Chapter - 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

Two stroke SI engines are preferred because of light weight, compact, high specific power output, less friction and constant less pumping losses [1] at various loads. However it has got poor scavenging process, loss of fresh charge due to short circuiting, poor combustion efficiency and irregular combustion under light load [2,3]. Hence research activities are concentrated to reduce fresh charge loss due to short circuiting and to improve the combustion process so as to reduce the Hydrocarbon emission, Carbon monoxide emission levels.

The overall idea about previous research activities to achieve the above objectives are described below.

2.2 PREMIXED FUEL AIR SCAVENGING

The fuel air mixture enters the cylinder and sweeps out the burnt gases out side of the cylinder. Hence gas flow in the intake, transfer and exhaust passages is unsteady and needs synchronization of pressure wave in the intake and exhaust to improve the scavenging. Several suggestions made in the literature such as fixing of branched pipe in the intake [4,5] optimization of crank case volume and port timing [6-12]. The problem of back flow is overcome to improve the scavenging [5] [10], desirable pressure time history to provide a high delivery ratio is achieved [6-9] by the above suggestion. The engine performance can be improved through the exhaust flow control devices such as rotary valve [11], butter fly valve [14,15] and variable area exhaust port [11-13], only for a narrow range of engine operation and such devices may cause complexity.
G.P. Blair et. al. [16] has compared loop and cross scavenged single cylinder research engines and shown that the performance of improved QUB type cross scavenged engine matched with loop scavenged design in some areas. He has also shown that the bore to stroke ratio influence the scavenging behaviour of QUB cross scavenging system.

David W. Blundell et.al. [17] has described a valve mechanism providing infinitely variable control of exhaust port opening point together with the ability to effectively close the exhaust port at the end of scavenge period and shown that there is improvement in performance due to improved scavenging efficiency.

2.3 SCAVENGING BY STRATIFIED CHARGING

The process of scavenging the cylinder with air alone and introducing the fuel through Carburettor can be called as scavenging by stratified charging [18], Batoni et. al. [19] had used opposed piston configuration of two engines – a 200 cc engine and a 50cc engine. Even though there was improvement in fuel consumption, exhaust emission there was mechanical complexity in the arrangement. Onishi et.al. [20] proposed the separation of mixture from the carburetor in to rich and lean between the inlet manifold and scavenging ports so as to control scavenging flows. But this system gave more specific fuel consumption.

Blair et. al.[21] developed a stratified charging system in which air is supplied to the crank case whereas the rich air fuel mixture from the carburetor is supplied to the cylinder through a reed value. The air and air fuel mixture are introduced in such a way that more air is used for scavenging and most of the air fuel mixture is trapped inside the cylinder. In addition to conventional transfer ports, two more transfer passages and ports for air fuel mixture are used in the engine. This system was reported to reduce the specific Fuel consumption about 300 grams/Kw-hr.
Ramesh et.al. [22, 23] developed a system of having two intake circuits, one for air through reed valves at transfer ducts and another for fuel air mixture through carburetor and found improvement in fuel economy and exhaust emissions during low speeds and part load operations.

G.P. Blair, R. Douglas et.al. [24] have discussed the application of an air head type stratified scavenging system to QUB cross scavenged engine and said that there is improvement in fuel consumption and HC emission. They have also noted that at light load, part throttle settings this air head system deteriorated brake specific fuel consumption.

P. Rochelle et.al. [25] have discussed about a simple delayed charging device to first scavenge burnt gases with fresh air and then introduce a fresh charge so as to reduce fuel losses during the gas exchange process in two stroke engine cylinder.

Rodney Houston et.al. [26] have discussed on stratified charge, direct injected 2 stoke engine which is capable of meeting current European and US automotive emission regulations and suggested lean burn stratified charge engine, manifold “EGR” system, optimization of the exhaust valve and cylinder cut strategy, catalyst light off strategy and catalyst wash coat development are methods for exhaust emission control.

G.P. Merker and M. Gerstle et.al. [27] have discussed scavenging models such as single zone, multi zone models and summarized that the problem of dealing with all models is how to get information about the used empirical parameters.

Toshiharu Sawada et.al. [28] have discussed on the effects of air head stratified scavenging and leaner combustion on reducing Hydrocarbon emission and improving thermal efficiency of two stroke SI engine for hand held operation and reported that there was improvement in thermal efficiency and reduction in Hydrocarbon emission.
Yukiteru Yoshida et.al. [29] have discussed on the development of stratified scavenging two stroke cycle engine for emission reduction and explained that the first stage of scavenging is by air only, then the second stage by air fuel mixture. The stratified scavenging system consists of long passages form crank case to scavenging ports and the supplemental air intake system directly to the scavenging port. It is reported that this system cuts Hydrocarbon emission to about ¼ of conventional two stroke engine.

R. Douglas et.al. [30] have discussed on stratified scavenging such as delivering the fuel in to rear transfer passage from a fuel metering device and air only is delivered in to the cylinder from the remaining transfer passages which are directed towards the rear transfer port, thus impeding fuel from reaching the exhaust during scavenging process. They have reported that there was reduction in Hydrocarbon emission and fuel consumption.

2.4 FUEL INJECTION

Fuel loss due to short circuiting can be eliminated if the fuel is injected after closing of exhaust port. Many investigators used high pressure, mechanical or electronic fuel injection systems [31-34] and they observed that it was difficult to obtain necessary turbulence for mixing of fuel and air. In the fuel injection system used at Moto became et. al. [35-37] loss of fuel through exhaust port occurred and in the system used by Vieilledent et. al. [37] the difficulties of low pressure injection system was over come and specific Fuel consumption was improved. In the system used by Douglas et.al. [38] there was improvement of fuel economy at the cost of specific Power output. The pneumatic fuel injection system [39] was used in Orbital 2 stroke engine where compressed air was used to atomize the fuel and fuel consumption was improved by 40%. Duret et.al. [1] has developed a system where crank case was used rather than air pump to provide low pressure air for fuel atomization purpose. Further
the charge was injected in to the engine at the time of opening of intake valve and a lower fuel consumption was achieved.

Mashiro Asai et al. [40] have discussed about a timing controlled auto ignition named “A R Combustion” with ARC valve for exhaust throttling, which could improve irregular combustion in the part load operation of conventional two stroke engines.

Huci Huy Huang et al. [41] have discussed the approaches for reducing exhaust emissions of two stroke engine with In cylinder injection system and suggested that the air assisted fuel injection system can reduce Hydrocarbon emission due to improved fuel atomization and increase of temperature of combustion chamber can also reduce Hydrocarbon emission.

Stephen Glover and Brain Mason et al. [42] have discussed the evaluation of the stratified charging concept using electronic fuel injection to provide the fuelling and suggested that the Hydrocarbon emission can be reduced at medium to higher load without a loss in wide open throttle torque and this concept is more sensitive to changes in air fuel ratio which requires development to improve its tolerance to leaner mixtures.

Marc L. Syvertsen et al. [43] have stated that spray type was the most important factor affecting Hydrocarbon emission followed by in-cylinder flow related factors and injection spray was also more important for other emissions and efficiency for direct injected two stroke engine.

Magnus Christensen et al. [44] have discussed about Homogeneous Charge Compression Ignition (HCCI) and stated that in HCCI, a homogeneous charge is used as in a spark ignited engine but the charge is compressed to auto ignition as in a diesel. They have reported that indicated efficiency of HCCI was better than for SI operation
and generation of very little NO\textsubscript{x}. However, HCCI generated more Hydrocarbon and Carbon monoxide than SI operation.

Yoichi Ishibashi et.al. [45] have discussed on a low pressure pneumatic direct injection engine by Activated Radical Combustion concept and reported that the scavenging is performed by air only prior to fuel feed process and there was remarkable reduction in exhaust emission and fuel consumption.

R. Gentili and S. Frigo et.al. [46] have discussed on combination of Active Thermo Atmosphere Combustion (ATAC) and liquid high pressure direct injection to solve the combustion problems at light loads and to reduce exhaust emissions. It is reported that ATAC is the best alternative to stratification since it turns the effect of residual gas from negative to positive by exploiting its energy to ignite fresh gas and direct injection avoids fuel loss from exhaust port.

2.5 DEVELOPMENTS IN COMBUSTION PROCESS

The performance and emission characteristics are depending upon the combustion process and presence of large residual gases reduces the flame propagation leads to unstable combustion [47], higher Hydrocarbon emission and poor fuel economy [3]. These difficulties can be reduced by stabilized combustion of lean mixture but it needs improvements in mechanism of conventional combustion process [3, 48]. Sonk et.al. attempted to improve combustion by proper control of gas flow into the cylinder [49] and Onishi et.al. attempted by controlling the ratio of mixture to residual gases and mean charge temperature [50]. But suitability of these methods is yet to be established for regular use.

To control the combustion at the source the following in cylinder modifications are considered.
i) combustion
ii) Insulation of combustion chamber
i) High Energy Ignition System
ii) Using high octane fuel blends

2.5.1 Catalytic Combustion

For reducing exhaust emission levels the catalysts were used for treatment and promotion of oxidation/reduction reaction [51-55]. However, many people have proposed to use of in cylinder catalyst to improve combustion mostly in diesel engines [56-60]. The use of catalyst in the combustion chamber is to allow heterogeneous oxidation on the surface of the catalyst. Pfefferle et.al. [61] had found that this method to be an efficient method for burning of fuels in lean mixture [62,63] Murray et.al. [59] and Rychter et.al. [60] used this technique in lean burn engines. Ravi Prasad et.al. [64] and Margolis et.al. [65] have explained the catalytic HC oxidation mechanism. Thring et.al. [58] used Platinum wash coat wire mesh for both direct and indirect injection diesel engines and reported that there was improvement in fuel economy and emission level at part loads. Karim et.al. [66] had established the reasonable improvement in lean blow out limits due to catalytic effects and also found the effectiveness of many metallic surfaces to be in the following descending order Platinum-copper Silver-Brass Chromium-Nickel – Stainless Steel.

Rychter et.al. [60] have analysed the effect of various catalyst and found the ignition delay, rate of pressure rise with various catalyst. Later a catalytic pre chamber was suggested to lean burn SI engine by placing Platinum catalyst in auxiliary combustion chamber in the form of wire coil and observed that the reduction in ignition delay and a strong flame Kernel in the initial phase of combustion are due to presence of catalyst. Beyerlin et.al. [67-70] developed adiabatic pre chamber and found that the
pre chamber to be a knock free compression ignition source when the catalytic prereaction was more extensive.

Wonnam Lee et.al. [71] have analyzed the effects of Chromium oxide and partially stabilized Zirconia as catalysts and observed that both catalysts can make a large effect on ignition characteristics of low heat loss diesel engines. The use of Platinum as catalyst was analyzed [72-75] for a variety of combustion systems applications [76-79] and found that it would have limitation due to its high cost and limited high temperature durability. Hence the alternative catalysts can be metal oxides such as Nickel oxide, Manganese oxide, Vanadium oxide which are having higher catalytic ignition temperatures than Platinum and the next alternate can be ceramic catalysts[80]

Krzysztof Z. Mendera et.al. [81] have discussed on effectiveness of plasma sprayed coatings for engine combustion chamber and reported that plasma sprayed Zirconia coatings being partially transparent to thermal radiation are not effective as heat barriers in diesel engines.

2.5.2 Thermal Insulation of the Combustion Chamber

This concept was widely investigated in diesel engines [82-87] from both material and engine component development point of view Kabori et.al. [88] and Amann et.al. [89] have analyzed this concept on diesel engines aiming to reduce the size of cooling system or to eliminate it to improve the engine efficiency and to burn lower grade fuels without cooling [88]. This application of this concept was found difficult in SI engines due to chances for preignition leading to knocking problem. However, Assanis et.al. [90,91] investigated the use of thin ceramic coatings to improve performance and emission characteristics of SI engines and found that at low speed part load conditions the ceramic engine would achieve up to 18% higher brake
power and 5% lower specific fuel consumption. Further he found that ceramic coating did not produce knock and Hydrocarbon. Carbon dioxide emission level were lowered. Thus a thin ceramic coating can be effective for improving the performance and fuel economy but the degree of insulation will be a factor for knocking problem.

2.5.3 Ignition Enhancement

The magnitude of energy required from the ignition system to cause the required temperature to initiate preflame reactions to develop the flame Kernel increases with leaner fuel air mixtures and with higher charge flow velocity near the spark plug [92]. Hence modification of the conventional ignition system is required for burning lean mixture and the following techniques were suggested [93-97].

i) Extended reach spark plug with wide gap
ii) Dual spark plugs
iii) Multi point and multi electrode spark plugs
iv) Platinum tipped electrode spark plug
v) High energy ignition system

Anderson and Asik et.al. [98-100] analysed the influence of different types of spark plugs, the number of spark plugs, ignition system, location of plug and ground electrode position and found that ignition limit of the long duration ignition system with surface air gap plug has the largest spark angle tolerance. Rado et. al. [101] found that the 3 gap spark plug improves fuel economy. Kuroda et. al. [102] found that the dual spark plugs reduces the cyclic variation and extends the lean misfire limit. Nakamura et.al. [103] investigated a multi point spark ignition having 12 spark gaps and found that the combustion duration is reduced by 50%, fuel consumption lowered by 5% and reasonable extension of lean misfire limit.
Platinum tipped spark plug were found effective since reduction in the required voltage for ignition and a larger plug gap [104]. Quader et.al. [105] found that improvements in spark duration, plug extension and plug gap have resulted on limited effect on flame propagation and lean ignition limits can be eliminated by using high energy ignition system. It is reported that a plasma jet [106-110] with ignition energy as high as 14 times that of normal spark has extended lean operation air fuel ratio limits by about 24% [110] by drawing too much power from the engine.

Noriaki Ishibe and Tetsuya Ohira et.al. [111] have discussed about cyclic variation of combustion characteristics in a moment of quick throttle opening and suggested that multi timing ignition system prevents unstable combustion since it can ignite the spark plug three times in one cycle to strengthen the ignition probability.

2.5.4 High Octane Fuel Blends

Methanol has been found to be suitable fuel with lean mixture when compared to Gasoline and other fuels [112-115] due to wider flammability limits and higher flame speeds under lean conditions [116-120]. However some difficulties of use of Methanol for commercial application are yet to be solved and therefore the use of gasoline Methanol blends was suggested since they have improved octane quality, lean limits, thermal efficiency, power output and NOx emissions. Lindguist et. al. [121] and Menrad et. al. [122] suggested that the upper limit for Methanol blend concentration is 15% due to phase separation difficulties. Blending of Alcohol to Gasoline without carburettor modifications result in lower Carbon monoxide-emission, fuel economy and performance and the separate fuel distribution system is required due to water sensitivity of Methanol/Gasoline [123].

Indolene – Methanol plus high Alcohols blends can increase the water tolerance, octane number and to reduce the production cost of the fuel [124] Sapra et.
al. [125] asserted that Methanol Gasoline blends containing 30 to 70 percent by volume Methanol have the potential to eliminate or to reduce the major technical problems with the use of neat Methanol such as cold starting, safety etc.

The Eucalyptus oil and Orange oil also have high octane values and can be blended with Gasoline [126,127] to increase octane value. Both the oils can be easily miscible with Gasoline, and engine starting, drivability are nearly equal to Gasoline. Further Eucalyptus oil also contains co solvent to minimize the phase separation problems of Alcohol – Gasoline blends.

### 2.6 SUMMARY

In summary, the above literature review concerning possible techniques available to improve the performance of a two-stroke SI engine suggests the following:

- The scavenging process of the conventional two-stroke SI engine is one event of its cyclic operation where considerable performance improvements can be achieved. To reduce short-circuiting loss of the fresh charge, while maintaining usual carburetor charging, mechanically simple systems are to be aimed at. Stratified charging, therefore, seems an attractive method.

- Enhanced pre-flame reactions and lower ignition energy requirements can be achieved through catalytic combustion. Catalysts such as Copper, Chromium and Nickel are useful for lean mixture combustion.

- An appropriate ceramic coating or thermal insulation of the SI engine combustion chamber can provide benefits in fuel economy and Hydrocarbon emissions due to better fuel vaporization and lower heat transfer losses in the two-stroke SI engine.
A breakerless, high energy electronic ignition system and a Platinum tipped electrode spark plug eliminate the drawbacks of the conventional magneto-coil ignition system. They can be used with lean fuel-air mixtures and at high compression ratios.

High Octane fuels such as Turmeric oil, Methanol, Ethanol, Eucalyptus oil and Orange oil can be blended with low octane commercial Gasoline to increase the octane rating of the blend and thereby increase the knock limited compression ratio. Eucalyptus oil can be added to solve the Methanol/Ethanol Gasoline phase, separation problems.