The Ultra Light Urban Vehicle project at Bradley University has evolved over four years (courtesy of Winzeler Gear).

The Efficiency Experts

BRADLEY UNIVERSITY AND WINZELER GEAR COLLABORATE ON URBAN VEHICLE PROJECT

Matthew Jaster, Associate Editor

The idea sprang from the mind of Dr. Martin Morris, professor of mechanical engineering at Bradley University, a few years back. "I'm sure it was not an original idea, but it became obvious to me that most of the energy required to transport my wife to the grocery store was used to move more than a ton of automobile across town and back," Morris says. "The weight of the important cargo was a small fraction of the weight of the total vehicle. Every time she would hit the brakes, all the kinetic energy of the car dissipated into the atmosphere through the brake pads. Think of all the people doing similar tasks. What a complete waste of energy."

These thoughts led Morris to a discussion with Jesse Maberry, a Bradley alumnus, on a proposal for a three-wheeled vehicle licensed as a motorcycle that carried two people and baggage, weighed about 350 lbs., with regenerative braking and a maximum top speed of 45 mph.

"Maberry liked the idea so much that he suggested we develop a mechanical engineering senior project to design, build and test such a vehicle at Bradley," Morris says. "He helped with the funding, and for about four years now the Ultra Light Urban Vehicle (ULUV) project has been evolving."

In its latest form, the ULUV weighs about 430 lbs., has regenerative braking, a top speed of 45 mph and a range of about 40 miles in stop-and-go traffic. "The cost of travel is about 0.6 cents per mile," Morris says. "Next year, we're targeting weight reduction and increasing the range, which should further reduce the cost per mile."

A Perfect Fit for Plastic

John Winzeler, president of Winzeler Gear in Harwood Heights, Illinois, has been a supporter of the mechanical engineering program at Bradley for many years. "He has helped us by supporting our Formula SAE program and has been an annual client for our senior design course

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Students at Bradley University worked with Winzeler Gear on the gear train for the Ultra Light Urban Vehicle.

sequence by providing challenging projects for our student teams," Morris says. "Our teams have delivered custom equipment and software developed for the testing of plastic gears. Winzeler has also funded research assistantships to support graduate student research to study the failure of plastic gears."

Plastic gears can be lightweight, durable, quiet and affordable. Morris thought a prototype urban vehicle would be an outstanding test bed for a lightweight transmission system designed with plastic gears. Using this transmission system, the team could run the drive motor at higher speeds without generating excessive noise. "The higher speeds contributed to improved performance of our energy management system," Morris says.

He proposed the idea to Winzeler and gear engineer Mike Cassata, both alumni of Bradley University.

"Two years ago, we were working with TTC Transmission Technologies on a transmission for a 25 hp electric motorcycle," Winzeler says. "We were brought in to look at that design and convert it from metal to plastic. We actually had done the stress calculations and believed there was a high probability of success. Once we started the prototype transmission, unfortunately, the motorcycle company went under during the recession."

The knowledge collected for this project, however, convinced Winzeler and his staff to look further into the ULUV concept. Cassata began running design calculations and determined that it could be a plastic transmission. "We designed the transmission, Dupont provided the material and Forest City Gear hobbed the sun and planet gears and shaped the ring gear. The students took a tour of Forest City Gear's Rockford plant so they could see how the gears were machined." Cassata says.

"They were very supportive of the idea," Morris adds. "Cassata worked with our students to design the gear train using Delrin plastic. The student team benefited from a real exercise in designing a gear train using plastic gears."

There were several challenges for the engineering team tasked with designing the transmission. "The first thing was to come up with the general design. We were talking about having a single spur gear reduction, but found out we couldn't get the needed reduction in the size restraints they had. This car had to weigh a certain amount according to the project definition," Cassata says. "We found out that with the reduction they needed, we needed to go with a planetary drive."

Once the team determined the drive system and the amount of space they had to work with, the next step was designing a planetary drive that had the correct reduction and thickness to withstand the forces. "It was then a matter of calculating the stresses," Cassata says. "We have a program written by our senior engineer to calculate the stresses on the teeth. We were able to meet the stresses based on the worst case scenario of the motor. After that, we had conversations with Bradley students about lubrication, temperature, how are you going to fix it to the motor, and other details concerning the vehicle."

"At the end of the day," Winzeler says. "Our main goal was to make sure the teeth don't break or the car refuses to go forward."

The planetary drive consists of a brass sun and Delrin planets and ring gear. The drive has a reduction of approximately 4.57:1 using the sun as an input and the planet carrier as the output. Gear face widths were set to 25.4 mm for all gears. A standard three-module, full-fillet hob was used for the sun and planets and a full radius shaper was used for the ring. The outside diameter of the ring gear was 200 mm. The system is sealed within an aluminum housing and uses automatic transmission fluid for the lubricant.

"The speed reduction of the system allows us to run our electric motor at the higher speeds that are required for better performance of our energy management system," Morris says. "We were originally planning to use a belt system, but we calculated a very high belt speed and excessive noise. The system was designed to transmit about 20 hp."

The Bradley engineering team consisted of eight students, four working on energy management and four working on the vehicle itself. "The students did all the other machining at Bradley University," Cassata says. "This was part of the parameters of the project and allowed the engineers direct feedback on the design."

With Young's quick response at Forest City Gear to supply the gear hobbing machines, the students were able to observe and participate in the fabrication of the gears as well. "Fred has a big heart, this can't be overstated," Winzeler says. "He quickly agreed to get involved in the project and supply the materials despite FCG's very busy schedule."

Winning Results

For projects that bring manufacturing companies together with educational institutions, the benefits are endless. Winzeler Gear makes money selling gears, but the company supports its customers with R&D assistance or even product design. "We're gray box designers," Winzeler says. "A customer comes to us and says 'we have this much space, this much work to do, how do you suggest we accomplish this?' We never turn down a project that can help the company grow in other areas. This is what makes something like the ULUV project so valuable."

Thanks to the plastic transmission design, Winzeler Gear now has a prototype that they can do in four weeks and build a business case for. "Now we have to invest the money to make it a production item. I recently went to SAE in Detroit and listened to some of the latest transmissions developments and technologies on the market," Winzeler says. "This project has allowed us to develop a deeper knowledge of power transmission in small vehicles. At the end of the day, this is what all the large transmission companies are talking about. Borg Warner and Getrag are discussing weight, friction reduction and sound quality. This all can be applied to larger horsepower vehicles. Our goal is to show our work to automotive transmission companies and discuss the options of plastic gear-

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Bradley engineering students worked with Winzeler on sizing the gears on the Ultra Light Urban Vehicle project.

The plastic transmission design gives Winzeler Gear a prototype for which they can build a business case.

ing in these applications."

By continually working with Bradley University on engineering projects, Winzeler Gear also has a great recruiting tool. "We're always looking for prospective employees and senior projects like this one can be a great resource for future engineers. Plus, we enjoy getting students involved in gearing and plastics. It also educates the college faculty on what's currently going on in the manufacturing industry."

Morris sees the relationship between Bradley and Winzeler Gear as a win-win for all participants. "We have collaborated on senior projects for the past ten years. I think the projects have delivered value to Winzeler Gear and I am certain the students have benefitted by working on their projects. We plan to continue refining our urban vehicle concept to look for weight savings, perhaps by modifying other parts of the power train to include plastic gears/components."

Morris hopes by demonstrating the life and load carrying capacity of the plastic gears for this type of application that it benefits Winzeler's business.

As for Winzeler's concerns about teeth breaking or an electric vehicle that fails to move forward, there was never any reason to panic.

"The gear system is quiet, and it resulted in a system of reasonable size and speed for the drivetrain. The vehicle is an improvement over the previous vehicle, and it will be licensed for street driving," Morris says.

Morris notes that the electric car design is an important component to the country's energy future, a future where President Obama hopes to see one million electric cars operating on U.S. roads by 2012. For now, he's simply satisfied with a compact vehicle that can take his wife to the grocery store and back without wasting energy.

"Our economy, our manufacturing base, our standard of living is linked to the availability of affordable energy in the United States. Everything we do involves the conversion of available energy. As a nation, we cannot afford to waste this," Morris says. "Furthermore, I believe that our consumption and dependence on foreign oil is a critical issue of our national security. Roughly 1/3 of our national energy consumption can be related to transportation. That's a lot of energy. The significance of this work is directly linked to energy, its cost, and the resulting effect on our economy."

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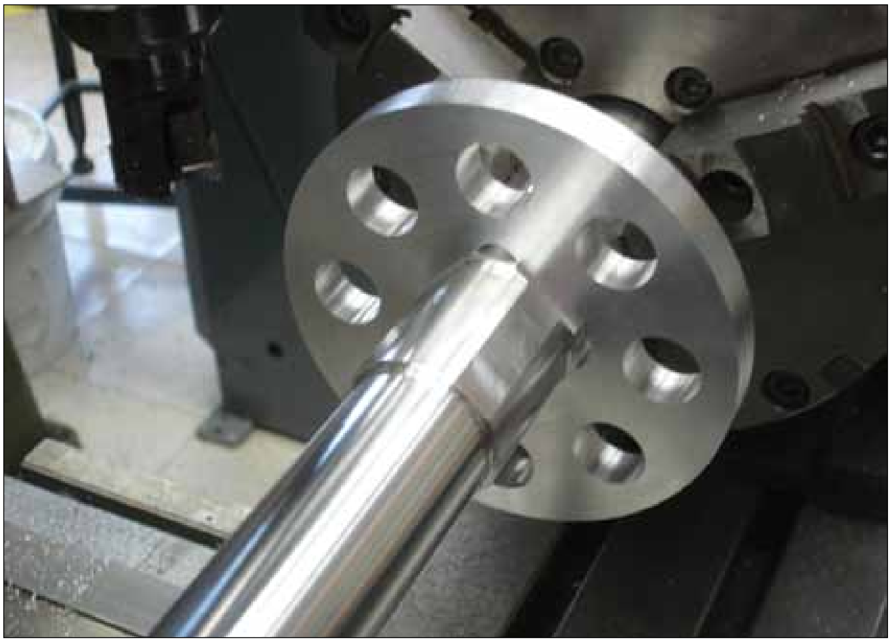

Bradley students were also involved in the machining of the housing and carrier shaft (pictured above).

The Electric Car: A Timeline

Robert Anderson invented the first crude electric carriage sometime between 1832 and 1839. American inventor Thomas Davenport and his Scottish counterpart Robert Davidson created electric road vehicles with non-rechargeable electric cells in 1842. An improved capacity storage battery came in the late 1800s as the electric concept began to flourish. In 1897, the first commercial application was established with a New York City taxi fleet built by the Electric Carriage and Wagon Company of Philadelphia. Woods Electric Phaeton, built in 1902, had a range of 18 miles, a top speed of 14 mph and a cost of $2,000.

In 1916, Woods invented a hybrid car that had both an internal combustion engine and an electric motor. By 1935, due to a long list of new inventions, the electric vehicle had all but disappeared. Once the 1960s and 1970s came along, electric vehicles began making a comeback with concerns over fuel emissions and the dependency of foreign crude oil. Sebring-Vanguard and the Elcar Corporation were two electric car leaders at this period of time.

Energy legislation, including the U.S. 1990 Clean Air Act Amendment and the U.S. 1992 Energy Policy Act, renewed electric vehicle developments in the 1990s. But by 2000, the vehicles weren't getting the attention of anyone but environmental activists. A documentary film released in 2006 titled Who Killed the Electric Car discussed a possible conspiracy involving the automakers and oil companies against energy efficient alternatives. In addition, the recent economic recession brought energy and sustainability back to mainstream media.

Today, energy advocates and consumers all but demand more energy efficient products from auto manufacturers. The Detroit Three and foreign automobile companies alike are providing more electric and hybrid options. As for urban transportation, rapid bus transport, bicycle superhighways and small energy efficient vehicles like the ULUV, might be the answer to solving energy problems in the future. The fact that Google is full of electric urban vehicle concepts is a sign that engineers all over the world are taking energy efficient vehicles very seriously. For more information, visit *www.hybridcars.com*.