CHAPTER 1

INTRODUCTION

Diesel engines, particularly direct injection types, have been an important choice as prime movers in heavy-duty applications such as on-road, off-road, marine and industrial usage due to their high brake thermal efficiency. In diesel engines, a high cetane fuel is injected into the cylinder and mixed with air. The fuel-air mixture thus formed burns under compression ignition. Diesel engine processes exhibit complex features, perhaps more than any other mechanical device. Despite these complexities, diesel engines have gone through very ambitious developments over last one century or so, and still the margin for their improvement are relatively wide. The improved efficiency in diesel engines is caused by the relatively high compression ratios, low pumping losses due to unthrottled mode of operation, the use of lean mixtures, and the fact that crevice volumes have air or products of combustion instead of unburned fuel mixture. Diesel engines are basically low speed high torque engines, suitable for hauling loads in trucks. They have high backup torque unlike gasoline engines and thus eliminating need of frequent gear changes when used in automobile applications. Diesel engines are sturdier and withstand rough duties. Their power rating is limited only by smoke and not the maximum power output delivered.

As far fuels in diesel engines are concerned, the alternative fuels such as biomass, vegetable oil, alcohol, hydrogen, liquefied petroleum gas, compressed natural gas etc. are being used them in straight or dual fuel modes without many problems. With the increasing concern about the green house effects on the world climate, lower CO₂ emission of diesel engine (about 30%) compared to gasoline engine, remains an advantage. The suitability of diesel engine for supercharging, which is extensively used
on stationary and mobile applications, leads to a high power output and reduced smoke and other exhaust emissions from this variety of engine.

From the stand point of their disadvantages, the diesel engines emit high oxides of nitrogen, smoke and particulate emissions in exhaust. Larger forces arising out of high compression ratio on various parts of the engine makes these engines heavier. Also, due to lean mixture operation, their power to weight ratio and the power to volume ratio are lower than the SI engine. Due to heterogeneous nature of charge, there is no regular flame propagation like in SI engine, hence multiple auto ignition mode makes CI engines much more noisier than SI engines. A higher ignition delay in diesel engine leads to a greater accumulation of fuel prior to the onset of combustion causing a higher rate of pressure rise and consequently the roughness in engine operation.

The fuel economy and exhaust emission regulations, new technologies, development time and cost reduction require increasingly sophisticated solutions to improve the diesel engine performance and reduce exhaust emissions. Combustion process is central to the majority of engine development related issues and requires varied approaches to achieve desired improvements. The diesel engine combustion process involves flows of air and fuel into the combustion chamber, their mixing and ignition. The degree of homogeneity of the air-fuel mixture, cycle-to-cycle variation of thermodynamic and mixing parameters, -and turbulence intensity variations are the conditions affecting engine performance and emission characteristics.

Several methods available for improving diesel engine performance and emissions, namely oxides of nitrogen, smoke and particulates, include high pressure injection, split injection, water injection, exhaust gas recirculation, water diesel emulsion, retarded injection timing, intake charge oxygen enrichment and combustion chamber design for
better fuel-air mixing. Among these methods, some require modifications in fuel injection system, while many other methods include modifications in the combustion chamber or fuel. This work, however, concerns investigating the effects of the modifications in the engine combustion chamber and the fuel in order to achieve improvements in diesel engine performance and emission characteristics. The increase in demand for petroleum fuels and consequent depletion of their reserves has given rise to a need for identifying and investigating new energy resources and/or finding the optimum way of using the present resources. In this regard, generally the following two approaches are pursued

a. Tailoring fuel at the refining stage i.e. improving refining processes for producing better quality fuel from different crude oils, and
b. Improving performance of available fuel i.e. using some additives for improving the quality of existing fuels to a desired level.

The effects of fuel quality variations on diesel engine emissions is rather complex due to wide variation of engine response to fuel quality changes and the extent of inter-correlation of the various fuel variables.

The diesel fuel has higher carbon content and is heavier than other conventional fuels and thus poses problems during use in engine. Due to its high freezing point, diesel fuel causes blockage of filters and nozzles especially under cold conditions. Towards these and other problems, the use of additive is in vogue. Some additives achieve a specific objective of improving either physical or chemical characteristics of the fuel or improving the combustion characteristics.

In diesel engines, the fine atomized fuel particles sprayed into the cylinder mix with air during compression stroke. For efficient combustion in diesel engines, the fuel and air are required to attain proper mixing between them. The requirements of in-
cylinder fuel-air mixing in desired range of quality (proper fuel-air mixture), has to be supported by organized and unorganized in-cylinder air motion such as swirl, turbulence, etc. There are various techniques used to generate turbulence in engine combustion chamber, involving either hardware modifications, or using process like pre-combustion. Also, fuel injection in finely atomized form produces turbulence.

In order to provide complete combustion at a constant rate, there is common design objective of bringing sufficient air in contact with the injected fuel particles. For this purpose, the piston crown and the cylinder head are shaped to induce a swirling motion to air, while during compression piston is moving towards TDC. The production of turbulence by different means, however, is considered necessary for better fuel-air mixing. The complexities of production and the higher costs of these methods of creating turbulence are the limiting factors in their wider use.

The present work is aimed at studying the effects of modifications in fuel and fuel-air mixing respectively for improving diesel engine combustion and emission characteristics. These modifications include use of

a. Polymer based additives in fuel, and

b. In-cylinder turbulence inducement through bluff bodies or internal jets.

The discussions in this thesis are focused mainly on these two aspects concerning fuel with additives and the turbulence inducement for better fuel-air mixing. A discussion on the existing literature concerning these aspects is presented in the next chapter, prior to the details of the work carried out during this investigation.