COST AND BENEFITS OF THE GASOLINE DIRECT INJECTION ENGINE

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Executive Summary

Gasoline direct injection (GDI) engine technology has received considerable attention over the last few years as a way to significantly improve fuel efficiency without making a major shift away from conventional internal combustion technology. In many respects, GDI technology represents a further step in the natural evolution of gasoline engine fueling systems. Each step of this evolution, from mechanically based carburation, to throttle body fuel injection, through multi-point and finally sequential multi-point fuel injection, has taken advantage of improvements in fuel injector and electronic control technology to achieve incremental gains in the control of internal combustion engines. Further advancements in these technologies, as well as continuing evolutionary advancements in combustion chamber and intake valve design and combustion chamber flow dynamics, have permitted the production of GDI engines for automotive applications. Mitsubishi, Toyota, and Nissan all market four-stroke GDI engines in Japan.

GDI technology has potential applications in a wide segment of the automotive industry. It is attractive to two-stroke engine designers because of the inherent ability of in-cylinder injection to eliminate the exhaust of uncombusted fuel during the period of overlap in intake and exhaust valve opening. In fact, much of the technological improvement in fuel injection technology that made production GDI a reality can be traced to recent two-stroke engine research. In principle, however, GDI technology’s inherent efficiency advantages make it attractive to both two- and four-stroke engine designers. While the greatest fuel efficiency advantages of direct gasoline injection can be realized in direct-injection stratified charge (DISC) lean combustion applications, significant fuel savings can be achieved even under stoichiometric operation. As in current production engines, the theoretical fuel efficiency gains of GDI technology must be balanced against its emissions performance.

The basic attraction of GDI technology is not new. Direct-injection spark-ignition engine development can be traced back to the 1930s. The basic appeal of GDI can be best understood by comparing it to the direct-injection diesel engine. Like the diesel engine, GDI controls engine load through the volume of fuel injected into the cylinder and requires no air throttling, resulting in significant thermodynamic efficiency improvements through excess air combustion and the elimination of throttling losses. In an optimum configuration, the efficiency of a GDI engine approaches that of a diesel direct-injection engine both in fuel consumption (when corrected for density differences between gasoline and diesel) and carbon dioxide emissions. This efficiency is also achieved without the stress-related design requirements associated with the diesel engine.

Although the GDI concept is not new, the complex fuel injection and charge control technology required to make it a production reality has only recently been developed. Sophisticated high-pressure injectors capable of producing very fine, well-defined fuel sprays, coupled with advanced charge air control techniques, now make stable GDI combustion feasible. There are impediments to widespread GDI introduction, however, especially in compliance with stringent emission standards. This report addresses both the efficiencies inherent in GDI technology and the emissions constraints that must be addressed before GDI can displace current spark ignition engine technology.

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