Mini Baja Flotation, Propulsion, &Aquatic Maneuverability

University of New Hampshire
TECH 797 – Undergraduate Ocean Research Project

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2004 UNH Mini Baja Website
http://www.unh.edu/sae/

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Abstract

The 2004 UNH Mini Baja team designed and implemented a flotation and propulsion system for this year's vehicle. The following report describes in detail the process this year's team went through from design and analysis to production and implementation onto the vehicle. This year's design was based on the achievements and flaws of past vehicles, both UNH and other schools, as well as the rules and regulations put forth by the Mini Baja East Competition, sponsored by the Society of Automotive Engineers (SAE). Production and implementation of this year's flotation and propulsion system will be discussed in detail, defining all the trials and tributes this year's team faced. A breakdown of the budget is also included. Finally, a discussion section is included with lessons learned and suggestions for future UNH teams.

Acknowledgements

Our team would like to thank all those involved in helping us design and build the flotation and propulsion system for this year's vehicle. Our team explored and implemented the use of many new materials for use in this year's design. Through many trials and tribulations, we were able to successfully utilize these materials to meet our goals. This success would not have been possible without the donated money, material, and time of our sponsors. MPT, Inc. in Dover, NH provided time, expertise and material for the creation of the fenders and flotation. Jack and Allan at MPT were invaluable in the suggestion and making of different plastics and composites and teaching the team the finer points of plastic molding. Flotation Technologies in Biddeford, ME provided the material and labor necessary to coat the flotation in a tough and resilient elastic polymer. We would also like to thank our team advisor, Professor Sedor. His advice and experience with the competition was very helpful in the design and implementation of this year's flotation and propulsion system. Finally, we would like to thank the entire 2004 UNH Mini Baja team. This year's vehicle would not have been possible without the dedication and team work of the entire team.

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Introduction

The SAE Mini Baja Competition originated at the University of South Carolina in 1976. Since then, the goal of this intercollegiate competition has been to simulate real-world engineering design projects and their related challenges by having student teams design and build off-road vehicles. The off-road vehicles must be built strong to survive the extreme terrain of the competition where teams come together to compete for their vehicle design to be accepted for manufacture by a fictitious firm. In addition to designing, building, testing, and promoting, each team is individually responsible for generating financial support for their vehicle.

Each team's goal is to design and build a prototype of a rugged, single seat, off-road recreational vehicle that satisfies the following design and functional requirements of the fictitious firm:

- **Safety**
- **Performance**
- **Reliability**
- **Ease of Operation and Maintenance**
- **Aesthetics**
- **Easily Transported**
- **Fun to Drive**

Because the Mini Baja Competition is a real world event with prototype vehicles, the most important criteria of all vehicles is safety. SAE sets strict rules regarding all aspects of vehicle design and construction; everything from seatbelts to roll cages has a safety tolerance specification which is inspected before the vehicle is allowed to participate.

Performance, aesthetics, and being fun to drive are all criteria that, although not important to the eligibility of a vehicle to be entered into the competition, are important when considering the teams are competing to have their design accepted by a fictitious firm. In industry, the performance and aesthetics of an off-road vehicle are the keys to that vehicle's success or failure.

Other design factors to consider include ease of operation and maintenance, reliability, and ease of transport. Ease of operation and maintenance are important criteria for an off-road vehicle to be successful in today's competitive market. Nobody wants to buy a vehicle that requires a whole machine shop of tools to maintain – simplification of parts and tools is essential. This criterion also goes along with that of reliability. While a vehicle should be easy to maintain, it should also be built strong enough to not need maintenance all the time. Ease of transport is the last, but not least important, design criteria. The average off-road fanatic is not going to have a swamp or a sand pit in their backyard. For this reason, he/she is going to have to transport their off-road vehicle to a separate location to use it. To aid in this transportation, SAE has set competition guidelines restricting the vehicle's overall weight, height, and length.

Each year the Mini Baja East Competition is held in a different location, always keeping teams on their toes with new terrain and challenges to face. This year's competition is being held just outside of Montreal in Quebec, Canada. Over a three day competition, vehicles compete in the following dynamic events:

- Acceleration
- Power
- Maneuverability/Suspension
- Water Maneuverability
- Endurance

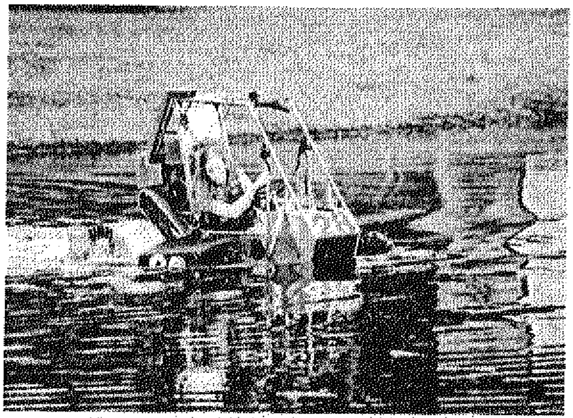

Figure 1: 2003 UNH vehicle participating in water maneuverability event

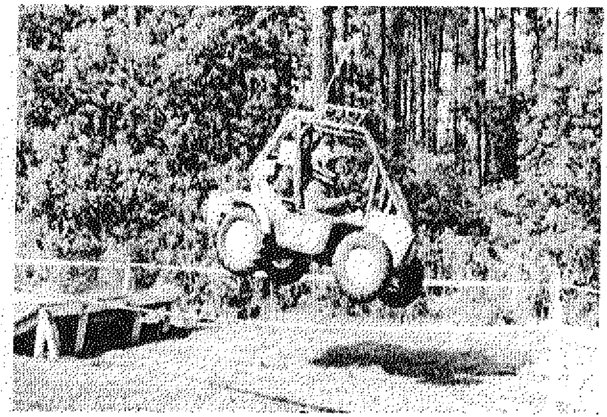

Figure 2: 2003 UNH vehicle participating in endurance event

Beginning in 1999, UNH has been a repeat competitor in the Mini Baja East Competition. Starting off with little to no prior experience, UNH did not do very well that first year finishing 33/40. The following year, in 2000, UNH was able to improve its overall placement to 19/44. The year after, with two years experience under its belt, the UNH team finished in it best showing to date at 7/38. In 2002, the vehicle placed 11/45. And finally, last year in 2003, the vehicle ended up finishing 25/51. Over the past five years, UNH teams have shown that they have the ability to succeed and improve through observing the successes and failures of past year vehicles. The UNH Mini Baja team has proven itself to be a fierce competitor against other engineering schools in the competition. This year's team is no different. This year's team consists of a very talented and diverse group of individuals who have worked very hard, putting in many long nights. With any luck, this year's team and vehicle will be UNH's best finish yet.

The following report takes the reader through all aspects of the design and construction of the flotation and propulsion system for the 2004 UNH Mini Baja vehicle. All steps of the process this year's team went through to complete the flotation and propulsion system are explained in detail; starting first with a summary of the flotation system, followed by a summary of the propulsion system, and ending with a budget breakdown and some concluding remarks.

Flotation

In the Mini Baja East Competition, all vehicles are required to compete in a specialty event called water maneuverability. This event was created to determine each vehicle's ability to propel itself through the water while maneuvering around obstacles. Past UNH Mini Baja vehicles have historically just placed two large pontoons on the sides of the vehicle, while filling additional empty space with flotation. After talking with the team advisor and captains of the 2004 team, it was apparent that they were looking for something new and innovative. This is where the idea for a uni-body flotation came out. Other concerns emerged from the faults found in the 2003 Mini Baja flotation and were addressed by the 2004 flotation team. Of these faults the majority involved in the design were related to lack of research in material choice.

Design Criteria

In the beginning the primary flotation design criteria was simply to make the Mini Baja float, but the 2004 flotation and propulsion team soon found out that the project was much more involved than just making the vehicle float. The most important criterion of the flotation was the ability to meet the competition rules. This includes a tilt test performed in the water where the vehicle must be able to recover from a 30 degree tilt without rolling over in the water. This must be met in order to participate in the competition. This meant that the flotation would need to be wide enough to provide the stability needed to keep the vehicle upright.

In designing the flotation several important criteria were analyzed and addressed. The list includes weight, impact resistance, buoyancy requirements, durability, reliability, repeatability, and aesthetics. The flotation had to be light weight, resistant to impact of common off road objects, meet buoyancy needs to support a max weight of 750 pounds, last the entire endurance competition, continuously float the vehicle at the same depth, and incorporate the flotation in the desired vehicle appearance.

Design

The flotation design for the 2004 Mini Baja was based on past flotation faults along with the innovative uni-body approach. Some of the past Mini Baja flotation faults included the use of open-celled foam and the failure to incorporate a protective layer other than a rubber like substance called elastomer. This lack of additional protection left the flotation vulnerable to permanent deformation and damage. These challenges were met through careful material selection.

The first decision made on the flotation was what type of material to use for buoyancy. This stemmed off of the failure in the 2003 flotation which consistently became less buoyant as the protective layer was punctured and the open-celled foam absorbed water. To address this concern the 2004 flotation would be built using closed-cell foam. Various types of closed-cell foam exist, but the chosen material was an extruded polystyrene foam board which can be found at any local hardware store in 8 x 2 square foot sections with a thickness of 1.5 inches. Some of the reasons behind this choice were the relatively low cost of the foam board, the resistance to water absorption, and the ability to be shaped easily. Once the choice was made the next question was how to bond the multiple layers. For this decision the manufacturer of the foam board, Owens Corning, was contacted and recommended using an adhesive called Liquid Nails 604.

The flotation design itself then needed to be created. This was based on the buoyancy calculations performed for a max weight of 750 pounds which includes the weight of the vehicle and driver. Buoyancy force is equal to the density of freshwater multiplied by the volume of freshwater displaced. So, knowing that the buoyancy force needed was 750 pounds and looking up the density of freshwater allowed for the volume of water displaced to be calculated. This volume was the amount that the flotation must be submerged to keep the vehicle afloat. Given that the optimal tire depth was 1/3rd submerged and that the Mini Baja team requested a ground clearance of 10 to 12 inches left the flotation team with a difficult list of requests to be addressed in the design.

The design itself incorporated as much surface area as possible as to reduce the amount of the Mini Baja submerged. Knowing the vehicle's physical configuration allowed for the placement of flotation and it was calculated that approximately 10 inches of the Mini Baja would be submerged and the excess foam board not submerged would be removed. While the Mini Baja team requested 10 to 12 inches of ground clearance the release of air in the rear and front suspension allowed for the ground clearance to be approximately one inch for the water maneuverability portion of the competition, giving a tire depth of 11 inches submerged, which is a little less than ½ of the tire. This was much better than the 3/4th of the tire submerged by the 2003 flotation team. Besides the uni-body flotation there was additional flotation designed for the rear wheel rims. This added buoyancy along with the natural buoyancy of the tires was not accounted for in the amount of the Mini Baja that would be submerged, but would provide a small amount of added buoyancy that is unpredictable.

The next design decision to be made was how to protect the flotation once it was fabricated. In order to make this decision research was done and two experts were contacted. The first was MPT plastics where a fiberglass reinforced epoxy resin was recommended as the protective coating. Samples were created and tested for material properties. Overall the fiberglass was found to be stiff, moderate in weight, and inexpensive. However, the fiberglass had a tendency to crack after large impacts. The second expert contacted was Flotation Technologies. They provided a list of several different options each with their own positives and negatives. This list can be seen below in Table 1. From the list sent by Flotation Technologies the ABS Plastic and Rotomolded Polyethylene were ruled out due to budget concerns. Samples of Polyurethane Elastomer and Fiber Reinforced Plastic (FRP) were then requested for testing purposes.

Protective Coating Specifications	
Coatings:	**Notes:**
ABS Plastic	Plastic is 0.06"-0.13" thick. The coating offers a stiff, durable, and moderate weight coating at relatively high cost due to the thermo-molding process.
Rotomolded Polyethylene	Plastic is 0.15"-0.38" thick. The coating offers a stiff, durable, and moderate weight coating at relatively high cost due to the thermo-molding process.
Polyurethane Elastomer	Polyurethane is 0.08"-0.20" thick. The coating offers a flexible, durable, and light weight coating at a relatively low cost.
Fiber Reinforced Plastic	Fiber Reinforced Plastic layer is 0.06"-0.13" thick. The coating offers a stiff, brittle, durable, and moderate weight coating at moderate cost.

Table 1 – Protective coating specifications provided by Flotation Technologies.

After testing the two materials it became apparent that the FRP was too brittle and heavy, while the elastomer had a tendency to puncture from sharp objects. The final two coatings were narrowed down between the fiberglass epoxy resin and the elastomer. Both possessed properties important to the flotation. The fiberglass was puncture resistant and structurally rigid, but can become quite heavy when applied everywhere on the flotation and has a tendency to crack after impact. The elastomer is durable, light weight, and allows the flotation to flex upon impact without failure, but unlike fiberglass it is not puncture resistant. There was no clear decision on which material would be better by itself so the team decided that both of the properties were needed on the flotation.

Upon deciding the materials for the protective coating, the next issue became weight. Several different scenarios were analyzed for different coating placements. These scenarios were calculated by knowing the surface area of the sides and bottom of the flotation along with the weight densities of the foam board, fiberglass, and elastomer. These different scenarios can be seen below in table 2. From the table below it was determined that 1 layer of fiberglass would be applied on the sides of the flotation and 2 layers on the bottom for added structural rigidity, while a single layer of 0.06 inch thick elastomer would be sprayed everywhere including on top of the fiberglass to create added structural support with little weight. The fiberglass placement was determined by impact prone areas of the flotation that included both the bottom and sides of the flotation. This structural support along with the flexibility of the elastomer gave the flotation the properties needed to withstand impact without deformation and failure.

Weight Table (lb)

		Elastomer	
		None	0.6"
Fiberglass	None	31.63	54.22
	1 Layer (bottom and sides)	41.34	63.92
	1 layer (sides) 2 layer (bottom)	45.91	68.50
	2 layer (sides) 1 layer (bottom)	45.39	67.98
	1 layer (everywhere)	50.54	73.13
	2 layers (bottom and sides)	49.97	72.55
	2 layers (everywhere)	67.35	89.93

Table 2 – Weight analysis of protective coating scenarios.

The last design decision was the support structure for the flotation. The frame was incorporated into the pontoons of the flotation due to the fact that the pontoons carry the majority of the weight. The material chosen for the frame was aluminum, because of its light weight and strength. The aluminum tubing used was a 1 inch OD with a 0.75

inch ID. Attached to the aluminum frame was a 30 mil aluminum sheet pop-riveted on in order to spread stress out within the flotation. The frame itself was attached to the sides of the vehicle using tabs and 3/8 inch bolts.

Fabrication

After designing the flotation and its components the flotation then had to be built. In order to get a feel for how to work the foam and fiberglass a 1/3rd scale model was built as seen to the right in figure 3. Understanding how the foam reacts to sawing and sanding was important for obtaining the desired shape. In building the 1/3rd scale model the drying time for the Liquid Nails adhesive and curing time for the fiberglass were measured. This knowledge was important in planning the building process. The next step was then to build the full size flotation and this would begin with the fabrication of the aluminum frame.

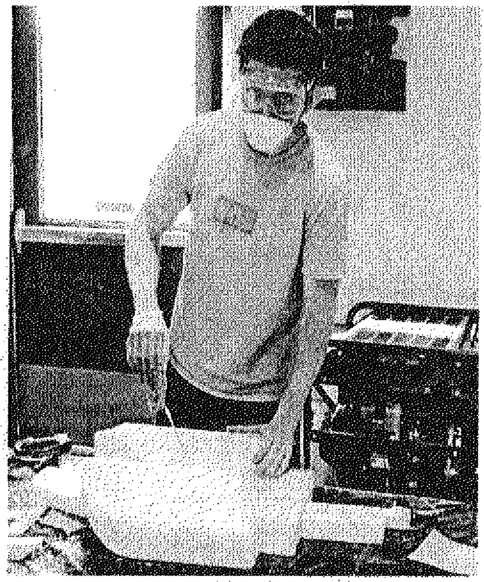

Figure 3 - Flotation 1/3rd scale model

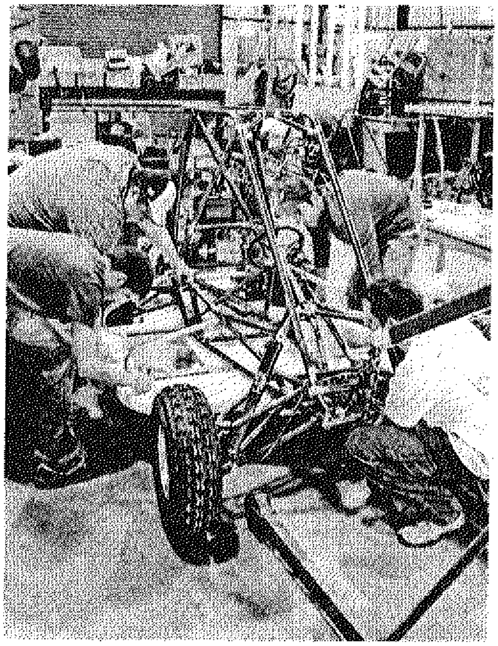

Figure 4 - Fitting of the flotation frame and foam board onto the Mini Baja

The aluminum frame was fabricated using a pipe bender and pneumatic snips. The tubing was then welded together and the aluminum sheet metal was pop-riveted on.

Finishing the aluminum frame allowed for the beginning of the flotation fabrication. The flotation involved cutting the foam board to the correct sizes and sanding off any excess foam on the edges. As the fabrication process continued the flotation was constantly fit to the Mini Baja frame as seen to the left in figure 4. The layers of foam board were glued down using the Liquid

Nails 604 adhesive. The flotation was built layer by layer while incorporating the aluminum frame as seen to the right in figure 5. The desired height was obtained and the flotation was cut and shaped to the final design. The flotation was once again sanded and all cracks and seams were filled with adhesive. The finalized flotation was fitted to the Mini Baja using tabs welded to the frame. It was then taken up to Biddeford, Maine to be sprayed with elastomer by Flotation Technologies. The final product can be seen below in figure 6. The final fitting was administered following the application of elastomer.

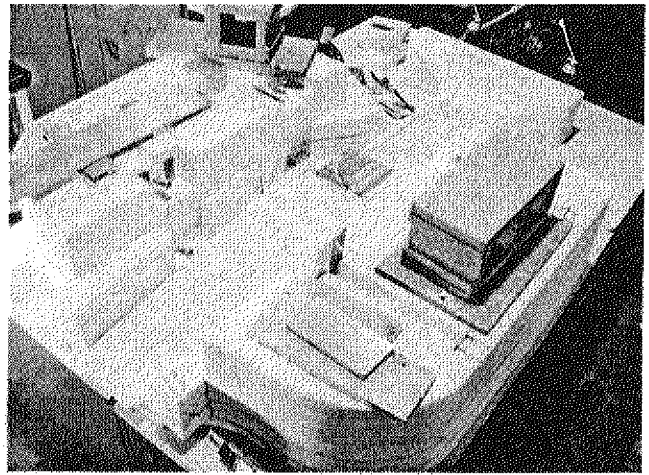

Figure 5 - Flotation fabrication before shaping

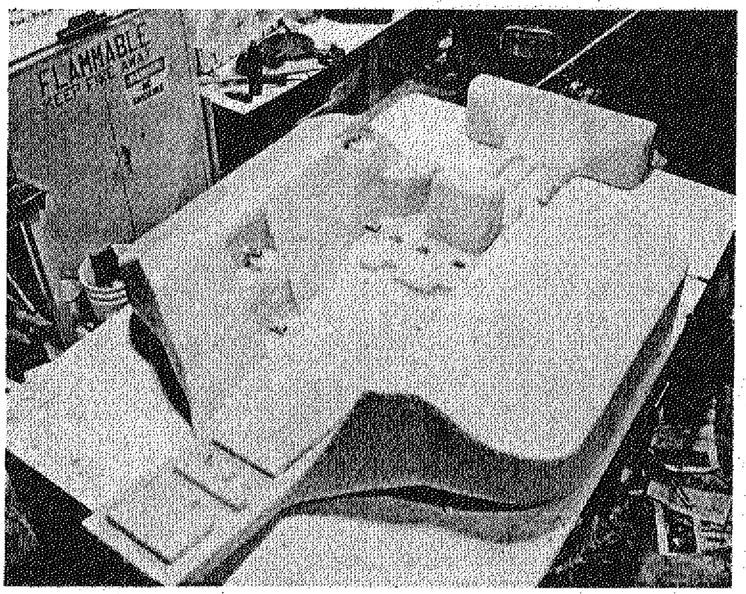

Figure 6 - Flotation sprayed with elastomer protective coating

The last and final step in the building stage involved the flotation placement in the rear wheel rims. Three layers of foam board were cut in 11.5 inch circles and glued to a 1/8th inch polyurethane carbon fiber composite used for the wheel hub. The flotation was then bolted to the wheel rims using two threaded rods with end caps. This was done for both the rear wheels.

The fabrication process was finished and all that was left to do was test the flotation. The flotation was tested for two weeks and was then painted before the Mini Baja competition in the team colors of blue and white.

Propulsion

The ability of the Mini Baja to propel it's self through the water is essential for the completion of the water maneuverability event in the competition. In the past, the tires, in conjunction with shaped sheet metal fenders have been used to provide and direct propulsion. Many ideas have been suggested for alternate ways of propelling the Mini Baja through the water such as propellers or jet drives. These devices, while being very efficient, unfortunately add a complexity and fragility to the Mini Baja which is not acceptable. The fenders make the most sense for the competition, however, even the simple sheet metal fenders rarely make it through the competition without having to be patched or repaired. This year's team decided to investigate alternative materials such as composites and plastic to make the fenders lighter and more durable.

Design Criteria

The fenders appear to be a simple part of the Mini Baja but they actually do a lot for the car in and out of the water. The fenders must clean mud and water from the tires and protect the drive train, engine, and driver from water and mud thrown by the tires. The fenders must also redirect water turned up by the tires back into the water rather then up into the air. The fenders are the part of the car that sticks out furthest to the left and right making them the first thing to impact a tree, rock, or ground during a side impact. To defend against this the fenders must be durable enough not to tear or shatter but flexible enough to crumple and deform to absorb the energy of the impact. The fenders must be as light weight as possible, which is a requirement for every part that goes on the car for obvious reasons. Mounting the fenders on the car is another important design consideration. The fenders must be mounted in a way that allows them move up and down with the tire. The mounts themselves must be strong, stiff, light weight and hold the fender in the correct position over the tire.

Analysis

In order to accurately design the fenders for the propulsion system, this year's team had to first analyze the hydrodynamics of a tire spinning in water to determine the optimal tire depth for the maximum thrust. Once the optimal tire depth was known, the fenders could accurately be designed to maximize performance.

To perform this analysis, a test tank located at the University of New Hampshire was employed. This test tank can be seen to the right in figure 7. As one can see, the test tank consists of a large steel tub with a sliding assemblage on top. This assemblage consists of a hydraulic lift that can lower the motor and tire assembly into and out of the water. A load cell can be seen mounted between the sliding assemblage and the steel tub.

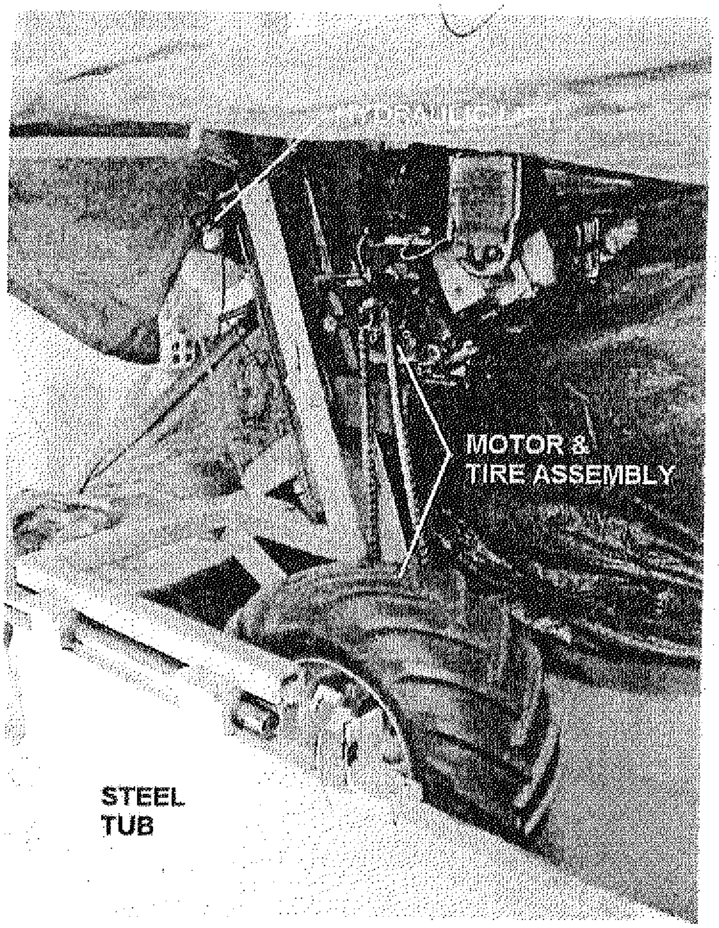

Figure 7: UNH test tank major components

Once the setup of the test tank was complete, the experimental data was ready to collect. Six separate tire submergence depths were run from 2 to 12-inches at 2-inch intervals. For each run, the motor was started and lowered into the water to a specific tire depth until a thrust force could be read from the load cell. Because the thrust of a spinning tire is a function of tire speed as well as submergence depth, the tire speed was held constant for all runs using a tachometer. A plot of the experimental data points can be seen in figure 10 on page 13.

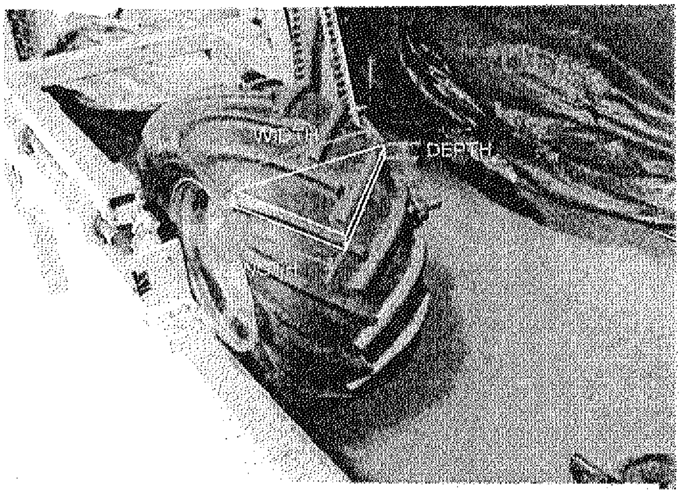

Figure 8: Dimensional parameters of off-road tire

To check the experimental results, a theoretical procedure was performed using hydrodynamic theory. To do so, the complex off-road tire geometry was simplified down to that of a paddlewheel. Dimensional parameters used in the theoretical analysis can be seen to the right in figure 8. From these simplified parameters, tread area and volume were calculated. Once the tread volume was known, the tangential velocity of the tread was determined knowing the engine speed, gear ratio, and tire radius.

After the tread velocity was established, it was essential to determine the number of submerged treads as well as the angle of the water at a specific tire depth. The number of submerged treads was measured during the experimental procedure while the angle of the water was determined knowing the submerged depth and tire radius. These two parameters can be seen below in figure 9.

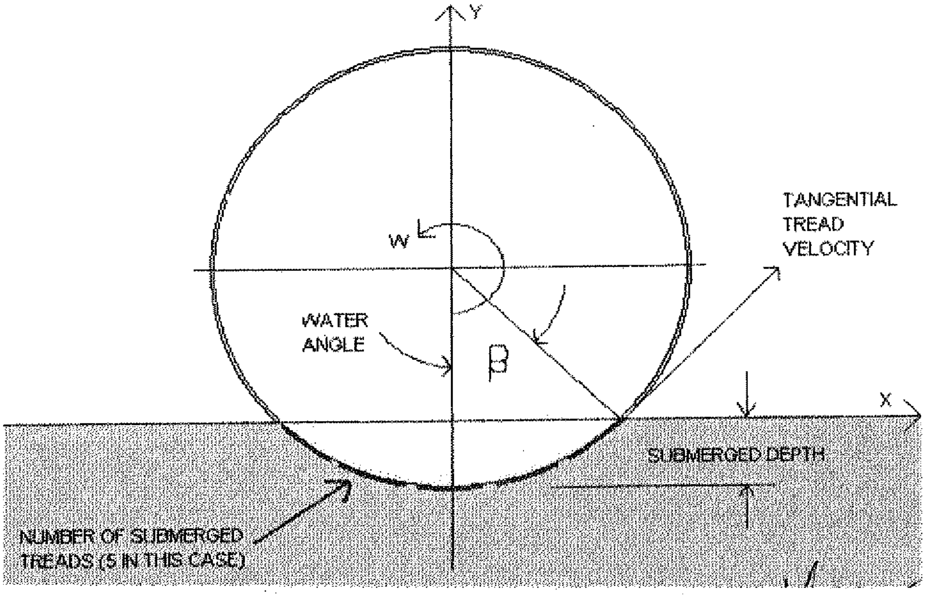

Figure 9: Submerged tire parameters

Once the number of submerged treads and the water angle were known, the momentum calculation could be performed for each tire depth. The dynamic momentum principle of $\Delta M_x = F_x$ was used to calculate the theoretical tire thrust. By observing the difference between the momentum of the water in front of the tire and that in back of the tire, one is able to determine the tire's forward thrust. For this analysis, the momentum of the water in front of the tire was assumed to be stationary since there was no way of measuring its velocity. For the water's momentum in back of the tire, it was assumed all of the water picked up by the submerged treads was thrown back at a tangential angle and at a velocity equal to that of the tire speed. The theoretical thrust results can be seen in figure 10 below. Theoretical calculations can be seen in the appendix.

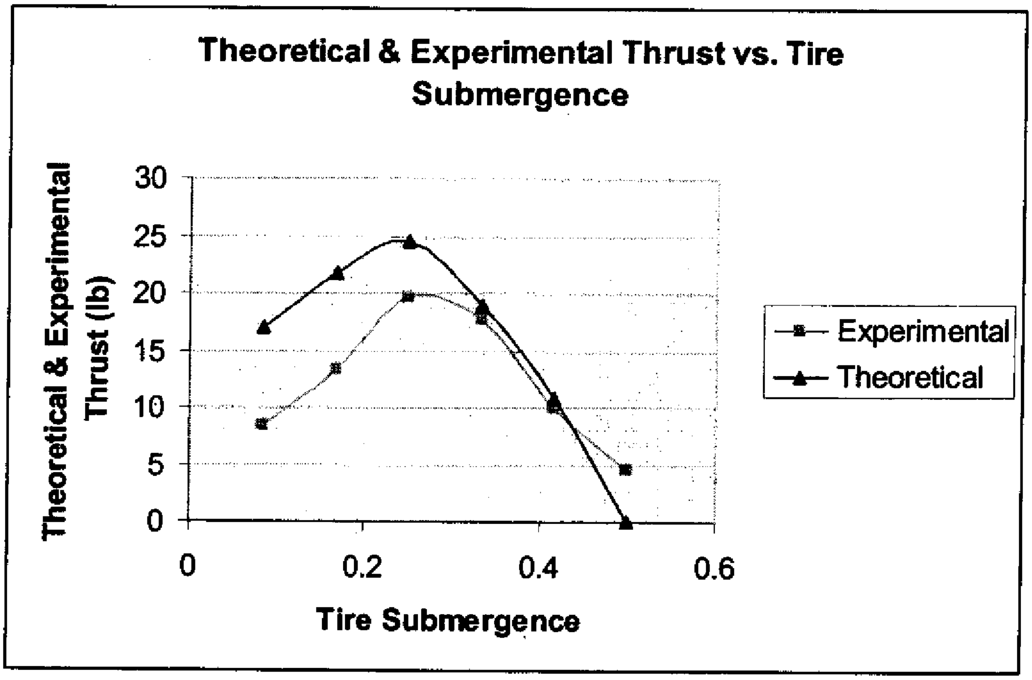

Figure 10: Experimental and theoretical thrust results

From figure 10 above, one can see the experimental results coincide fairly well with the experimental results. Once can also see that in each case, the maximum thrust of the tire is experienced at a tire submergence of 0.25. This optimal tire depth is comparatively close to the accepted value of 1/3rd submerged. It is this range of tire submergence which this year's flotation and propulsion team hopes to accomplish and which this year's team considered when designing the fenders.

Fender Design

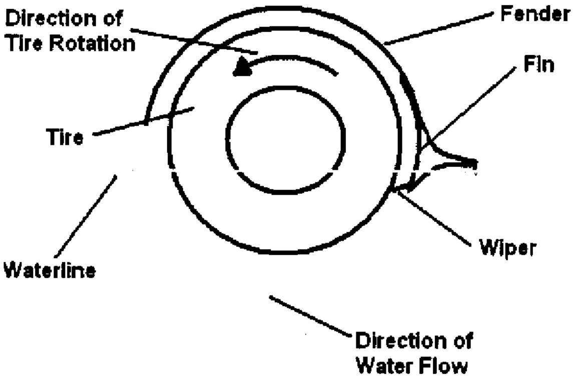

Figure 11 : Cut-away diagram showing how the fender directs the flow of water

This year's fender design was inspired by careful study of a spinning tire in the test tank. The tire is run in such a way that the tread acts as a paddlewheel, pushing water around the tire. It was observed that much of the water was thrown up into the air or pulled around the tire rather then being thrust to the rear. If one was to break up the water moving around the tire into a series of velocity vectors it would show that as the water reached the back of the tire the direction of the water's motion changes from horizontal to vertical. A cut-away of the fender and tire assembly, seen above in figure 11, shows the flow of water when the tire spins. The thrust is achieved only from the water moving in the horizontal direction. Therefore more energy will go into propelling the car if the water moving in the horizontal direction is maximized. To achieve this, a fin inside the fender cuts water from the spinning tire and directs it through the outlet at the rear of the fender. The outlet sits at the water line directing the moving water into the static water behind the car rather then into the air. To reduce mud and water spatter the fender is designed to surround the tire closely from the front of the tire, along the sides, and all the way to the water line where the fender forms an outlet. In addition to the fin, close-fit, soft rubber wipers scrape off mud and excess water from the tires. A 3-D image of the fender can be seen in figure 12.

Material Design

The material choice for a part is the most important choice in a design process. In contrast to past teams this year's team spent the majority of design time on experimenting with different materials such as composites and plastics. Three materials were tested: fiberglass reinforced resin, D scale polyurethane, and spinner polyurethane.

Figure 12 : 3-D CAD rendering of fender

To test these materials a 1/3rd scale mold was made using poured foam. The full sized mold can be seen below in figure 13. The foam was poured in a block and then shaped to the specified dimensions using wood working tools. Once the mold was cut to size a coating of polyester resin was added to protect the foam and add a hard smooth surface to mold on. This process is identical to the process used to make the mold for the full-sized fender.

The sample fender made of fiberglass reinforced resin was created first and used to make a female mold for the polyurethane fenders. A coating of wax and then a coating of water saleable release agent was put on the mold to allow the fiberglass fender to be easily removed. The fiberglass fender was left on the mold and plastic was poured over it to create a female mold slightly larger then

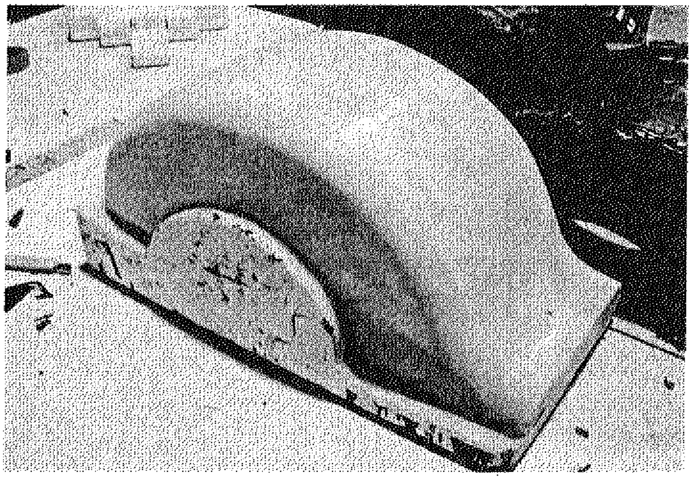

Figure 13 : Full-sized male mold used to create fenders

the male. Then two fenders were made using hard polyurethane for one and a softer polyurethane for the other. These fenders were made by pouring the plastic into the female then pushing the male mold inside forcing the plastic up the sides. Both molds were coated with a layer of silicon mold release to allow easy removal of the fender.

Once the three scaled down fenders were created they were tested for strength, flexibility, and weight. Since the forces that the fenders are subjected to are unknown and the material properties of plastics and composites are difficult to determine the fenders were tested by applying forces of different types and amounts until they failed. The fiberglass fenders were the lightest and were also very strong; however they were not very flexible. When distorted enough the resin would crack and the fibers would break. The hard polyurethane was also very strong however they were heavy and would fail explosively by shattering like glass. The softer polyurethane was strong, very flexible and fails by stretching rather then through cracking. The soft polyurethane weighed the same as the hard polyurethane however to gain the same stiffness the fender would have had to be twice the thickness and weigh twice as much.

The soft polyurethane offered the best flexibility and good strength but was not stiff enough for use on the fender. A layer of carbon fiber was sandwiched between two layers of soft polyurethane to gain stiffness without adding more plastic. A 1/3rd scale fender was created by pouring a layer of the soft polyurethane onto the silicon coated mold then laying a section of carbon fiber on the liquid plastic and pouring another layer of soft polyurethane on top of the carbon fiber. The mold and fender were placed in a 90° F oven overnight and then the fender was removed from the mold. This composite provided an optimal combination of strength, flexibility, and weight. The full sized fender can be seen in figure 14.

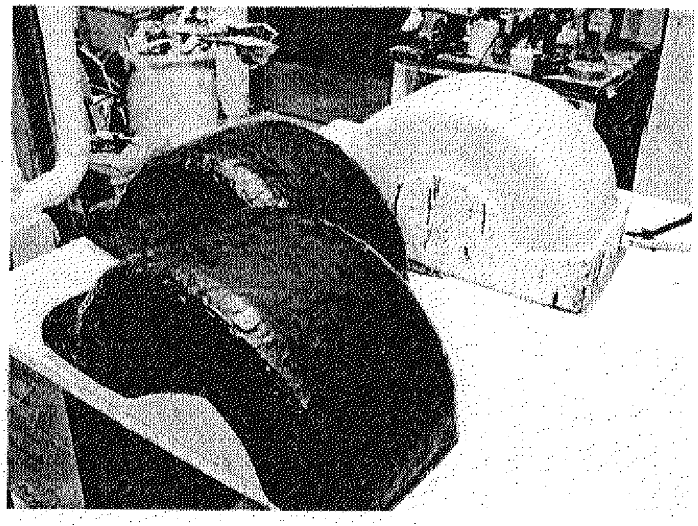

Figure 14 : Full-sized fenders with the mold used to create them

Fender Mount Design

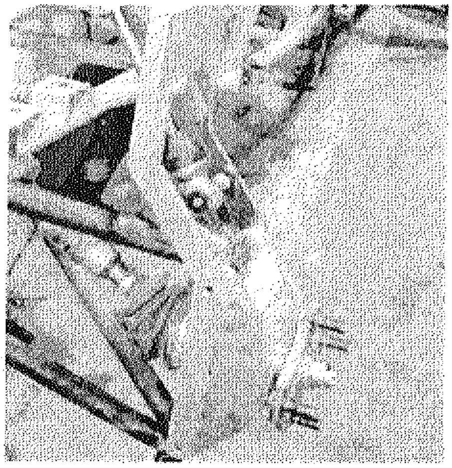

Figure 15 : Fender mount attached to upright of rear suspension

The way the fender is mounted is very important and often left to the last minute. The fenders must be mounted so that they move up and down with the tires. The uprights which hold the drive shaft and attach to the rear a-arms are the only static mounting point with respect to the tire. The mount was then designed to attach to the pre-existing rear upright design as seen in figure 15. Two 1/4" aluminum arms welded at right angles onto a 1/8" aluminum square make a light weight and geometrically strong mount. The mount attaches at 4 points to the uprights and the flat 1/8" square provides an excellent attachment point for the fender. Attaching the fenders to the mounts also takes planning because bolted plastic under shear behaves differently then bolted metal. It becomes necessary to spread the force to all bolts using a sandwich of sheet metal. The sheet metal sandwich also keeps the bolt heads from pulling through the flexible plastic that makes up the fenders.

Summary

This year's fender is designed to clean the tires, protect the driver and drive train from mud and water, and direct the tire's thrust in the water portion of the competition. The fenders must be strong, durable, and light weight to withstand the rigors of competition. A composite of soft polyurethane and carbon fiber offered the best combination of the desired properties. Strong, stiff, light weight mounts were designed to position the fenders on the tire and hold the plastic fenders in place under stress.

Budget

Given a budget of two thousand dollars, this year's team completed the flotation and propulsion system under budget. With the exception of a few unnecessary, unexpected expenses, the only real expenses were miscellaneous tooling and parts – a lot of materials were graciously donated. This year's team did have a miscommunication with the UNH Machine Shop in which we were required to pay $380 to repair last year's fenders when it was implied this work would be pro bono. Another unnecessary expense came with the purchased hydraulic pump that was later deemed impractical by the Mini Baja team. Shown below is a breakdown of this year's budget between the different project aspects.

Flotation	
Extruded Polystyrene Foam Board	$140.00
Aluminum Frame Material	Donated
Liquid Nails / Fiberglass Mat	$85.00
Miscellaneous	$175.00
Propulsion	
Fender Material	Donated
Mounting Bracket Material	Donated
Miscellaneous	$160.00
Test Tank	
Drive Chain	$15.00
Miscellaneous	$20.00
Miscellaneous	
2003 Fender Work	$380.00
Hydraulic Pump	$250.00
Travel	
4 People	$400.00
Total	$1625.00

Discussion

Final Thoughts

This year's Mini Baja flotation and propulsion project focused on the use of alternative materials to improve the weight, durability, and strength of designed components. The team relied on careful research of materials, which included talking to outside companies about fiberglass, plastics, and foams. The team learned knew skills such as fiberglassing, plastic molding, machining, and wood working. Every team member focused their abilities to troubleshoot problems by developing solutions that solved these problems quickly, effectively and in a cost effective way. The result of unprecedented teamwork, dedication, perseverance, and hard work is an elevation in the quality of manufacturing and design of the flotation and propulsion systems. The flotation system is the most durable, lightest, most streamlined and strongest that UNH has put into competition. The fenders are more flexible, stronger, lighter and much more durable then they have ever been. All these advances were achieved while spending barely half of this year's budget. None of these achievements would have been possible of course without the help of our sponsors, especially MPT in Dover, NH and Flotation Technologies in Biddeford, ME.

Future Flotation and Propulsion Ideas

Flotation made great strides in 2004 with the use of closed-cell foam board for the flotation. For future teams it is imperative that closed-cell foam is used so that in the case of deformation or failure in the protective coating the flotation will not absorb water. Future teams should attempt to find less dense foam to cut weight and raise the buoyant force even more. Another possibility for improvement would be in the flotation fabrication. The use of foam blocks instead of foam sheets would help make the flotation fabrication much easier. Using a foam block requires fewer cuts, would it make it easier to assemble, and it would strengthen the overall flotation structure.

The flotation itself was not the only area of improvement in 2004. The protective coating on the flotation made progress in using a combination of fiberglass and elastomer to create the mechanical properties desired for protection. Some areas for possible improvement would include analyzing the failures in the 2004 flotation. This means looking at areas that failed and did not fail. Finally there is always room for improvement in material selection. Researching protective coatings with similar material properties that are lighter and just as strong if not more so is always an improvement.

Propulsion benefited greatly from the use of plastics and plastic based composites. Future teams should look more into the use of plastics for fenders and different molding techniques. Future teams should consider carefully how they will fabricate the fenders with the chosen material when designing fenders. They should also try to design a good way to use hydraulics or some other way to raise the rear tires so that they are at the optimal tire depth. When ever possible fabricate in house to avoid the cost and wasted time of contracting out fabrication.

Appendix

Appendix A3: Theoretical Calculations

1. Tread/Tire Geometry

Measured Tire/Tread Dimensions (inches):

Tread:

$\text{widthin} := 10.625$

$\text{lengthin} := 7.5$

$\text{depthin} := 0.925$

Tire:

$\text{diameterin} := 26$

$$\text{radiusin} := \frac{\text{diameterin}}{2}$$

Measured Tire/Tread Dimensions (meters):

Tread:

$\text{width} := \text{widthin} \cdot 0.0254$

$\text{length} := \text{lengthin} \cdot 0.0254$

$\text{depth} := \text{depthin} \cdot 0.0254$

Tire:

$\text{diameter} := \text{diameterin} \cdot 0.0254$

$$\text{radius} := \frac{\text{diameter}}{2}$$

Calculation of Simplified Tread Area (meters^2):

$$\text{height} := \sqrt{\text{length}^2 - \left(\frac{\text{width}}{2}\right)^2}$$

$$\text{area} := \left(\text{height} \cdot \frac{\text{width}}{2}\right)$$

Calculation of Simplified Tread Volume (meters^3):

$\text{volume} := \text{area} \cdot \text{depth}$

2. Tread Velocity (meters/second)

$\omega motorRPM := 3000$

$$\omega motor := \pi\ \omega motorRPM \cdot \left(\frac{\pi}{30}\right)$$

$Ngear := 11$

$Nsprocket := 42$

$$\omega sprocket := \omega motor \cdot \frac{Ngear}{Nsprocket}$$

$vtread := \omega sprocket \cdot radius$

3. Wheel Submergence Geometry

- Number of treads in the water
- Angle to the water surface

Case 1: 2" Submergence

$N1 := 2.5$

$\beta 1 := 0.586$

Case 2: 4" Submergence

$N2 := 4$

$\beta 2 := 0.841$

Case 3: 6" Submergence

$N3 := 6$

$\beta 3 := 1.047$

Case 4: 8" Submergence

$N4 := 7$

$\beta 4 := 1.231$

Case 5: 10" Submergence

$N5 := 8$

$\beta 5 := 1.403$

Case 6: 12" Submergence

$N6 := 9$

$\beta 6 := 1.571$

4. Momentum

- Initial momentum of water is zero
- Final momentum is shown
- Change in momentum represents thrust

$\rho := 998.2$

$M0 := 0$

$M1 := \rho \cdot volume \cdot vtread \cdot N1 \cdot \cos(\beta 1)$ $M1 = 75.655$

$M2 := \rho \cdot volume \cdot vtread \cdot N2 \cdot \cos(\beta 2)$ $M2 = 96.866$

$M3 := \rho \cdot volume \cdot vtread \cdot N3 \cdot \cos(\beta 3)$ $M3 = 109.003$

$M4 := \rho \cdot volume \cdot vtread \cdot N4 \cdot \cos(\beta 4)$ $M4 = 84.742$

$M5 := \rho \cdot volume \cdot vtread \cdot N5 \cdot \cos(\beta 5)$ $M5 = 48.529$

$M6 := \rho \cdot volume \cdot vtread \cdot N6 \cdot \cos(\beta 6)$ $M6 = -0.067$