ETHANOL BOOSTING SYSTEMS, LLC

Ethanol Turbo Boost for Gasoline Engines: Diesel and Hybrid Equivalent Efficiency at an Affordable Cost

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Affordable, Clean, High Efficiency Options for Addressing Future Fuel Economy Requirements

Heightened concerns about energy security and global warming along with increased customer interest in high fuel economy point to the need for an enhanced set of options for affordable, clean, high efficiency engines. Affordability is a key issue for mass market penetration and the prospect of more stringent future emissions standards require that these options be extremely low polluting. Use of Ethanol Boosting Systems (EBS) technology in turbo gasoline engines could provide a major addition to the set of high fuel efficiency options being intensively developed today by auto manufacturers around the globe, particularly because of its cost effectiveness.

EBS technology could offer a much more affordable approach than either the "clean" diesel or gasoline/electric hybrid propulsion technologies now in intensive development. The advantage is particularly strong for light duty trucks and other vehicles which utilize high torque, high horsepower engines. The EBS technology would be much more attractive to consumers because of the lower upfront incremental cost – less than one third of the diesel or hybrid options – and a much shorter payback time (approximately 3 years versus 10 years, at present US gasoline prices).

EBS Technology

Using Ethanol To Realize The Full Potential Of Gasoline Engines

EBS technology makes it possible to realize the full potential of gasoline engines by utilizing the special performance enhancing properties of ethanol in conjunction with recent advances in direct injection (DI) and turbocharging. It builds on the growing interest and availability of ethanol. The EBS approach uses controlled direct ethanol injection to add a very significant "vaporization-enhanced" on-demand octane increase that essentially removes the knock limit on engine performance. The elimination of the knock constraint has been proven by systematic engine dynamometer tests. This allows a small gasoline engine to provide the same or higher torque as compared to a conventional engine of much larger size. This downsizing, combined with the use of high compression ratio, enables gasoline engine operation with 25% to 30% greater efficiency in typical city-highway driving. The ethanol can be in the form of E85.

Ethanol Consumption and Refueling

The EBS technology essentially eliminates the knock limit in spark-ignited engines, allowing operation at higher compression ratio (12 or greater) and increased turbocharging. Large engine downsizing along with stoichiometric operation provides the highest possible efficiency in a spark ignition gasoline engine while maintaining the very low emissions levels attainable with three-way catalytic converters. The relatively light, compact, high power-density engine enabled through the use of EBS technology is an especially cost effective way to increase efficiency. By using E85 only when needed to prevent knock (at higher levels of torque), its use can be limited to ~ 5% of the gasoline use for regular metro/highway driving.

For regular metro/highway driving, refueling could be as infrequent as once every four to six months and could be done at the dealer or at a garage at the same time as regular servicing. Alternatively, the driver or a service station attendant could replenish the octane boost fuel using 1 or 2 gallon containers – similar to the case of using the containers of methanol-water mix that are used as windshield cleaner. 100% methanol containing a small amount of gasoline could, in fact, be used as a backup option to E85. Due to its higher effectiveness in suppressing knock, use of methanol can reduce the octane boost fuel requirement by about a factor of two. The driver could also use one of the currently limited but rapidly increasing E85 pumps, now numbering ~ 1300 nationwide.

The octane boost fuel additive refill frequency requirements for the EBS technology are similar to those for urea for the SCR aftertreatment for clean diesels. If ethanol or methanol are not available, the vehicle can still be operated satisfactorily, though at a lower maximum power level.

Octane Boost Additive For Enabling High Efficiency Gasoline Engine Vehicles

An immediate large market application of EBS technology is to provide octane boosting that greatly enhances the capability of gasoline engines. This is feasible with the on-demand octane additive of the secondary fuel. The ethanol is stored in a separate fuel compartment from the gasoline and is used only when needed to prevent engine knock at high torque. The large evaporative cooling effect of directly injected ethanol provides a knock suppression effect that is equivalent to gasoline with an octane number of more than 150. With appropriate control, typical ethanol use can be limited to 5% or less of gasoline use in first generation EBS systems and 3% or less in advanced systems. With this small requirement, the ethanol tank refill could occur as infrequently as once every 4 to 6 months. If E85 pumps are not available, refill could be done at the dealer at the time of regular servicing. The refill could also be carried out at fleet refueling stations. As more E85 fueling stations become available, the driver will have increased opportunity for refill in a typical manner. An additional option is for the driver or a service station attendant to refill the octane boost fuel additive tank using containers of E85 or some other form of ethanol.

Gasoline Engines With Diesel Equivalent and Hybrid Efficiency At Much Lower Cost

For a typical light duty truck, the EBS technology is projected to provide a 25% - 30% increase in city-highway efficiency over a state of the art conventional naturally aspirated gasoline engine for a cost of approximately $1,400. In contrast, a clean diesel provides an equivalent efficiency (in miles/BTU of fuel or the km/gm CO_2 standard which is used in Europe) at an incremental cost of around $5,000. EBS technology provides a substantial cost savings in addition to the benefit of much greater assurance in meeting future, more stringent air pollutant emission standards, while delivering higher horsepower.

EBS technology can also provide an important cost advantage relative to the full gasoline/electric hybrid, especially for trucks and SUVs that require large, high power engines. The additional cost of the full hybrid powertrain for these vehicles is estimated to exceed $5,000. The EBS technology provides an efficiency gain that approaches that of the full gasoline/electric hybrid at a much lower cost (the typical city-highway efficiency gain for full hybrid is 25% - 40 %). For EBS technology, the incremental cost divided by percentage efficiency gain has a value of approximately $50/% increased efficiency. This value is on the order of one-third that of the clean diesel and the full hybrid. The EBS engine is also projected to have a cost/% efficiency gain 40% lower than GTDI.

Enhanced Performance Of Flex Fuel Vehicles

EBS technology can be used to enhance the practicality and performance of emerging dedicated E85 fueled vehicle concepts that use DI to obtain high performance and high efficiency. These concepts have limited turbocharging in order to prevent knock when operated with gasoline alone or with a low concentration ethanol-gasoline blend. Present dedicated E85 fueled vehicle concepts do not provide the desired combination of high efficiency and ability to operate without degraded performance when used as flex fuel vehicles with gasoline operation. This drawback can be eliminated by use of EBS technology. By using an additional fuel compartment which is only filled with E85 and where the E85 is used only when needed as an octane boost additive for gasoline operation, the need to reduce performance can be essentially eliminated. It is thus possible to operate with no reduction in torque/power when E85 is not available every time the primary tank is refilled. The E85 in the additional tank could be refilled as infrequently as once every 6 months and, if desired, the extra tank could be topped off every time that the primary tank is filled with E85. The presence of the additional fuel compartment for only E85 effectively guarantees that the vehicle will always have the capability be powered with close to 100% gasoline without degrading performance. The extra components for obtaining this capability are a second fuel compartment or tank and a set of port fuel injectors. This additional cost is estimated to be around $300.

Lower Cost, High Efficiency Hybrid Powertrains

EBS technology can also be used with a hybrid powertrain and could be particularly attractive when combined only with a relatively simple engine shutdown-restart capability. The highly downsized EBS engine would be considerably easier to restart than the larger engine that it would replace. This option has not been explored in detail, even by computer modeling. Basic physical considerations indicate that it should add approximately another 10% in efficiency gain, primarily in city driving, bringing the total efficiency gain to well above 30% for combined city/highway driving, with a possible 35% to 40% gain. The cost for the engine shutdown-restart system is preliminarily estimated to be $1,000. If this estimate is correct, the EBS approach combined with engine shutdown-restart could yield an efficiency gain which is equal to or greater than the present full hybrid at a cost of approximately $2,500 for a light duty truck. The cost per percentage increase in fuel efficiency would be around $70% efficiency gain. This cost would be about one half or less of that of present full hybrid for light duty trucks.