Hybrid Cars

In conventional automobiles, more than 80% of the energy that goes into the engine is lost. First, most of the energy value of the fuel is given off as heat; then the engine continues to run while the car is slowing down or stopped. At those times, the fuel driving the engine is wasted. When a car accelerates it gains kinetic (motion) energy, but during braking all of that energy is dissipated as useless heat. The goal of hybrid automobile technology is to use electrical power as a buffer to reduce these wastes to a minimum.

Hybrid cars combine a conventional internal combustion engine with an electric generator and batteries to use fuel only when it is needed, and to recapture some of the kinetic energy dissipated when a vehicle is slowing. There are two basic designs: parallel hybrids and serial hybrids.

In a parallel hybrid, such as the Toyota Prius, a gasoline engine drives the wheels directly through a mechanical transmission, and also can charge storage batteries through a generator. The generator can also be driven by the car’s wheels during braking, a process known as regenerative braking. Energy thus stored in the batteries is released when not very much power is need to drive the vehicle, such as low-speed driving or constant-speed cruising on level highways or slight downslopes. Under these conditions the generator serves as an electric motor to drive the vehicle. When peak power is required, the engine and the electric motor work together to propel the vehicle. The engine is turned off when not required, and automatically restarted to recharge the batteries or when power needs are too great for the electric drive alone. Restarting is through the large electric motor powered by the propulsion battery pack, so it is silent and transparent to the driver. This can be disconcerting to new hybrid drivers, when the engine quits while the vehicle is moving. Eventually the hybrid driver, when switching to a conventional vehicle, wonders why the engine is running when it’s not needed. Some of the hybrid advantage is not realized for short trips because the engine runs continuously to warm it up upon starting.

A second variety of parallel hybrid, such as the Honda system, returns energy to batteries by regenerative braking. During acceleration, the gasoline engine is aided by the generator, which then functions as a motor. The engine does not directly charge the batteries, though, and it runs constantly during normal operation.

Serial hybrids have no direct connection from the gasoline engine to the wheels. Instead, the engine runs a generator, which then powers electric motors at the wheels. This design requires a larger generator and separate electric motors, because they must provide enough power to run the vehicle during peak loads (acceleration and uphill operation). Unlike the parallel design, the generator cannot double as a motor when electrical power is required, because both generator and motor are in constant operation. As of this writing there are no serial hybrid vehicles on the market, though the Chevrolet Volt will be a series design. The closest approach to the serial design in current use is in diesel-electric locomotives, where the engine drives a generator that drives the wheels. Braking is partly regenerative to reduce wear on friction brakes, but in current locomotives the regenerated power is wasted by running it through air-cooled resistors on the roof of the engine.
Because of the extra weight of the larger generator and electric motor, the serial design is generally heavier than the parallel design. Both designs share the use of batteries that can be charged for assistance with peak loads, so that the gasoline engine can be smaller than would be required in a conventional automobile. A substantial portion of the weight of the engine in conventional automobiles is dedicated to peak-power capacity that is hardly ever required. Only when the accelerator is ‘floored’ can a conventional automobile use all of the power available in the engine, and then the maximum power is available only at an optimal engine rotation speed, higher than that used in normal operation. Running such an engine at less than its maximal throttle reduces its efficiency and gasoline mileage. Hybrids, in contrast, can use maximum or optimum engine settings at any speed, so a much smaller and less powerful engine is required.

The most popular of the hybrids, the Toyota Prius, has sold over a million vehicles, and the technology has been licensed to several other manufacturers. The vehicle has several other energy-saving features in addition to the basic hybrid technology. It offers less wind resistance than any other automobile, and is equipped with stiffer tires that give less rolling resistance than conventional tires. Software replaces hardware for many of the vehicle’s functions, such as the instrument panel and cruise control. There is no mechanical reverse gear—the direction of rotation of the electric motor is simply reversed by the motor control software. Reverse is always a low-speed operation, so the vehicle is driven only by electric power when going backward. The delivery of electric energy to the motor’s rotors is also managed by software, without mechanical brushes. The gasoline tank is smaller and therefore lighter than in other vehicles of similar size and weight, because of the higher mileage rating. Engine cooling is passive when the engine is temporarily turned off, saving the energy that would otherwise be needed to run a water pump. The transmission consists of a planetary gear with only a handful of moving parts, in contrast to the hundreds of parts in a conventional automatic transmission. With all of these strategies, the Prius gets nearly twice the gasoline mileage of a conventional sedan of comparable weight.

The next step in hybrid automobile technology will be the plug-in hybrid, a vehicle with enough battery capacity to drive the car for short trips on electricity alone. The Volt is proposed to have a battery-only range of about 40 miles (65 km); since most trips are shorter than this, the gasoline engine will seldom engage. The practicality of this design depends on high-efficiency batteries. All hybrids use batteries that offer more power for a given amount of weight than the traditional lead-acid battery of conventional vehicles. The only function of that battery is to start the engine and to run accessories such as lights and radio. Hybrids also have a small lead-acid battery that acts as a buffer to run the vehicle’s 12-volt accessories. That battery is charged by the main batteries but has no role in propelling the vehicle. The propulsion batteries, in contrast, are linked in series to provide several hundred volts to the electric motor.

Nickel-metal-hydride (NiMH) batteries constitute the main battery pack of the Prius. They have substantially higher power density (energy stored per kg of battery weight) than lead-acid batteries, and can handle thousands of discharge cycles if managed properly. Software in the Prius optimizes battery life to roughly correspond with the expected service life of the vehicle. Future hybrids will probably use lithium batteries that offer an even greater power density, enough to make electric-only operation practical for
significant distances. Issues of safety and service life have been largely overcome by intelligent computer-controlled battery management schemes.

The hybrid is a transition technology, developed to conserve dwindling oil supplies. The technology required has been available for decades, but was introduced only when gasoline became so expensive that the hybrid scheme was justified economically. Inexpensive oil, meaning oil pumped from onshore wells not in the arctic, peaked in 2005, and worldwide production as a whole will probably peak between 2010 and 2015. It is physically impossible to pump oil for much longer at the present rate of about a thousand barrels per second. Most oil currently produced comes from a handful of giant oil fields that are becoming depleted; the smaller fields that replace them cannot provide the volume previously available. Since the 1970s more oil has been pumped each year than has been discovered in that year. Alternative sources such as tar sands cannot approach the current rate of consumption, and biofuels are an illusion – it takes nearly as much fossil fuel energy to produce them as is recovered from burning them. Hybrid technology makes it practical to continue current driving habits with gasoline at twice its traditional price, but even that situation will not last for very many years as oil supplies dwindle while population continues to increase.

Another function of hybrids is as a test platform for electric drive technology. Alternative energy sources such as wind, solar and geothermal will have to replace gasoline for powering vehicles; these sources provide electricity, not liquid fuel, so all-electric vehicles will become necessary. Wind and solar electricity will be intermittent, so that batteries can be charged only while the sun is shining or the wind blowing, and the power will be more expensive than present electricity, but for limited uses it will be possible to propel vehicles far into the future.

Bibliography


Bruce Bridgeman
University of California, Santa Cruz

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