CHAPTER 1
INTRODUCTION

1.1 Background

The fast growth of industrialization and motorization of the world has led to a sudden rise for the demand of petroleum based fuels. As a result, the reserves of the fossil fuels are decreasing constantly. Scientist forecasted that known petroleum reserves to be reduced in less than 50 years with the present rate of consumption. The petroleum cost is also increasing in this situation there is a great anxiety about the shortage of energy because of shortage of finite reserves of the fossil fuel. Instead of designing the efficient engines, we need to search for the substitute for the fuels, we are using at present, to fulfill our future needs. Environmental protection issues have been emphasized all over the world in modern years, so it is needed to find some hygienic and renewable fuel for spark ignition (S.I.) engines [1]. Alcohols and other low molecular weight oxygenates which are known to be potentially valuable gasoline substitutes. While these are generally of interest in relation to the continuing need to secure future motor fuel supplies. There is an urgent essential for substitutes which will increase the octane rating of unleaded fuels. For environmental reasons, oxygenates containing alcohols could be preferred to additional fuel ingredients which are currently proposed or introduced to interchange lead compounds. In addition to octane enhancement qualities, oxygenates were assessed with regard to power output and exhaust emissions hence confirming that no great deficiencies in these parameters would be introduced. In particular, most oxygenated bio-fuels produce a twofold leap in knock reduction [2]. The oxygen contained in the fuel helps to produce a high chemical resistance to auto-ignition whilst improving the charge-cooling effect.

1.2 Fuels for Spark Ignition Engines

Actually gasoline is a complex mixture of hydrocarbons obtained from crude oil distillation and processing, as well as different organic chemicals derived from other energy sources. Modern gasoline is a heavily processed product that can also contain various synthetic components, which adds to improve its performance and meet the demands of today’s advanced engine technology.
1.3 Chronicle of Gasoline

From 1850’s to 1900’s, gasoline was considered a useless by-product of kerosene production and was apt for burning. However, with the invention and the popularity of the automobile, the demand for gasoline increased quickly between 1900 and 1920. Thermal cracking, a process for breaking down heavier hydrocarbons in gasoline-range hydrocarbons, came into use by approximately 1913 to meet to the increasing demand for gasoline [3]. In the late 1930s, the Houdry catalytic cracking process, produced a higher octane product. Which replaced thermal cracking. In the following years a lot of new techniques and advancement being done in catalyst process. Platinum catalysts were used for catalytic cracking in the late 1940s. Premium gasoline, many containing proprietary additives, began to appear in the mid-1950s. Gasoline demand continued to increase until the mid-1970s. The demand levelled to at about 1.5 billion m$^3$ per year. The primary factors in the stabilization of mandate were the fuel shortages of the 1970s, and the improvement in fuel economy in cars has produced since then.

1.4 Chronicle of Ethanol

Ethanol is an alternative energy source. It is an alcohol prepared by fermenting corn or other similar biomass materials. There are essentially three principal ways that ethanol can be used as a transportation fuel

As a blend of 10 percent ethanol with 90 % unleaded petrol called “E-10 Unleaded”.

As a component of refined gasoline, both directly or as ethyl tertiary butyl ether.

As a primary fuel with 85 parts of ethanol blended with 15 parts of unleaded petrol called“E-85.”

When mixed with unleaded petrol, ethanol increases octane levels, decreases exhaust emissions, and extends the supply of gasoline.

In ancient times ethanol was known as an intoxicating drink. Ethanol is produced mainly by the fermentation process. It is the same alcohol used in beverage alcohol but meets fuel-grade standards. Ethanol which is to be used as a fuel is “denatured” by adding a small amount of gasoline to it [7].
1826: Samuel Morey established an engine that ran on ethanol and turpentine.

1876: Otto cycle was the first combustion engine designed to use alcohol and gasoline.

1920’s: Standard oil began adding ethanol to gasoline to increase octane and to reduce knocking.

1908: The initial Ford Motor Company automobile Henry Ford’s model T was designed to use corn alcohol, called ethanol.

1980: Oxygenates added to MTBE and ETBE made from ethanol and petroleum

1988: Denver, Colorado was the first state of the world to mandate ethanol oxygenates fuels for winter use to reduce carbon monoxide emissions.

1992: Energy policy act of 1992 was accepted by congress to reduce our nation's dependence on imported petroleum by requiring certain fleets to obtain alternative fuel vehicles which are capable of working nonpetroleum fuels.

September 7 2006: The Renewable fuel standard program (RFS). In this national renewable program is designed to encourage the blending of renewable fuels like ethanol into our nation’s motor vehicle fuel.

December 2007: Energy Impedance and security act signed by congress and the president, which needs the usage of billion gallons of renewable fuel (ethanol) by 2015.

Ethanol is the most important member of a huge group of organic compounds which are called alcohols. Alcohol is an organic compound which has one or more hydroxyl (OH) groups are attached to a carbon atom and it is shown as: C-O-H or C-OH. Which is attached to the carbon by the three remaining bonds or locations which determines the particular kind of alcohol. Ethanol has hydrogen present at two sites, and a carbon atom presents on the remaining sites. This carbon atom, in turn holds three more hydrogen atoms [8].

1.5 Objectives and Approaches for Case I

The main objective of this present study is planned to develop and evaluate the combustion. The performance and emission of the ultra-lean fuel injection opening pressure burn on Internal Combustion engine was modified to operate on ethanol fuel blends. The study looks at part throttle, constant speed operation of 0%, 10%, and 15% of ethanol which blends with gasoline mixtures operating in ultra-lean fuel IOP at
constant compression ratio operating systems. Enhancement of ultra-lean combustion of homogeneous mixtures can be attained by (i) using ethanol blends with gasoline (ii) using high-ignition energy (iii) creating high swirl in the combustion chamber.

1.6 Objectives and Approaches for Case II

The main objective of this present research work is carried out with an aim of increasing the performance of engine by reducing emissions with application of different fuel blend ratios of hydrogen, (0%, 10%, 20%) ultra-lean fuel injecting opening pressures (200 and 220 bar) and compression ratios (17.5 and 18.5). All the experiments were carried out at a constant speed of 1500 rpm and the injection timing was set to a value of 23° BTDC. The experimental results were analyzed and characteristics of combustion and emissions are illustrated.

A series of engine tests have been carried out on a CI engine with hydrogen, as an enrichment fuel. In this aspect the present investigation has been done on corresponding to the study of effect of different engine parameters such as ultra-lean fuel injection opening pressures and compression ratios, based on the performance, combustion characteristics and emissions in a diesel engine.

Next the engine performance of hydrogen, is analyzed with performance parameters such as Brake power, specific fuel consumption, and volumetric efficiency being emphasized and combustion parameters such as in-cylinder pressure, net heat release rate and mass fraction burned. The gaseous emission types are also explained by examining the formation and causes of pollutants such as carbon monoxide, oxides of nitrogen and unburned hydrocarbons.

1.7 Research Background

Internal Combustion Engines have developed an integral part of our life deprived of which the world would stop moving and will not meet its daily necessities. These engines act like the hearts of majority of the prime movers. The fuel used by these engines are generally non-renewable. This demands for the search for an alternative fuel, which promises to be harmonious in correlation with sustainable development, conservation, running efficiency and environmental preservation. It has become a prime subject of study in the transportation, agriculture, industrial, submarines, and many more applications (Madhujit Deb et al., 2014). The maximum
energy used by the world is supplied by the fossil fuels. As it is observed that there are several disadvantages in using fossil fuels such as generating waste materials, emitting pollutants and is limited to usage. Today, the development of any country is measured on the basis of the number of automotive vehicles used by the public of that country. In order to go with the ever-stringent emission norms of the world and crunch in petroleum reserves, the up-to-date day automobile industry is compelled to search for new alternative means of fuel sources to keep the wheels more globally. With rising fuel price and more strict emission legislations, recent studies are emphasis on high efficiency and low emission skills in the field of internal combustion engines. As the world finds itself in the middle of universal energy shortage, compounded by a parallel need to reduce pollutants of all kinds. We must take an increasingly serious appearance at novel abundant energy sources, and methods for the best utilization of the source (Lakshmanan et al., 2010).

1.8 Research Significance

In the recent years, many studies as have been carried out about substitute fuel mostly concentrated on economy and emissions. Though diesel engines are the most trusted power sources in the transportation sector, due to stringent emission standards and rapid depletion of petroleum resources. There has been a continuous effort to use alternative fuels. We must take serious look at smart and abundant energy sources and methodology to use. The combination of both hydrogen and diesel as a fuel under various operating conditions such as injection opening pressures and compression ratio. In case of CI engines affects the performance, combustion and emissions. Hydrogen is a potential alternative for gasoline its resources are vast and it is considered as one of the most promising fuel for automotive sector because of its wide flammability limits, minimum ignition energy, high calorific value and high flame velocity. Hydrogen can be used advantageously in internal combustion engines as substitute to a hydro carbon fuels. However, hydrogen is currently a rare commodity compared to hydrocarbon fuels partly due to a lack of the distribution; infrastructure, transportation, re-fuelling and handling of hydrogen are not meeting the demand. Current use of hydrogen is possibly limited became to the role of fuel enrichment and wide spread introduction of hydrogen vehicles is not conceivable in the near future. One of the solutions for this hurdle is to
blend hydrogen with diesel; such type of blend takes advantage of the unique combustion properties of hydrogen and at the same time reduces the demand of pure hydrogen. (Kasiananthem Nanthagopal et al., 1998)

Natural gas vehicles are potential alternatives to gasoline vehicles in a short a run, because of the extensively available fuel and less pollution. In order to further decrease their pollutants, hydrogen enriched diesel has been burnt for natural gas vehicles. The important effects of hydrogen addition can be pointed the laminar burning velocity of hydrogen is higher than that of CNG. So the hydrogen addition can increase the burning velocity of mixture, and it brings some benefits such as shorter combustion duration, ignition delay, and greater constant volume degree as well as improved brake thermal efficiency.

1.9 In-cylinder pressure

Although the internal combustion engine has been developed for more than a century, combustion conditions inside the engine cylinder are still not exactly predictable yet, mostly because of the cycle-by-cycle variations from unexpected fuel air mixture charge and the unknown heat transfer circumstance. (Amann., 1985) said that the in-cylinder pressure, indicator is the most significant diagnostic tool in engine study. Combustion is the most important chemical behaviour inside an engine cylinder. Engine combustion is complex and happens suddenly in a very short time, the behaviour of the flame strongly depends on the inlet charge mixtures. Understanding the combustion progress can help researchers to develop better knowledge for engine design to improve performance emission results. One of the real-time applicable models is by Rassweiler and Withrow. They produced a widely used classical method to analyses burn rate and reveal combustion circumstances inside engine. Regardless of heat transfer and crevice leakages if maintaining accuracy. The pressure increase due to combustion is proportional to the mass of burned charge.

1.10 Diesel Knock

If the delay period is long, large amount of fuel is injected and accumulated in the combustion chamber. Due to long delay period, large amount of fuel may cause high rise of pressure and maximum pressure occurred which results knocking the diesel
engines. In CI engines knocking occurs at the beginning of combustion as shown in Fig. 1.1.

It is the process of auto ignition subject to the ignition time lag characteristics of the fuel. Detonation in CI engine occurs near the beginning of combustion. There is no question of pre ignition or premature ignition since the fuel is injected into the cylinder, only at the end of compression stroke. In CI engine there is no definite distinction between normal and knocking combustion. The maximum rate of pressure rise may reach as high as 10 bars per crank degree angle.

![Pressure Vs. Crank angle showing knocking in CI engines (Mathur., 2013).](image)

**Fig. 1.1.** Pressure Vs. Crank angle showing knocking in CI engines (Mathur., 2013).

### 1.10.1 Factors tending to reduce knocking in CI engines

- Self-ignition temperature of fuel should be low
- Ignition delay period of time lag for fuel should be short
- Compression ratio should be high
- Inlet temperature should be high
- Inlet pressure should be high
- Combustion chamber wall temperature should be high
- Speed should be less
- Cylinder size should be large

### 1.11 Dual Fuels

Internal combustion engines operate on gaseous fuels which have been known for a long time. Many large stationary engines use two fuels. Normally of these two fuels, one is gaseous and the other a liquid fuel these two fuels can be taken in widely varying proportions to run an engine; such as engine is usually called a dual fuel
engine. The shortage of liquid fuel and the realization that gaseous fuels are far inexpensive than liquid fuels have led to increase attention on the dual-fuel engine. Moreover, due to recent concern about air and water pollution it has become necessary to utilize sewage gas from municipal sludge digesting tanks, which is available in huge quantities, economically. The town gas and other type of gases from large industrial plants can be utilized to enhance the economy of the country.

1.11.1 The Working Principle

The gaseous fuel also known as primary fuel is added to the air inducted by the engine at a pressure slightly above the atmospheric pressure. This combination of air and gaseous fuel is compressed in cylinder just like air in a normal diesel process, in the compression stroke and near top dead center, a small charge of liquid fuel called pilot fuel, is injected concluded a conventional diesel fuel system. This trial injection acts as a source of ignition. The gas-air mixture in the vicinity of the injected spray burns at an amount of places establishing a number of flame-fronts. Thus combustion starts smoothly and rapidly. The power output of the engine is normally controlled by changing the amount of primary gaseous fuel added to inlet manifold.

1.11.2 Factors Affecting Combustion in a Dual Fuel Engine

Large number of factors affect the combustion in a dual fuel engine among them most important parameters are :

- The amount of pilot fuel injection
- Injection operating pressure
- Compression ratio

1.11.2.1 Pilot Fuel Quantity

The pilot fuel undergoes pre-combustion reactions and releases thermal energy which increases temperature of the gaseous fuel and a flame front is developed. Large quantity of pilot fuel will result in knocking because of very rapid rates of pressure rise. At very small amount of fuel injection the power output is very low. If the fuel injection is increased more thermal energy is released due to pre-combustion reactions of droplets. When large quantities of pilot fuel are injected very rapid combustion occurs and high rates of pressure rise results in knocking and a reduction in power output. It has a marked effect only at small values of injected fuel but has little effect on
the onset of knocking. The pilot fuel injection starts at 18° BTDC for loads up to 7 bar BMEP, gradually retarding to zero degree at maximum

1.11.2.2 Injection Pressure

In C.I. engine in order to achieve complete combustion in very short time available, the liquid fuel should be injected in droplets of smallest size to obtain largest surface volume ratio. A smaller droplet will have lesser momentum and hence lesser relative velocity. The smaller the size and greater the number of droplets the larger will be the aggregate area of inflammation. As the size of droplets depends on the injection pressure it can be said that the lower the injection pressure the lower the rate of pressure rise during the uncontrolled phase and smoother the running.

1.11.2.3 Compression Ratio

The air fuel cycle increases with compression ratio same as it increases with air standard cycle efficiently. The compression ratio of an internal combustion or external combustion engine is a value that represents the ratio of the volume of its combustion chamber from its maximum capacity to its minimum capacity. It is a fundamental specification for many common combustion engines. Automotive engineers can improve fuel efficiency and fuel economy by designing engines with more compression ratios. The higher the ratio, the more compressed the air in the cylinder is. When the air is compressed, we develop a more powerful explosion from the air-fuel mixture, and more of the fuel gets used.

A high compression ratio is desirable because it permits an engine to extract more mechanical energy from a given mass of air-fuel mixture due to its maximum thermal efficiency. This occurs because internal combustion engines are heat engines, and maximum efficiency is created because maximum compression ratios permit at the same combustion temperature to be reached with low fuel, while giving a longer expansion cycle, creating more mechanical power output and lower the exhaust temperature. It may be more cooperative to think of it as an "expansion ratio", since more expansion decreases the temperature of the exhaust gases, so then the energy wasted to the atmosphere. Diesel engines actually have a higher peak combustion temperature than SI engines, but the greater expansion means they reject less heat in their cooler exhaust.
Higher compression ratios will though make SI engines subject to engine knocking. If lower octane rated fuel is used, also called as detonation. This can reduce efficiency or damage the engine if knock sensors are not present to retard the timing. On the other hand, diesel engines operate on the principle of compression ignition, due to that a fuel which resists auto ignition will cause delay ignition, which will also lead to engine knock.

1.12 Thesis Structure

The thesis is organized in six chapters. The following sections give the brief summary of the chapters.

Chapter 1:

This chapter presents the different fuels for spark ignition engines with the chronicle order incorporating with the research outline, objectives and approach, In-cylinder pressure, diesel knock, dual. The main purpose of this chapter is to give early understanding of the overall project.

Chapter 2

This chapter presents a brief literature survey on the application of the oxygenated additives and Hydrogen as an alternative fuel. The combustion, nature of knocking is also proposed in this chapter. The conclusions from the literature survey and the objectives of the present study are described in this chapter.

Chapter 3

The objectives of the thesis are discussed in this chapter. Problem formulation is also explained in this chapter

Chapter 4

Describes the experimental setup, engine modifications, measuring systems, test matrix and also the experimental procedure.

Chapter 5

Depicts the results and discussions pertaining to the variable load conditions, variable compression ratio and injection opening pressures conditions using the hydrogen, as an enrichment fuel.

Chapter 6

Describes the summery and conclusions of the present work, and the recommendations for the future work.