eVI ELECTRIC VEHICLE INSTITUTE

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Hybrid Booster Drive™ Description

The Hybrid Booster Drive™, or HBD, is a system which complements the existing propulsion system in the vehicle in which it is installed. That vehicle then becomes a hybrid vehicle, using a combination of two types of energy, fuel and electric. The HBD equipped vehicle is an engine dominated, parallel electric hybrid.

The HBD system is intended for vehicles with missions (or routes) requiring numerous stops and speeds primarily below 35 mph. Testing of the prototype on such routes has demonstrated up to 30% increase in mpg. Actual savings depend on drive cycle.

The HBD™ does not affect the normal operation of the internal combustion (IC) powered system and an HBD™ equipped vehicle will operate under IC power alone if the HBD™ is disabled.

The Hybrid Booster Drive™ consists of four component modules: an AC electric traction module, a motor controller module, an ultracapacitor storage module and supervisory control module with integral operational software. The HBD supplements the existing IC drive system in the vehicle. At no time does the HBD do it all. The engine always remains running, although it is not used as hard. Even during braking, the HBD may provide all the stopping power needed, but blends seamlessly and unobtrusively with the existing service brakes when needed.

All four component modules of the HBD™ are scalable in design, require little or no maintenance, and are expected to last the life of the vehicle.

Operation

The HBD electric motor is close-coupled to a planetary speed reducer which is then connected to a parallel shaft transfer case. The transfer case is coupled to the vehicle's power train via the vehicle's drive shaft, located between the transmission and the rear end. The reducer transfer case provides a speed ratio reduction. The transfer case also provides a means to clutch the electric motor from the vehicle drive shaft with a 12 volt electrical signal. The HBD supervisory control automatically disengages, synchronizes and re-engages the electric motor from the drive shaft depending on the vehicle speed. The electric motor provides torque for acceleration and regeneration only below 40 mph. Above 40 mph, the electric motor is disengaged.

The electric motor is an induction motor which is liquid cooled using automatic transmission fluid (ATF). ATF also provides lubrication for the motor bearings and the close-coupled planetary gear box. ATF is contained in an oil sump attached to the bottom of the electric motor. The coolant oil is circulated, via a lube pump, from the sump through a filter and heat exchangers (radiators) and then to the motor and gearbox. The pump is gear driven from the transfer case. This coolant oil is used only for the electric motor and close-coupled planetary box. The transfer case lubricant is self contained.

The electric motor is designed to operate at speeds up to 12,000 rpm. It requires power in the form of three phase alternating current (AC). The electrical energy storage system (EESS) operates on direct current (DC). A three phase full bridge inverter is used to convert the DC to AC and visa versa. This is the main power component of the motor controller. The motor controller operates in flux vector mode with velocity feedback from the electric motor via an encoder (pulse generator) attached to the end of the motor. This control mode allows for four quadrant torque control, although only two quadrants are used, forward rotation, positive and negative torque. The electric motor is not used for vehicle reverse travel.

The HBD supervisory controller monitors state functions of the vehicle systems, both internal combustion (IC) and electric propulsion (EP), and the operator (driver) inputs to determine the torque requirement, both IC and EP. The torque produced by the electric motor and engine is determined by the HBD supervisory controller which communicates with both the motor and engine controllers. The torque is proportioned between the IC and EP to yield required acceleration while using the appropriate amount of electrical energy from the EESS and minimizing the torque from the IC engine, which reduces the fuel consumption and emissions.

During the braking event (deceleration) below 40 mph, the electric motor produces negative torque, or regenerates. This action converts the kinetic energy of the vehicle into electric energy which is stored in the EESS, while slowing the vehicle's speed. A sensor is attached to the brake pedal which provides a proportional signal to the supervisory controller which then determines the appropriate torque command to send to the motor controller. The HBD supervisory control is not physically connected to the vehicle electronic brake control or hydraulic system.

Below 40 mph, regenerative braking can provide sufficient torque (power) to nearly bring the vehicle to a complete stop. Regeneration captures energy normally lost as heat in the friction brakes. This captured energy can be viewed as free energy because fuel is not used to produce it. The supervisory control is programmed to maximize the amount of energy derived in this method, taking into consideration all conditions. The service brakes (friction) come into use only at very low speed or in the event of an emergency stop.

The energy captured during the regeneration event is stored aboard the vehicle in the EESS. The HBD system features ultracapacitors as the primary electrical storage device. Ultracapacitors function in a similar manner as do batteries, but offer advantages in areas such as maintenance, efficiency, charge rate, temperature range, cycle life and cost. Ultracapacitors are high power devices compared to batteries, but store less energy, pound for pound. The size of the ultracapacitor system in the HBD is optimized for the vehicle mass and mission. Typically, the HBD ultracapacitor is sized to store energy from one deceleration from 40 mph to zero.

The EESS is charged during deceleration. While the vehicle is stopped, the ultracapacitors are at a high state of charge (SOC), ideally fully charged (100% SOC). This energy is then used to supplement the IC engine through the EP for the next acceleration. The IC engine output is held back by the supervisory control, in most cases, to about 50 %. This is done proportionally at different speeds in order to minimize fuel consumption while providing seamless operation.

After the vehicle has accelerated to 35 or 40 mph, the energy which had been stored in the EESS is nearly depleted (low SOC). Vehicle operation at cruising speeds or above 40 mph is not aided by the HBD. The EESS is intentionally left at a low SOC while the vehicle is cruising so that there will be capacity to store the energy from the next deceleration. The control also adjusts SOC and "electric boost" based on the vehicle drive cycle to maximize performance. There are also times when a small amount of energy is siphoned from the vehicle IC driveline and added to the EESS during cruise to adjust the system state. All of these actions are done automatically by the supervisory control.

Environmental Benefits

The HBD™ reduces emissions and increases fuel mileage. These benefits are achieved by allowing the engine to operate at a steadier and efficient load range and recovering energy from stopping events. In many applications the engine can be downsized to further increase mileage, lower emissions and reduce weight. HBD™ can be used on vehicles with diesel, gasoline, CNG, LPG, or 'Clean Diesel' fueled engines.