Today is: July 8, 2003

http://www.machinedesign.com

CURRENT ISSUE

Wired for speed

The battery-powered Buckeye Bullet streamliner returns to Bonneville for another shot at the world speed record.

Lawrence Kren
Senior Editor

"The car could not have run better," laments Todd Rodrick, Buckeye Bullet team leader and engineering student at Ohio State University. "But Bonneville racing rules mandate teams build to top speed in a series of qualifying runs and rigorous technical inspections. Unfortunately the narrow time window closed before we could get licensed to make a run for the record." The car hit 240.894 mph in trials, less than 5 mph shy of the current world speed record for electric cars (245.524 mph) now held by the White Lightning streamliner of Dempsey's World Record Associates. That was last October.

The Buckeye Bullet racing team at Bonneville last year. OSU students were involved in all aspects of the car's design. That's driver Craig Taylor on the far right.

This August the OSU team plans a return trip to Utah's ancient salt flats for another shot at the record. Lessons learned from the previous year should improve their chances. It also doesn't hurt to have successfully raced electric cars for the past decade.

Buckeye Bullet is the second electric race car fielded by OSU students. The Smokin' Buckeye sprint car that preceded it has won every national championship sprint-car race from Indianapolis to Mid-Ohio and even ran at Bonneville. But students wanting a fresh challenge free of collegiate racing rules temporarily shelved the sprint car and focused efforts on the Buckeye Bullet. The sleek, 30-ft-long Bonneville streamliner took about three years and $500,000 to build, excluding student (free) labor, which by some estimates exceeds $2.2 million. Students were involved in every aspect of its design. The first order of business: selecting a powertrain.

It turns out that a three-phase ac motor has about a 15% higher power-to-weight ratio than an equivalent dc motor, despite the added weight of an inverter. The ac motor in this case makes about 500 hp at 1,000 Vac. Inverter input at 1,000 Vdc comes from 12,000 thumb-sized, 1.5-V nickel-metal hydride batteries, the same kind used in RC racing and found at hobby shops. NiMH batteries weigh far less than lead-acid cells and deliver twice the current. Batteries go one pass between charges and can be fully recharged in about half an hour. Hysteresis hasn't been a problem because the two-year-old batteries still take a full charge. Rounding out the powertrain is a five-speed manual transmission and a rear differential. Powertrain total efficiency is estimated at 80%.

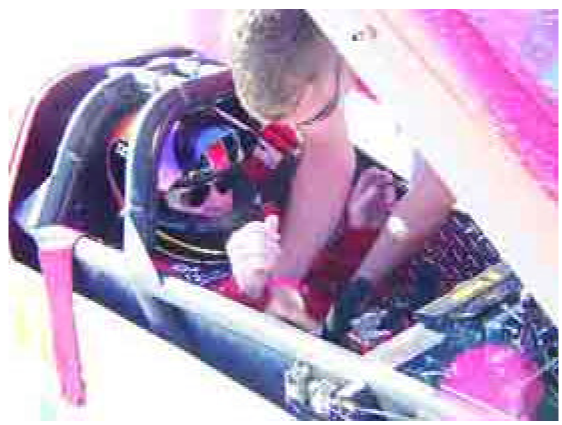
Students next designed a space-truss chassis from 4130 chromoly tubing. A professional weldor experienced in NASCAR fab from the Edison Welding Institute TIG welded it together. The chassis minimizes frontal area and includes a fully independent and adjustable coil-over-spring damper suspension front and rear. Testing at the Transportation Research Center outside Columbus helped tweak the suspension. Students also ran a car down Bonneville's 5-mile-long course with an LVDT mounted on its suspension. One-quarter inch was the biggest bump measured, half the 0.5-in. ground clearance on the Buckeye Bullet. Minimizing airflow beneath the car cuts drag and improves high-speed stability.

A look under the "hood" reveals a truss chassis flanked by rows of battery packs up front. The car rides on special slick-smooth tires built to withstand the high speeds and Bonneville's coarse salt surface. Only three companies make the tires which are characterized by a special rubber compound, cord design, and extremely stiff sidewalls. The tires work as advertised though the team may eventually opt for all-aluminum wheels to lower rolling friction.

Shell game

Design of the body shell went to a now ex-team member from Honda R&D's FEA division. A wind-tunnel modeling program called Fluent helped identify the basic body shape. Wind-tunnel tests of a one-third-scale wooden model at the Auto Research Center, Mooresville, N.C., validated the simulations and optimized the stabilizer and rudder. These control surfaces help steer the car at high speeds. Drag coefficient is said to be about 0.3.

OSU then turned to **Ashland Inc.**, Columbus (**www.ashland.com**), for fab of the full-scale, three-piece fiberglass/carbon-fiber shell. Ashland supplied the resin and farmed out mold building and the vacuum-infusion process.



Driver Craig Taylor "preflights" the Buckeye Bullet then heads out for another pass down the 5-mile-long course.

Here's how vacuum infusion works: Fiberglass cloth and other reinforcement materials go into a mold, dry. A plastic film covers the layers and is sealed around the mold edges. In contrast, conventional lay-up techniques wet materials with resin as they are layered, making them difficult to handle and place. A slight vacuum drawn between the mold and film feeds resin at atmospheric pressure through a tube inserted into the film. For reference, the mold surface becomes the show surface of the finished part and the film, the part backside.

"Vacuum infusion permits much higher fiber content than conventional lay-up techniques which lowers part weight and boosts stiffness, important metrics for the Buckeye Bullet shell," explains Ashland engineer Dwight Russ. "The use of a vacuum reduces air bubbles and encourages resin penetration through fibers. Hand lay-up typically produces parts with no more than 25 to 45% fiber content depending on fiber type. Vacuum infusion can boost fiber fractions to 70%."

Low-resin viscosity further helps penetration. Ashland spec'd vinyl-ester resin for the Buckeye Bullet shell. Ashland starts with an epoxy resin then modifies it to act as a polyester. Unlike epoxies that begin curing immediately and take hours to set, the vinyl-ester resin remains liquid for about an hour and a half before curing, allowing it to flow and permeate fibers. In OSU's case both fiberglass and carbon fibers were used depending on stress levels predicted in FEA models. The approach let the team optimize strength-to-weight ratio. Long spans without underlying support prompted use of carbon fiber, for example. The entire job, from mold building to finished parts, took about six weeks.

A student-built $^{1}/_{3}$-scale wooden wind-tunnel model verified computer flow simulations and helped tweak rudder and stabilizer shapes.

Speed thrills

For all the apparent attention to design detail, the car's tiny cockpit appears an afterthought - until you meet driver Craig Taylor. At 5-ft -2-in. tall, Taylor is one of the few adults who can shoehorn into the cramped roll cage. "We basically designed the car around him," says Rodrick. What Taylor lacks in height he makes up for in experience. The ex-Navy attack-jet pilot and engineer is a 3X National SCCA champion and a driver for the Smokin' Buckeye team. His suggestions drove the original design of the driver's controls as well as the latest upgrades.

The cockpit contains only the bare essentials to minimize distractions. There is no speedometer, only a tachometer from which speed can be figured. A hand shifter works the transmission. Last year's design included a hand throttle and a pair of rudder foot pedals for high-speed steering corrections, an arrangement familiar to pilots and requested by Taylor.

A technique called vacuum infusion built the fiberglass/carbon-fiber body shell in three sections. The process permits higher fiber loading than possible with conventional lay-up techniques so parts can be made stiffer and lighter weight.

But unlike an airplane there are also brake and clutch pedals to contend with. During a trial run Taylor went for the clutch and hit a rudder pedal instead and nearly lost control of the car. The hand throttle has since been replaced with a conventional foot throttle and the rudder pedals are gone. Eliminating rudder control limits runs to those in less severe crosswinds, a chance the team is willing to take.

Another problem: cooked batteries. A so-called brake resistor, an idea forwarded by OSU electrical engineering students, would help squeeze more power into the car than needed to run. The resistor dumps the extra power as heat. But attempts to deflect resistor heat away from the body sent it back to a battery pack and fried it. That issue has been resolved, says Rodrick.

Probably the biggest challenge facing the team will be recharging the batteries quickly enough. A pass is five miles long; two miles to accelerate from brake stop and three timed flying miles (the car actually accelerates the entire run). A battery charge lasts one pass or about 88 sec. But rules say a record speed run is the average of two consecutive passes - up and down the course - spaced no more than 1 hr apart. Charging batteries consumes about half an hour.

Meanwhile more serious mishaps at Bonneville underscore the dangers of extreme speeds. Last year 45-year Bonneville veteran Nolan White was attempting to break 500 mph in his twin-engine streamliner when something went terribly wrong. Witnesses say White tried veering away from a highway at the track end when the car's drag chute and reserves failed to deploy and the brakes proved ineffective. The car rolled at about 320 mph. White later died of his injuries. The Buckeye Bullet also relies on disk brakes and chutes to stop.

Then there's the competition, though it may be less than first thought. The current-record-holding White Lightning was for sale recently on Ebay; opening bid, $450,000, or buy it now for $600,000. There were no bidders. "They're scared we'll win," laughs Rodrick. A scan of the Internet suggests at least two other possible contenders.

But "winning" in this case means nothing more than bragging rights and a plaque. There is no prize money to offset hefty expenses. And if Buckeye Bullet does break the world record this August, what next?

"The car could top 300 mph in its current form given unlimited real estate and battery power," says Rodrick.

"Obviously this isn't possible. But more capable batteries and a bigger inverter to handle the higher voltages would let us go even faster, though it's not in the budget right now."