Alternate Fuel Technology – Hybrid Electric Vehicles

This is another in a continuing series of articles on alternate fuel vehicles. For comments or questions, contact ASE's Bob Rodriguez at 703-713-3086, or brodriguez@asecert.org.

Look out, hybrid electric vehicles are ~~coming~~… here!

So, what's a hybrid? A "hybrid" is normally an offspring of two dissimilar plants or animals, but the US Dept. of Energy defines a hybrid as a type of electric vehicle (HEV) which "…combines two or more energy conversion technologies (e.g., heat engines, fuel cells, generators, or motors) with one or more energy storage technologies (e.g., fuel, batteries, ultracapacitors, or flywheels)." Hybrid power is hardly new; it's been around for years. Pre-nuclear era submarines are diesel-electric hybrids; so are most of our railroad locomotives, many industrial machines, etc. From an automotive perspective, hybrids are still rare, but that's changing. Let's look closer at HEVs—what they are, where they are, and why they're showing up on our highways. After reading this, you might even find yourself shopping for one.

Hybrid electric vehicles (HEVs) are somewhat similar to today's conventional automobile except for their two "engines" (sources of power). Production and prototype HEVs are now on our streets and highways. Some are using gasoline or diesel internal combustion "heat" engines (or ICEs), a few use electricity-generating micro-turbines, and a few are using fuel cells. The fuel cell is an electro-chemical generator of electricity which uses pure hydrogen as fuel. While there's a lot of R&D focused on developing fuel cell "engines" for hybrids, various power sources may be used with traction batteries to power an electric motor connected to the wheels.

In today's gasoline-only vehicles, the ICE is "sized" to the vehicle for peak load demands like accelerating, hill climbing etc. Under straight and level cruising, only a fraction of the horsepower is used, making the ICE mostly an oversized and overweight parasitic load. While "pure" battery electric vehicles (BEVs) are considered pollution free, they unfortunately lack extended range, quick recharge, and a charging infrastructure… plus the batteries are heavy.

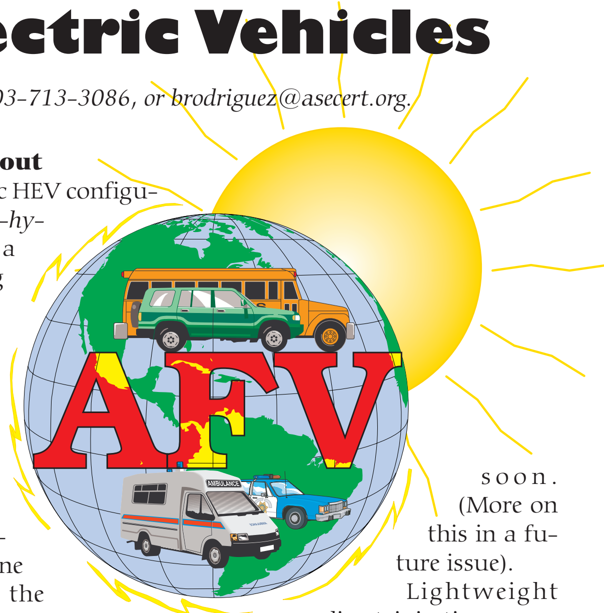
To overcome these obstacles, the lighter, cleaner, more fuel efficient hybrid-electric vehicle provides an alternative: the HEV uses an electric motor to serve as a supplemental power source for peak-load conditions. In a conventional vehicle, the engine must rev up to reach peak torque and horse power; whereas, an electric motor delivers full torque at low speeds, providing excellent acceleration—with low noise to boot. The traction storage batteries serve as an "on-demand" power source under load.

Thus, with the hybrid, the heat engine can be downsized and run at peak efficiency (peak-torque RPM) to propel the vehicle and to run the battery-charging generator. In some cases, planetary gear sets and continuously variable-speed transmissions (CVT) further optimize economy and performance. All components are harmoniously "load-controlled" by sophisticated computer algorithms programmed into high-speed integrated power modules. These modules oversee and manage virtually all vehicle functions, possibly including ICE shut-off when the vehicle is cruising, coasting, traveling at low speeds, or isn't moving. Coasting and braking conditions further enhance operating efficiency by allowing a return of energy to the batteries. All these strategies make perfect sense for drastically cutting fuel consumption and emissions.

Unlike battery EVs most hybrids are not set up for off-board overnight recharging. Nonetheless, by mating an electric drive with another power source, hybrids serve as a means of realizing the advantages of battery EVs while minimizing the range and weight issues. One industry spokesperson stated that the strengths of two-drive systems make hybrids an important step in our on-going quest for cleaner air, greater fuel economy, and energy independence. As David Baxta at Toyota stated "…we must work to reduce CO2 [global warming] by building lighter vehicle packaging, making powertrain improvements, and more intelligently managing vehicle systems."

Configurations

Most production hybrid-electric cars use a relatively small (~1 liter) gasoline or diesel ICE in concert with batteries and electric traction motor(s). Some HEV gasoline and diesel engines use direct fuel injection (into the combustion chamber). Diesel-electric hybrid transit busses are now using relatively small engines for lower emissions, and one bus configuration instead uses a pair of propane-powered micro-turbines to generate the needed power.



Component layout

There are two basic HEV configurations: The *series-hybrid system* uses a small fuel-burning engine to drive a generator for electricity—sent to one or more electric motors which drive the wheels. When the traction storage batteries need recharging, the engine starts up to run the generator for recharging. Some vehicles can be intentionally operated in an all-electric (zero-emissions) mode around town.

In the *parallel-hybrid system* there are two power paths. Either the fuel burning (heat) engine, the electric propulsion system, or both, power the wheels. For longer trips, the heat engine provides primary power to the vehicle with the electric motor assisting under peak loads.

Variations to these two basic systems exist. DaimlerChrysler's "through the road" system uses an ICE to power the vehicle's rear wheels and generator, while the electric propulsion system powers the front wheels. Military and commercial customers are testing hybrid electric vehicles with individually controlled in-wheel traction motors (E-wheels). While not new for non-road applications, wheel-hub motor placement can eliminate the need for a torque converter, transmission, transfer case and drive shafts, thus offering engineers radical space and weight savings design flexibility, and improved vehicle handling and traction.

Both battery EVs and hybrid EVs use advanced electronics to optimize load control and charging system operations under different driving conditions. "Fuzzy logic" programs remember individual motorist driving styles and are sometimes called upon for input to the integrated power module. Advanced design batteries like nickel-metal hydride and lithium-ion are often used in hybrid EVs (as in battery EVs) for high-power energy storage.

Where are we at with hybrids?

There's a lot going on. Two production HEVs are Honda's gasoline-electric Insight 2-seater sports coupe, and Toyota's Prius 4-5 passenger sedan. Both are on the road and buyers are standing in line. We'll see more HEV autos, vans, pickups and SUVs for sale soon. (More on this in a future issue).

Lightweight direct-injection gasoline (SIDI) and diesel (CIDI) engines, micro-turbines, and hydrogen fuel-cell hybrid vehicles are being evaluated in various cities and regions. Government funded research continues with partnerships between our nation's labs, universities and industry to find better HEV component designs, lighter and stronger materials, cleaner fuels and improved power-electronics programming.

Engineering students are applying hybrid vehicle design concepts to working vehicles as they compete in the U.S. Council for Automotive Research (USCAR) challenge. The U.S. Department of Energy's Office of Advanced Automotive Technology, GM, Ford, Chrysler and the National Renewable Energy Lab are all working together under the President's PNGV initiative (Partnership for a New Generation of Vehicles) to produce by 2004 a variety of automobiles featuring all the comfort and performance of today's passenger cars, yet achieving 80 miles per gallon. The use of production-feasible hybrid-electric propulsion system technologies, lighter and stronger materials throughout, aerodynamic styling, advanced electronics and special tires all help to achieve this aggressive goal.

Way down the road…

Will internal combustion engine (ICE) hybrids take over and dominate the vehicle landscape of the future? Experts say probably not. While HEVs featuring various heat engines—using a variety of fuels—will penetrate the marketplace, Ben Knight of American Honda summed up industry speculation when he stated that the heat-engine hybrid is a "bridge" technology ultimately paving the way for *hydrogen* powered fuel-cell hybrids. The fuel-cell vehicle (FCV) is projected to take market share from conventional heat engine vehicles, ICE hybrids and other alternate fuel vehicles, but not for some time to come. A lot of this has to do with vehicle and component costs and fueling station infrastructure. An American Methanol Institute report predicts that by 2020, seven to 20% of all new cars sold will be powered by fuel cells. As stated by Hiroyuki Watanabe at Toyota, "…there will be a time when various engines and power sources will exist simultaneously."

For now, those who service and repair today's vehicles will have plenty of work to do. And for those trained and equipped for hybrid vehicle service and repair, hybrids have *two* power sources to work on.

Editor's Note: *Further details on hybrid-electric vehicles and hydrogen fuel-cell vehicles will be covered in future editions of* TechNews.

Hybrid EVs from Toyota and Honda

Clockwise from top left:

Toyota Prius HEV. *Toyota's 4 cyl. "Generation 1" hybrid seats 5 and gets around 50 mpg.*

Toyota Prius Underhood. *Not exactly what you'd expect when you pop the hood of a Toyota… You're looking at the engine on the left and the inverter module on the right.*

Honda Insight HEV. *Honda's 3 cyl. seats 2 and gets around 70 mpg.*

Honda Insight Underhood. *Look close… under the cover is the Insight's 3 cyl. Engine.*