Ethanol Boosting Systems LLC (EBS)

Turbo Gasoline Engines Using Direct Injection Alcohol Boosting:
An Affordable Solution for Clean, High Efficiency Cars and Trucks

Summary

Ethanol Boosting Systems (EBS), an MIT spinoff company, is commercializing a near-term solution for high fuel efficiency in cars and light duty trucks at an affordable cost
Our engine technology is called Direct Injection (DI) Alcohol Boosting, and is used with turbocharged gasoline engines. It involves on-demand injection of an alcohol containing fluid, such as an ethanol or methanol-water mixture similar to windshield cleaner) or E85, into the engine. This on-demand direct injection allows operation of a given size gasoline engine at much greater power and at higher compression ratio. This makes it possible for automakers to use much smaller and more efficient engines to achieve the same or better performance as today's engines. The amount of alcohol containing fluid that is used is small- on the order of 1 to 2 gallons per 100 gallons of gasoline and could be replenished at the same time that the oil is changed. DI alcohol boosting is especially attractive for improving the efficiency of light trucks at a low cost. Improving the efficiency of light duty trucks could have the largest transportation sector impact in reducing US oil imports and greenhouse gas emissions due to their high fuel consumption.

DI Alcohol boosting provides a much more cost effective way to meet higher fuel efficiency CAFE and possible California CO_2 emission standards for cars and light duty trucks than the clean diesel or hybrid propulsion solutions. The cost effectiveness of a high efficiency solution can be measured by the ratio of incremental cost (relative to today's port fuel injected engines) to percent fuel savings. This metric provides both a measure of economic attractiveness to the consumer and a means for determining the cost per gram of CO_2 reduction. The cost / % fuel savings for DI alcohol boosted gasoline engines is around 25- 30% of the ratio for the hybrid and clean diesel solutions. At present US gasoline prices, the fuel savings back payback time is around 4 years in contrast to more than 12 years for these other solutions.

DI alcohol boosting enables an energy efficiency and torque in gasoline engines comparable to turbo diesel engines and can provide significantly higher power. Because of their high efficiency and performance, turbo diesel engines are used in around half of the new cars produced in Europe. However, the use of diesel engines in cars and light duty trucks in the US has been very limited due to the high levels of pollutants generated by diesel engines and the resulting need for new, complex and expensive treatment systems. A higher price of diesel fuel relative to gasoline can be another drawback. EBS technology can provide the benefits of diesel engines without these drawbacks.

DI alcohol boosting is a new combination of existing technologies and can be deployed on production vehicles at affordable cost within four years. Because of its affordability, it makes

possible large volume market penetration of high fuel efficiency cars and light duty trucks in the near term. It does not require reinvention of the car or costly retooling of existing plants.

In addition, DI Alcohol Boosted gasoline engines could also be used to further improve the efficiency and lower the cost of longer-term solutions such as conventional hybrids and plug-in hybrids.

EBS has been working in collaboration with Ford Motor Company. Engine tests at Ford support the EBS projections for the performance and efficiency gains that can be provided by DI alcohol boosted engines.

EBS technology provides the lowest cost and most rapid means for America to reduce oil dependence and CO_2 emissions from vehicles. It can greatly accelerate the mass-market deployment of high fuel efficiency cars and light trucks and reduction of oil dependence. It also provides a way for American industry to pioneer a new automotive technology in a way that is analogous to the pioneering of hybrid vehicles by Japanese companies and diesel engine cars by European companies. This new technology could help in the revitalization of the American automobile industry

EBS technology can also provide substantially improved engine technology for medium and heavy duty vehicles. In comparison to diesel engine technology, DI Alcohol boost can be used as a lower cost, cleaner solution for meeting more stringent emission requirements, particularly recent California regulations, for medium –heavy duty trucks and buses. In addition to these advantages, DI alcohol boost can provide considerably more horsepower for a given level of torque and fuel efficiency.

Our Company

EBS was founded by Dr. Leslie Bromberg, Dr. Daniel R. Cohn and Professor John Heywood. In addition to the MIT founders, the EBS team includes Dr. Neil W. Ressler, former vice president and Chief Technology Officer of Ford. Other members are John A. Casesa, former head of automotive research at Merrill Lynch, John M. Bradley, a former member of the board of Cabot Corporation, J. Bennett Johnston (D. LA) former U.S. Senator who chaired the Energy and Water Appropriations Sub Committee and later served on the Chevron Texaco board.

Direct Injection Alcohol Boosting In Light Duty Vehicles

Relative to today's common port fuel-injected gasoline engines in cars and light duty trucks, DI Alcohol Boosting provides an efficiency gain for typical combined city-highway driving of 25%-30%, at an incremental cost of $1,100-$1,500 depending on the size of the vehicle. The energy efficiency gain and torque are comparable to turbo-diesel technology, but at around one third of the incremental cost and with the advantages of lower emissions and less costly fuel. Emissions of pollutants such as nitrogen oxides are suppressed to the very low levels of state-of-the-art gasoline engine vehicles using the same highly effective catalytic converter technology that is employed in these vehicles.

DI Alcohol boosted gasoline engines are a natural extension of the gasoline turbocharged direct injection (GTDI) engine technology that is planned for substantial introduction in light duty vehicles in 2011. GTDI engines using regular gasoline provide a 10 -15% efficiency gain relative to today's port fuel injected gasoline engines. The 25 -30 % efficiency gain provided by DI alcohol boost is at least two times greater than that provided by GTDI. The incremental cost for this efficiency gain is less than twice that for GTDI, resulting in a lower incremental cost/% fuel savings ratio.

A schematic diagram of the technology is shown in the figure below. Direct injection of a an appropriate fluid such as an alcohol –water mixture or E85, essentially removes a basic limit on gasoline engine operation, the occurrence of knock (uncontrolled detonation which can damage the engine) at high torque. The direct injection effectively increases the octane of the fuel in the engine, which is a measure of knock resistance, to more than 150. The technology can thus also be referred to as "DI Octane Boost™ "This makes it possible to use a much smaller and more efficient engine to obtain the same performance as today's large engines. Representative parameters for these high power density engines are a manifold pressure of 2.5 bar and a compression ratio of 12.5. The direct injection of an appropriate liquid into the engine provides exceptionally effective knock suppression due to its large vaporization cooling. The alcohol is directly injected from the separate tank only when and in an amount needed to prevent knock at high torque, minimizing the alcohol consumption so that it can be limited to a very small fraction of gasoline consumption

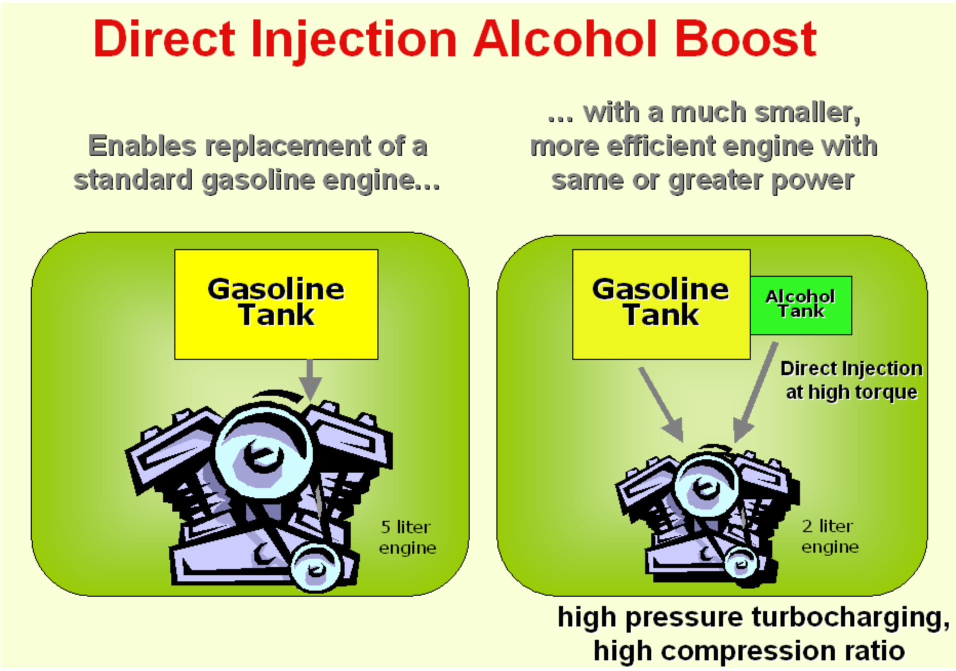

Illustration Of DI Alcohol Boosting

DI Alcohol Boosting is flexible and practical in that a variety of alcohol forms may be employed, including E85 ethanol and windshield cleaner fluid.

With an appropriate size tank, the typical E85 refill interval in cars and light duty trucks could be as long as five thousand miles — if desired — and could either be provided by service station pumps where available or at the dealer or garage at the time of regular servicing. In addition to use in gasoline powered vehicles, E 85 is a natural fit with flex fuel vehicles. Use of DI alcohol boosting can compensate for most of the miles per gallon loss of around 30% that occurs when E85 is used in present flex fuel vehicles due to the lower energy density of E 85 relative to gasoline.

Alternatively, an alcohol –water mixture can be used as the anti-knock fluid instead of E85. It has the advantage of widespread availability and a substantially lower consumption rate than E85. For typical car and light duty truck driving the amount needed to prevent knock is 1 to 2 gallons for every 100 gallons of gasoline. The refill could either be done by the motorist using windshield cleaner containers or at the dealer or garage at the time of regular servicing. With an appropriately sized tank, the refill interval could be ten thousand miles. The alcohol –water mixture can be an ethanol –water mixture or a methanol –water mixture similar to the mixtures that are used for windshield cleaner in the Europe and the US. This octane boost fluid could be distributed to service stations and other retail establishments by the same companies that distribute windshield cleaner. The amount of the octane boost fluid that is used for DI alcohol boost in typical driving is comparable to the amount of urea that is used for NOx exhaust after treatment in diesel engine vehicles that meet new environmental standards.

EBS has been collaborating with Ford to test DI Alcohol Boost’s practicality. Ford engine tests using E85 type ethanol fuel have been carried out in a 3.5 liter engine. These tests are being published in paper that will be presented at the April 2009 Society for Automotive Engineers (SAE) meeting. These results are consistent with the knock suppression projections of an MIT computer model. Based on this model, use of an alcohol –water mixture will provide a substantial reduction in the anti-knock fluid requirement relative to the use of E85.

Ford and AVL North America are presently performing tests of E 85 in a larger engine in a Department of Energy (DOE) cost share program. EBS is a participant in this program. Results of these tests will be presented in a DOE peer review in May 2009.
EBS expects that these results will also be consistent with the projections for performance and efficiency improvements that have been made by EBS.

Direct Injection Alcohol Boosting in Heavy Duty Trucks and Buses

EBS technology can also substantially reduce the cost of meeting new nitrogen oxide emissions regulations for heavy duty truck and bus by replacing present diesel engines with DI octane boosted gasoline engines. Federal NOx emission standards require a complex and costly exhaust treatment system in new diesel vehicles produced after 2010. In addition December 08 California regulations require phased in replacement of heavy duty diesel engines produced prior to 2010 in existing heavy duty vehicles. Use of DI octane boosted gasoline engines in place of diesel engines can reduce the upfront engine and exhaust system cost by around $10,000.

In addition, the use of DI alcohol boosted gasoline engine technology can provide a means to considerably lower fuel costs if, when the current recession ends the price of diesel fuel again increases substantially relative to the cost of regular gasoline. In 2008 this price difference was as high as $ 1.00 /gallon.

An additional advantage is the removal of the issue of insuring that the driver will refill the urea tank needed for NOx emissions control and the implementation of a urea distribution network. In contrast, if the alcohol knock suppressant tank in a DI octane boosted gasoline engine is empty, NOx emissions will still be controlled and the vehicle will still be drivable, albeit at a lower maximum level of torque. Moreover, through the use of the highly effective three-way catalytic converter technology, DI octane boosted gasoline engines provide greater assurance of meeting possible further tightening in emissions regulations.

EBS has completed a computer modeling study of DI alcohol boosted for heavy duty engines, funded by Mack Truck/ Volvo AB. This study showed that DI alcohol boost could allow a significant reduction in engine size relative to a diesel engine with the same torque and could provide comparable fuel energy efficiency. The study showed that an 11 liter diesel engine could be replaced with a 7 liter DI Alcohol Boosted™ gasoline engine.

EBS anticipates a collaborative arrangement with a company in the heavy duty diesel engine business in the near future.

DI Alcohol Boosting could also be used to significantly improve the efficiency of natural gas engines and other spark ignition engines that operate on fuels other than gasoline.