

## **AC 2007-1591: HYBRID MINI-BAJA CAR PROJECT**

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## Hybrid Mini-BAJA Car Project

### Background

The hybrid mini-BAJA car project at Northern Michigan University has its roots in two different initiatives. The car was originally built by the Northern Michigan University SAE (Society of Automotive Engineers) Club as its initial entry to the 2005 SAE BAJA competition (A SAE event in which the students compete with “miniature” off-road vehicles they have built.) The vehicle was entirely designed and fabricated by the club according to SAE guidelines. It was innovative in that it was designed with hydraulic drive instead of a mechanical transmission. Unfortunately this design along with a very conservative frame (very strong – very heavy) caused the vehicle to be extremely heavy. The club did successfully compete in the SAE competition and drew many positive comments about the design; however the weight of the vehicle caused the performance of the vehicle to be poor. (Competition vehicles use a standard 10hp gasoline engine and the vehicle weighed in at 750 pounds. The next vehicle they built weighed in at 350 pounds)

The second initiative that inspired the program was Dartmouth’s Formula HYBRID competition which they proposed and built a prototype for in 2005-2006. (The first formula HYBRID competition is scheduled for May 1-3, 2007.) Initially we considered competing in this program, but after some consideration decided we didn’t have adequate access to facilities (a track to test the vehicle) or a formula frame since our SAE club participated in the BAJA competition. (The SAE formula competition is a parallel SAE sponsored event in which student organizations build essentially miniature Indy-type race cars.)



**Figure 1 Car with Original Hydraulic Drive**

### Initial Hybrid Conversion during the Spring of 2006

The work in the spring semester of 2006 was done by a senior projects class with four mechanical engineering technology students and four electrical engineering technology students. Their project was to redesign the hydraulic drive BAJA vehicle and convert it to a serial electrical hybrid drive train using the same 10 hp Briggs and Stratton gasoline engine.

This was a major project as the entire rear of the vehicle had to be redesigned to convert from hydraulic drive with a motor on each wheel, to solid axle driven by an electric motor. Also space had to be found for four 12V batteries and the associated electronics and control elements required for the drive and gasoline motor control.

As for the electrical configuration, it was decided to employ a serial gas-electric hybrid configuration using a commercially available controller for the drive motor, but the controller that controlled the gasoline engine and thus the charging of the batteries was built from scratch using a PIC12F675 Microcontroller.

Overall the work by the senior class project was a major success. The design was efficient and all major areas of concern were addressed. The car would run under electrical power and proved to have performance at least equal to and in several areas far superior to the original hydraulic drive. (Starting torque and acceleration were definitely superior; we did not have time or available facilities to test top speed with this version.) There were problems remaining however with the vehicle and these remained unresolved mainly because the group ran out of time. The vehicle was only totally assembled during the last week of the semester not allowing any time for test or troubleshooting. Consequently the controller operating the charging circuit was never really functional having some problems after installation and the rear wheel bearings were found to be inadequate.



**Figure 2 Original Hybrid Drive**

#### Work Done in the Fall 2006

During the Fall 2006 semester work continued on the car with a select group of students (four electrical engineering technology and one mechanical engineering technology students) in a directed study research class. All of the students except one were involved in the initial conversion of the car and thus brought valuable background knowledge allowing the project to get a quick start to bring the vehicle to “running” status.

While the results from the senior project the preceding year were impressive, they fell short or having the vehicle operating in a reasonable manner. In fact although the car had been demonstrated running off the electric motor, the charging controller had not been made to operate when actually on the car and ended up needing quite a bit more work. Also as mentioned above the rear bearings were marginal at best and finally that the car was heavy enough it really needed to have a reverse “gear”. In addition it was decided the switch positions were not ergonomically correct and we wanted to have indicator lights for both the car being “on” and forward or reverse.

Work during the semester proceeded with only a few modifications causing major problems. The replacement of the rear wheel bearings was pretty uneventful probably because the student in charge had a lot of experience with four-wheelers and other off-road vehicles. The entire car was rewired as both the control wiring and power wiring had to be replaced due to the addition

of reverse which required the addition of a reversing contactor and relocation of two of the four batteries. Again there were not many problems here.

Where problems did arise is the hand-soldered circuit board which demonstrated some quality issues causing a couple of shorts that were difficult to track down. This caused problems with the controller and at times it was difficult to troubleshoot if the problem was with the controller or with the board. However eventually all the faults were isolated and the vehicle was ready for track testing.



**Figure 3 Modified Hybrid Drive**

Unfortunately while the weather had been very mild all fall – during the last two weeks of the semester when we needed to get the vehicle outside for testing turned off cold with precipitation – both rain and snow. So we have documented the vehicle is now fully operational, however the actual performance testing done is still very limited.

### Tech Competition

The next step planned for the vehicle is the Michigan Technological University's (MTU) Winter Baja Competition. We have minor work required in "ruggedizing" the vehicle which mainly consists of protecting the contactors and motors from snow and/or mud. We don't expect to be competitive as the car is still very heavy but we hope to prove our systems and get a feel for where we stand and how far we will have to go with the next generation vehicle.

### Future Plans

The mini-baja hybrid project is still a very active program and there are several different avenues that we intend to pursue simultaneously with the project. The ability to involve students in projects that interest them and are in timely research areas is an invaluable teaching and recruiting tool.

First while the current vehicle has deficiencies that will keep it from ever becoming a competitive competition vehicle it is still a valuable research vehicle. We intend to instrument the vehicle to collect valuable data on efficiencies and other characteristics that need to be investigated. In particular we are still not happy with the recharging algorithm that controls the gasoline engine throttle and thus both battery charge level and fuel efficiency.

Second to make the mini-baja hybrid project a viable long-term research area we must prove the technology can compete with the SAE specification vehicles. To that end we intend to develop a new vehicle from the ground up. We will start in the winter semester of 2007 by having a senior projects class of four mechanical engineering technology students design a SAE specification

frame optimized for hybrid drive. At the same time a directed study research class will start looking at what improvements can be made to the hybrid drive train to improve efficiency and performance. Using the current vehicle as a test bed we hope to be able to construct the second vehicle and have it operational in less than a year. The short-term goal at this point is to have a vehicle that will be competitive in February 2008 Winter Baja Competition. Long term we would like to either host or co-sponsor a Baja competition for hybrid vehicles that is similar to the SAE events for conventional vehicles.

## Conclusions

Overall we have found the mini-BAJA car project to be very satisfying from several perspectives. The students enjoy working on the car as a challenging project that mirrors their outside interests. It is excellent publicity for the program and university in general drawing positive comments in a number of different forums. And finally we hope to demonstrate the utility of the hybrid drive train in smaller vehicles and eventually draw funding support for the research into hybrid technology in smaller vehicles from four-wheeler to snowmobiles.