

Shell ECO-MARATHON® AMERICAS

TEAM FACT SHEET

Rose-Hulman Institute of Technology

Country: United States

Design Class: Prototype

Fuel Type: Gasoline (Petrol)

Team Name: Rose-Hulman Efficient Vehicles

Vehicle Name: RHEV 74++

Team Members:

Aren Thompson - Team Manager

Berry Mayfield - Team Member

Blake Lin - Team Member

Jason Kohler - Team Member

John Cergnul - Team Member

Kevin Collins - Team Member

Tony Bowden - Team Member

Cheyenne Arrowsing - Driver

Dr. Allen White - Advisor



Award Submission(s):

Technical Innovation

This year we decided to continue the work we started last year in developing our own engine controller. Bought from Mototron, the 112-pin module we are using works on code we write in Matlab's Simulink, which is then translated into C code. As purchased, the module is a blank slate, onto which we build everything we need to run the engine and interact with the driver. This same module is used by another Rose-Hulman team to control a hybrid SUV. The reasoning behind going this direction is to give the level of control afforded to modern vehicles, where previously we relied on a carburetor or a simple aftermarket controller. The controller bridges several subsystems including the engine, clutch and driver.

Engine

With this goal in mind, we designed the architecture of our controller to provide active feedback to our fueling decisions. In order to supply the correct amount of fuel to the engine, we must measure how much air enters the intake. To do so, we are utilizing a TMAP (temperature-manifold air pressure) sensor, which feeds into our controller. Knowing the temperature and pressure, we calculate the mass of oxygen in the volume of air and determine the mass of fuel required to achieve the desired AFR (air-fuel ratio). This value then enters a lookup table based on a calibration we performed on the fuel injector's flow rate for different duty cycles. Now knowing the time we want to keep the fuel injector open, we set the appropriate spark and fuel advance based on engine rpm, which is read by two sensors, located on the cam and crank. These signals output the controller and activate the injector and spark coil as instructed. After a few cycles have passed, the controller then looks at the exhaust oxygen sensor, which serves as the correction in our control loop. This sensor tells us the whether we are running lean or rich based on the oxygen content of the exhaust gases. With this information, we modify our fueling values as needed to maintain a constant AFR. All of these calculations in our code are executed every 5 ms, or 200 times a second, while the controller runs its own internal logic at 80 MHz.

Clutch

Another technological advance this year for the Rose-Hulman Efficient Vehicles Team is the addition of new rear wheel clutch. We implemented a clutch at the rear wheel to eliminate the losses associated with the traditional approach, a bike sprag clutch. The issue with a sprag is that while coasting, the wheel drags every time the clutch indexes and clicks. While a small amount, this constitutes energy that we are putting into our vehicle in terms of gasoline that we do not get back, which harms fuel economy.

For the 2008 competition, we designed and built a clutch for the rear wheel that was activated by a lever arm connected to a linear-drive stepper motor. While the principle of this design was sound, it put the rear end under high stress and due to the size of the stepper motor, proved difficult to control.

Taking this experience in mind, we redesigned our clutch from the ground up, making our way through several design iterations from an AC compressor electromagnet to an engine side clutch, to a pneumatically actuated clutch. After several months of research and development, we decided that the simplest to manufacture and control solution would be to use a power screw to translate our sprocket carrier and clutch to the rear wheel, making the link between the engine and



the road. To actuate the clutch, we selected a rotary stepper motor that was much more powerful than our old motor, which is connected by chain to the sprocket carrier. Another issue corrected from last year's experience was that of clutch material wear. In the past, we used actual clutch material purchased online, but due to the amount of slip between surfaces, they wore quickly and spread dust particles throughout the engine compartment. To address this we changed to standard, rubber bike brake pads that were attached to our rear wheel sprocket. Not only do they have a higher coefficient of friction, but also the wear particles are not as fine and invasive. Using a standard part also means that if we need to replace the pads, we can just go to the store and pick some up.

Signals for the speed and direction of the stepper are sent via the controller to the stepper motor driver, which regulates the current and voltage.

Driver Interaction

Connecting the driver and the rest of the vehicle components is a finite state machine coded in StateFlow. When the driver pushes down the run button, a sequence of lights activate, indicating their state. After a delay to prevent accidental running, the driver releases the run button and the controller then turns on the starter motor, bringing up the engine to a software-defined speed. Once the engine can sustain itself, the starter shuts down and runs through the code explained in the engine section above. Measuring the vehicle speed through another speed sensor, the controller brings the engine as close to the vehicle speed as possible, so that the clutch can be engaged with as little slip as possible. Next, the vehicle accelerates and once the driver pushes the button again, the clutch disengages and the engine is shut down.

All of this control comes at the price of complexity, in terms of both hardware and software, but we feel that the flexibility afforded will push our team into a higher level of competition.

Besides the controller, we also made advancements in terms of our chassis. In the past, we used a carbon fiber composite panel with Nomex honeycomb that had large machined aluminum plates built into the panel at key locations. The team used that chassis for several years and we were concerned with the structural integrity, specifically at the areas around the inserts. We began this year by searching for a replacement panel, but had great difficulty finding someone who would be willing to make us one at a reasonable cost. Therefore we began to explore alternatives and decided on an aluminum skinned, aluminum honeycomb panel.

Our calculations showed that the new panel would be approximately 30% stiffer than our old panel and cost only a fraction of what else was available. The main issue became that because the panel was prebuilt, we had to devise a way of adding mounting points that would be secure enough to handle the loads encountered during driving. Initially, we planned on getting stock aircraft style inserts, but both the cost and lead-time were prohibitive. We then decided to make our own inserts out of aluminum that we would pot in using resin. The team made up several sample parts of different designs and ran tensile tests on them to see the load that would cause failure in either the panel or insert. Concurrently, we ran a finite element analysis (FEA) of the insert and panel, simulating the same loading we saw on the tensile tester. From both the analysis and experiments, we decided on an hourglass shape for the inserts.

Once we selected a design, we began the process of manufacturing the 64 inserts needed for the 74 and 74++ cars. We also had to develop a procedure for potting the



inserts in, including how to seal and hold them in place during the gluing process. It is our hope that these panels will hold up for several years and provide a reliable base on which to build our car.

