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STUDIES ON THE ENHANCEMENT OF DIESEL ENGINE COMBUSTION THROUGH THE USE OF PIB-SUCCINIMIDE TYPE FUEL ADDITIVE AND INTERNAL JETS FOR TURBULENCE INDUCEMENT TO REDUCE ENVIRONMENTAL POLLUTION

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ABSTRACT

In this work, an attempt has been made to compare the measured performance of a diesel engine and the smoke and oxides of nitrogen emissions with PIB-succinimide fuel additive and two internal jets of 2.5 mm diameter positioned at 180 degrees to each other in a cavity to induce turbulence in the combustion chamber. A detailed analysis on the performance and emission on these samples has been attempted for understanding the effect of the additive and the turbulence inducement using internal jets. PIB-succinimide additive was extensively tested in diesel engines to determine its effect on exhaust emissions. Testing with this additive and internal jet resulted in exhaust smoke being reduced, with slight increase in oxides of nitrogen.

Key words: PIB-succinimide Additives, Emission control, Internal jets, Turbulence Inducement Technique.

INTRODUCTION

Direct injection (DI) diesel engines becoming acceptable choice as prime movers in many applications, it has become necessity to improve their fuel consumption and emission characteristics. For this purpose, several attempts are ongoing to improve the emission characteristics of DI diesel engines without having to sacrifice their fuel consumption advantage. The increase in demand for petroleum fuels and consequent depletion of their

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reserves has given rise to the need for investigating new energy resources or finding the optimum way of using the present resources. The particulate emission reduction could be attained using the ash less additive technology[1].

It is observed that the particulate matters (PM) and the oxides of nitrogen (NOx) emissions were statistically insignificant with different poly-aromatic and total aromatic levels. However, there was a definite trend in their results showing higher NOx emissions with increasing total aromatic or poly-aromatic levels of the fuel[2]. Different additives are used along with diesel and biodiesel. The purposes of these additives are to improve the cold flow properties of the fuel and engine performance and emission characteristics. In this paper detailed review of effect of additives on fuel properties, combustion characteristics engine performance and emission from the engine is done[3].

The emission reduction is possible by a new bio-derived oxygenated compound, 1, 1-diethoxyethane, used as additive in an automotive diesel engine[4]. 2-methoxyethy acetate can be used to decrease exhaust smoke as a new oxygenated additive of diesel[5]. The study of the different behaviors in the combustion between the diesel-diglyme blends and the other five diesels-oxygenate blends as the diglyme has the higher cetane number than that of diesel fuel while the other five oxygenates have the lower cetane number than that of diesel fuel[6].

The diesel fuel additives such as cetane improvers, combustion improvers, diesel detergents, low aromatic and sulphur content in fuel and lubricity additives can give a desirable effect[7-9]. Properly formulated diesel additive with the above measures will result in desirable changes in the emissions and performance of the engine. The tightening environmental legislations can only be satisfied by high performance detergent-dispersant additives. In a long period these additives are not only responsible for the cleaning of the engine, but they also decrease fuel consumption[10]. The detergent-dispersant additives have about 40-50% share of the additive market; they are usually long chain hydrocarbons with polar groups[11,12]. The synthesized additives such as polyisobutylene (PIB)-succinimides showed same or better detergent-dispersant properties compared to the conventional diesel and biodiesel blends. They also provided corrosion inhibiting and lubricity improving effects when applied in diesel fuel, 5% biodiesel containing diesel fuel and 100% biodiesel[13,14]. In this investigation the role of PIB-succinic anhydride (PIB-SA) combinations with 2.5 mm diameter internal jet positioned 180 degrees to each other were analyzed to improve engine combustion characteristics and to reduce emission.

EXPERIMENTAL

Test engine

A single cylinder air cooled four stroke direct injection (DI) compression ignition diesel engine was chosen for the investigation. Engine Cylinder pressure and Top Dead Center (TDC) signals were acquired and stored on a high speed computer based digital data acquisition system. The engine was coupled with the swinging field electrical dynamometer. It is basically a shunt motor that can operate as a generator and a motor. A photo sensor along with the digital rpm indicator was used to measure the speed of the engine. Fuel flow rate was measured on the volume basis using a burette and stopwatch. During the engine operation the air to the engine from the atmosphere was through the flow meter. Temperature of the exhaust and the mean cylinder wall temperature were measured using chromel-alumel (k-Type) thermocouples. Smoke level was measured using a standard AVL smoke meter system. Nitric oxide emission in the exhaust gas was measured with the chemiluminescent analyzer.

Engine experimentation

The experiments using additives with fuel were carried out at a constant engine speed of 1500 rpm with varying loads between no load to full load conditions. The tests were performed with diesel, 0.5% of fuel-additive with diesel. The polymer based additive is PIB-succinic anhydride (PIB-SA). The samples of the additive were prepared in a solvent viz. the mineral turpentine oil (MTO) in the ratio of 30% to 70% by mass, respectively. These samples of additives with MTO were then added to the commercial diesel fuel in proportions of 0.5% by volume for the tests. Also to increase turbulence in the combustion chamber, two 2.5 mm diameter internal jets were positioned at 180 degrees to each other in the cavity. The internal jet is introduced through holes on the piston crown, allowing a tangential entry of the working fluid into the piston cavity along the direction of swirl. The experimental cylinder pressure data obtained in each case and also combined performance of additives and internal jets are analyzed on the engine combustion and emissions characteristics.

RESULTS AND DISCUSSION

The present investigation concerns improvement in performance, combustion and emission characteristics of a direct injection diesel engine through methods enabling improvement in ignition characteristics of the fuel by the use of additive and by internal jet for turbulence inducement. The experimental results obtained and the combustion analyses carried out during this investigation forms the basis of the discussions presented in the following paragraphs.

Combined effects of fuel additive and in-cylinder turbulence modification

From the investigations carried out in the present work on the fuel additive and in-cylinder turbulence inducement, the following cases yielded the best of the improvements in the diesel engine performance, combustion and emission characteristics in the respective categories:

1. The PIB-SP additive with 0.5% by volume in the base fuel, and
2. The two internal jets of 2.5 mm diameter in the base engine

It is considered necessary that a typical evaluation of the combined effects of these two independent cases is examined and the net improvements in the engine performance ascertained. For this purpose, a selective set of experimentation was conducted involving the aforesaid modifications of fuel with additive and the internal jets combined together and compared with base engine and their independent test results. The results of these experiments on BSFC, combustion parameter, exhaust smoke and oxides of nitrogen emissions with varying loads are shown in Figs. 1 to 6.

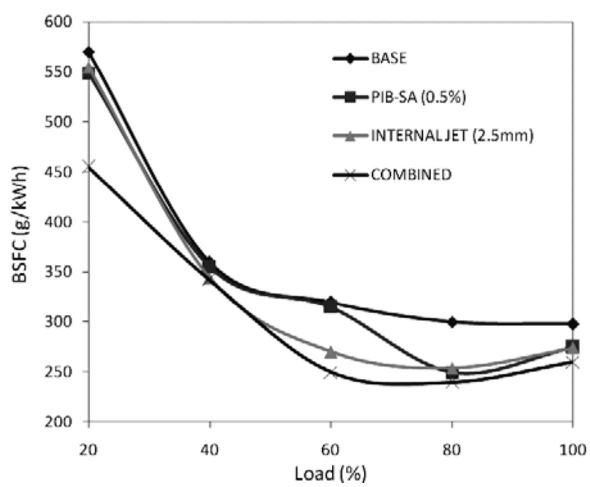

Fig. 1: Variation of brake specific fuel consumption with load

Fig. 1 shows a comparison of brake specific fuel consumption (BSFC) at various loads obtained for base engine, independent and combined changes of fuel and fuel-air mixing as identified. It is observed that while fuel and fuel-air mixing modifications independently yielded 7.7% and 8.05% reduction in BSFC, their combined effects provided 12.75% improvement over the base engine value. This effect is attributed to the simultaneous effects of additive in fuel which acts as a combustion enhancer and better fuel dispersion in conjunction with better fuel-air mixing due to inducement of turbulence in presence of the internal jets.

The variations of ignition delay and combustion durations are shown in Figs. 2 and 3, respectively. Generally, a marginal increase of 1°C A is observed in the ignition delay values over base engine conditions.

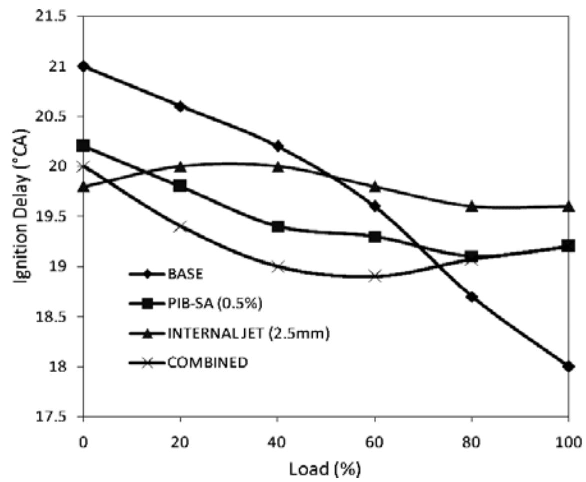

Fig. 2: Variation of ignition delay with load

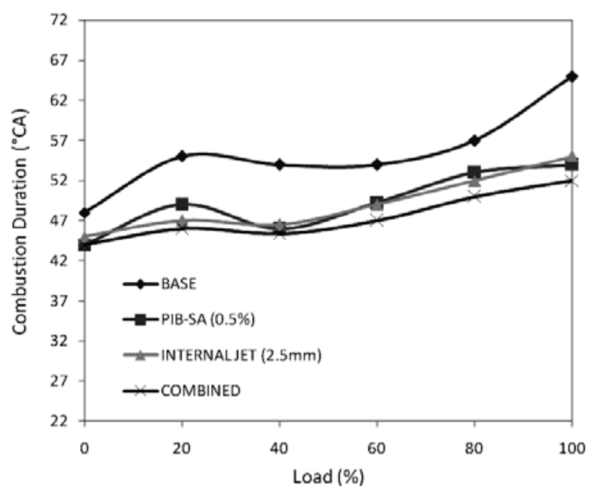

Fig. 3: Variation of combustion duration with load

While the effect on the ignition delay is not considered too significant, the combustion duration under the combined effect of fuel and fuel-air mixing modifications seem to have shortened considerably. This would imply that a better mixture formation due to well timed jet induced turbulence in conjunction with better combustion with fuel additive have surfaced together for the efficient burning of the fuel and more importantly during the diffusion phase of the diesel engine combustion.

Fig. 4 shows a comparison of the peak pressures, it is observed that under the combined effects of modifications in fuel and fuel-air mixing, the peak pressure and the maximum rate of pressure rise values decreased over base engine values and that obtained during the independent modifications in fuel and the engine turbulence. These results reveal a smoother combustion is attained in the engine with the modifications in place. The peak pressure using internal jet is considerable reduced compared to all other modes, due to the delay in ignition during this mode. At rated power output the peak pressure for combined mode is same for internal jet mode.

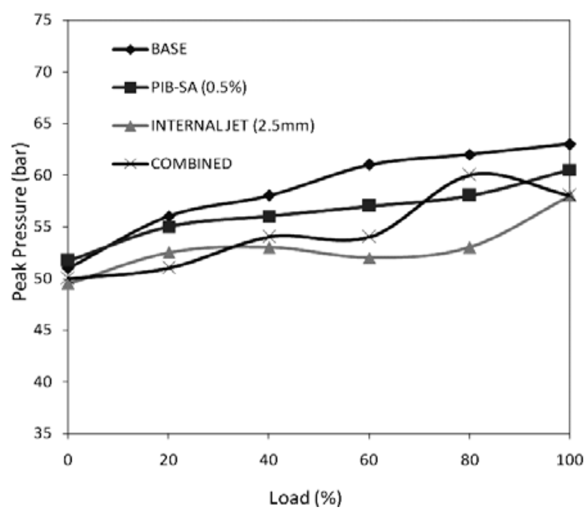

Fig. 4: Variation of peak pressure with load

It appears that the changes in engine combustion have resulted in significant influence on the exhaust smoke values, as shown in Fig. 5. The exhaust smoke values under the combined changes of fuel and fuel-air mixing decreased by 55.35% (5.6 BSU to 2.5 BSU) over the base value. However, the effects of additive in fuel and fuel-air mixing independently observed to be 46.42 percent (5.7 BSU to 3 BSU) and 28.57 percent (5.7 BSU to 4 BSU), respectively.

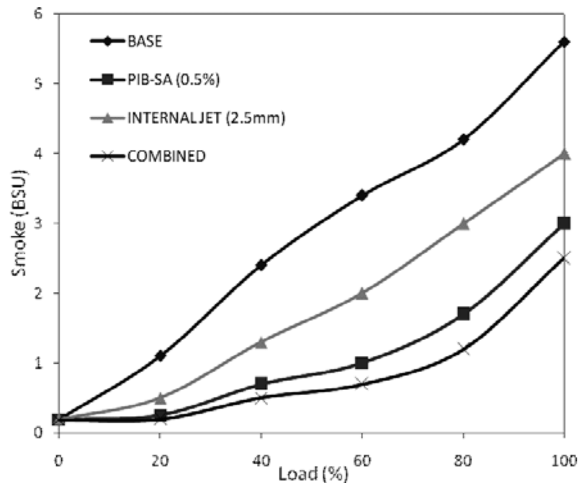

Fig. 5: Variation of smoke with load

As regards nitric oxide emissions (refer Fig. 6) are concerned, there is no change is observed in case of combined changes in fuel and fuel-air mixing conditions over the base engine value of oxides of nitrogen concentrations at full load. At part load condition the quantity of the injected fuel is less, which indicates that a lean combustion occurs at part load condition which resulted in higher oxides of nitrogen emissions whereas at full load the fuel quantity injected is more for the same quantity of air where the air fuel mixture tends towards stochiometric condition, which has resulted in less oxides of nitrogen at full load condition.

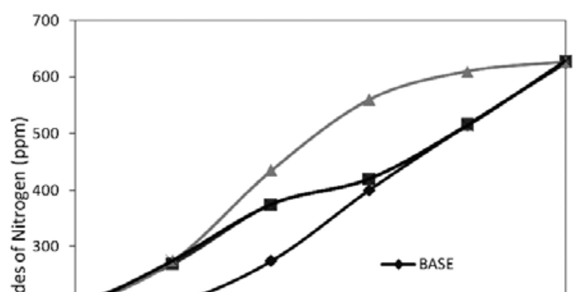

Fig. 6: Variation of nitric oxide with load

From these experimental results a lower BSFC, reduced smoke and improved and smoother combustion are observed by combining PIB-SA additive with diesel fuel and also internal jet of 2.5 mm diameter. A lower BSFC values authenticate with larger fraction of heat release around top dead center with the decreased combustion duration and higher mass burnt fraction. These experimental results, in turn, suggest a better combustion. The extensive experiments carried out here enable arriving at the effective and economical proportions of the additive mixture giving a better performance and emission characteristics.

CONCLUSION

From this analysis, it is observed that the engine combustion has become smoother in presence of additive proportions used here. It is observed that the internal jet introduced through the tangential holes showed improvement in the engine brake thermal efficiency and exhaust smoke level with only a marginal increase in oxides of nitrogen. The maximum improvements in brake specific fuel consumption and exhaust smoke level are found to be 12.84 % and 55.35%, respectively in case of 0.5% additive mixture and internal jet as compared to that of the base diesel fuel. The increase in oxides of nitrogen with the additive mixture, internal jet injection and combined mode is 0.16%, 0.32%, and 0.48% at rated output for 0.5% addition of additive respectively, compared to that of the base diesel fuel.

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