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PERFORMANCE SIMULATION OF DIESEL ENGINE FUELLED WITH DIESEL-DIGLYME BLEND BY USING UNIVERSAL LOAD ANDOXYGENATE CORRECTION FACTORS IN WIEBE HEAT RELEASE FUNCTION

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ABSTRACT

One of the proven ways of achieving low emission in diesel engine is oxygenate additive blending with diesel. Diesel-oxygenate blends are reducing gaseous and particulate emissions from diesel engines. However, reducing emissions by oxygenating additives may inflict penalty in the power output due to their energy content lower than that of diesel. Computer simulation of performance of a diesel engine fuelled with diesel and with diesel-oxygenate blend will identify any improvement or decrement in the power output. Such an improvement with identical heat input under identical operating conditions of the engine will decrease emission. Hence, heat release rate of a diesel engine fuelled with diesel-diglyme blend is synthesized by Wiebe function under identical operating conditions relating to base diesel. Limitation of predicting Wiebe efficiency factor with diesel-diglyme blend by trial and error method in the old model is removed. The Wiebe efficiency factor is computed directly without engine specific constant by multiplying the fitted diesel fuel Wiebe factor of all power outputs by the universal oxygenate correction factor in the new model. The universal oxygenate correction factor has been defined earlier as the ratio between the mass flow rate of diesel-oxygenate blend and diesel fuel under identical power output. Performance simulation of direct injection diesel engine fuelled with diesel-oxygenate blend by using the universal oxygenate correction factor is simplified in this paper.

Key words: Load correction factor, Oxygenate correction factor, Wiebe function, Performance simulation, Diesel engine.

INTRODUCTION

Ever spreading application of diesel engines in smaller trucks and cars is increasing the concern over environmental protection from the resulting engine out emissions.

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Therefore, modern day diesel engines will require stringent control over emissions to complaint with future exhaust gas regulation standards. Fuel additive technique by oxygenates seems to be very promising path towards achieving stringent emission control so as to complaint with future regulation standards. Oxygenate-diesel blends can reduce particulate matter emission and help No_x control strategy[1-5]. Oxygenates having very high cetane number can be used as ignition improver also. Almost all the oxygen containing chemical compounds such as alcohols, ethers and esters of vegetable oils found in the experimental literature were reducing emissions. But only some of them were improving engine performance. Hence, oxygenates screening to provide improvement in engine performance also is very difficult by experimental investigations. However, computer simulation of engine performance improvement by oxygenates well before the experimental investigations would simplify the screening process. Therefore, a generic performance simulation model for diesel-oxygenate blends is acquit necessary to screen the number of oxygenates available for blending.

Synthesized oxygenated chemical compounds such as ethers, glycol ethers, alcohol, methylal and carbonates or biomass products such as esters of vegetable oils can be used for diesel blending. Experimental and theoretical findings reveal the earlier initiation of combustion by oxygenates having cetane number higher than diesel and consequent increase in cylinder pressure. Slight increase in brake specific fuel consumption is also recognized by oxygenates having calorific value lower than diesel[6]. Theoretical and experimental studies were conducted in a direct injection compression ignition engine to investigate the performance improvement due to oxygen presence and higher cetane number of oxygenate blended fuel. The performance improvement investigations were carried out by conducting simulation study with existing sub models[7-8] and experimental validation on a single cylinder, naturally aspirated, constant speed diesel engine with 1.5% by volume of the oxygenate, Diethyleneglycol dimethyl ether (diglyme)[7-8]. Further, the Wiebe shape factor (m) is also corrected by the universal oxygenate and load correction factor in this paper and the new model predictingmass rate input and Wiebe factors at optimum and all other power output of the engine fuelled with diesel-diglyme blend is presented as under.

Combustion model

A two-zone combustion concept considering the volume of jet as burning zone and the remainder of cylinder contents as non-burning zone is employed to model the combustion. The Wiebe heat release function based on exponential rate of the chemical reactions is utilized to compute heat release and the fraction of heat released is expressed by non-dimensional equation (1). Whereas, heat released per degree crank angle is given by the equation (2).

$$X = 1 - \exp\left[-a \cdot \left(\frac{\theta - \theta_i}{\Delta\theta_c}\right)^{m+1}\right] \quad \ldots(1)$$

$$\frac{dQ}{d\theta} = a \cdot (m+1) \cdot \left(\frac{Q}{\Delta\theta_c}\right) \cdot \left(\frac{(\theta - \theta_i)}{\Delta\theta_c}\right)^{m} \cdot \exp\left[-a \cdot \left(\frac{\theta - \theta_i}{\Delta\theta_c}\right)^{m+1}\right] \quad \ldots(2)$$

The Wiebe shape factor (m) and the Wiebe efficiency factor (a) are adjustable parameters used to fit the experimental data. However, these parameter values depend on the engine load, speed and type of fuel. Therefore, two correction factors, universal load correction factor and universal oxygenate correction factor were employed in the Wiebe heat release rate function given by the equation (2) to predict the heat release rate at different power outputs of the direct injection diesel engine fuelled with diesel-oxygenate blend. The definition of the two correction factors are given below.

(1) The universal load correction factor (lc) is defined as the ratio of base fuel input for a power output to the base fuel input for the optimum power output (engine power output with lowest specific fuel consumption) in order to calculate the power output at various fuel inputs[7-8].

(2) The universal oxygenate correction factor (oc) is defined as the ratio of base fuel-oxygenate blend input to the base fuel input in order to calculate the equivalent power output as that of the base fuel[7-8].

RESULTS AND DISCUSSION

Wiebe factors computation-diesel

From the experimental investigation with base diesel fuel, apparent heat release rate of optimum power output was fitted with factor m = 1.435, efficiency factor a = 2.75 with dynamic injection timing of 9°. The heat release rate prediction at all other power outputs after correcting the factor ‘m’ also is carried out by multiplying optimum factors ‘m’ and ‘a’ by the load correction factor, factor m = 1.435 x lc, factor a = 2.75 x lc with dynamic injection timing of 9°.

Wiebe factors computation-diesel-oxygenate blend

The diesel-oxygenate blend’s input, the factor ‘m’ and Wiebe efficiency factor ‘a’ are corrected with the help of oxygenate correction factor so as to produce the same optimum power output as that of base diesel. The cumbersome exercise of trial and error method of fitting the factor' a' in the old model is replaced by multiplying the fitted diesel factors of optimum and other power outputs by oxygenate correction factor, m = 1.435 x lc x oc and efficiency factor a = 2.75 x lc x oc with dynamic injection timing of 9° except at 20% power output where it is reduced to 8°.

Performance comparison-diesel and diesel-oxygenate blend

Performance parameters predicted by the new model are presented in Figs. 1 and 2.

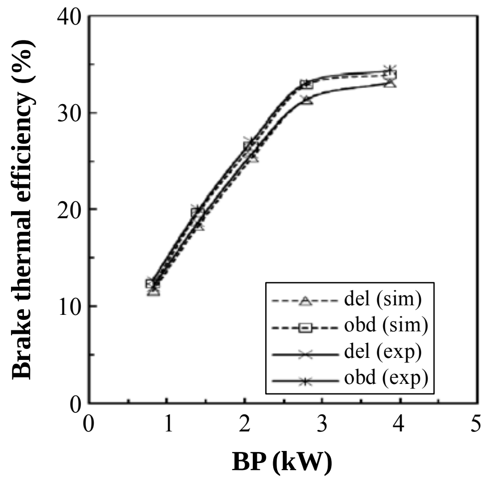

Fig. 1: Comparison of synthesized and experimental brake thermal efficiency of diesel and diesel-diglyme blend after correcting factor 'm'

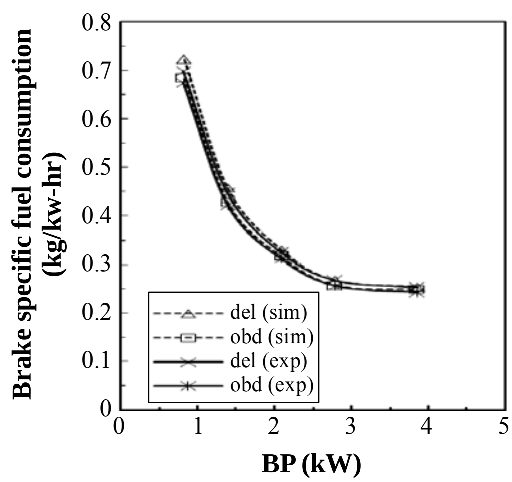

Fig. 2: Comparison of synthesized and experimental brake specific fuel consumption of diesel and diesel-diglyme blend after correcting factor 'm'

Percentage increase predicted in brake thermal efficiencies for diesel-diglyme blend over diesel are 6.47, 7.59, 4.93, 4.91 and 2.75 at 20%, 30%, 45%, 65% and 85% power output respectively after correcting the factor 'm' also. Under identical conditions, the measured experimental percentage increase in brake thermal efficiencies are 6.10, 6.73, 5.04, 5.45 and 4.22. Percentage decrease predicted in brake specific fuel consumptions are 5.40, 6.36, 4.03, 4.01 and 3.16 at 20%, 30%, 45%, 65% and 85% power output respectively. Under identical conditions, the experimental percentage decrease measured in brake specific fuel consumptions are 3.48, 5.61, 4.10, 4.53 and 4.19. The simplification of the model by removing trial and error method of prediction reduced the deviation in percentage increase or decrease in performance parameters at all power outputs.

CONCLUSION

Apparent heat release rate of a direct injection diesel engine fuelled with diesel-oxygenate blend is predicted by using universal oxygenate correction factor in Wiebe function. The Wiebe dimensionless equation and its derivative is found successful in predicting mass fraction burned and heat release rate respectively. The Wiebe function factors 'm' and 'a' are fitted with the help of universal oxygenate correction factor because universal oxygenate correction factor is the quantitative measure of the relationship exists between diesel and diesel-oxygenate blend heat release rate. The close agreements between simulated and experimental performance parameters of the engine establishes the consistency in the prediction by the universal oxygenate correction factor. The cumbersome exercise of trial and error prediction of Wiebe efficiency factor 'a' is removed by the direct computation of the factor by the universal oxygenate correction factor in the new model.

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