parents without whose guidance and ever persuading efforts this project work would have been a layman's chore.

Executive Summary

The purpose of the design project is to gain a further knowledge of the skills and design methods involved in a complex engineering design solution. This project will incorporate all of the previous learning obtained by team members as well as the utilization of outside sources to develop a proven final product. In addition to individual contributions, teamwork will be a vital component during the scope of this project. A further objective of this senior design project is to compete in the SAE Mini-Baja competition. All of these skills and objectives will be used to develop a finalized Mini-Baja vehicle that is capable of meeting and exceeding the preliminary design specifications.

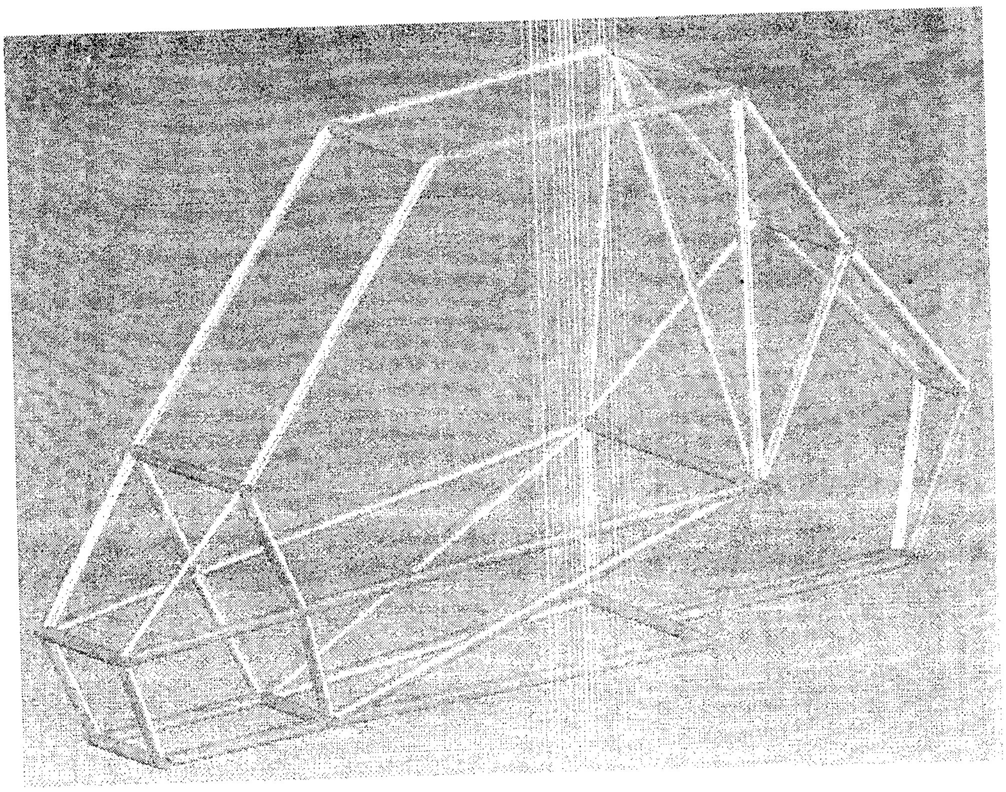

Fig.1: Model of the frame

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Glossary

Ackerman Steering – Is a way of determining the angles for front wheels, suspension arms, ball joints, tie rods. This eliminates bump steer and minimizes scrub radius.

Adaptive – showing or having a capacity for or tendency towards adaptation.

Attention – The process of selecting things to concentrate on, at one point in time, from the range of possibilities available.

Bump steer – The car turning with out turning the wheel due to misaligned suspension and tie rod connections.

Camber – is the angle of the wheel relative to vertical, as viewed from the front or the rear of the car. If the wheel leans in towards the chassis, it has negative camber; if it leans away from the car, it has positive camber.

Caster – The angle to which the steering pivot axis is tilted forward or rearward from vertical, as viewed from the side is the caster. If the pivot axis is tilted backward (that is, the top pivot is positioned farther rearward than the bottom pivot), then the caster is positive; if it's tilted forward, then the caster is negative.

Final Drive Unit – A mechanism of distributing power from the engine to the wheel utilizing gear reduction and or the ability to shift gears and change direction.

Rod Ends – Threaded connector with a swivel hole on one end used for attaching items such as a-arm, tie rods to frame.

Roll Center – Is virtual point where the suspension lines from the A-arms meet, in race cars this is below the vehicle.

Electric Arc welding – Electric discharge creates melting of flux coated electrode to provide adherence between two metal pieces.

ACRONYMS

SAE: Society of Automotive Engineers

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

CHAPTER-1

INTRODUCTION

Throughout history man has always wanted to be faster and better. Work, production and the most important - transit.

His most important invention of the millennium has been judged as the bicycle- the first mode of personal transport. Ever since man has the inherent urge to go faster and longer. This led to various inventions- internal combustion engines, turbochargers, engine management systems etc.

Speed wasn't the only motivation behind the advent of automobile systems; it was the necessity to reach distant lands inaccessible by walk and conventional modes of transport.

The goal of this project is to design, build and race an off-road vehicle that can withstand the harshest elements of rough terrain. The vehicles used in Baja racing are often similar to dune buggies.

CHAPTER-2

HISTORY

The Buggy was created out of necessity, in Naples, Florida, as a vehicle with which to traverse the vast, boggy swamp known as the Everglades during early development of that region in the 1930's and 1940's. The versatile "Swamp Buggy" was a tall, ungainly and strange looking vehicle, riding on huge balloon tires, which could be used for everything from hunting expeditions deep into the Everglades to Sunday afternoon outings.

The early years as more and more hunters built buggies, they would gather together to share a few homespun-engineering tips, and before long, one hunter would challenge another to a buggy race through the local muddy potato patch. The first organized races started to take place around 1943, featuring a dozen or so local hunters.

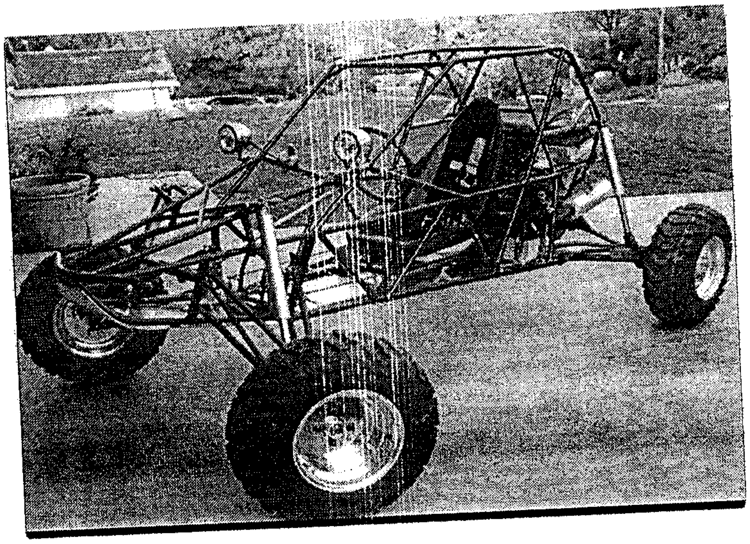
By the late forties, 30 to 40 racers would gather the week before hunting season to race for the valued prize, which was usually a new shotgun donated by a local merchant. On November 12, 1949, the first "Official" Swamp Buggy Races were held, with a field of almost 50 competitors, in Naples, Florida. The mid 1950s saw continued growth of Swamp Buggy

Racing. ABC's Wide World of Sports featured the mud madness in a national television special and Hollywood stars like Gary Cooper were seen in Naples riding Swamp Buggies.

Present day

As the popularity of the sport has continued to grow, cash prizes purses of several thousand dollars replaced the shotgun, and the incentives to go faster also grew, until the swamp buggies became far too fast and too loud to be used for hunting wild game. Today's high-tech buggies are designed for racing only. The pontoon-like bodywork fully encloses a powerful racing engine, and rather than relying upon big fat flotation tires, they stand upon tall and skinny tires, with paddle treads on the rears designed solely for forward motivation and almost bicycle-narrow front tires for rudder-like steering.

There are three races a year, January, March, and October, and all three races are taped and televised by the Sunshine Network. The races are also nationally televised by the National Geographic Channel, ESPN and the Travel Channel. Before every October Race there is a Swamp Buggy Parade in downtown Naples. Each of these events finds Naples pulling thousands of spectators from many states, and gives Naples and the Swamp Buggy sport some awesome publicity.



Buggy Racing:

There are seven different classes of racing buggies:

- Jeeps
- Air-Cooled (Usually powered by motorcycle or Volkswagen Beetle engines)
- 4-Cylinder, 2 and 4-wheel drive
- 6-Cylinder, 2 and 4-wheel drive
- V-8 Super Stock
- Pro Modified 2-Wheel Drive
- Pro Modified 4-Wheel Drive

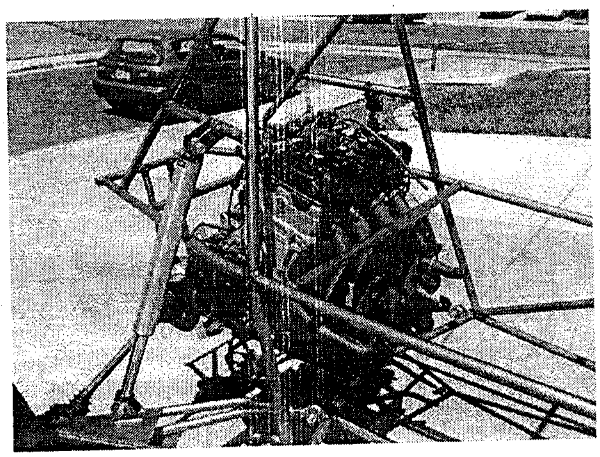
CHAPTER-3

DESIGN TYPES

Dune buggies are usually created using one of two to three different methods.

Method 1:

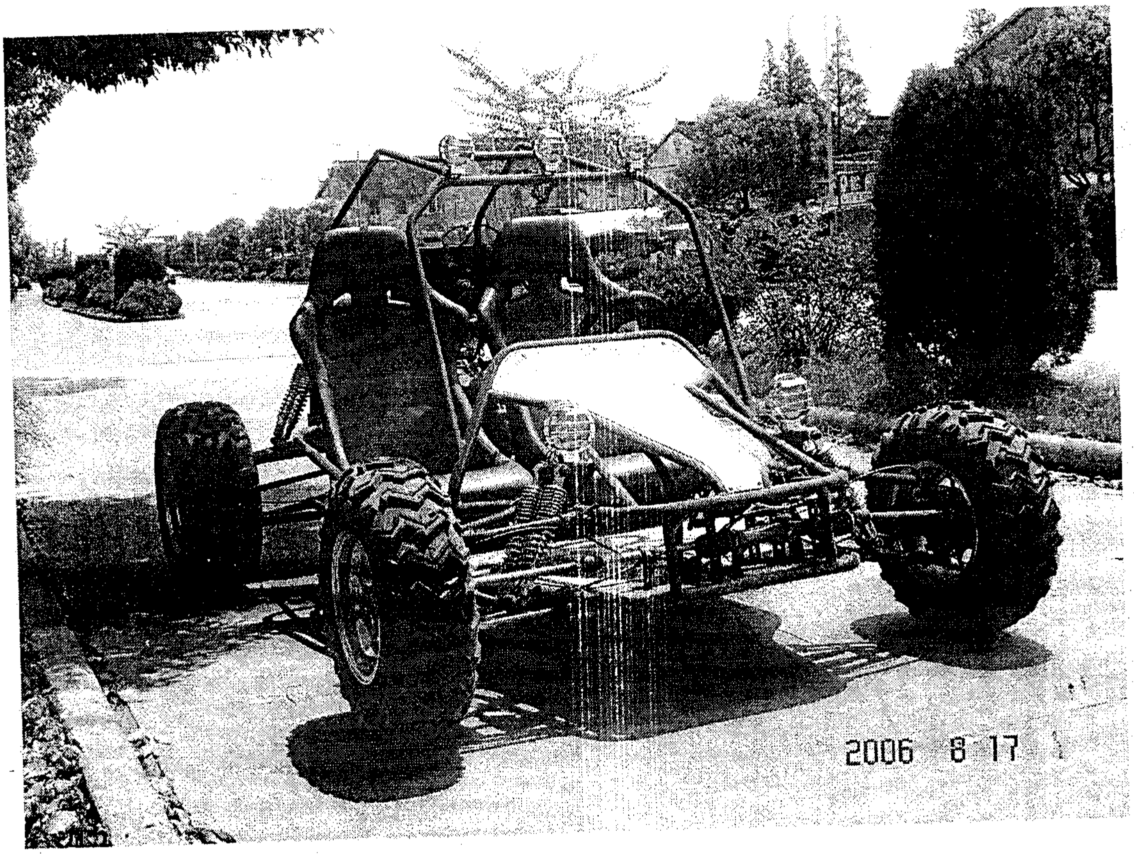
The first involves alteration of an existing vehicle, most notably the older Volkswagen Type One (Beetle, or Bug). The Beetle is preferred for a variety of reasons.



Most significant is the position of the rear mounted Volkswagen engine, which with removal of bodywork transfers a high proportion of the weight to the rear driven wheels for extra traction. The engine is air cooled, simplifying engine modification, and the absence of a radiator eliminates a source of failure. The low price; robustness of the front suspension; and the sizable quantity of spare parts from other VW Beetles and Type 2 buses are a further advantage.

Corvair engines are also a popular way to upgrade to 6 cylinders and sometimes vehicles are fitted with turbochargers to provide as much as 180 horsepower. For example, one such conversion was a 1970 Manx 2 on a 1961 VW chassis. It was fitted with a 180 HP turbocharged Corvair engine, with reverse rotation, mated to a VW transaxle.

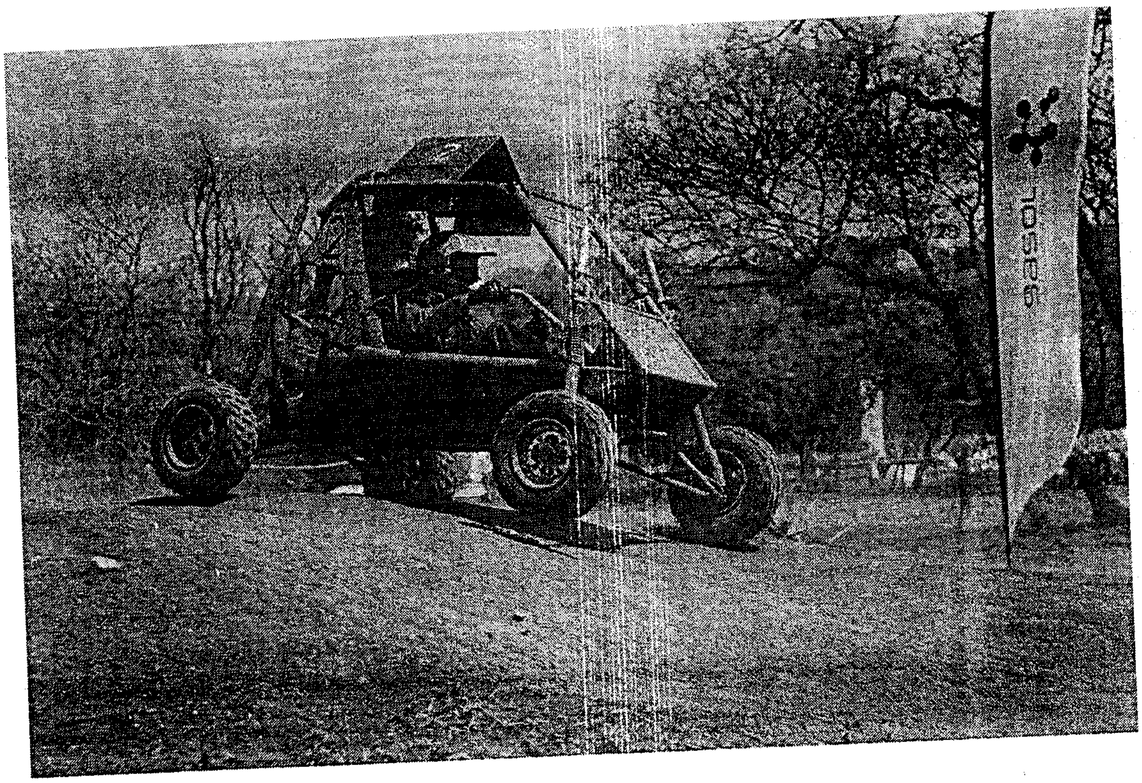
Method 2:



The second method involves construction of a vehicle frame from steel tubing formed and welded together. The advantage of this method is that the fabricator can change fundamental parts of the vehicle (usually the suspension and addition of a built-in roll cage). Buggies of this type are called sand rails because of the rail frame. Sand rails, as with the VW Bug, often have the engine located behind the driver. Sizes can vary from a small engine one seat size to 4 seat, 8+ cylinder vehicles. Sand rails can have panels or custom shaped body coverings over the rails and tubing that comprise the vehicle, though many are left bare.

Method 3:

The third is only a temporary fix. These dune buggies represent mixes of the above two design philosophies, typically after a converted vehicle sustains damage from age, hard use, or accidents and spare parts are not available or affordable. This type of creation is called The Boston-Murphy style.



Chapter 4

Function

Initially dune buggies were designed for navigating desert or beaches (hence the word "dune"). However, dune buggies have become more diversified in terms of the terrain they can handle and are being built for more generic off road tasks, such as CORR / SCORE indoor track racing. Some are even built for and used as on-road vehicles. Typically the function is determined before the buggy is created in order to maximize the comfort or abilities of the vehicle.

Although dune buggies can be bought (as a kit), many drivers make their own. This is done by separately buying chassis, engine, tires, steering wheel, and axles. Some builders make their own chassis, which creates a special, customized vehicle.

A 1961 or later Volkswagen sedan is the preferred donor to create a Dune Buggy. The VW Type 2, Type 3 and Type 4 do not make good donor cars, however the engine, transaxle, wheels, and instruments can be used from these models.

Other parts that can be salvaged from a donor VW for use in a Dune Buggy include the front axle and suspension, frame, pedal assembly, shock absorbers, seats, battery, fuel tank (1961 or later), steering column, brakes, instruments and switches, windshield wiper, horn and emergency flasher unit.

Military Buggies:

Because of the obvious advantages a buggy can afford on some terrain, they are also used by the military. The buggies built for the US military are called Desert Patrol Vehicles (or DPV). They were previously called Fast Attack Vehicles or FAV and are used by US Navy Seals. The DPVs are built by Chenowth Racing Products Inc., a San Diego based company. As with most military material, they are not sold outside the government.

CHAPTER 5

BODY MATERIAL

Tube Framed Buggies:

Over time Buggies have been altered to allow maximum recreational use. They are now available in varying sizes.Professional racing buggy with a V8 engine and fibre-glass body on a tubular steel frame The most common form of non-racing buggy consists of a 'tube frame' which is simple to construct and sturdy. If the frame bends or breaks it is simple to fix. Steel tubing is preferred to "pipe" as pipe is rolled and welded, tubing is mandrel drawn, making it stronger and with consistent wall thickness.Engine size varies depending on the suspension, frame strength and performance needs. Engine size has varied from 50 cc for small light buggies to 7+ liter engines designed for professional racing. Dune buggies use both 'automatic and manual transmissions, sometimes based on application and engine power, but often based simply on personal choice.

Fiber Glass Dune Buggies:

Fiberglass dune buggies come in many shapes and sizes. The most popular are those seen on TV like Wonderbug and Speed Buggy. These types of dune buggies are known as "clones". Many companies worldwide have, to varying degrees, attempted to copy the original fiberglass dune buggy the "Meyers Manx" built by Bruce Meyers.

Kit cars are a variant that use the dune buggy philosophy of substituting significant amounts of a car with custom parts to resemble production, modified or prototype cars. For instance: American Fiberglass Product's "Humbug" has similar features to a classic Corvette, Berry's

"Mini-T" was a nod to the Ford Model T, or BMB Automotive's "Surviver" is a scaled down version of the Lamborghini Cheetah.

DESIGN & DEVELOPMENT

CHAPTER 6

CHASSIS

A chassis is the supporting frame of a car. It gives the car strength and rigidity, and helps increase the car's crash-resistance through energy absorption. If a car were a human body, the chassis would be the skeleton. During a fall, a person with strong bones is likely to be hurt less than someone with weak bones. The same goes for a car in an accident. The chassis helps keep a vehicle rigid. A strong chassis will keep the back end of a car from falling out of alignment with the front end, while remaining as stiff and unbending as possible.

The chassis is especially important in ensuring low levels of noise, vibration and harshness (NVH) throughout the vehicle. Not only does a reduction in NVH allow for a more pleasant driving experience, but by putting less stress on connecting components it can help increase the life span of these components. The key determinant permitting reduced levels of NVH is energy absorption. By having a high level of energy absorption, NVH levels are lowered, but more importantly, passenger protection can be enhanced in the event of a collision.

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 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.

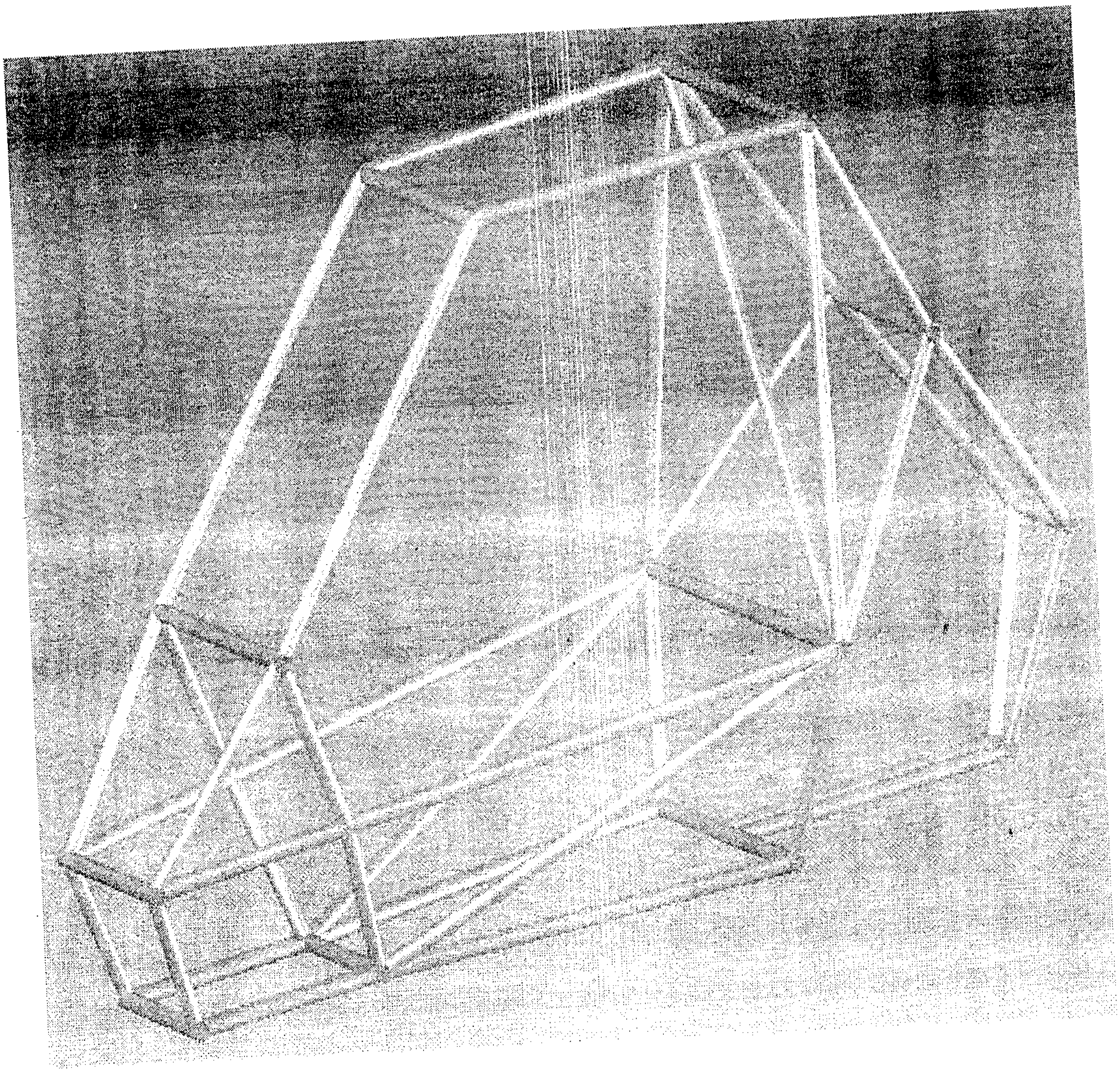
DESIGN

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

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)., 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. 2

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



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 team elected to use PRO E 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 PRO E 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 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 3

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.

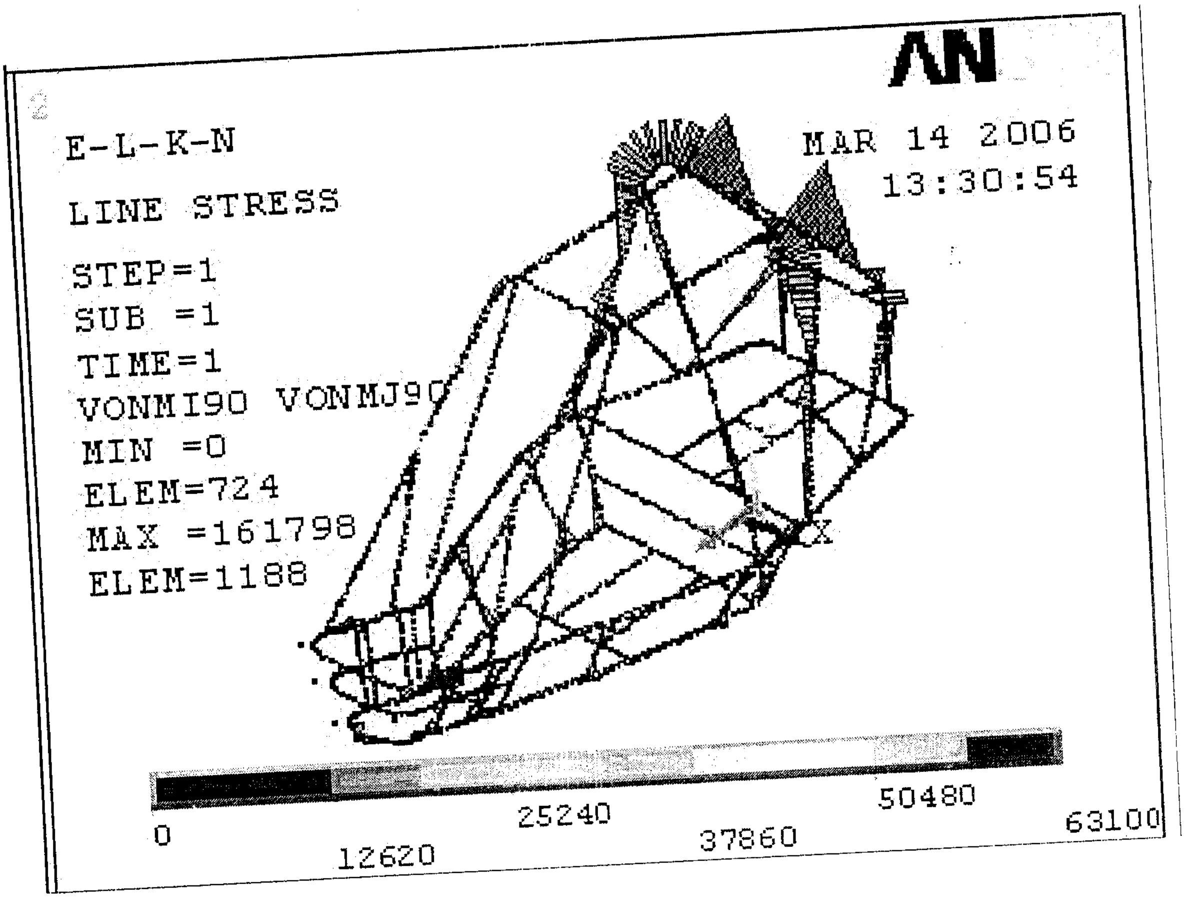


Figure 3. Stress Analysis of Nose Impact at 3g. (Courtesy UTC- University of Utah)

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).

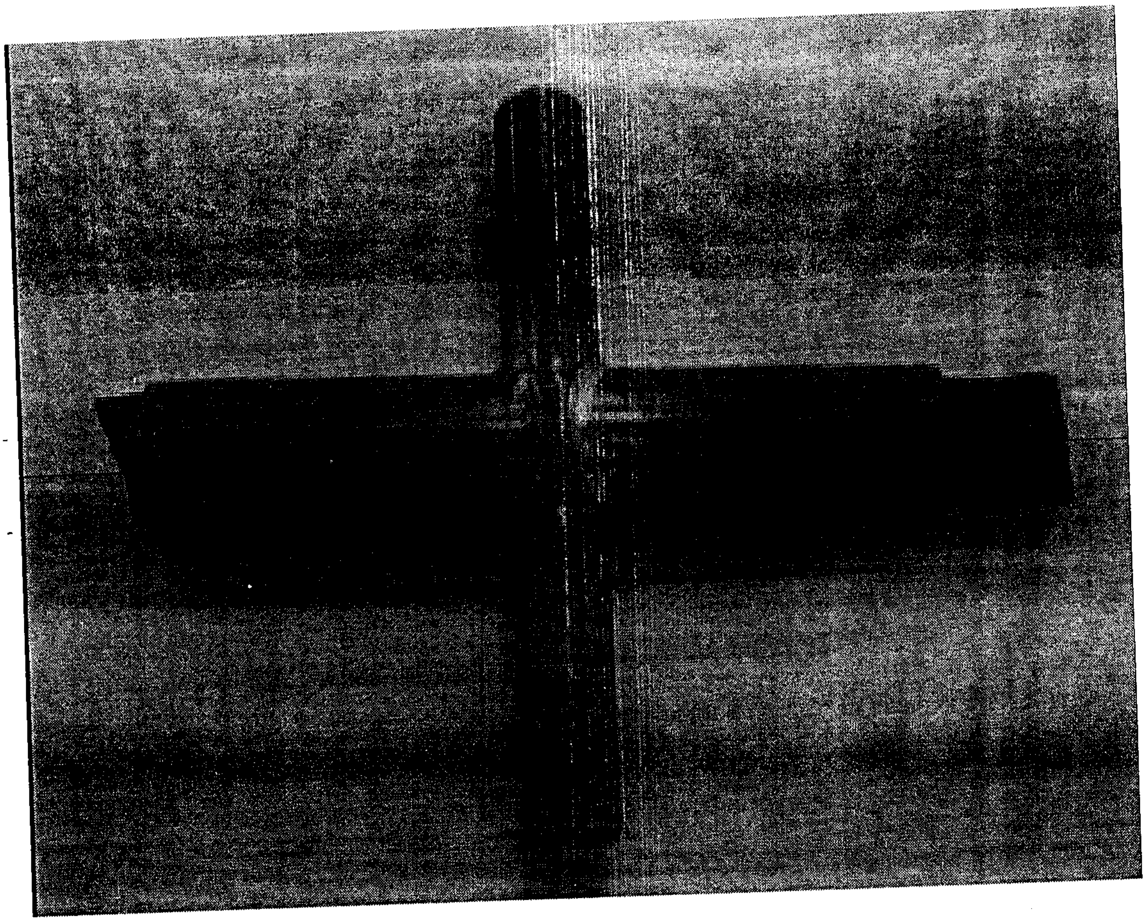
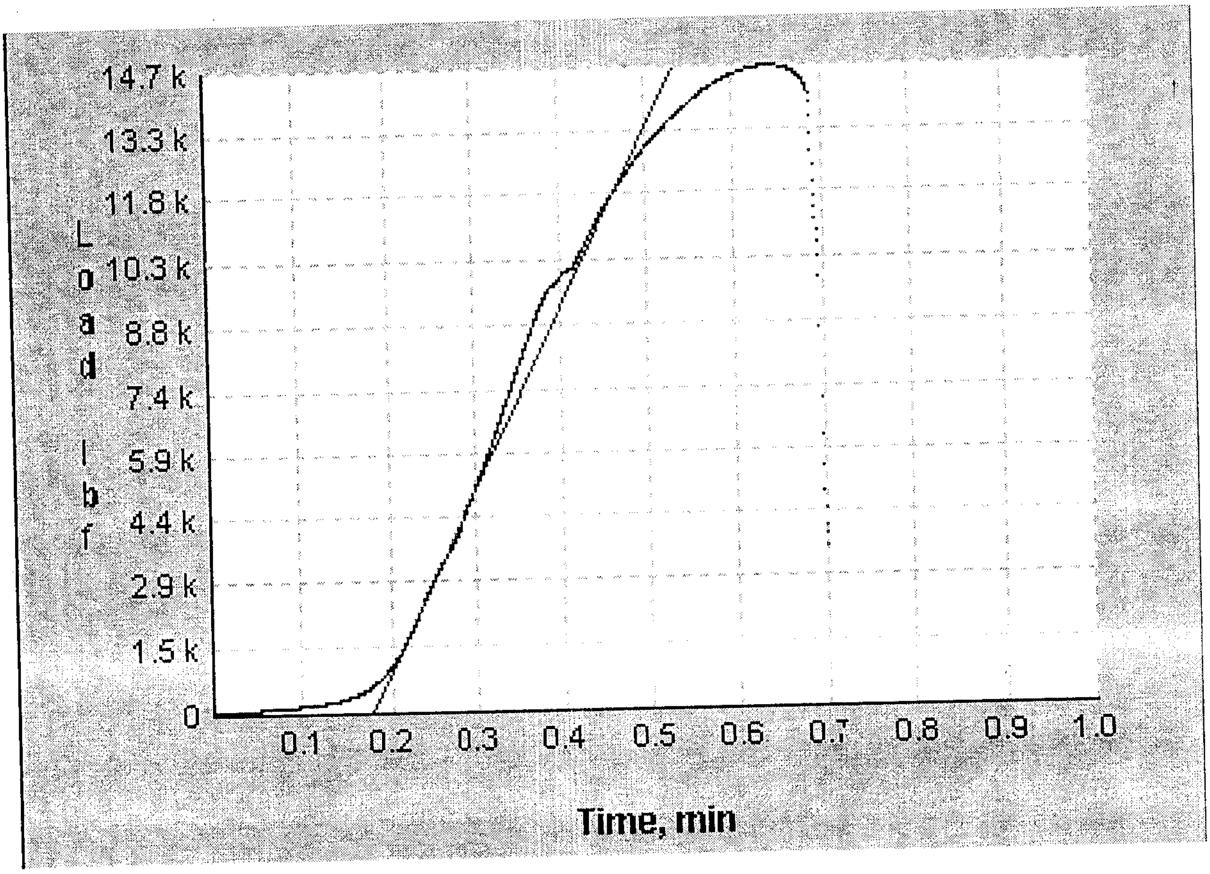


Figure 4. Weld Test Specimen (Courtesy -University of Utah)

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.



Courtesy:UTC

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

Chassis

After all the design rules and regulations have been overviewed and the prototype created, the chassis dimensions were finalized. The chassis dimension can be found in the appendix. A well designed chassis will allow for a maximum driver safety in case of a roll over. The suspension design and mounting points will determine the chassis roll center. The chassis will be rigid enough to handle the torque and vibration caused by the engine and transmission. The bends in the chassis design reduce manufacturing cost while maintaining high strength. If bending was not employed then the welded areas would need to be heat treated so as to produce the same strength in the members. All chassis material for the main roll cage must have a minimum wall thickness of 0.065 inches. The figure below shows the finalized chassis design.

Chapter 7

Power Train

For the Drive-train design, the transmissions from previous Mini Baja vehicles were evaluated. The 2007 Mini Baja vehicle designs used a single speed, single direction final drive unit manufactured by Lombardini Engines ltd.Power was delivered from the engine to the transmission by means of a Hoffco Comet torque converter. Two different transmissions were manufactured during this time period, one utilizing an approximate 10:1 ratio, while the other had a slightly lower final drive ratio of approximate 11:1. This was coupled to a Model 40 torque converter that offered a ratio ranging from 3:1 to 5:1, thus giving the cars a final gear ratio ranging from approximately 30:1 to 55:1. Power was transmitted to the wheels directly from the gearbox with the absence of a differential unit. Without the differential, the transmission caused undesirable steering as was noted during testing of the 2003 vehicle performed in the summer of 2007.

For the 2007 transmission unit, the design was far more complex and involved than previous ones. Power was transferred through the shaft directly from the engine to the transmission unit. The range of gear ratios was achieved by means of toroidal discs rotating against a fixed plate. The power was transferred to the wheels utilizing a common ATV differential carrier and aftermarket differential locker unit. This allowed some degree of slip in the rear wheels allowing easier steering on high traction surfaces. The overall turning radius was also reduced by incorporating this locker. This designs calls for the engine to be held at its ideal torque and horsepower output, which allows the transmission to control the range of speed. The

2005 design also featured the addition of reverse capability. The reverse mechanism can be very instrumental to the success in the specific events of the competition such as Rock Crawl.

Research was also conducted on the final drive units being used by the competition (other engineering schools participating in the SAE Mini-Baja). There are 6 basic designs styles utilized by other teams, they include:

- **Centrifugal Clutch to Axle Design**

This setup consists of a centrifugal clutch which transfers power to axle via chain and sprocket. The centrifugal clutch can be adjusted to engage at various RPM ranges on the motor. This clutch system is very cheap to design and employ, however it does not provide additional gear reduction like a torque converter would. In addition, this setup mandates a solid "live" rear axle versus the independent rear axle.

- **Centrifugal Clutch to Non-Machined Transmission Design**

This setup consists of a centrifugal clutch which transfers power to a system of sprockets, which then reduce the gear ratio further. The centrifugal clutch can be adjusted to engage at various RPM ranges on the motor. This clutch system is fairly cheap to design and employ, however it does not provide additional gear reduction and increase the range of speed like a variable range torque converter does.

- **Centrifugal Clutch to Final Drive Transmission**

This setup consists of a centrifugal clutch which transfers power to the final drive unit through a chain. The centrifugal clutch can be adjusted to engage at various RPM ranges on the motor. This clutch system is fairly cheap to design and employ, however it does not provide additional gear reduction like a torque converter would.

- **Torque Converter to Non-Machined Transmission Design**

This setup consists of a torque converter that delivers power to an idler shaft that is supported by bearings on each side. Sprockets and chains are then used to transfer the power either to a live axle or a carrier assembly that sends the power to the half-shaft axles.

- **Torque Converter to Final Drive Transmission**

This setup is similar to the 2002–2004 design. It relies heavily upon the design and construction of the final drive gearbox. Power can be transferred to the wheel utilizing either half-shaft axles directly from the final drive unit, or a chain/sprocket setup.

- **Solid Final Drive Transmission Design**

This setup is similar to the 2005 design. Weight and size becomes a major factor in these types of design as well as the ability to have a clutch (whether automatic or manual). These transmission designs rely heavily upon machining abilities, and large budgets.

Upon completion of Benchmarking the team chose to go with a Torque Converter to Final Drive Transmission style of a final drive unit.

DRIVE TRAIN DESIGN

OBJECTIVES

The purpose of the drive train is to transmit shaft power and torque of the Yamaha RX 100 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, 4-speed gearbox with reverse and a chain driven solid steel axle. The Constant Mesh 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 constant mesh has been determined to be 0.82:1 thus serving as an "overdrive" for the car. At low engine speeds the constant mesh produces a reduction of 3.38:1 providing necessary torque.

The CONSTANT MESH is assisted by a Polaris model number ME25P8 two-speed gearbox. The gearbox is a "shift on the fly" unit so the car will not 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.

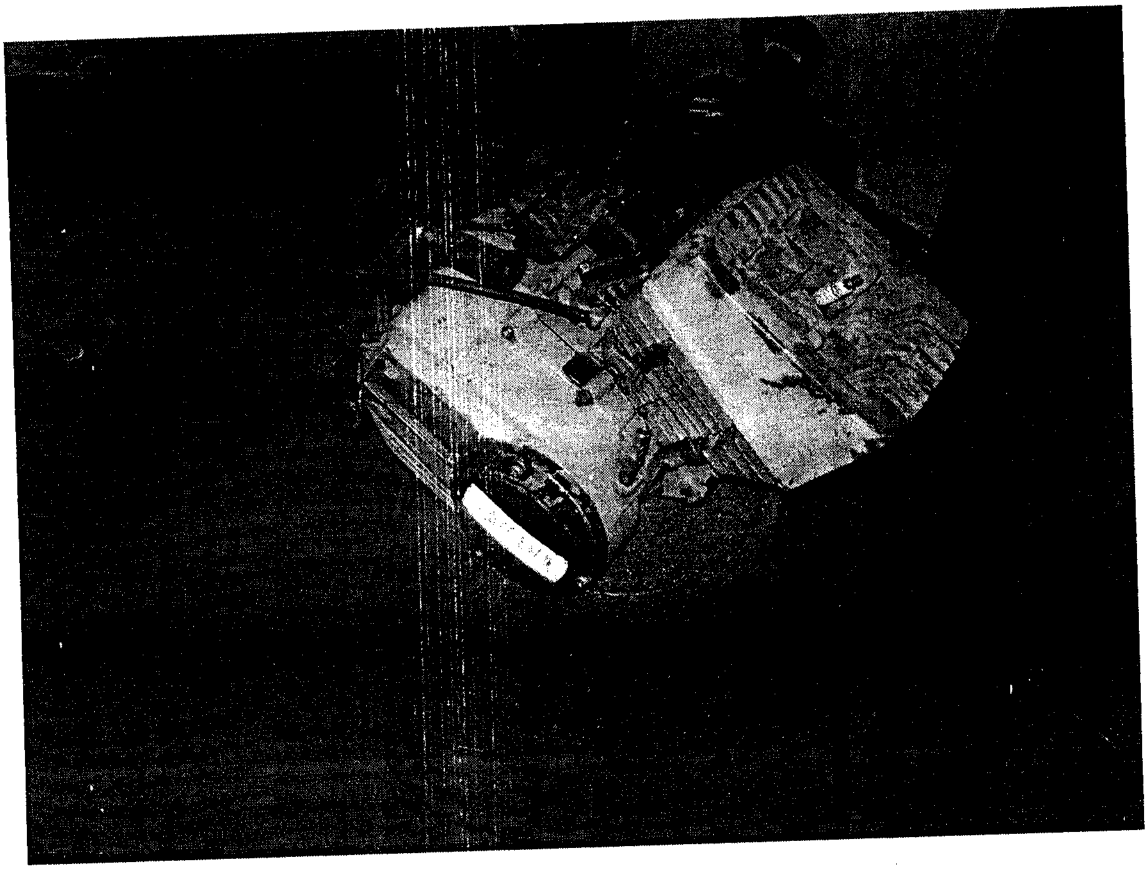
The final gear reduction for the drive train comes from the sprocket sizes on the gearbox output shaft and the driven sprocket located on the axle. Several combinations of drive and driven sprockets were analyzed. The analysis was performed with the goal of maximizing the relationship between vehicle 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

Engine Specifications



The **Yamaha RX 100** was a motorcycle produced by Yamaha, and is no longer in production. It was a 2 stroke motorcycle, with a 4 speed gearbox and a top speed of 100 kmph. Fuel efficiency is low at 30-35 kilometres/litres.

Prior to the release of the RX100 in India, there were only three bike manufacturers - Escorts, Royal Enfield as well as the Jawa (later renamed to Yezdi). During the 1980's the government decided to allow foreign manufacturers to sell bikes in India, partnering with existing Indian companies. Honda partnered with Kinetic as well as Hero cycles to release Kinetic Honda and Hero Honda respectively.

Kawasaki partnered with auto manufacturer Bajaj. And Yamaha partnered with Escorts to release the Yamaha RX100 2-stroke bike with 11bhp. The pickup and top speed were the best during that time in all the bikes manufactured in India.

This bike was embraced by the youth of that time. Whether it was the original with it's energetic looks or modifications, Indian youth at all times (including now) respect this vehicle.

Competitors

While the mileage of an RX100 (also known as rx, colloquially) was never a USP, it's only competition was in pickup and speed. The Kawasaki KB100 RTZ was the only bike of its class that could claim to beat it in a drag. Though a lot depended on the individual riders. Suzuki released the Shogun, a 110cc vehicle that beat the rx in all departments of the same game where rx was the leader, but it was too little too late.

The Decline

Stricter emission norms by the Government of India lead to the ban on several 2-stroke vehicles. The rx, the Kawasaki 100, the Suzuki 2-stroke bikes were all banned by the mid-1990s. Yamaha's response was to bring out the 135cc RXG. Though it retained the classic looks of the rx, it never really clicked with the public, and Yamaha lost terribly. They brought out a better bike called the RXZ which was shaped a lot better but it never lived to see the new millennium. The 135cc 5-speed rx135 met with the same fate. Yamaha released its last 2-stroke vehicle in India - the

4-speed RX135 that could be bought legally first-hand till August 2005 in select cities.

Legacy

Even today in India, most of the young working employees have awe for this vehicle, and would prefer a 10 yr old 2-stroke Yamaha to the fashionable bikes available on the road. This despite the fact that the original version does not come out with modern enhancements like fuel indicators, saree guard and side box. The headlamp has also not been good enough to ride at night. But the engine is one that lasts long. People who bought this bike in the 80's and 90's would get approximately the same fuel efficiency they got when the bike was brand new. The engine quality was such that it could be rebored the maximum in all the bikes manufactured in India. Owners of this vehicle flaunt it as a status symbol of their youth.

Specifications:

- **Engine:** 2-stroke 99.8 cc air-cooled engine
- **Cylinder arrangement:** Forward-inclined single cylinder
- **Displacement:** 133 cc
- **Max power:** 20 PS (15 kW) @ 8,500 rpm
- **Max torque:** 1.85 kgf·m (18.1 N·m) @ 7,500 rpm
- **Max speed:** 165 km/h
- **Bore x stroke:** 56.0 x 54.0 mm
- **Compression ratio:** 7 : 1
- **Transmission:** 6-speed return
- **Clutch:** Multiple-disc, wet manual
- **Frame Type:** Underbone steel tube
- **Suspension (Front):** Telescopic
- **Suspension (Rear):** Dual shock
- **Brake (Front):** Single-piston disc
- **Brake (Rear):** Drum
- **Dry weight:** 106 kg
- **Fuel tank capacity:** 13.0 L

Suspension

For the suspension design a pros and cons of different types of suspension were analyzed. These suspension types were the following:

- **Beam type:**

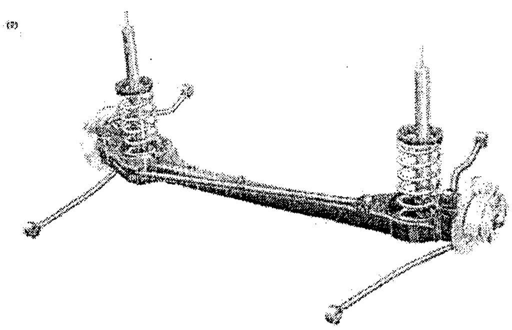


Figure 2: Beam type suspension

The figure above shows a typical beam axle design, showing the wheels connected by the axle and the whole assembly connected to the chassis by the springs and shocks.

- **Swing Axle:**

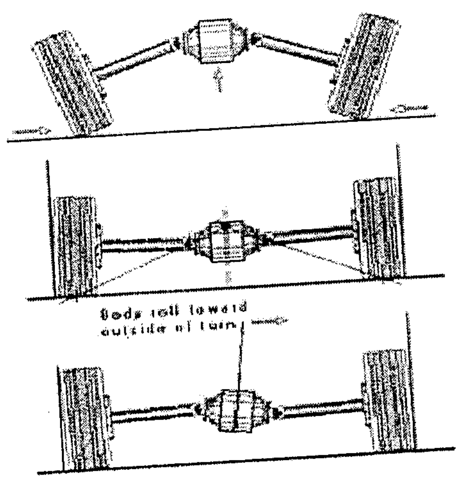


Figure 3: Swing Axle type suspension

The figure above shows a swing axle suspension at different positions. Notice the huge degree of positive camber when the axles jack up (top) this is what causes the distinct loss in cornering power.

- **Trailing arm type suspension:**

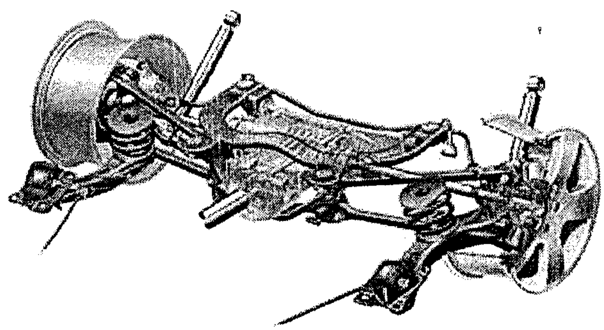


Figure 4: Trailing arm suspension setup

This figure above shows a single link trailing link rear suspension. While this is not exactly the same as the double link front (due to the differential) the concept is the same.

- **Mac Pearson Strut**

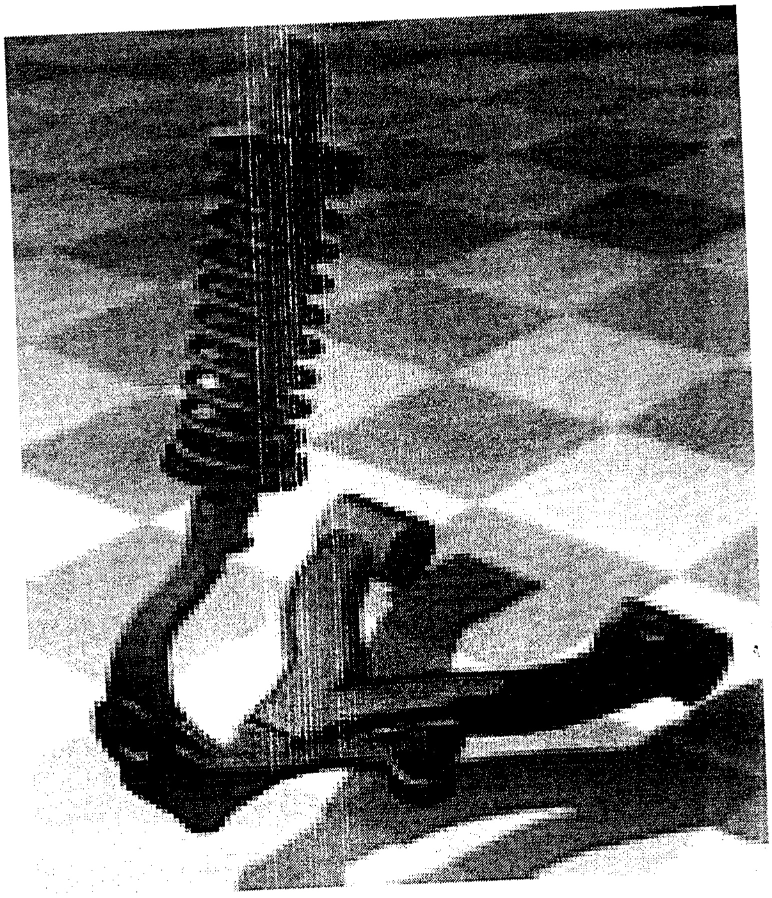


Figure 5: Mac Pearson Strut suspension type

The figure above shows a solid model of a typical Mac Pearson assembly, with the strut acting as the upper suspension link.

- **Unequal length Double A-arm suspension type**

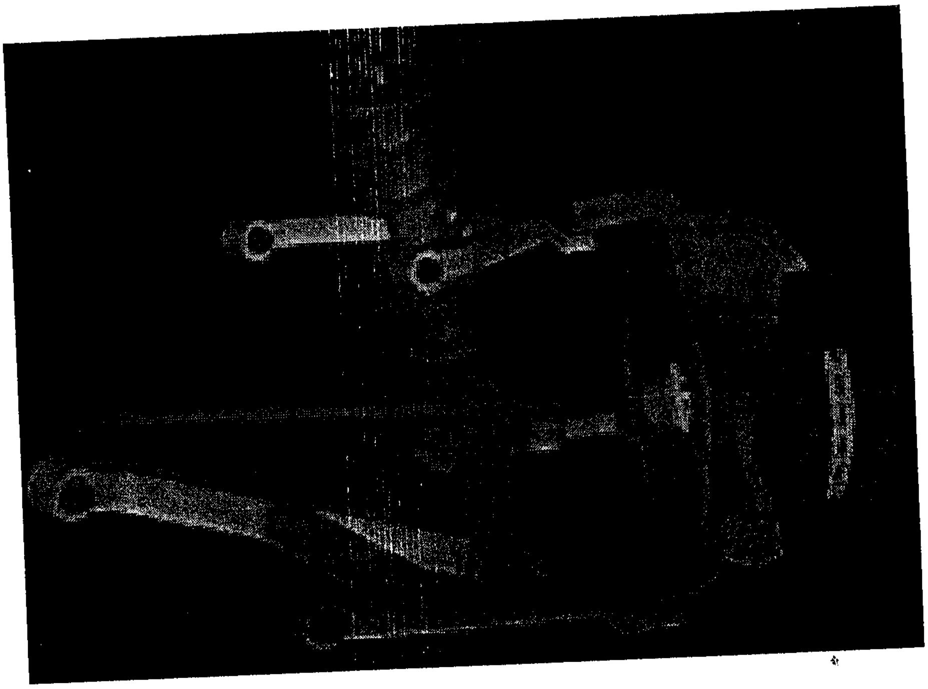


Figure 6: Unequal length Double A-arm suspension type

The figure shows a typical unequal length double A-arm setup. Note the difference in length between the upper and lower arms. This is what gives this suspension its ability to generate negative camber in bump.

After benchmarking the above designs, the team chose to go with an unequal length double A-arm type suspension design as shown in figure 6 above. Thus by using an upper control arm that is shorter than the lower one, as the wheel travels up it tips in, gaining negative camber. This is because the upper arm swings through a shorter arc than the lower and pulls in the top of the tire as the wheel travels upwards. By adjusting the length of the arms and their respective angles to the ground, there are infinite possibilities in the design of a vehicles roll center height and swing arm length. This flexibility gives suspension designers unlimited options on how to best setup the suspension. There is no right answer or best geometry that is why a Honda will have different geometry than a Corvette. It ultimately comes down to what design will get the vehicle around a corner the fastest. However, in production cars the manufacturers have many other things to consider. Depending on the target market and type of car, there are a host of variables that must be considered and result in a less than optimum suspension design for most vehicles. Lastly, when comparing the unequal length double A-arm setup to all the previous iterations of the independent front suspension from a performance standpoint, it has real no disadvantages and is currently the most advanced suspension design used. Simply look at what suspension the most advanced race cars use if you have any doubts. The only cars that do not feature this design are vehicles where price and space are of more concern than performance.

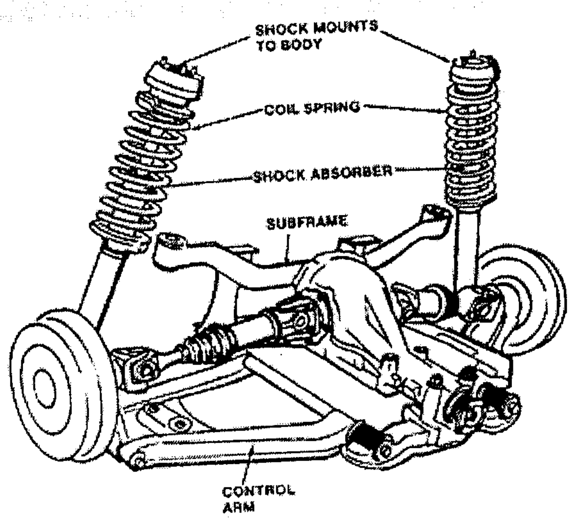
SUSPENSION DESIGN

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

Rear Suspension

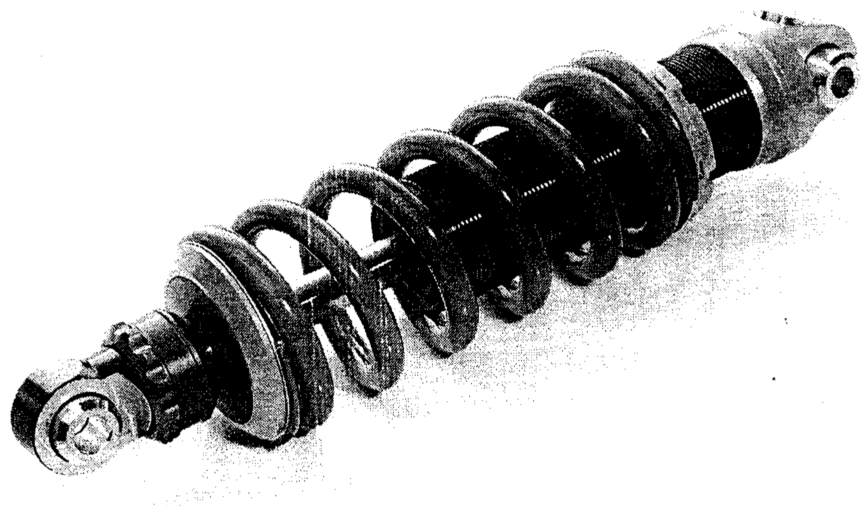


A swing arm design was chosen over a fully independent rear suspension because of its simplicity. This was important because the final approval for this project was not received until the third week of the fall semester of 2005 which limited the amount of design time. The pivot point of the swing arm 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 PRO E 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.

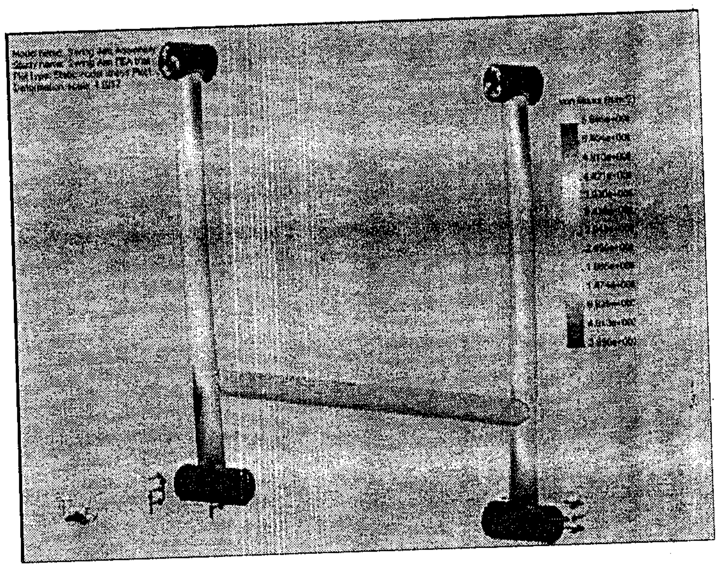


Figure 7. FEA of Swing Arm performed (Courtesy University of Utah)