

Experimental Analysis of Ignition Delay in Dual-Fuel Diesel Engine with Secondary Fuel

D B Lata^{*a}, Chandra Bhushan Kumar^b

^aDepartment of Energy, Central University of Jharkhand, Ranchi, India

^bDepartment of Mechanical Engineering, Birla Institute of Technology, Mesra, Ranchi, India.

Abstract. In the present research work, experiments were conducted on four cylinder water-cooled DI compression ignition diesel engine with diesel as base fuel, LPG and hydrogen gas as substitute fuel. For the experimental work diesel engine was modified to run on base fuel diesel and secondary fuel gas. The experiments were conducted to measure the variation of pressure, ID period at varied conditions of load and different substitution of diesel with LPG and hydrogen fuel with and without EGR at rated speed. For the comparative study, the experimental result of ID were compared and contrasted with Hadenberge-Hase equation for the diesel engine and DFD diesel.

Keywords: Dual-fuel, Dual fuel compression ignition diesel engine, Alternative fuel, Ignition delay, Exhaust gas recirculation.

1. Introduction

In conventional diesel engines, overall just around 82% fuel burns completely. When gaseous fuel like H₂ or LPG inducted in the dual fuel diesel engine by intake manifold, 98% of fuel can be burnt. It is starting at now comprehended that emissions issues like are PM, CO and NO_x are, as it were, associated with the diesel engine. By using gaseous fuel like H₂, LPG or mixture of H₂ and LPG, pollution can be reduced [1].

Saket verma et al. [2] experimented on dual-fuel diesel engine using jatropha as a biodiesel and hydrogen gas as secondary fuel. They were used up to 80.7% and 24.5% of hydrogen (by energy basis) in the DFD engine at high and low loads conditions. Brake thermal efficiency was increased and exhaust emissions like CO, NO_x smoke were decreases as compared to parent diesel engine. Exhaust emission NO_x was reduced with addition of EGR in the DF with bio-diesel as primary source of fuel and hydrogen as substitute fuel. Utilisation of hydrogen improves at the comparable brake thermal efficiency and NO_x emissions [2].

S.K Karthica et al. [3] have experimented on DFD single cylinder diesel engine at constant speed to study the effective utilization of madhuca longifolia oil (ML) in a diesel engine. Experimental work were done by utilising primary fuel hydrogen. Hydrogen was inducted in the engine with air by the help of intake manifold where as ML was injected directly into the engine cylinder for ignition source. They were claimed that the performance of DFD engine increased from 25% to 28% with ML used as pilot fuel and hydrogen as base fuel for diesel engine. However, they were facing the knocking in the DFD engine when hydrogen used as base fuel and as a result brake thermal efficiency decreases. In their experiment, they used water injection to increase the knocking limit so that more percentage of ML can be replaced. Further they claimed that BTE exhaust gas emissions were increases upto 18% to 76% with 5% of water addition along with hydrogen fuel.

Pavlos Dimitriou et al. [4] were tested hydrogen gas under different conditions of load on a HD DFD engine. They used different hydrogen energy share ratio to substitute diesel fuel under different conditions such as diesel injection pressure, EGR and injection pattern to compared the performance and exhaust emissions of dual fuel diesel engine with parent diesel engine. Engine operation was smooth over 98% use of hydrogen on the energy basis. Further it was observed that 90% reduction in NO_x and carbon monoxide while soot emissions was reduced upto 85% compared to the base diesel engine.

Appeared differently concerning natural gas LPG has the advantage of low-pressure storage, straightforwardness of transportation and more secure managing. Natural gas liquids (NGL), available in different gas fields in India, are a potential wellspring of hydrocarbons from which LPG can be conveyed locally. LPG can be use as the substitute fuel for diesel fuel in the DFD engines and a choice fuel with diesel for CI engines in DF operation [5-7]. The usage of liquid petroleum gas (LPG), as an alternative fuel, is a promising course of action. The higher auto-ignition temperature, higher calorific value, and likewise, easy mobility make LPG a good alternative fuel for diesel replacement [8-9]. The reasonably high auto-ignition

temperature of LPG is used, allowing the compression extent of conventional diesel engines to be kept up and making minimum engine adjustments. It has the capacity of significant diesel save supports and extended vitality to the system [9]. Engine response is smoother and snappier when gas is incorporated, and substitution is high [11].

Modifying timetable can be connected in view of fumigation of gaseous fuel, lessened injector updating, and longer oil change between times in light of less contamination of engine oil. Furthermore, the engine can continue running on diesel as it did before change, paying little heed to the likelihood that it misses the mark on LPG [12].

The present work introducing LPG using gas fumigation technique is a way for thinking the distinct parts of using LPG as a DF with diesel in a conventional CI ignition engine [13].

From the above literature, it was conclude that LPG and hydrogen gas can be used as base fuel with some modification in the diesel engine. Use of LPG and hydrogen in the diesel engine not only increases the performance but also reduces the exhaust emissions .The objective of this paper is to study the ID of DFD diesel engine using base fuel diesel with LPG and hydrogen gas with and without EGR.

2. Methodology

2.1 Experimental Setup

The experimental work were done on four-cylinder turbocharged, intercooler with 62.5 Kilo Watt diesel engine with generator, which was modified to work on DFD mode. The system was fitted with arrangements for measurements of air-flow, fuel flow (diesel LPG & hydrogen), various temperatures, engine speed and torque etc.

2.2 Testing

The trial were performed under three cases.

- (i) Case I: DFD engine runs on diesel only.
- (ii) Case II: DFD engine runs on blend of diesel and hydrogen gas.
- (iii) Case III: DFD engine runs on blend of diesel and LPG gas.

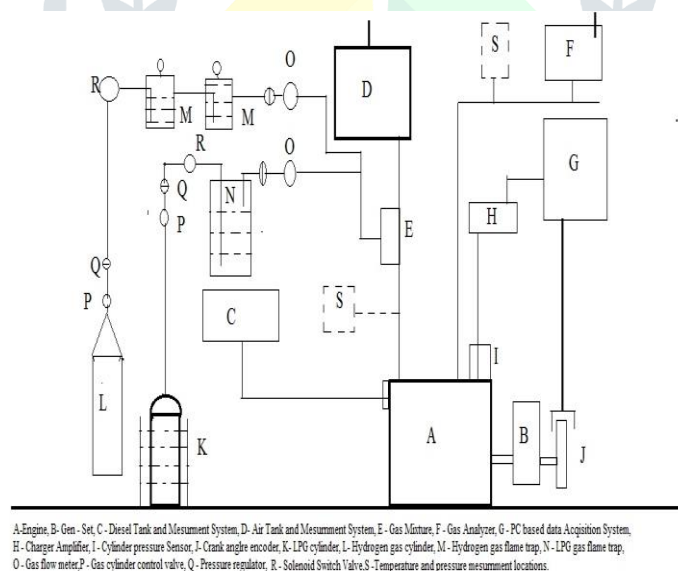


Fig.1. Diagram of experiment

3. Experimental Results

The experimental work were performed on four-cylinder turbocharged diesel engine at speed with different load conditions. The experimental results of ID were comparing and contrasting with Hadenberge – Hase equation. The consequences are talked about beneath.

Load (%)	LPG (CA)	Hydrogen (CA)	Diesel(CA)
2	14	13	10
20	12	11	9
40	9	8	6

Table 1.- Ignition delay at various fuel substitutions

It is found that at light load ignition delay is less as compared to heavy load. When the load increases on the engine, the mean temperature of the charge also increases. At higher load vapor pressure increases, which increase the temperature and reducing the ID period, This might be the reason of decreasing ID with increasing load. When the hydrogen gas used in the diesel engine, the ID increases. With utilisation of hydrogen in diesel engine the partial pressure of O₂ decreases and specific heat of charge increases as a result ID increases. Also, it is found that pre-ignition is responsible for ID.

LPG has higher ID as compared to other cases of the experiment. This may be because of the low specific heat of LPG; hence, the ID is more. We had also found that as the EGR% increases, the ID increase, this is because in the case with EGR the space covered by the combustion phenomena in the cylinder of the engine is smaller than in the case without recirculation.

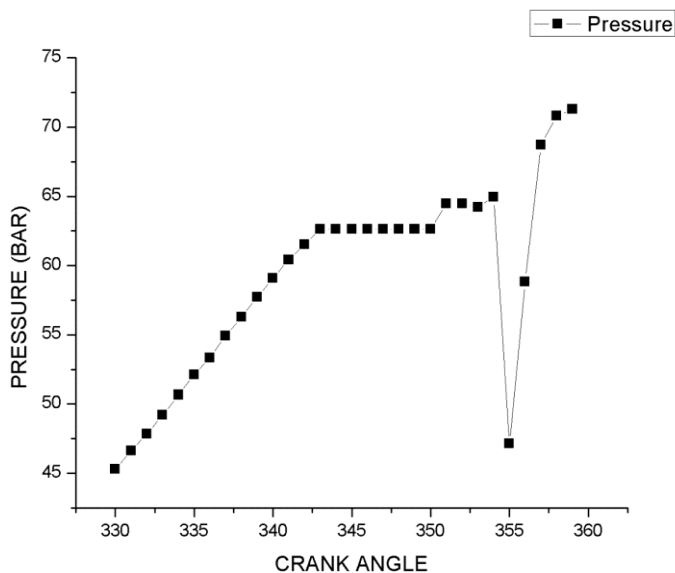


Fig. 2. Mean pressure vs. crank angle

The experimental results of ignition delay has been compared with Hadenberge –Hase equation for diesel engine [14-15].

$$\tau_{id} = Ap^{-n}e^{\left(\frac{E_a}{RT}\right)}$$

The linear regression has been done to find the empirical constant A, n & E_a by putting the experimental value of τ_{id} , p, R & T. By doing this we get the value as follow:

$$A = 0.072309$$

$$n = -0.46347$$

$$E_a = 15741.75$$

Hence the formula with an empirical constant of ignition delay will be [16-17]

$$\tau_{id} = 0.072309p^{-0.46347}e^{\left(\frac{15741.75}{RT}\right)}$$

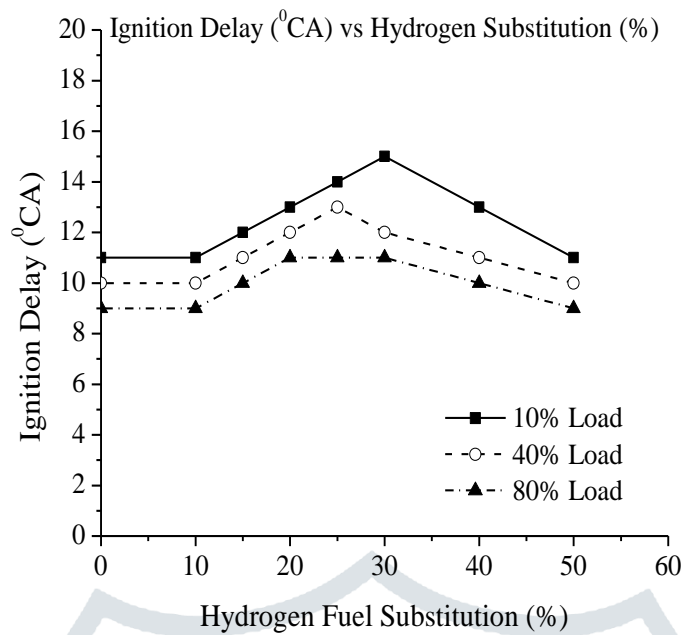


Fig. 3 Ignition Delay ($^{\circ}$ CA) vs. Hydrogen Substitution (%)

The ignition delay with respect to hydrogen substitution at various load condition is depicted in Fig. 3. It is observed that ignition delay get increased by the addition of hydrogen this might be due to less ignition centre.

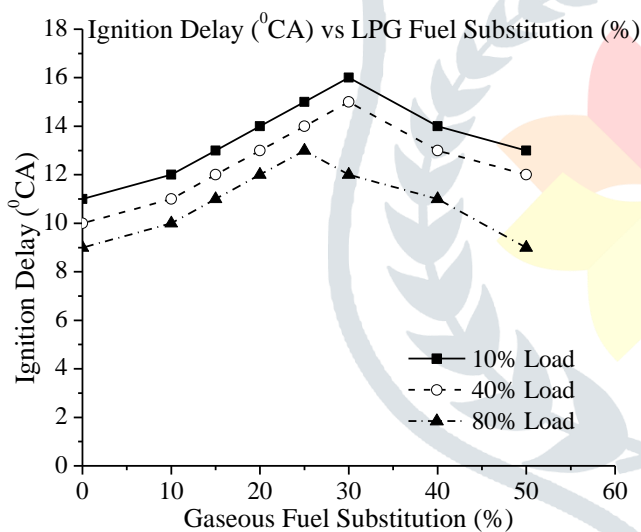


Fig. 4 Ignition delay ($^{\circ}$ CA) vs. LPG substitution (%)

Similarly, the ignition delay by submission of LPG (Fig. 4) also get increased by the substitution as compared to pure diesel engine.

4. Conclusions

From this research work, a few conclusions can be drawn that the ID of DFD engine depends on the nature and type of the fuel used in the engine. The ID of DFD dual-fuel is the function of mean temperature, mean pressure and oxygen concentration of the changes. The ID of DFD engine running on hydrogen & LPG decreases with the increase in loads and gaseous fuel substitution. The ID of DFD engine increases with increase in the percentage EGR. The presence of hydrogen or LPG before combustion might be influences energy release rate, pre-ignition reaction rate and as a results the ID increases.

Nomenclature

DFD	Dual fuel diesel
DF	Duel fuel
ID	Ignition delay

CNG	Compressed natural gas
NG-	Natural gas
NGL	Natural gas-liquid
MMCFD	Million cubic sustain everyday
CI	Compression ignition
PM	Particulate matter
DPF	Diesel particulate filter
CN	Cetane number
HRR	Heat release rate
BTDC	Before top dead centre
EGR	Exhaust gas recirculation
E _a	Activation energy

References

- Eiji Tomita, Nobuyuki Kawahara, Yoshisuke Hamamoto, Zhen-Yu Piao And Shogo Fujita "A Study On Hydrogen Combustion Ignited With Light Oil In A Dual-fuel Engine" 4th Jsme-Ksme thermal Engineering Conference october 1-6, 2000, Kobe, Japan.
- Saket Verma, Abhishek Suman, L.M. Das, S.C. Kaushik, S.K. Tyagi " An experimental investigation of exergetic performance and emission characteristics of hydrogen supplemented biogas-diesel dual-fuel engine" Int. journal o f hydrogen energy 43 (2018) 245 2-2468
- S.V. Karthica, M. Senthil kumara, P. Pradeepa, S. Vinoth Kumar. "Assessment of hydrogen-based dual fuel engine on extending knocks limiting combustion. Fuel 260 (2020) 116342.
- Pavlos Dimitriou, Madan Kumar, Taku Tsujimura, Yasumasa Suzuki. Combustion and emission characteristics of a hydrogen-diesel dual-fuel engine. Int. Journal o f hydrogen energy 43 (2018) 13605- 3617
- L. M. Das "Hydrogen-Oxygen Reaction Mechanism and Its implication to hydrogen engine combustion" Int. J, Hydrogen Energy Vol. 21. No. 8, Pp. 70.; 715. 1996 International Association For Hydrogen Energy Elsevier Science Ltd.
- S. Verhelst , R. Sierens "Hydrogen Engine-Specific Properties" International Journal Of Hydrogen Energy 26 (2001) 987–990.
- Steven C. Amendola, Stefanie L. Sharp-Goldman, M. Saleem Janjua, Nicole C. Spencer, Michael T. Kelly, Phillip J. Petillo, Michael "A Safe, Portable, Hydrogen Gas Generator Using Aqueous Borohydride Solution And Ru Catalyst" International Journal Of Hydrogen Energy 25 (2000) 969-975.
- S. Orhan Akansu, Zafer Dulger, Nafiz Kahraman, T. Nejat Veziroglu "Internal Combustion Engines Fueled By Natural Gas—Hydrogen Mixtures" International Journal Of Hydrogen Energy 29 (2004) 1527 – 1539.
- Ali Mohammadi, Masahiro Shioji, Yasuyuki Nakai, Wataru Ishikura, Eizo Tabo "Performance And Combustion Characteristics Of A Direct Injection Si Hydrogen Engine" International Journal Of Hydrogen Energy 32 (2007) 296 – 304.
- P. Van Blarigan And J. O. Keller "A Hydrogen Fuelled Internal Combustion Engine Designed For Single Speed/Power Operation" Int. J. Hydrogen Energy, Vol. 23, No. 7, Pp. 603-609, 1998.
- Wentao Wang, Jose M. Herreros, Athanasios Tsolakis , Andrew P.E. York, "Increased No₂ Concentration In The Diesel Engine Exhaust For Improved Ag/Al₂O₃ Catalyst Nh₃-Scr Activity" Chemical Engineering Journal 270 (2015) 582–589.
- Antony Misdariis, Olivier Vermorel, Thierry Poinot "A Methodology Based On Reduced Schemes To Compute Autoignition And Propagation In Internal Combustion Engines" Proceedings Of The Combustion Institute 35 (2015) 3001–3008.
- A. Tsolakis, J. J. Hernandez, A. Megaritis And M. Crampton "Dual Fuel Diesel Engine Operation Using H₂. Effect on Particulate Emissions" Energy & Fuels 2005, 19, 418-425.
- Jabbar, Abdulkhakim I., and Umit O. Koylu. "Influence of operating parameters on performance and emissions for a compression-ignition engine fueled by hydrogen/diesel mixtures." International Journal of Hydrogen Energy 44, no. 26 (2019): 13964-13973.
- Juknelevicius, Romualdas, Stanislaw Szwaja, Michal Pyrc, and Michal Gruca. "Influence of hydrogen co-combustion with diesel fuel on performance, smoke and combustion phases in the compression ignition engine." International Journal of Hydrogen Energy 44, no. 34 (2019): 19026