Hydrogen-Fueled Hybrid Internal Combustion Engines

A potential near-term, environmentally-sound bridge to hydrogen fuel cell vehicles

Summary

Ultimately, the use of hydrogen fuel produced from renewable energy sources could solve the air pollution, global warming, and energy security problems associated with today's fossil fuel-powered passenger vehicles. Although commercial application of hydrogen fuel cell technology for passenger vehicles is still over a decade away, optimization of today's hybrid internal combustion engines (ICE) to run on hydrogen may provide a vital intermediary step. This paper summarizes recent technological developments, studies, and emissions tests which indicate that these vehicles could substantially reduce air pollution and greenhouse gas emissions. With regulatory and legislative support, they could soon be produced on a commercial scale across the United States.

Key Results:

- Gaseous hydrogen fuel made from renewable energy and used in a hybrid ICE could reduce well-to-wheel greenhouse gas emissions by nearly 100 percent, relative to today's conventional vehicles.
- If produced from natural gas, hydrogen used in a hybrid ICE could reduce greenhouse gas emissions 20-30 percent, relative to existing conventional gasoline vehicles.
- The hydrogen-fueled hybrid ICE produces near-zero regulated air pollution emissions even without exhaust after-treatment.
- Ford has developed a hydrogen-fueled hybrid ICE concept vehicle that is 25 percent more efficient than gasoline-fueled vehicles, and has a range of 300 miles. This vehicle—the Model U—was specifically designed with mass production and affordability in mind.

Greenhouse Gas Emissions

Gaseous hydrogen produced from natural gas appears to provide an overall, well-to-wheel greenhouse gas benefit when used in a hybrid ICE. Argonne National Laboratories is in the process of completing a study that includes analysis of well-to-wheel greenhouse gas emissions of various hydrogen fuel production pathways coupled with a hydrogen-fueled hybrid ICE. Their preliminary results demonstrate that use of gaseous hydrogen produced from natural gas in a hydrogen hybrid ICE results in 20-30 percent reduced greenhouse gas emissions on a well-to-wheel basis, relative to existing conventional internal combustion engines.[1] Ultimately, well-to-wheel greenhouse gas emissions from hydrogen fuel could be nearly eliminated if the hydrogen were produced with renewable energy, such as via electrolysis of water using wind, solar, or other renewable energy.

Criteria Air Pollutants

In addition to reducing tailpipe greenhouse gas emissions, a hydrogen hybrid ICE can significantly reduce criteria air pollutants. Ford reports that the Model U hydrogen hybrid ICE they introduced at the 2003 Detroit auto show produces near-zero regulated emissions even without exhaust after-treatment. This is consistent with previous

[1] Personal communication with Dr. Michael Wang, Argonne National Laboratory.

research, including a study by Sandia National Labs which concluded that a hydrogen-fueled hybrid ICE would achieve extremely low NOx emissions without the need for post-combustion cleanup—all operating conditions tested produced less NOx than the California SULEV standard.[2] Since hydrogen is not a carbon-based fuel, the only source of carbon-based pollutants, such as hydrocarbons and carbon monoxide, is burned and unburned engine oil present in the combustion chamber, which results in total emissions that are far below the California SULEV standard.[3]

Other significant air quality advantages of a hydrogen-fueled hybrid ICE over a gasoline-fueled hybrid include the fact that emissions performance will not degrade over time (since no catalytic converter is necessary), and that there are no cold-start or idling pollution problems. Furthermore, reducing hydrocarbons, carbon monoxide, and NOx reduces the formation of tropospheric ozone—which has recently been identified as a significant localized global warming pollutant.

Technology Status & Costs

With recent research and testing, and Ford's introduction of the Model U concept SUV, the technology to produce a hydrogen-fueled ICE appears to be just around the corner. Ford's Model U has a 2.3-liter, four-cylinder internal combustion engine (based on the 2.3-liter I-4 engine used in the Ford Ranger and other vehicles) that is supercharged and optimized to run on hydrogen, coupled with a hybrid electric transmission. According to Ford, the Model U achieves overall efficiency of 38 percent, which is 25 percent more fuel efficient than gasoline-fueled ICE vehicles—affording the equivalent of 45 miles per gallon of gasoline. The Model U was designed for mass production and affordability, and has a range of approximately 300 miles.

The other important cost consideration is the hydrogen fuel itself. The cost of producing hydrogen from natural gas ($/GJ) could be comparable to gasoline, though transportation costs are likely to be higher. If hydrogen were produced using electrolysis, large-scale production could provide efficiencies of scale, reducing capital costs to only an additional $0.10 to 0.20 per gallon-equivalent. Electrolysis using dedicated renewable electricity such as wind or solar would add additional cost.

Conclusion

We do not have to wait for fuel cell technology to mature to realize the benefits of hydrogen for passenger vehicles. Optimization of hybrid ICE engines for hydrogen appears to offer near-term, cost-effective progress on fossil fuel dependence, air pollution, and greenhouse gas pollution. Policy makers interested in solving these problems could help to jump-start commercial introduction of these vehicles. First steps include verifying emissions results, filling in cost information gaps, and initiating policy mechanisms to encourage fuel and vehicle production. Given the substantial greenhouse gas emissions reductions possible, it is also highly advisable that policy makers set up mechanisms to ensure that the transition to hydrogen production from renewable energy occurs as soon as possible.

[2] Keller, Jay and Andrew Lutz, "Hydrogen Fueled Engines in Hybrid Vehicles," Society of Automotive Engineers, 2001-01P-441, 2001.
[3] Swabowski, Steven J., S. Hasehmi, et al, "Ford Hydrogen Engine Powered P2000 Vehicle," Society of Automotive Engineers, 2002-01-0243, March 2002.