Advanced Direct Injection Combustion Technology -Research paper

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Abstract— Most of the researchers wanted to work with diesel engine because of complexity in the gasoline engine. Author tried to review gasoline direct injection (GDI) a new technology in the gasoline engine with the objective to motivate the researchers to work with this field. This paper reviews the benefits of direct injection in the gasoline engine in terms of fuel consumption and emission. The effect of stratified and homogeneous mode on the performance parameter along with combustion system (wall guided/ spray guided and air guided), its extend feasibility and complexity in the individual and combine mode of operation is reviewed in detail. The review comes up with the need of optimization in mixture formation to reduce in-cylinder wall wetting, increase combustion stability, and extend up to which charge cooling occurs and feasibility of stratified mode operation in GDI engine. Optical diagnostic and CFD are the tools which can help in optimizing this complex system.

Key words: Combustion Technology

I. Introduction

Continuous hike in petroleum products and tighten global emission standards made the engine development towards notable engine technology whose objective to 1) minimize fuel consumption at the inlet, pollutant and noise emissions at exit of engine 2) maximize the fuel energy conversion efficiency and 3) higher specific power output.. The fuel conversion efficiency is the function of mixture formation process i) internal ii) external iii) internal plus external. Gasoline direct injection engine is the new thought of in cylinder mixture formation technology in which gasoline like fuel is directly added into the cylinder and ignited with spark which enables to combine best features of diesel and gasoline engine. BSFC approaching that of the diesel engine, specific power output of the SI engine [1]. 20th century was fully dedicated to external mixture formation by using carburettors and low pressure manifold injection system which dominated SI engine development in the full century. External mixture formation allows larger time for the mixture preparation hence it is independent of phase transformation within cylinder, leads towards good fluid dynamic condition, simple and better control [1, 3, 14] in spite of these advantages Throttling and liquid fuel film formation in the inlet port and charge loss during valve overlap are still disadvantages of the PFI engine, even PFI engine is at its development peak. GDI engine does not have these limitations and during part load condition operates in unthrottled manner which significantly improves specific fuel consumption and emissions and permits for the leaner combustion. Charge cooling occurs in early injection (homogeneous condition) benefits in terms of higher compression ratio, lower octane requirement and improvement in specific fuel consumption up to 30%.

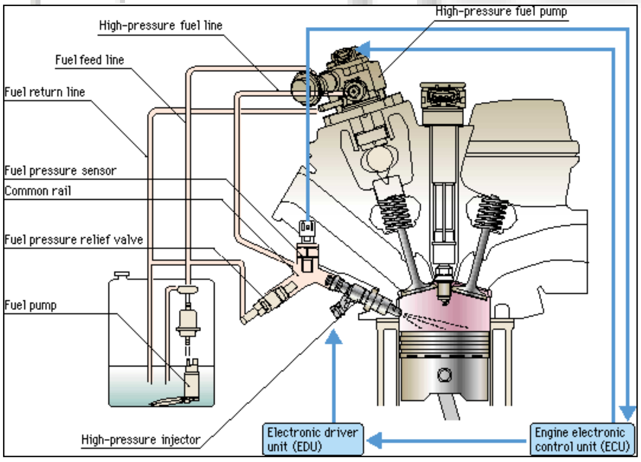
II. Combustion Research

The objective of these projects is to identify how to achieve more efficient combustion with reduced emissions from advanced technology engines. • Sandia National Laboratories (SNL) is developing the physical understanding to guide engine combustion research and the modelling tools to refine the design of optimal, clean, high-efficiency combustion engines. In the past year they: (1) measured the evolution of in-cylinder mixture distributions for four different swirl ratios and three different injection pressures; (2) demonstrated that engine-out emissions are strongly correlated with the formation of over-lean mixture in the pre-combustion mixture formation process for all operating conditions; (3) identified shortcomings in the modelling of the initial mixture formation process and areas for focusing future efforts; (4) established the dominance of kinetics in determining the engine-out emissions when injection is excessively retarded; and (5) examined the potential of photo-fragmentation with subsequent C2 laser-induced fluorescence as a diagnostic for in-cylinder detection of C2 H2 . (Miles, SNL).

III. Literature Survey

From the literature it is observed that for many years gasoline vehicles were considered as clean vehicles as there was no visible smoke from them, however, recently, researchers found that gasoline vehicles are also equal contributor to ultrafine and nano particle 18 emissions like diesel vehicles which is a severe heath concern. International research work shows that generally, gasoline particulate emissions both in terms of mass and number were lower compared to diesel vehicles but at high speeds the numbers emitted from gasoline engines were similar to diesel. Experimental data indicates that gasoline emit smaller size particles compared to diesel (Hall et al., 1998). Mayer et al. (2012) studied metal oxide particles of nano size which are coming out in the diesel and gasoline engine exhaust as a result of incomplete combustion of fuels, or lube oil and, due to abrasion of the metal components. The cytotoxicity of zinc and copper is particularly high. The total concentration count of particles smaller than 400 nm was observed in the range between 1×103 and 3×103 . Experimental investigation carried out on 4-cylinder, 2.25 liter spark ignition engine at constant speed of 120 km/hr equivalent operating condition, showed that particle number emissions per kilometer were in the order of 1011 to 1012 particles (Graskow et al., 1998). Air- fuel ratio found to have high impact on particle number (PN) in case of direct injection spark ignition (DISI) engine (Mickey et.al., 2011). Similarly, particle number and size distribution is sensitive to change in engine control parameters. A substantial increase in the number of particles was observed for the early start of injection (SOI) and late EOI (End of Injection) due to wall wetting or impingement on the piston (Mickey et al., 2011; Farron et al., 2011; and Choi et al., 2011). Experiment carried out by per Choi et al. (2011) on GDI engine at steady state conditions showed that reduction in total particle number concentration for 100 bar injection pressure was 5.9E+5 N/cc, compared to 2.3E+6 N/cc at 40 bar injection pressure which is almost 75% reduction, and the nucleation mode particles observed below 30 nm size contribute approximately 73~78% of total particle number. Optimization of fuel pressure for GDI engine will reduce the particle number. Particle size distribution observed from Indian study for the gasoline motorcycles shows that it is tri-modal and PN concentration peaks are from nucleation mode particles of nano size below 50 nm. The average particle size observed over entire Indian driving cycle was 39.5 nm, 40.1 nm and 26.5 nm respectively for the vehicles of different technology and model years. The particle size spectrum for all the vehicle models tested on different fuel levels viz. Euro-2, Euro-3, BS-3 and Euro-4 gasoline observed to fall in between 6 nm to 340 nm (Nakhawa et al., 2011). The coolant temperatures affects the in-cylinder fuel and air mixing and lower coolant temperature result in higher PM mass and number (Farron et al., 2011). Experiment was carried out by Peckham et al. (2011) to measure the particle number emissions from a GDI (Gasoline direct Injection) engine 19 passenger car using PMP-compliant particulate measurement system to measure the effect of various engine parameters on the particulate emissions on NEDC regulatory cycle. Peckham observed that cold starting and initial 200 seconds are very significant as near 50% of total PN get emitted within this period and later on particle concentration drops down on further driving on test cycle and the mean particle size of accumulation mode particles falls within 50 nm to 150 nm. Second generation GDI show lower particulate emissions compared to first generation GDI engines, but they are significantly higher than port fuel injected engines. This may be due to comparatively less time available for mixture preparation and increase in the fuel impingement on the piston crown and combustion chamber surfaces.

IV. GDI TECHNOLOGY LAYOUT



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