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DIESEL ENGINE EMISSION CONTROL TECHNIQUES A REVIEW ON SPLIT INJECTION

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Abstract

Modelling of the combustion process inside compression ignition engine has become extremely important for both improving combustion efficiency and describing the conditions in which pollutant emission formation occurs. Heavy duty engines have been shown to be a significant source of regulated exhaust emissions, contributing 50% of the NO_X, 17% of hydrocarbons and 90% of particulate matter originating from mobile sources. NO_X are the major concern, as it is a component of both smog and acid rain and with combination of HC, NO_X forms ground level ozone, which is highly polluted. In response to concerns over the exhaust emissions of these engines; EPA has established a progressive schedule of emission requirements. Diesel engines are of great concern with a regulated level of NO_X and particulate matter. Hence it is necessary to take preventive steps to attack NO_X formation processes by limiting the development of peak temperatures during combustion and to take necessary measures, which tend to inhibit soot formation. Turbo charging, now widely applied in modern CI engines, which is tending to increase the compression ratio by increasing the trapped air fuel ratio. However, the increase in compression ratio will increase the cycle peak temperature which results in higher NO_X exhaust emissions. The application of charge inter cooling to turbocharged CI engines has been shown to be effective to counteract the increased NO_X levels and is widely applied. Second way of controlling the NO_X is by retarding fuel injection timing, thereby extending the combustion to a more degree crank angle in the expansion stroke which limits the peak cycle temperature. Third way of reducing NO_X is high pressure injection with EGR has shown reduction in NO_X to some extent but as EGR increases particulate matter increases and hence optimization is required with different percentage of EGR. Hence it is necessary to reduce NO_X and soot simultaneously. It is possible to have simultaneous reduction in NO_X as well as soot by multi pulse injection (split injection).

***Keywords**:* split injection, exhaust gas recirculation, start of injection, duration of injection.

1. Introduction

The diesel engine, because of its highest thermal efficiency among currently available engines, has been a main power source for over a hundred years. Its advantage in thermal efficiency is due to its combustion characteristics. Diesel fuel is injected into a high temperature and pressure environment (compression ratio as high as 24:1).The higher the compression ratio, the more efficient the cycle [Hey Wood, 1998].

However, for some of the same reasons that the diesel engine is highly efficient, its power density and exhaust emissions have traditionally been less desirable than spark ignition (SI) combustion engines. In a diesel engine, the combustion rate is controlled by the fuel injection rate, mixing and diffusion rates which are usually slower than the premixed combustion rate in typical gasoline engines. Diesel engines usually emit more particulate and NO_X than their gasoline counter parts. The high temperature and pressure environment in the diesel engine cylinder because of its high compression ratio and high combustion temperatures makes it impossible to completely prevent NO_X from forming. The soot formed in the fuel – rich regions, although partially oxidized in the expansion stroke, also remains in considerable amounts at exhaust valve opening (EVO).

The problem of diesel engine emissions is exacerbated because of the trade- off feature between NO_X and soot emissions. It is usually impossible to reduce both kinds of emissions simultaneously, since factors that tend to decrease one usually increase the other. For example, retarding the fuel injection timing is effective to reduce NO_X formation by reducing the peak cylinder temperature and pressure. However, this method results in an increase of soot production because more soot formed due to the lower in – cylinder gas temperature has shorter time to be oxidized [Lee, 2002]. Increasing the EGR rate can decrease the NO_X emission level, however less oxygen is available to oxidize soot .Eventually, any change in these engine parameters will unavoidably affect other important engine performance measures , like retarding injection timing causes lower thermal efficiency and higher Brake Specific fuel consumption(BSFC) [Hey Wood,1998]. Increasing environmental concerns and legislated emission standards have led to the necessity of considering both conventional and unconventional means for reducing soot and NO_X emissions in diesel engines, which is also a motivation of the present study. For example, diesel engine manufacturers are facing the challenges of the extremely low diesel engine –out soot emission mandates to be implemented in the near future. Engine simulation, compared to expensive engine experiments, is an efficient way to investigate various novel ideas to improve current engine performance, and hence becomes an essential part of engine research and development. In addition, simulations can investigate the transient properties of physical processes.

However, adequate accuracy of modeling particulate matter emission remains a challenge. Soot formation in diesel combustion involves both gas phase and particulate reaction mechanisms, therefore, it is more compared than other pollutant species such as NO_X and CO. Current computing power capabilities and model parameter uncertainties in many of the diesel spray and combustion related mechanisms limit the possibility of using detailed chemistry description of the soot formation process. On the other hand, the widely –applied and highly –efficient empirical soot models have become less sufficient for the emerging demands for accuracy and detailed soot particulate information. For example, newly proposed emission mandates will specifically enforce the emitted soot particulate's size.The challenges of the stringent mandates have also increased interest in engine optimization studies. Engine performance is determined by many factors such as emissions, fuel consumptions and output power, among which many trades- off relation occur. In order to consider both conventional and non conventional means to optimize engine performance, the space will have to be large. Engine operating and design parameters are not only subject to many practical limitations, but also interact with each other to have a complex influence on the engine performance. All these search techniques that are specifically designed for this type of problem, with plenty of flexibility to include desired and practical limitations, accuracy, resolution, and so on.

The High Speed Direct Injection (HSDI) diesel engine can partially overcome the limitations of typical large bore diesel engines because of its design features reentrant and deep piston bowls, strong intake flow motion, small squish height, are the factors that increase combustion rates. However, the stricter emission standards remain a serious challenge to HSDI diesel applications. It has long been recognized that diesel engine combustion quality highly depends on the mixing of fuel and air. High injection pressures and multiple injections are commonly adopted in HSDI engines to achieve better mixing of the fuel and air and to enhance the brake up of the fuel droplets. The common – rail injection system has brought a great deal of flexibility to diesel engine development, since it decouples the three parameters engine speed , injection pressure and injector opening –closing times. This feature provided the possibility of performing multiple injections per engine cycle. With the increased freedom of injection control, the multiple injection strategy has been studied in recent years with regard to its capability to improve engine performance, which mainly includes: reducing pollutant emissions, due mainly to very precise control on injection timing and rail pressure over the entire engine operating range, and reducing combustion noise due mainly to the addition of small pre-injection which enables a reduction of the main injection ignition delay.

Split injection, with two injection pulses in each engine cycle, along with EGR and boost pressure has been widely studied. However, injection strategies of three or more pulses in each cycle have not been studied widely. Previous experimental researchers at the Engine Research Centre (ERC) , UW – Madison, have revealed that the use of multiple injections with three or more injection pulses per engine cycle has the potential to reduce heavy duty diesel engine NO_X and soot emissions simultaneously without significant penalty on the fuel consumptions [Tow,1994][Montgomery, 1995]. Therefore, it is interesting to investigate the potential of using multiple injections strategies to improve HSDI diesel engine performance, including emissions and fuel consumption.

2. Body of the article

COMMON RAIL INJECTION SYSTEM

The improvement of DI diesel engines for passenger cars are struggling with the stringent exhaust emission standards is linked to a continued development of the injection system. Lot of research work is going on fuel injection system of electronically controlled high pressure injection system which can inject the fuel at any point in the cycle without the injection rate changing owing to injection timing or engine speed. The major difference between common rail system and standard diesel injection system is the free choice of the injection pressure and timing [2]. In addition, modern electronically controlled common- rail injection systems are capable of multiple high- pressure injections at various engine speeds.

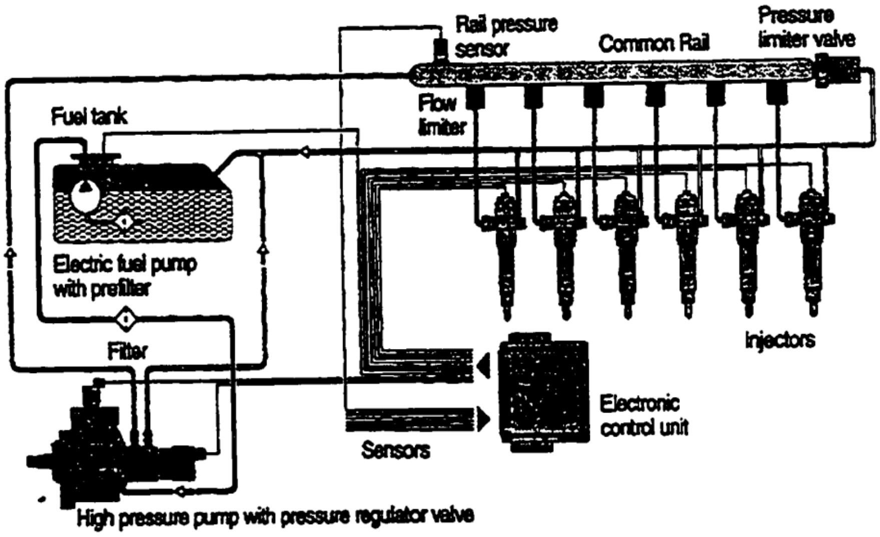

Fig .1 Common rail injection

INJECTION PRESSURE

It has been shown that the particulate emissions can be reduced with high pressure injection systems into modern diesel engines. This allows the use of smaller injection holes for the same fuel delivery rate, resulting in common fuel droplets.

Badami.et.al [4] accomplished 27% reduction in particulate emissions with 2.7% reduction in BSFC when the injection pressure was increased from 1300 to 1500 bar in a HSDI diesel engine at slightly under full load at 4000 rpm. Shimazaki.et al. [5] Observed the combustion process in a single cylinder two- stroke DI diesel engine increase in the injection pressure generally results in higher NO_X emissions.Shundoh.et al. [6] accomplished significant smoke reduction by increasing the injection pressure at a 1000 rpm full load condition on a DI diesel engine, while NO_X emissions increased.. Pierpont and Reitz [7] found that increasing the injection pressure on a heavy duty engine at 75%load, 1600rpm resulted in a reduction of particulate emissions but an increase in BSFC, if NO_X levels were held the same by retarding timing.

SWIRL

Swirl is used in diesel and some stratified charge engine concepts to promote more rapid mixing between the inducted air charge and the injected fuel [1].Swirl is usually defined as organized rotation of the charge about the cylinder axis. Arcoumanis.et al. [8] measured the three components of velocity and their fluctuations by Laser-Doppler anemometry mainly near TDC of compression in a model IC engine motored at 200 rpm. They observed that interaction of swirl, carried from intake and persisting through compression, with squish generated near TDC profoundly altered the axial flow structure.

Espey.et al. [9] used an optically accessible DI diesel engine to investigate the effect of swirl on fuel – air mixing and flame evolution. Ogawa et al. [10] used a modified version of the Turbo KIVA code to analyze the combustion and emission characteristics of a DI diesel engine and found that increasing the swirl ratio reduced soot emissions, but increased NO_X. Fuchs and Rutland [11] modeled intake, compression, and combustion of a cater pillar diesel engine using a modified version of the KIVA-II and KIVA-III CFD codes .Their results revealed that high swirl ratios distributed the fuel such that it remained in the bowl, thus depleting almost all of the bowl oxygen during combustion, which resulted in a peer late diffusion burn.

SUPERCHARGING

Supercharging, which refers to increasing the air by increasing its pressure prior to entering the engine cylinder, has been considered as a method of increasing the specific performance of diesel engines.

Uchida et al. [12] studied the effect of supercharging on DI diesel combustion. They reported that supercharging could favorably reduce ignition delay and enhance diffusion combustion. Tanin.et al. [13] studied boost pressure effects using a single cylinder version of a heavy duty diesel engine. They found that particulate emissions decreased significantly with increased intake boost pressure. Zhang et al. [14] conducted and experimental study to investigate the effects of supercharging on an optically accessible DI diesel engine. They observed that in the diffusion combustion stage, the flame movement was less active and the impingent effect of the fuel jet was smaller in the case of high boost pressure during the injection period indicating that the turbulent effect caused by the fuel injection was weakened. As a result, they argued that, although higher boost pressure brought more air into cylinder, the entrance of air to the flame covered sprays would not be improved much.

MULTIPLE INJECTIONS (SPLIT INJECITON)

Multiple injections divide the total quantity of the fuel into two or more injections per combustion cycle. Splitting the injection sequence into two events is called pilot or split injection. A pilot injection is usually defined as an injection where 15% or less of the total mass of fuel is injected which reduces combustion noise and allow the use of poor ignition quality fuel (low cetane numbers) [15]. Many researchers are now investigating pilot and split injection as an effective means to simultaneously reduce NO_X and particulate emission. Shundhoh.et al. [16] reported that NO_X could be reduced by 35%, and smoke by 60 to 80 %, without a penalty in fuel economy if pilot injection was used in conjunction with high pressure injection. Yamaki.et al. [17] investigated the effects of pilot injection on exhaust emissions in a turbocharged heavy duty Diesel engine and found that with partial load, when the pilot fuel quantity was increased, Fuel consumption and smoke was increased, but NO_X was found to decrease and then increase. Minami et al. [18] studied the effects of pilot injection s in a turbocharged DI diesel engine and found that the pilot injection was effective to reduce NO_X and HC at low load conditions, through it deteriorated smoke to some degree.Zhang et al. [19] used a single cylinder HSDI diesel engine to investigate the effect of pilot injection with EGR on soot, NO_X and combustion noise, and found that the pilot injection increased soot emission.

Nehmer and Reitz.et al. [20] Studied the effect of split injection in a heavy –duty diesel engine by varying the amount of fuel in first injection from 10 to 75% of the total amount of fuel. They found that split injection better utilized the air charge and allowed combustion to continue later into the power stroke than for a single injection case, without increased levels of soot production. Tow et al. [21] found that using a double injection with a relatively long dwell on a heavy duty engine resulted in reduction of particulate emissions by a factor of three with no increase in NO_X and only a slight increase in BSFC compared to a single injection.

Han et al. [22] Multidimensional computations carried out to understand the mechanism of soot and NO_X emissions reduction in a heavy – duty diesel engine with multiple injections. The high momentum injected fuel penetrates to the fuel rich, relatively low temperature region at the jet tip and continuously replenishes the rich region, producing soot .However in a split injection, the second injection enters into a relatively fuel – lean and high temperature region that is left over from the combustion of first injection. Therefore, soot formation is significantly reduced. Tow et al. [21] pointed out that the dwell between injections was very important to control soot production and there would exist an optimal dwell at a particular engine operating condition. Durnholz.et al. [23] investigated the influence of pilot injection for a turbocharged and intercooled DI diesel engine for passenger cars. Their optimized pilot injection contained about 1.5 mm^3 of the fuel in the pilot injection independent of engine load and their optimal dwell was 15°CA. Fuchs and Rutland [11] found that high swirl ratios distributed the fuel such that it remained in the bowl, thus depleting almost all of the bowl oxygen during combustion. Therefore, they asserted that in high swirl ratio split injection cases the dwell should be optimized to prevent the second injection from landing in the fuel rich region left in the bowl from the first injection.

D.A.Peirpont.et al. [60] Studied multiple injections are effective at reducing particulate. Two nozzle spray angles were used with included spray angles of 125° and 140° the results show that the combined use of EGR and multiple injections is very effective at simultaneously reducing particulate and NO_X. D. T. Montgomery et al. [63] observed the emissions and performance effects of exhaust gas recirculation (EGR) and multiple injections on the emission of oxides of nitrogen (NO_X), particulate emissions, and brake specific fuel consumption (BSFC) over a wide range of engine operating conditions. NO_X and particulate could be simultaneously reduced to as low as 2.2 and 0.07g /bhp-hr, respectively. P Carlucci et al. [69] studied that, particularity at lower values of engine torque and speed, a reduction in NO_X and particulate is observed, while the level of unburned hydrocarbons increased. Experimental study has been performed J.M. Desantes.et al. [77][78] on the effects of injection rate shaping on the combustion process and exhaust emissions. results show how this system to reduce NO_X and to increase soot and fuel consumption, emissions and performance trade-offs can be improved for some specific boot shapes.

Kuen Yehliu.et al. [79] focuses on characterization of the produced by three substantially different diesel fuels In all modes the engine was tested with single and split injection.He has been observed and this increase of the PM emission is due to unburned or partially burned hydrocarbon (HC) emissions. Fang Tiegang. et al. [80] Studied the effects of injection angles and injection pressure on the combustion processes injection strategies in a high-speed direct-injection diesel employing multiple injections are presented in this work. NO_X emissions were measured in the exhaust pipe No evidence of fuel-wall impingement is found for the first injection of the 150-degree tip, but for the 70-degree tip, some fuel impinges on the bowl wall and a fuel film is formed. C.Y.Choi et al. [81] focused on experimental studies on effects of oxygenated fuels in conjunction with single and split fuel injections were conducted at high and low loads. At high loads, a significant beneficial effect of oxygenated fuels was seen to reduce soot emissions with little or no penalty on NO_X emissions.

Jean Arrègle et al. [82] carried out comprehensive study in order to better understand combustion behavior in a direct injection diesel engine when using post injections. More specifically, the aim of the study is twofold: (1) to better understand the mechanism of a post injection to reduce soot and (2) to improve the understanding of the contribution of the post injection combustion on the total soot emissions. For the effect of the post injection timing, the physical parameter found was the temperature of the unburned gases at the end of injection. Carlucci.et.al. [84] investigated multiple injections. Results show that, mainly for medium values of engine torque and speed, the injection of a small fuel quantity during the early stage of the compression stroke, coupled with the pilot injection, may be effective in reducing specific fuel consumption. ManshikKim.et al. [123] performed numerical simulations to investigate the combustion process in the Premixed Compression Ignition (PCI) regime in a light-duty diesel engine. Simulation results have shown good levels of agreement with the measured in-cylinder pressure, heat release rate and exhaust emissions.

Mark P. et al. [124] worked on In-cylinder spray, mixing, combustion, and pollutant formation processes with early fuel injection (SOI=-22° ATDC) at two different charge densities were studied. W. L. Hardy et al. [125] performed Optimizations on a single-cylinder heavy-duty. A micro-genetic algorithm was utilized to optimize a hybrid, double-injection strategy. The optimization produced a parameter set that met the 2007and 2010 PM emissions mandate of 0.0134 g/kW hr, and was within the limits. Yi Liu, et al. [126] conducted experiments on multiple injection strategies and computationally studied for simultaneously reducing diesel engine NO_X and particulate emissions. However, It was found that widely separated injection with two-stage combustion appears to provide optimal HSDI diesel performance at part load. More pulses per engine cycle can lead to better engine performance through the increased flexibility. HarmitJuneja.et.al [127] investigated effect of injection rate shape on spray evolution and emission characteristics his experiments was obtained for liquid and vapor penetration lengths, over a broad range of gas densities and temperatures. SanghoonKook.et .al [128] studied a two-stage injection strategy showed that the two-stage injection could be used as a combustion phase controller only. WanhuaSu.et.al [129] studied controlling the pulse injection is to limit the spray penetration. The combustion of fuel injected in the main injection proceeds under the effect of the BUMP combustion chamber at much higher air/fuel mixing rate than does in a conventional DI diesel engine.TaewonLee.et.al [130] demonstrates the emission reduction capability of split injections, using an RSM (Response Surface Method) optimization method, which resulted in simultaneous reductions in both

NO_X and PM emissions, while even improving BSFC (Brake Specific Fuel Consumption). D.D.Wickman.et al. [131] investigated design optimization on Combustion chamber geometry has been performed. An experimental parametric study was performed resulting design features a novel chamber geometry that is demonstrated to be able to achieve low emissions.

R.Shrivastava.et.al, [132] performed computational optimization. It was observed that the effect of the flow field (i.e., swirl and tumble ratios) at IVC on engine-out emissions was predominant only for the high-speed low load case. Gunnar Stiesch.et al. [133] worked on a spray model for pressure-swirl atomizers simulation results and experimental data are compared for several different injection timings and the agreement is generally good.

G. M. Bianchi. et al. [134] carried out multiple injections in reducing NO_X and soot emissions of HSDI Diesel engines. D. T. Montgomery et al. [135] demonstrated the capabilities of a state-of-the-art heavy -duty diesel engine when using split injections, EGR, and flexible boosting over a wide range of engine operating conditions. Using the new response surface optimization scheme, emission levels could be decreased.C.Hasse.et al. [136] indicated that experiments using multiple injections. The computations as well as the experiments confirm the possibility of reducing soot with only a slight increase in NO_X emissions. It is shown that soot is reduced due to a different mixing process resulting in fewer rich regions. MarcoBakenhus.et al. [137] experimented on luminous combustion an in a modern diesel engine was performed to investigate the effect of injection parameters on NO_X and soot formation via flame temperature and soot. The two-colour results confirm that retarding the injection timing causes lower flame temperatures and NO_X emissions but increased soot formation, independent of injection strategy. Split injections have been shown to be a powerful tool to simultaneously reduce soot and $NO_{X.}$ Steven J et al. [138] observed the rate in which gas concentration gradients change, to provide gradients in number density, droplets were admitted into the engine. Takeshi Hashizume, et al. [139] studied a new diesel combustion concept, which can reduce NO_X emissions at high load conditions. Michael Chan et al. [140] modelled the effects of multiple injection the results showed excellent agreement between predicted and measured in cylinder pressure.

Y Choi.et al. [141] studied the effects of methyl soyate (biodiesel) blends with #2 diesel fuels in conjunction with various high pressure injections slight increase in NO was observed with the biodiesel blends. Laura M. et al. [142] worked on Endoscope-based image acquisition-and-processing camera system was used for diagnostics of pilot injection combustion in a single-cylinder heavy duty diesel engine. As the start-of-injection timing was retarded some evidence of ignition above the impingement point was observed. P. V. Farrell et al. [143] performed series of experiments were to study the effects of injection pressure, back pressure, and injection strategy on the spray characteristics for multiple injections and observed that NO_X were reduced. JianwenLi.et al. [144] studied a multimode phenomenological combustion model, The results predicted by the model show that the soot can be effectively reduced without increasing NO_X emission and fuel consumption with the split injection.Hiroshi Ishiwatal et al. [145] describe the development status of pilot injection. The results show the advantages of pilot injection for NO_X, HC, BSFC and noise reduction. The pilot quantity is required to be as small as possible in order to minimize the penalty in smoke emission. Glenn R.et.al [146][147] focused on the effects of split injection on combustion in a diesel environment. Results have shown split injection reduces NO and NO_X by 50 - 60 % when compared to a single injection while limiting the peak rate of pressure rise to 75% of a single injection.

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3. CONCLUSIONS

The combination of tight criteria pollutant tailpipe regulations combined with proposed limits on CO_2 emissions will place new demands on diesel engines and systems. However, this review of the state of diesel emissions and control in 2007 shows that the challenges of the emerging regulations can be met with a number of engine and after treatment options.Highlighted LD engine technologies show the same technology packages can be used with different calibrations to hit the tight NO_X requirements of the US or potentially the CO_2 targets in Europe. Emerging engine technologies are showing better potential for hitting the SULEV emission levels, a goal that seemed unrealistic only a few years ago. On the HD side, generally the same technologies are being proposed to hit the emerging US2010, Japan 2009, and Euro VI (proposed) regulations. In addition, to dramatic reductions in NOx, research engines are showing 10% fuel savings using incremental technologies. These engines are hitting 47% BTE, with goals of going to 53% BTE by 2013. Non-road engine technologies are generally following the model set forth in the highway sector. In general, this points to 2-stage turbocharging; increasing EGR, cooling, and control; higher pressure flexible fuel injection; and premixed or low temperature combustion strategies.

In the tailpipe, SCR efficiencies are approaching 90%+, with better mixing and control. Low temperature deNOx efficiency is being addressed with increased understanding on limitations, such as ammonium nitrate formation at T<200°C, and with urea decomposition catalysts. Advances are also being made on liquid urea substitutes – solid urea, and gaseous ammonia storage in magnesium dichloride. LNT advances include a better understanding of HT aging issues via potassium migration, and the development of a sulfur trap that might last 40,000 km. Lean NOx catalysts made significant strides, with improvements to a double layer concept utilizing ammonia generated in a NOx adsorber material, and a new HC-SCR catalyst that is performing nearly as good in preliminary work as ammonia SCR catalysts.More is being learned on DPF regeneration pertaining to control, in-cylinder injection strategies, and fundamentals on how soot interacts with catalyst. More information was provided on the newest DPF substrate material, aluminum titanate. Studies are summarized on emissions from the latest European HD commercial engines, wherein Euro V engines with SCR perform similarly to Euro IV engines with open filters, but not nearly as well as retrofit Euro III engines with DPFs. Although low-temperature combustion strategies can have very low PM levels, emissions can be similar to those with conventional combustion systems.Finally, on DOCs, the high HC emissions from low temperature combustion engines might be difficult to treat perhaps due to the class of hydrocarbons generated. More was learned on the NO_2 generation capabilities of DOC in that NO_2 is not formed at temperatures below the light-off temperature of HC and CO.

Multiple injections were very effective at reducing particulate. However, the multiple injections must be optimized for best Particulate reducing effects by varying the fuel distribution in each pulse and the dwell between pulses for each operating condition.Multiple injections with secondary injections following the main injection were found to be most effective at reducing particulate.The optimal multiple injection appears to depend on many factors. Some that are known include injection timing, spray included angle, and load. Presumably there are many others including the turbocharger map operating condition. Optimal multiple injections can reduce particulate at all NOx levels, but they are most effective at retarded timings.Multiple injections allow timing to be retarded to reduce NO_X while holding particulate at low levels. Multiple injections can help control combustion to reduce engine noise. Multiple injections with relatively small quantities of fuel in the secondary pulses have little effect on BSFC. However, when the fuel distribution in each pulse becomes more even with significant dwells between injections there is a 3% to 4% increase in BSFC.

References

Heywood, J.B., "Internal Combustion Engine fundamentals" Mc Graw- Hill publishing company New York, 1988.

Flaig, U., Polach, W., and Ziegler, G., "Common rail system (CR- System) for passenger Car DI Diesel Engines; Experiences with Applications for series production projects", SAE Paper 1999-01-0191, 1999.

Stump, G.adn Ricco, M., "Common Rail –an attractive Fuel Injection System for Passenger Car DI Diesel Engines", SAE Paper 960870, 1996.

Badami, M., Nuccio , P., and Trucco G., " Influence of Injection Pressure on the performance of a DI Diesel Engine with a Common Rail Fuel Injection system" ,SAE Paper 1999-01-0193, 1999.

Shimazaki, N., Hatanaka H., Yokota, K., and Nakahira, T., "A Study of Diesel Combustion Process Under the Condition of EGR and High Pressure Fuel Injection with Gas Sampling Method", SAE Paper 960030, 1996.

Sundoh, S., Kakekawa, T., and Tsujimurwa, K., "The Effect of Injection Parameters and Swirl on Diesel Combustion with High Pressure Fuel Injection", SAE Paper 910489, 1991.

Pierpont, D.A. and Reitz, R.D., "Effects of Injection Pressure and Nozzle Geometry on D. I. Diesel Emissions and Performance", SAE Paper 950604, 1995: 15-24

Arcoumanis, c., Bicen, A.F., and Whitelaw, I. H., "Squish and Swirl –Squish Interaction in Motored Model Engines", ASME Journal of Fluids Engineering, Vol. 105, 1983, p.105

Epsey, C. Pinson, J. A., and Litzinger, T.A., "Swirl Effects on Mixing and Flame Evolution in a Research DI Diesel Engine", SAE Paper 902076, 1990:1-10

Ogawa, H., Matsui, Y, Kimura, S., and Kawashima, J., "Three- Dimensional Computation of the Effects of the Swirl Ratio in Direct- Injection Diesel Engines on NO_X and Soot Emissions", SAE Paper 961125, 1996.

Fuchs, T.R. and Rutland, C.J., "Intake Flow Effects on Combustion and Emissions in a Diesel Engine", SAE Paper 980508, 1998.

Uchida, N., Daisho, Y., and Saito, T., "The Control of Diesel Emissions by Supercharging and Varying Fuel-Injection Parameters", SAE Paper 920117, 1992

Tanin, K.V., Wickman, D.D., Montgomery, D.T., Das, S., and Reitz, R.D., "The Influence of Boost Pressure on Emissions and Fuel Consumption of a Heavy-Duty Single-Cylinder D.I. Diesel Engine", SAE Paper 1999-01—0840:1-22

Zhang, L., Takatski, T., and Yokota, k., "An Observation and Analysis of the Combustion under Supercharging on a DI Diesel Engine", SAE Paper 940844, 1994.

Jafer, D., "Pilot Injection", Engineering. October 15, 1937.

Shundoh, S., Komori, M., Tsujimura, K., and Kobayashi, S., "NO_X Reduction from Diesel Combustion Using Pilot Injection with High-Pressure Fuel Injection", SAE Paper 920461, 1992:25-36

Yamaki, Y. et.al. "Application of Common Rail Fuel Injection System to a Heavy Duty Diesel Engine", SAE Paper 94229, 1994:85-96

Miyami, T., Takeuchi, K., and Shimazaki, N., "Reduction of Diesel Engine NO_X Using Pilot Injection". SAE Paper 950611, 1995:89-96

Zhang, Long, "A Study of Pilot Injection in a DI Diesel Engine", SAE Paper 1999-01-3493, 1999:1-8

Nehmer, D.A. and Reitz, R.D., "Measurement of the Effect of Injection Rate and Split Injections on Diesel Engine Soot and NO_X Emissions", SAE Paper940668, 1994:55-66

Tow, T.C., Pierpont, A., and Reitz, R.D., "Reducing Particulates and NO_X Emissions by Using Multiple Injections in a Heavy Duty D.I. Diesel Engine", SAE Paper 940897, 1994:1-14

Han, Z., Ulugogan, A., Hampson, G.J., and R.D.Reitz, "Mechanism of Soot and NO_X Emission Reduction Using Multiple –Injection in a Diesel Engine", SAE Paper 960633, 1996:87-102

Durnholz, M., Endres, H., and Frisse, P., "Pre injection A Measure to Optimize the Emission Behavior of DK-Diesel Engine ", SAE Paper 940674, 1994:123-129

Williams, F.A., "Combustion Theory", The Benjamin/ Cummings publishing Company, 1985.

Ladommatos, N., Abdelhamim, S.M., Zhao, H., and Hu, Z, "The Dilution, Chemical, and Thermal Effects of Exhaust Gas Recirculation on Diesel Engine Emissions, SAE Paper 971660, 1977.

Hentschel, Wand Richter, J., "Time- Resolved Analysis of Soot Formation and Oxidation in a Directed – Injection Diesel Engine for Different EGR- Rates by an Extinction Method", SAE Paper 952517, 1995.

Ladommatos, N., Abdelhalim, S.M., Zhao, H., and Hu, Z., "Effects of EGR on Heat Release in Diesel Combustion", SAE Paper 980184, 1998:1-15

Dec, J.E. and Kelly-Zion, P. L., "The Effect of Injection Timing and Diluent Addition on Late- Combustion Soot Burnout in a DI Diesel Engine Based on Simultaneous 2-D Imaging of OH and Soot ", SAE Paper 2000-01-0238, 2000:1-18

Durnholz, M., Fifler, G., and Endres, H., "Exhaust – Gas Recirculation – A Measure to Reduce Exhaust Emissions of DI Diesel Engines", SAE Paper 920725, 1992.

Ladommatos, N., Balian, R., Horrocks, R., and Cooper, L., "The Effect of Exhaust Gas Recirculation on Combustion and NO_X Emissions in a High-Speed Direct Diesel Engine", SAE Paper 960840, 1996.
Arcoumanis, C., Nagwaney, A., Hatchel, W., and Ropke, S., "Effect of EGR on Spray Development, Combustion and Emissions in a 1.9L Direct-Injection Diesel Engine", SAE Paper 952356, 1995.
Mattarelli, E., Bianchi, G.M., and Ivaldi, D., "Experimental and Numerical Investigation on the EGR system of a New Automotive Diesel Engine", SAE Paper 2000-01-0224, 2000.
Mikulic, L. Kuhn, M., Schommers, J., and Willig, E., "Exhaust –Emission Optimization of DI- Diesel Passenger Car Engine with High – Pressure Fuel Injection and EGR", SAE Paper931035, 1993.
Uchida, N., Shimokawa, K., Y., and Shimoda, M., "Combustion Optimization by Means of Common Rail Injection System for Heavy-Duty Diesel Engines" SAE Paper 982679, 1998.
Uchida, N., Daisho, Y., Satio. T., and Sugano, H., "Combined Effects of EGR and Supercharging on Diesel Combustion and Combustion and Emissions", SAE Paper 930601, 1993:103-109
Mehta, P.S. and Tamma, B., "Effects of Swirl and Fuel Injection Characteristics on Premixed Phase of Diesel Combustion", SAE Paper 980534, 1998:1-6
Bowman, C.T., "Kinetics of Pollutant Formation and Destruction in Combustion" Prog. Energy Combustion Science vol. 1, pp 33-45, 1975.
Lavoie, G.A., Heywood, J.B. and Keck, J.C., "Experimental and Theoretical Investigation of Nitric Oxide Formation in Internal Combustion Engines" Combustion Science and Technology, vol. 1, pp 313-326, 1970.
Blumberg, P. and Kummer, J.T., "Prediction of NO Formation in Spark- Ignited Engines – An Analysis of Methods of Control," Combustion Science and Technology, Vol. 4, pp 73-95. 1971.
Lavoie, G, A. and Blumberg, P.N., "A Fundamental Model for Predicting, Fuel Consumption, NO_X and HC Emissions of the Conventional Spark-Ignited Engine" Combustion Science and Technology, Vol. 8, p25, 1973.
Plee, S.L. and Ahmed, T., "Relative Roles of Premixed and Diffusion Burning in Diesel Combustion" SAE Paper 831733, 1983.
Merryman, D.L. and Levy, "Nitrogen Oxide Formation in Flames: The role of NO_2 and Fuel Nitrogen," Proceedings of Fifteenth International Symposium on Combustion, p 1073, The Combustion Institute, 1975.
Hillard, J.C. and Wheeler. "Nitrogen Dioxide in Engine Exhaust" SAE Paper 790691, 1979.
Heywood J.B., and Rublewski M., "Modeling NO Formation in spark Engines with a Layered Adiabatic Core and Combustion Inefficiency", SAE 2001-01-1011, 2001.
Missaghi M., Pourkashanian M.P., and Yap T.L., "Reduction of NO_X, Emissions Using CFD as a Design tool," ASME, FACT Vol. 17. 1993.
Heywood J.B, Lavoie G. A., and Keck J.C., "Experimental and Theoretical study of Nitric Oxide Formation in Internal Combustion Engines," Combustion Science and Technology, Vol. 1, 1970.
Hiroyasu H. and Kadota T., "Models for Combustion and Formation of Nitric Oxide and Soot in Direct Injection Diesel Engines," SAE 760129, 1976.
Hiroyasu H. Kadota T., and Arai M., "Diesel Engine Efficiency and Pollutant Emissions," JSME Vol. 261981.
Blumberg P., Kummer J.T., "Prediction of NO Formation in Spark- Ignited Engines – An Analysis of Method of Control". Combustion Science and Technology, Vol.4 1971.
Lavoie G., Miller R., Davis G., Newman C., and Gardner T., "A Super - Extended Zeldovich Mechanism for NO_X modeling and Engine Calibration" SAE 98078, 1998.
James E.H., Errors in NO Emission Prediction from Spark Ignition Engines", SAE 820046, 1982.
Police G., Diana S., Giglio V., and lorio- B., "A model based evaluation of Emission for Manifold Injected Engines," SAE 2000-01-0955, 2000.
Reitz R. D., Rutland C.J., and Eckhause J., "Toward Predictive Modeling of Diesel Engine Intake Flow, Combustion and Emissions," SAE 941897, 1994:1-14
Reitz R. D., Patterson M. A. Kong S.C., and Hampson G. J., "Modeling the Effects of Fuel Injection Characteristics on Diesel Soot and NO_X Emissions" SAE 940523, 1994:1-17
Jackson N. S., "The High Speed Direct Injection Diesel Engine – Future Potential," THIESEL 2000 Conference proceedings, Valencia, Spain, pp .33, 2000.
Azzoni P. M., Minnelli G., and MORO D., "A Model for EGR Mass Flow Rate Estimation," SAE 970030, 1997.
Arise I., Genova F.D., C., Rizzo G., Sorrentino M., Caraceni A., Cilffi P., and Flauti G., "A Single-zone Model for Combustion and NO_X Simulation in Common – Rail Multi- jet Diesel Engines". SAE 2003-01-79, 2003
Molina S., "Influence of Pre and Post Injection on the performance and pollutant Emissions in a HD Diesel Engine," SAE 2001-01-0526, 2001.
Isida T., "Diesel Combustion Analysis Based on Two –zone Model," JSME Vol. 39, 1996.
D.A. Pierpont, D.T. Montgomery, and Reitz, "Reducing Particulate and NO_X Using Multiple Injections and EGR in a D.I. Diesel" SAE 950217 1995:1-13
M .A. Patterson, S.-C.Kong, G. J. Hampson, and R. D. Reitz "Modeling the Effects of Fuel Injection Characteristics on Diesel Engine Soot and NO_X Emissions" SAE 940523 , 1994:1-17

Caroline L. Genzale and Rolf D.Reitz, "A Computational Investigation into the Effects of Spray Targeting, Bowl Geometry and Swirl Ratio for Low-Temperature Combustion in a Heavy-Duty Diesel Engine" SAE 2007-01-0119 2007:1-15

D. T. Montgomery and R. D. Reitz "Six-Mode Cycle Evaluation of the Effect of EGR and Multiple Injections on Particulate and NO_X Emissions from a D.I. Diesel Engine" SAE 960316 1996:113-130

Yu Shi and Rolf D. Reitz "Assessment of Optimization Methodologies to Study the Effects of Bowl Geometry, Spray Targeting and Swirl Ratio for a Heavy-Duty Diesel Engine Operated at High-Load" SAE 2008-01-0949, 2008:1-21

K O Lee, J Zhu, and J Song "Effects of exhaust gas recirculation on diesel particulate matter morphology and NO_X emissions" JER02307 F IMech E 2008 Int. J. Engine Res. Vol. 9

H Ogawa, T Li, and N Miyamoto "Characteristics of low temperature and low oxygen diesel combustion with ultra-high exhaust gas recirculation" JER00607 IMech E 2007 Int. J. Engine Res. Vol. 8.

M.Nakano Y Mandokoro, S Kubo and S Yamazaki "Effects of Exhaust gas recirculation in homogeneous charge compression ignition engines" JER 01100 IMech E 2000 Vol. 1 no. 3

N Ladommatos, S Abdelhalim and H Zhao "The effects of Exhaust Gas Recirculation on Diesel Combustion and Emissions" Int J Engine Research JER00899 IMechE´ Vol. 1 no. 1 2000.

Carlucci, A Ficarella and D Laforgia "Effects on combustion and emissions of early and pilot fuel injections in diesel engines" JER02703 IMech E Vol.6 No. 1.

S Yamamoto, M Nagaoka, R Ueda, Y Wakisaka and S Noda " Numerical simulation of diesel combustion with a high exhaust gas recirculation rate" JER05309 IMech E Vol.11 2010.

Sudhakar Das "Fluid Dynamic Study of Hollow Cone Sprays" SAE 2008-01-0131, 2008:1-7

Gokul Vishwanathan and Rolf D. Reitz "Numerical Predictions of Diesel Flame Lift-off Length and Soot Distributions under Low Temperature Combustion Conditions" SAE 2008-01-1331,2008:1-14

Matthew E. Fife and Paul C. Miles, Michael J. Bergin and Rolf D. Reitz "The Impact of a Non-Linear Turbulent Stress Relationship on Simulations of Flow and Combustion in an HSDI Diesel Engine" SAE 2008-01-1363 2008.

Takeshi Yoshikawa and Rolf D. Reitz "Development of an Improved NO_X reaction Mechanism for Low Temperature Diesel Combustion Modeling" SAE 2008-01-2413,2008:1-13

Jerome Barrand and Jason Bokar Michelin Reducing "Tire Rolling Resistance to Save Fuel and Lower Emissions" SAE 2008-01-0154.

Yong Sun and Rolf D. Reitz "Adaptive Injection Strategies (AIS) for Ultra-Low Emissions Diesel Engines" SAE 2008-01-0058.

J.M. Desantes, J. Benajes, S.Molina, C.A. Gonzalez "The modification of the fuel injection rate in heavy-duty diesel engines. Part 1: Effects on engine performance and emissions" Applied Thermal Engineering 24 2004.

*J.M. Desantes, J. Benajes *, S. Molina, C.A. Gonz_alez "The modification of the fuel injection rate in heavy-duty diesel engines" Applied Thermal Engineering Part 2: Effects on combustion" 24 2004.*

Kuen Yehliu, AndreL.Boehman, Octavio Armas "Emissions from different alternative diesel fuels operating with single and split fuel injection" Fuel 89 2010: 423–437.

Tiegang Fang a, Robert E. Coverdill b, Chia-fon F. Lee b, Robert A. White b" Effects of injection angles on combustion processes using multiple injection strategies in an HSDI diesel engine" Fuel 87 2008: 3232–3239.

C.Y.Choi, R.D. Reitz "An experimental study on the DI effects of oxygenated fuel blends and multiple injection strategies on diesel engine emissions" Fuel 78 1999:1303–1317.

Jean Arrègle, José V. Pastor, J.Javier López, Antonio García " Insights on post injection-associated soot emissions in direct injection diesel engines" Combustion and Flame 154 2008:448–461.

J.Benajes a, S. Molina a, C.Gonza´lez a, R.Donde b, "The role of nozzle convergence in diesel combustion" Fuel 87 2008: 1849–1858.

*A.P. Carlucci *, A. Ficarella, D. Laforgia " Control of the combustion behavior in a diesel engine using early injection and gas addition" Applied Thermal Engineering 26 2006: 2279–2286.*

Dale R. Treea Kenth I. Svensson "Soot processes in compression ignition engines" Progress in Energy and Combustion Science 33 2007: 272–309.

K. Verbiezen , A.J. Donkerbroek, R.J.H. Klein-Douwel, A.P. van Vliet, P.J.M. Frijters, X.L.J. Seykens, R.S.G. Baert, W.L. Meerts, N.J. Dam, J.J. ter Meulen "Diesel combustion: In-cylinder NO concentrations in relation to injection timing" Combustion and Flame 151 2007: 333–346.

Jian Gao, Seoksu Moon, Yuyin Zhang, Keiya Nishida, Yuhei Matsumoto " Flame structure of wall-impinging diesel fuel sprays injected by group-hole Nozzles" Combustion and Flame 156 2009: 1263–1277.

F. Payri, V. Bermu´dez, R. Payri, F.J. Salvador "The influence of cavitation on the internal flow and the spray characteristics in diesel injection nozzles" Fuel 83 2004: 419–431.*

R. Payri, F.J. Salvador, J. Gimeno, J. de la Morena "Effects of nozzle geometry on direct injection diesel engine combustion process" Applied Thermal Engineering 29 2009: 2051–2060.

Richard Opat, Youngchul Ra, Manuel A. Gonzalez D., Roger Krieger, Rolf D. Reitz and David E. Foster "Investigation of Mixing and Temperature Effects on HC/CO Emissions for Highly Dilute Low Temperature Combustion in a Light Duty Diesel Engine" SAE 2007-01- 0193 2007:1-21

Yong Sun and Rolf D. Reitz "Modeling Diesel Engine NO_X and Soot Reduction with Optimized Two-Stage Combustion" SAE 2006-01-0027 2006.

Hoojoong Kim and Rolf D. Reitz, Song-Charng Kong "Modeling Combustion and Emissions of HSDI Diesel Engines Using Injectors With Different Included Spray Angles" SAE 2006-01-1150 2006:1-11

Jaeman Lim and Kyoungdoug Min "The Effects of Spray Angle and Piston Bowl Shape on Diesel Engine Soot Emissions Using 3-D CFD Simulation" SAE 2005-01-2117 2005.

Satbir Singh, Song-Charng Kong and Rolf D. Reitz, Sundar R. Krishnan and K. Clark Midkiff "Modeling and Experiments of Dual-Fuel Engine Combustion and Emissions" SAE 2004-01-0092 2004:1-10

Mark P.B.Musculus "On the Correlation between NO_X Emissions and the Diesel Premixed Burn" SAE 2004-01-1401 2004:1-21

Yi Liu, Amr Ali and Rolf D.Reitz "Simulation of Effects of Valve Pockets and Internal Residual Gas Distribution on HSDI Diesel Combustion and Emissions" SAE 2004-01-0105 2004.

R.Udayakumar and P. Valan Arasu,S. Sriram "Experimental Investigation on Emission Control in C.I. Engines Using Shrouded Inlet Valve" SAE 2003-01-0350 2003.

Hanho Yun and Rolf D. Reitz "An Experimental Study on Emissions Optimization Using Micro-Genetic Algorithms in a HSDI Diesel Engine" SAE 2003-01-0347 2003.

Stefan Simescu, Scott B. Fiveland and Lee G. Dodge "An Experimental Investigation of PCCI-DI Combustion and Emissions in a Heavy-Duty Diesel Engine" SAE 2003-01-0345 2003.

R. Udayakumar and S. Sundaram R. Sriram "Reduction of NO_X Emissions by Water Injection in to the Inlet Manifold of a DI Diesel Engine" SAE 2003-01-0264 2003.

Bruno Walter and Bertrand Gatellier "Development of the High Power NADITM Concept Using Dual Mode Diesel Combustion to Achieve Zero NO_X and Particulate Emissions" SAE 2002-01-1744 2002.

Yoshihiro Hotta, Kiyomi Nakakita, Takayuki Fuyuto and Minaji Inayoshi " Cause of Exhaust Smoke and Its Reduction Methods in an HSDI Diesel Engine Under High-Speed and High-Load Conditions" SAE 2002-01-1160 2002.

Franz X. Moser, Theodor Sams and Wolfgang Cartellieri "Impact of Future Exhaust Gas Emission Legislation on the Heavy Duty Truck Engine" SAE 2001-01-0186 2001.

Shuji Kimura, Osamu Aoki, Yasuhisa Kitahara and Eiji Aiyoshizawa "Ultra-Clean Combustion Technology Combining a Low-Temperature and Premixed Combustion Concept for Meeting Future Emission Standards" SAE 2001-01-0200 2001:1-8

Timothy V. Johnson "Diesel Emission Control in Review" SAE 2000-01-0184 2001.

Shuji Kimura, Osamu Aoki, Hiroshi Ogawa and Shigeo Muranaka "New Combustion Concept for Ultra-Clean and High-Efficiency Small DI Diesel Engines" SAE 1999-01-3681 1999:1-10

Yoshiyuki Kidoguchi, Changlin Yang and Kei Miwa "Effect of High Squish Combustion Chamber on Simultaneous Reduction of NOx and Particulate from a Direct-Injection Diesel Engine" SAE 1999-01-1502 1999:1-11

D. K. Mather and R. D. Reitz "Modeling the Inuence of Fuel Injection Parameters on Diesel Engine Emissions" SAE 980789 1998.

John E. Dec and Robert E. Canaan "PLIF Imaging of NO Formation in a DI Diesel Engine" SAE 980147 1998.

Michael P. Walsh "Global Trends In Diesel Emissions Control - A 1998 Update" SAE 980186 1998.

Kazutoshi Mori "Worldwide Trends in Heavy-Duty Diesel Engine Exhaust Emission Legislation and Compliance Technologies" SAE 970753 1997:19-29

Hisakazu Suzuki, Noriyuki Koike, Hajime Ishii, and Matuo Odaka "Exhaust Purification of Diesel Engines by Homogeneous Charge with Compression Ignition Part 1: Experimental Investigation of Combustion and Exhaust Emission Behavior under Pre-Mixed Homogeneous Charge Compression Ignition Method" SAE 970313 1997:1-9

Yoshinaka Takeda, Nakagome Keiichi, and Niimura Keiichi "Emission Characteristics of Premixed Lean Diesel Combustion with Extremely Early Staged Fuel Injection" SAE 961163 1996:19-28

Paul D. Wiczynski Siegfried Mielke Richard Conrow "A Spherical Joint Piston Design for High Speed Diesel Engines" SAE 960055 1996:45-55

H. Pitsch, H. Barths and N. Peters " Three-Dimensional Modeling of NOx and Soot Formation in DI-Diesel Engines Using Detailed Chemistry Based on the Interactive Flame let Approach" SAE 962057 1996:103-117

Ronald J. Donahue, Gary L. Borman, and Glenn R. Bower "Cylinder-Averaged Histories of Nitrogen Oxide in a D.I. Diesel with Simulated Turbo charging" SAE 942046 1994:1-13

Takuo Yoshizaki, Keiya Nishida, and Hiroyuki Hiroyasu "Approach to Low NOx and Smoke Emission Engines by Using Phenomenological Simulation" SAE 930612 1993:1-14

Paulo C. F. Gomes and David A. Yates "The Influence of Some Engine Operating Parameters on Particulate Emissions" SAE 922222 1992:1-11

Peter L. Herzog, Ludwig Bürgler, Ernst Winklhofer, Paul Zelenka and Wolfgang Cartellieri " NOx Reduction Strategies for DI Diesel Engines" SAE 920470 1992:1-17

Mitsuru Konno, Takemi Chikahisa, and Tadashi Murayama "Reduction of Smoke and NOx by Strong Turbulence Generated During the Combustion Process in D.I. Diesel Engines" SAE 920467 1992:111-118

Z. Bazari "A DI Diesel Combustion and Emission Predictive Capability for Use in Cycle Simulation" SAE 920462 1992:37-60

Timothy P. Gardner "Investigation of the Effects of Engine Design Parameters on Diesel Combustion and Emissions Using Taguchi Methods" SAE 920116 1992:1-18

Manshik Kim and Rolf D. Reitz "Modeling Early Injection Processes in HSDI Diesel Engines" SAE 2006-01-0056 2006:3-14

Mark P. B. Musculus "Multiple Simultaneous Optical Diagnostic Imaging of Early-Injection Low-Temperature Combustion in a Heavy-Duty Diesel Engine" SAE 2006-01-0079 2006:1-30

W. L. Hardy and R. D. Reitz "An Experimental Investigation of Partially Premixed Combustion Strategies Using Multiple Injections in a Heavy-Duty Diesel Engine" SAE 2006-01-0917 2006:1-20

Yi Liu and Rolf D. Reitz "Optimizing HSDI Diesel Combustion and Emissions Using Multiple Injection Strategies" SAE 2005-01-0212 2005:1-18

Harmit Juneja, Youngchul Ra and Rolf D. Reitz "Optimization of Injection Rate Shape Using Active Control of Fuel Injection" SAE 2004-01-0530 2004:1-20

Sanghoon Kook and Choongsik Bae " Combustion Control Using Two-Stage Diesel Fuel Injection in a Single-Cylinder PCCI Engine" SAE2004-01-0938 2004:1-18

Wanhua Su, Tiejian Lin and Yiqiang Pei "A Compound Technology for HCCI Combustion in a DI Diesel Engine Based on the Multi-Pulse Injection and the BUMP Combustion Chamber" SAE 2003-01-0741 2003:1-12

Taewon Lee and Rolf D. Reitz "The Effects of Split Injection and Swirl on a HSDI Diesel Engine Equipped with a Common Rail Injection System" SAE 2003-01-0349 2003:1-16

D. D. Wickman, H. Yun and R. D. Reitz "Split-Spray Piston Geometry Optimized for HSDI Diesel Engine Combustion" SAE 2003-01-0348 2003:1-22

R.Shrivastava, R. Hessel and R. D. Reitz "CFD Optimization of DI Diesel Engine Performance and Emissions Using Variable Intake Valve Actuation with Boost Pressure, EGR and Multiple Injections" SAE 2002-01-0959 2002:1-20

Gunnar Stiesch and Guenter P. Merker "Modeling the Effect of Split Injections on DISI Engine Performance" SAE 2001-01-0965 2001:1-17

G.M.Bianchi and P.Pelloni "Numerical Analysis of Passenger Car HSDI Diesel Engines with the 2nd Generation of Common Rail Injection Systems: The Effect of Multiple Injections on Emissions" SAE 2001-01-1068 2001:1-21

D. T. Montgomery and R. D. Reitz "Effects of Multiple Injections and Flexible Control of Boost and EGR on Emissions and Fuel Consumption of a Heavy-Duty Diesel Engine" SAE 2001-01-0195 2001:1-24

C. Hasse, H. Barths and N. Peters "Modeling the Effect of Split Injections in Diesel Engines Using Representative Interactive Flamelets" SAE 1999-01-3547 1999:1-10

Marco Bakenhus and Rolf D. Reitz "Two-Color Combustion Visualization of Single and Split Injections in a Single-Cylinder Heavy-Duty D.I. Diesel Engine Using and Endoscope- Based Imaging System. 1999-01-1112 1999:1-20

Steven J. Lacher, Li Fan, Brad Backer, Jay K. Martin and Rolf Reitz "In-Cylinder Mixing Rate Measurements and CFD Analyses" SAE 1999-01-1110 1999:1-21

Takeshi Hashizume, Takeshi Miyamoto, Hisashi Akagawa and KinjiTsujimura, "Combustion and Emission Characteristics of Multiple Stage Diesel Combustion" SAE 980505 1998:1-12

Michael Chan, Sudhakar Das, and Rolf D. Reitz " Modeling Multiple Injection and EGR Effects on Diesel Engine Emissions" SAE 972864 1997:1-24

C. Y Choi, G. R. Bower, and R. D. Reitz "Effects of Biodiesel Blended Fuels and Multiple Injections on D. I. Diesel Engines" SAE 970218 1997:1-22

Laura M., Ricart and Rolf D. Reitz "Visualization and Modeling of Pilot Injection and Combustion in Diesel Engines" SAE 960833 1996:1-22

P. V. Farrell, C. T. Chang, and T. F. Su "High Pressure Multiple Injection Spray Characteristics" SAE 960860 1996:1-12

Jianwen Li Jae Ou Chae and S. M. Lee. S. Jeong "Modeling the Effects of Split Injection Scheme on Soot and NO Emissions of Direct Injection Diesel Engines by a Phenomenological Combustion Model" SAE 962062:1-8

Hiroshi Ishiwata, Takashi Ohishi, Kotaro Ryuzaki, Ken Unoki, and Nobuhiro Kitahara "A Feasibility Study of Pilot Injection in TICS (Timing and Injection Rate Control System)" SAE 940195 1994:1-10

Glenn R. Bower and David E. Foster "The Effect of Split Injection on Soot and NO_X Production in an Engine-Fed Combustion Chamber" SAE 932655 1993:1-16

Glenn R. Bower and David E. Foster "The Effect of Split Injection on Fuel Distribution in an Engine-Fed Combustion Chamber" SAE 930864 1993:1-18

W.J.Mickel,"Hydrogen and synthetic fuels for Transportation". A summary, SAE Paper 740599, presented at SAE East Coast meeting Anahe in California, Aug1947.

H.Monrad , CA Motar vehicle power plant for Ethanol and Methanol operation presented at the third International Symposium on Alcohol Fuels Technology held at Asilomar California May 28-31 1979.

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