CHAPTER 2

REVIEW OF LITERATURE

The literature reviewed is exhaustive, and those having relevance to exhaust gas recirculation, blending techniques and mathematical modelling for simulation of the combustion processes are reported here.

2.1 Design of Experiments

In any research process, many experimental works must be carried out and when the number of process parameters increases, the time duration and expenditure for conducting the experiments also increases. Vincent and Udaykumar (2012) have recommended Taguchi methods for design of evolution of experiments, which could solve this problem. Taguchi method uses a distinctive design of orthogonal arrays to study the entire parameter space with only a small number of experiments. Vincent et al., (2012) have utilised these methods for optimisation of responsible parameters in many applications. Taguchi methods have been utilized widely in engineering analysis and consist of a plan of experiments with the objective of obtaining data in a controlled way, to obtain information about the behaviour of given engine performance. Statistical analysis using two-way ANOVA is given in Appendix 1. The advantage of this method is the saving of time and effort in conducting experiments; saving experiment time, reducing the cost, and discovering significant factors quickly.

Walpole et al., (2007) have provided a rigorous introduction to basic probability theory and statistical inference with relevant, interesting and motivational applications. It contains material on sampling and data analysis including all aspects of experimental design and graphical techniques.

Abu-Qudais et al., (2000) have reported the influence of air-fuel ratio on the cylinder maximum pressure for different air-fuel ratios. The maximum pressure rise is less when the air-fuel ratio is less due to incomplete combustion.

2.2 Alternative Fuels

Nayak and Mohanan (2001) have done experimental analysis on a single cylinder four stroke engine with modifications to work in dual fuel mode by having LPG line at inlet manifold. The brake thermal efficiency increased with increase in pilot fuel quantity for all loads with both EGR at 23 (deg. BTDC injection timing) and without EGR.

Experimental investigations on a two-stroke CNG SI engine by Marouf Wani and Gajendra Babu (2001) revealed the drastic reduction in COx and NOx emission using gasoline and CNG as alternative fuels. However, the power output of the engine reduces due to lower volumetric efficiency and slower burning rates with CNG.

Dasappa (2001) in his report brought out a simple procedure to estimate the power from diesel engine converted to run on gas. The parameters chosen for analysis are related to properties of the fuel apart from the only engine parameter, compression ratio.

John Panneer Selvam and Vadivel (2013) studied the possibility of using meat waste pork lard methyl ester and its diesel blends (B100, B25, B50, B75) in a diesel engine as fuel. They reported that the BTE was decreased by 6.2 % and the Brake Specific Fuel Consumption (BSFC) was increased by 23.5 % for meat Waste pork lard Methyl esters (WPLME) when compared to pure diesel at full load. However, the brake thermal efficiency (BTE) is very close for B25 compared with pure diesel at full load. There is a significant reduction in Carbon Monoxide(CO), hydrocarbon (HC), oxides of Nitrogen (NOx) and smoke emission at high loads with neat WPLME. The exhaust emissions CO, HC, NOx and smoke opacity, were decreased by 23.1 %, 31.5 %, and 64 % respectively for pure pork lard methyl ester at full load when compared to pure diesel. Lower heat release rate and shorter ignition delay were observed for WPLME compared to diesel fuel.

Lakshmi Narayana Rao et al. (2008) studied the use of Used Cooking oil Methyl Ester (UCME) on a single cylinder, 4.4 kW direct injection air cooled stationary CI engine coupled with swinging field electrical dynamometer. BTE of UCME is lower than that of diesel by 2.5 %. The BTE of blends of UCME lies between diesel and neat UCME at all loads. Since the engine is operated under constant injection timing, UCME has much lower calorific value than that of diesel. Hence the specific fuel consumption is slightly higher than that of diesel for UCME and its blends. The emission of CO is reduced by 15 % for 20 % UCME and by 50 % for UCME when compared to diesel at rated load conditions.

Singh (2013) has analyzed the performance of an indirect injection compression ignition engine by using diesel, unheated Jatropha Oil (JO) and preheated Jatropha oil as fuels. The effects of fuel injection pressure and fuel inlet temperature on engine performance and emission for the different fuels were analyzed. Their test results showed that the brake thermal efficiency of the engine with heated JO is superior compared to unheated JO, increasing from 28.4 % with neat unheated JO to a maximum thermal efficiency of 30.8 %. The specific fuel consumption was reduced from 0.301 kg/kWh to 0.266 kg/kWh. Smoke opacity was also reduced relative to the neat unheated JO operation compared with diesel.

Pughazhvadivu and Jeyachandran (2005) have tested the use of waste frying oil preheated to 70 – 1350C in a direct injection diesel engine. The study reported an improved performance and reduced CO and smoke emissions. It is further reported that an increased fuel inlet temperature increased NOx emission. It is concluded that the preheated oil at 1350C could be used as diesel fuel for short-term engine operation.

2.3 Engine Performance

Qi et al., (2015) reported that high EGR will dilute the engine charge and may cause serious performance problems, such as incomplete combustion, torque fluctuation, and misfire. An efficient way to overcome these drawbacks is to intensify tumble leading to the increased turbulent intensity at the time of ignition. The enhancement of turbulent intensity will increase flame velocity and improve combustion quality, therefore increasing engine tolerance to higher EGR.

Marco Nuti (1998), has compiled in his book, complete details on pollutant formation, active and passive pollutant controls. Scavenging port design, exhaust tuning, low-pressure, high-pressure and air-assisted injection systems are the control methods dealt in this work.

Prabhakaran and Dhamejani (2001) have discussed the modular concept and analyzed performance aspects of a 350cc engine under vertical inline and horizontally opposed twin cylinder configurations. Horizontally opposed cylinders were found to deliver better output.

Tamilporai and Jaichandar (2001) reported a reduction of HC emission up to 50% and CO emission up to 20% in their experimental investigation to highlight the impact of stratified scavenging and catalytic exhaust system of a typical two-stroke engine on exhaust emission and engine performance.

Over the years, various methods have been suggested to improve the power output and reduce emission levels from two-stroke engines. These include piston coating, chamber design, electronic injection, catalytic converter and some engine modifications. Manivel and Dhandapani (2001) have reported 45% more brake power using electronic injection system in the engine.

Mishra and Rahman (2001) have evaluated the influence of air flow velocity on the combustion behaviour and estimated minimum burning velocities of 5 to 8 cm/s for equivalence ratios of 0.48 to 0.53.

Deshmukh and Ravikrishna (2001) have developed a two-dimensional model for a two-stroke engine cylinder scavenging flow to get the optimized design for better scavenging and trapping efficiency.

Yujun Cao et al., (2012) reported that engine specification is having significantly different intake port engines were studied in their work. Particle Image Velocimetry (PIV) data in the equilibrium plane were compared during intake and compression stroke, showing the effect of intake jet arrangement. Moreover, a very low mean flow kinetic energy at TDC for one design of the intake ports can be interpreted as a much more efficient tumble breakdown of higher efficiency. 300 CAD was chosen because we observe a maximum of the kinetic energy of mean flow and a minimum of fluctuating kinetic energy at this CAD were observed. Moreover, the confined large-scale flow is believed to be intrinsically unstable near the end of the compression. Therefore, ignition occurs during this transition from an organized flow state to small-scale turbulence and projection on the flow before breakdown seems relevant to obtain a progress variable, distinguishing different engine cycles. A triple decomposition of the velocity reduced, and the main result was a breakdown of the relative contribution of large-scale coherence to the fluctuating kinetic energy peaks during tumble breakdown, 90 % of this contribution is due to longitudinal velocity fluctuations. Such decomposition is believed to be useful to propose a refined analyzing strategy for engine flow field near TDC and is presently used to analyze different engine configurations further.

Pandey et al. (2012) have investigated the turbulent kinetic energy, turbulent viscosity and dissipation rate contour and fluid that is almost uniformly spread throughout the inlet pipe. In the expansion chamber, kinetic energy varies from the lower zone to the middle zone at the outlet pipe. Dissipation rate at the corner of the expansion chamber varies except at the outlet where it remains constant and at the outlet pipe where it is found greater. The velocity contour is non-uniform and can be divided into three zones – inlet pipe, expansion chamber, and outlet pipe. The velocity at the inlet pipe remains almost constant, but it is greater in the expansion chamber as the pressure in the expansion chamber decreases. The pressure contours show that both static and dynamic pressures are almost uniform in the inlet pipe. The static pressure in the expansion chamber is not uniform and varies from the minimum value to the maximum value. The dynamic pressure in the expansion chamber is not uniform and varies from minimum to maximum value. Also, the static pressure at the outlet pipe remains uniform, but the dynamic pressure ranges from the middle zone to higher zone. Here creation of some vacuum is also seen in the outlet pipe in the static pressure contour. Pressure is reduced increasing flow velocity there as shown in Table below.

Table 2.1 Flow Velocity Details

S. No.	Pressure	Inlet Pipe	Expansion Chamber	Outlet Pipe
1	Static	Uniform	Non-uniform	Uniform
2	Dynamic	Uniform	Non-uniform	Non-uniform

Phaneendra et al. (2012) have optimized the design of inlet manifold by having helical threads of irregular pitch inside the manifold, which is a major issue affecting the performance of the engine. A four-stroke compression ignition engine using power 9 HP and rated speed at 1500 rpm was preferred for the present work to examine the performance uniqueness, which was intended and compared through the standard manifold and helically threaded manifold were intended and compared. The tests were approved with different configurations in unsteady pitch of the helical threads from 10 to 25 mm in steps of 5 mm inside the intake manifold. The middle diameter of the manifold was about 30 mm throughout. Helical threads, with outer diameter 30 mm and inner diameter 24 mm with10 mm pitch were adopted, and from the investigation results, this manifold showed better performance. The brake thermal efficiency was increased by 5.13 %.

Rajendran and Purushothaman (2014) point out that, the result of conventional throttle positions indicates flow recirculation at downstream, which causes pressure fluctuations and increased stagnation pressure loss which is undesirable. Moreover, the velocity vectors for various throttle plate positions also show the recirculation in the flow just before the throttle plate. The result of volumetric efficiency depends upon the position of the throttle plate. The double throttle plate, angle 600 it is equal to 69.82 %, at 750 it is equal to 71.33 %, and at 760 it is equal to 70.96 %. Therefore, in double throttle plate of 750, it has efficiency higher than that of another position. The further increased mass flow rate has been observed in the manifold model. The analysis of the modified model showed the design achieves as more symmetric with an organized flow at the downstream of the carburettor. This plain design change has the potential for improving mixture distribution downstream of the carburettor without major changes in the carburettor design.

Muralikrishna and Mallikarjuna (2009) reported that the overall inlet tumble flows are dependent on the crank angle positions irrespective of engine speed. At the end of compression stroke, anywhere spark is supposed to complete. A Turbulence Kinetic Energy (TKE) is high at higher engine speeds. At 330 CAD, flat piston top shows a development of about 85 and 23 % in tumble ratio (TR) compared to the dome and dome-cavity pistons respectively. At 330 CAD, flat piston top shows an enhancement of about 24 and 2.5 % in typical TKE compared to the dome and dome-cavity pistons respectively. The use of flat piston rather than dome is suggested. Dome-cavity pistons are rather difficult to manufacture as far as tumble flow is concerned.

Gosman et al., (1978) have made numerical and experimental studies on the laminar and turbulent flow of the engine without combustion through a cylinder port. Estimated and measured results were in good agreement. They analyzed that the mean velocity field was influenced more strongly by the engine geometry than by the engine speed. Hiren and Chaudhari point out that the primary function of the intake manifold is to evenly distribute the mixture to intake port in the cylinder head. An ideal intake manifold distributes flow evenly to the piston valves. Even distribution is important to optimize the efficiency and performance of the engine, and the inlet manifold design has a strong influence on the volumetric efficiency of the engine. An uneven air distribution leads to smaller volumetric efficiency, power loss, and increased fuel consumption.

Muralikrishna et al., (2010) have stated that the intake manifold inclination greatly influences the inlet flow structure. A flow reversal below the intake valve is seen with all the manifold inclinations with all intake valves lifts considered. For all the intake valves lifts with 200 intake manifold inclination, air flow is in the form of the jet near the intake valve exit, whereas for other manifold inclinations, the jet formation is not the same for all the lifts. It is found that at 300 intake manifold inclination, large-scale vortex below the intake valve at all intake valves lifts. TKE is found to be higher compared to all other manifold inclinations. Conclusion for all intake valve lifts with 600 manifold inclinations that the information obtained in this investigation is very much useful in the optimization of the geometry and orientation of the intake manifold of the modern internal combustion engines.

Rasul and Glasgow (2005) have prepared a convergent and divergent tube and tested regulation to increase the airflow into the engine, which possibly will increase the overall performance of an internal combustion engine. More particularly, the brake power improved up to 1.3 %; the air flow improved up to .2 % and the mechanical efficiency improved up to 3.7 % specifying an increase in the initiation system and the overall performance of the engine. Even though a slight increase in performance is evidenced by the results, more experiments are necessary to warrant any installation of any alteration.

Rizalman Mamat et al. (2009) reported that the air-fuel flow increases slightly as pressure drop decreases. At part load, the increase of fuel flow responds to pressure drop, while the fuel flow rate increases rapidly as pressure drop increases. Swirl coefficient is the ratio of circumferential airspeed in the cylinder to the axial speed of the airflow in the cylinder.

Yang Liang Jeng et al., (1999) reported that the potential of using a video-based particle image system in studying the inlet tumbling flow structure of an engine is demonstrated. No significant tumbling motion is found accompanying with the use of a non-shrouded intake valve. Adding a shroud to the intake valve will help the generation of large-scale vertical tumbling motion. A small-scale vortex will be reserved inside the bowl in the piston. The use of a bowl of the piston is uncertain to help in the generation and the maintenance of the tumbling flow pattern depending on the part of intake valve shrouded. Further investigation to relate the quality of the vertical flow in the axial plane with the generation of turbulence during the compression stroke is strongly recommended.

2.4 Emission Characteristics

Haagen-Smit et al., (1955), in their research on smog formation, have shown how ozone formation is difficult for typical operating conditions of two-stroke engines, whereas it results easily for four-stroke engines.

The study by Suresh et al., (2001) on data obtained from over 250 vehicles proved the influence of various parameters on exhaust emission levels and two-stroke engines are found to be the major source of HC emissions about 5 to 6 times that of four-stroke engines. It was also concluded that proper servicing and emission control system could considerably reduce emission levels.

Jagdale et al., (2001) have reported that nitric oxide and nitrogen dioxide, collectively called, NOx is a precursor to photochemical smog and contributes to acid rain and ozone depletion. Control of NOx emission is a crucial step towards maintaining a clean and green environment.

Kale et al., (2001) have analyzed the quantity of engine oil carried away with the blow-by gas into the inlet manifold, especially at full load conditions when the flow rate reaches a maximum value.

Maneesh et al., (2001) brought out the remarkable feature of using CNG as a cleaner and greener fuel in the engine. CO2 and CO is the product of incomplete combustion, totally depend on air-fuel ratio. The diffusivity of CNG at high pressure results in easy mixing with air giving lower CO emissions. However, CO2 emissions increased at higher throttle positions as less air was available for combustion.

2.5 Emission and EGR

Ken Santoh et al. (1997) investigated on a naturally aspirated single cylinder DI diesel engine with various combinations of EGR, fuel injection pressures, injection timing and intake gas temperatures affect exhaust emissions, and they found that NOx reduction ratio has a strong correlation with oxygen concentration regardless of injection pressure or timing. NOx reduction ratio is in direct proportion to intake gas temperatures. EGR will sometimes adversely affect the smoke emission since it lowers the average combustion temperatures and reduces the oxygen intake gases. This, in turn, keeps soot from oxidizing. Also, they suggested that for a given level of oxygen concentration the cooled EGR reduces the NOx with less EGR rates than at uncooled EGR.

Gukelberger et al., (2015) have patented a dedicated EGR (D – EGR) engine claiming high efficiency, low emissions internal combustion engines for automotive and off-highway applications.

Ghosh and Dutta (2012) have investigated and demonstrated the influence of using EGR of different rates on the engine performance and emission characteristics of single cylinder water cooled four stroke diesel engines. It is reported that EGR has a considerable reduction in oxides of nitrogen. When the engine was operated with PPME, the brake thermal efficiency decreases due to the lower calorific value and high viscosity of PPME compared to neat diesel fuel. The brake thermal efficiency increases at low EGR rates for both the fuels. However, increasing EGR in flow rates to high levels resulted in a decrease in brake thermal efficiency for both the fuels.

Rajan and Senthil Kumar (2009) studied the effects of EGR on the performance and emission characteristics of a CI engine fueled with sunflower biodiesel. The study involved a twin cylinder, naturally aspirated water cooled. DI diesel engine was used for experiments. Sunflower biodiesel was blended with diesel fuel in different percentages denoted by B20 (20 % biodiesel by volume blended with 80 % diesel) and B40. The experiments were conducted with B20 and B40 with different EGR rates. It was observed that higher amount of smoke emission in the exhaust compared to without EGR. Smoke emission was increased with increasing engine load and EGR rate. At full load conditions with 15 % EGR rate, B20 and B40 emitted NOx was lower by 25 % and 14 % respectively, compared to diesel fuel without EGR. They concluded that the use of EGR with biodiesel was able to reduce NOx emissions at the expense of an increase in smoke, CO and HC emissions.

Tayfun Ozgur et al., (2015) studied the effects of addition of oxygen-containing nano-particle additives, namely MgO and SiO_2 added to biodiesel on the dosage of 25 ppm and 50 ppm on diesel engine performance and exhaust emission. Their results showed that the engine emissions NOx and CO decreased, and engine performance slightly increased with the addition of nanoparticle additives compared to diesel.

2.6 Combustion Characteristics

Heywood (1988) in his earliest studies on internal combustion engine fundamentals briefly discussed SI engine mixture requirements and the design requirements for air flow and flow phenomena. The performance can be measured by the mass of air-fuel mixture retained in the cylinder. His contention was that the air path through inlet manifold presents a pressure (vacuum), a challenge posed to the system designer of air induction. The pressure drop across the air intake system is known to have a considerable influence on the indicated power of the internal combustion engine. The drop is created due to the suction generated by the descending piston in the case of the naturally aspirated engine. The pressure drop along the intake system is dependent on the engine speed and load, the flow resistance of different elements in the system, the cross-sectional area through which the fresh charge moves and the charge density. Depending on the engine sizes and operating conditions, Heywood indicates that, for a unit change in compression ratio, the relative change in efficiency is between 1 to 3 percentage.

Pundir (2012) has enunciated in his book, that the combustion generated emissions from internal combustion engines are significant sources of air pollution. He has explained the genesis and formation of general emissions from internal combustion engines and the control technology for mitigation.

Rajesh et al., (2001) have used vortex structures that enhance mixing and causes complete combustion of fuel within a short distance from the dump plane.

Som and Sharma (2001) have made a comparative study of variations in combustion efficiency and second law efficiency of a spray combustion process for different fuels with different volatilities. An increase in fuel volatility increases combustion efficiency only at higher pressures for a given swirl and inlet temperature.

Benny Paul and Ganesan (2010) state that the helical spiral manifold geometry creates a higher velocity inside the combustion chamber nearing the end of a compression stroke. Swirl ratio inside the cylinder and TKE are higher for the spiral manifold. The volumetric efficiency of the spiral, the helical combined manifold is 10 % higher than that of the spiral manifold. The results of the comparison are as follows: Helical spiral combined manifold creates higher swirl inside the cylinder than the spiral manifold. Helical manifold provides higher volumetric efficiency as compared to the normal manifold. Helical spiral combined manifold provides higher mean swirl velocity at TDC of compression. However, further investigations based on combustion and heat release rate analysis are essential for getting a better understanding of the flow inside the cylinder and its effect on the motions.

2.7 Model Simulations

Akira Kikusato et al., (2014) have developed a non-dimensional two zone SI combustion model an autoignition model in unburned gas and a heat transfer model in the combustion chamber wall. This model helps to predict the performance of an SI engine.

Gupta et al., (2001) have determined and compared the exhaust characteristics of a two-stroke engine using fluid flow equation (FFE) and pressure wave propagation methods and the results compared to determine the cylinder pressure variation with varying exhaust processes.

Raghunathan and Kenny (1997) reported that the turbulence consists of fluctuations in the flow field in time and space has a significant effect on the behaviour of the flow. Turbulence occurs when the inertia forces in the fluid become significant compared to viscous forces and are characterized by a higher Reynolds number. The k-ε model of turbulence is widely used for fluid flow analysis where k is turbulence kinetic energy, and the variance of the fluctuations in velocity and ε is the velocities of fluctuations dissipate.

Nureddin Dinler and Nuriyucel (2008) investigated the numerical simulation of flow and combustion in an axisymmetric internal combustion engine for inlet valve angle α= 300 combustion velocity is more than that for α= 450 and α= 600. However, the fuel consumption depends upon the valve angle.

Samimi Abianeh (2009) reported that the study demonstrates the ability of an inlet system using flow control baffle to induce swirling and tumbling motions in the four-valve engine and to investigate the influence of tumbling motions in increasing the lean limit of combustion. CFD calculation and flow bench test rig show that the flow control baffle can change the flow pattern significantly. Swirling motion can exist until the end of the compression cycle, but tumble motion diminishes faster. Also, a specific design of flow control allows evaluating and comparing the potential of different inlet systems concerning engine combustion characteristics. The ability to swirl motion to improve engine stability compared to tumbling motion in the current engine. The engine with a higher range of rotation ratio has better lean burn capability, and this matter is the result of two opposite subjects, the negative effect of more heat transfer and the positive effect of more turbulence and orderly bulk flow. The HC emissions of the engine with higher flow rotary motion are higher, due to thicker quench layer, higher heat transfer, and larger fuel wet area. Tumble Ratio (TR) is defined as the ratio of the angular velocity of in-cylinder flow to the engine angular velocity.

Saravanakumar et al., (2013) reported that their work aimed to induce the turbulence of intake charge through squish. The movement of air inside the combustion chamber can be brought about either by changing the inlet manifold and the inlet valve or by changing the contour of the piston crown. Here the latter option is implemented on the compression ignition engine which invariably has a heterogeneous charge mixture for combustion. The flow analysis of air inside the combustion chamber can be simulated analyzed by using CFD analysis for both the modified piston and a standard piston. It was found that there is a significant improvement for the squish generated by modified piston than the standard piston.

Arias et al., (1974) have studied the numerical model of a network of complex flow, which contains short metering orifices, compressible flow and two-phase flow in pipes of smaller diameter. They have done a detailed review of pressure drop effect of fuel and dynamic flow in the previously developed models. The homogeneous two-phase flow models were found to be very poor in agreement with the empirical correlation derived from experiments on small pipes. They solved the instantaneous one-dimensional Navier-Stoke equation in single phase pipes to access the dynamic flow model. They also used the model to derive a sensitivity analysis of geometries and physical properties of air and fuel.

Kamil Arslan (2014) point out to the results of numerical computations presented regarding average Nusselt numbers and average Darcy friction factors. It increases the Reynolds number has proved to increase the average Nusselt number. On the other hand, average Darcy friction factor gets decreased with increasing Reynolds number. For a turbulent flow condition in the hydrodynamic and thermal entrance region, the friction and heat transfer coefficients depend on the duct geometry and Reynolds number. Further, local heat transfer coefficient and local Darcy friction factor as functions of dimensionless position along the duct were obtained and given graphically in this investigation. The numerical results for different turbulence models were compared with, and similar experimental investigations carried out in the literature. Finally, k-ε standard, k-ε resizable models are found to be the most suitable for this investigation.

Saidur et al., (2009) have analyzed higher efficiency, lower fuel consumption by improving fuel economy, producing fewer emissions from the exhaust, and reducing noise pollution which has been made mandatory as standards in many countries.

Syed Ameer Basha and Raja Gopal (2009) found improved computational mesh generation techniques and efficiency widely influenced the application of CFD methods to reciprocating engine models, which requires movable domain boundaries and compressible and expandable meshes. Three-dimensional models can predict inlet means gas velocities with high accuracy. Most computational works on diesel engines employ two-equation turbulence models, predominantly the standard k-ε model for modelling turbulence. The simulation of evaporating droplet dynamics in diesel engine simulations is based mostly on models proposed for single droplet evaporation. A large number of combustion models are constituted for diesel combustion simulation but do not find validation. The laminar and turbulent characteristics of time scale model fin higher usage when compared to other models for simulating diesel combustion. Most combustion simulations are concentrated in the mid and high load range. However, given the importance of higher emission weighting factors at idling conditions in various duty cycle and until recently the availability of considerable amount of in-cylinder experimental data obtained under firing conditions at low loads, work on engine simulations are not available at low speeds.

Kurniawan and Abdullah (2005) have worked on the computational fluid dynamics simulation to examine the effect of piston crown shape to air motion characteristics of an internal combustion engine which is presented in this paper. The inlet air motion previous to the fuel introduction event plays an important role in the creation of swirl and tumble flows due to the high turbulence through the intake and compression strokes. Swirl is generated through suction of air flow into the combustion chamber during the intake stroke and significantly enhances the mixing of air and fuel to give either identical or stratified mixture inside the cylinder. At the beginning of intake stroke, the normal tumble ratio reaches a local peak value at 4000 crank angle for a homogeneous and stratified piston. Then it decreases nearly to zero around 4400 crank angle before increasing over again at the present crank angles. It happens due to the exchange of two main vortices among opposite direction inside the engine cylinder, which resulted from the strong air jet flow through the valve blind are during the intake stroke. The standard tumble ratio is also seen to increase slightly higher during the maximum intake valve opening for both pistons before regularly decreasing during the compression stroke. The standardized piston is still able to produce a higher tumble ratio on the normal side during the early intake stroke.

Rajendra Prasath et al. (2010) numerically studied the performance of a ceramically coated diesel engine with two-zone modelling of diesel/biodiesel blended fuel. The results showed an increase in the brake thermal efficiency and a decrease in the specific fuel consumption for LHR engine operated with diesel and biodiesel operation compared to conventional diesel engine operation. They have concluded that the model predicted the engine performance characteristics closer in approximation to those of experimental results. Hence the developed mathematical model was suitable for the prediction of the combustion and performance characteristics of the CI engine and LHR engine.

2.8 Bio-fuel and Emission Characteristics

Murugu Mohan and Sarangan (2001) have suggested alternative fuels and fuel blending for performance improvement. About 13.7 % drop in particulate matter with 12.7 % drop of total hydrocarbons were reported with B-20 blend fuel.

Swaroop Kumar Nayaka and Bhabani Prasanna Pat Tanaka (2014) have produced biodiesel from neat Mahua oil via base-catalyzed trans-esterification and mixing of the biodiesel with a suitable additive (Dimethyl Carbonate) in varying volume proportions to run the diesel engine. Their results showed an increase in brake power and brake thermal efficiency with load with an increase in the percentage of the additive. The CO, HC, NOx emissions decreased with an increase in the percentage of additive in biodiesel. It is also found that the overall performance and emission characteristics of the engine were satisfactory with all the test fuels.

Bhaskar et al. (2013) studied the performance and emission characteristics of Fish Oil Methyl Ester (FOME) and blends in a diesel engine with the effect of different EGR rates. Their results showed that 20 % FOME blend gives almost the same brake thermal efficiency with lower unburned hydrocarbons, carbon monoxide, and soot emissions but higher NOx emissions compared to diesel fuel. EGR is used to control NOx emissions. The percentage of EGR is varied to determine optimum EGR for 20 % FOME blend. It is also reported that 20 % EGR flow rate is optimum for 20 % FOME blend considering the emissions of NOx and soot.

Deepak Agarwal et al. (2006) have investigated the effect of linseed oil, Mahua oil, rice bran oil and linseed methyl ester in diesel. It has been reported that brake specific fuel consumptions were higher for vegetable oil compared to diesel fuel. It has been concluded that the 20 % of linseed oil methyl ester blend was optimum that improved the thermal efficiency and reduced the smoke density.

Devan and Mahalakshmi (2009) have studied various methyl ester of paradise oil (eucalyptus oil) blends in a single cylinder, four-stroke DI diesel engines to study the performance and emission characteristics. The results show a 49 % reduction in smoke, 34.5 % reduction in HC emissions and a 37 % reduction in CO emissions for the Me50-Eu50 blend with a 2.7 % increase in NOx emission at full load. There was a 2.4 % increase in BTE for the Me50-Eu50 blend at full load.

Ganesan and Elango (2014) have investigated the environmental aspects of lemongrass oil bio-fuel in a single cylinder diesel engine at 200 bar, 220 bar and 240 bar injection pressure to study its effect on performance and emission characteristics and compare it with neat diesel. Their results showed that the B20 blend exhibited lower engine emissions of unburnt hydrocarbon, Carbon Monoxideand oxides of nitrogen at 75 % load. The high injection pressure of 240 bar showed less significant emissions of unburnt hydrocarbon, Carbon Monoxideand oxides of nitrogen than 200 and 220 bar pressures at 75 % load.

Nurun Nabi et al., (2006) made biodiesel from neem oil by the esterification process with methyl alcohol and conducted the experiments with neat diesel fuel and different blends of diesel and biodiesel in a naturally aspirated direct injection diesel engine. They have reported a lower CO and smoke emissions and a higher NOx emission with diesel-biodiesel blends in comparison with conventional diesel.

Hountalaous et al. (2008) used a 3D multi-dimensional model to examine the effect of EGR temperature on a turbocharged DI diesel engine with three different engine speeds and reported that high EGR temperature affects the engine brake thermal efficiency, peak combustion pressure, air fuel ratio and soot emissions. The effect of increased temperature and decreased O_2 concentration together resulted in low NOx emissions. They also suggested that EGR cooling is necessary to retain the low NOx emissions and prevent the rising of soot emissions without affecting the engine efficiency at high EGR rates.

Lakshmi Narayana Rao et al. (2008) have also investigated the performance of diesel engine with Rice Bran oil Methyl Ester (RBME) and its diesel blends. It has been reported that the ignition delay and the peak heat release rate for RBME were lower for biodiesel and it was increased with increase in RBME blends. The study also reported that the CO, HC, and soot emissions were increased, and the NOx emissions were slightly increased with increase in blends compared to diesel fuel operation.

Venkata Subbaiah and Raja Gopal (2011) investigated the performance and exhaust emission characteristics of a Direct Injection (DI) diesel engine experimentally when fueled with Rice Bran Oil Biodiesel (RBD), and it's 2.5 %, 5 % and 7.5 % ethanol blends over the entire load range. Their test results showed that the maximum brake thermal efficiency was obtained with 2.5 % ethanol blended with RBD and are 6.98 % and 3.93 % higher than that of Diesel Fuel (DF) and biodiesel respectively at full load. The ethanol blending reduced the exhaust gas temperature of the biodiesel. The low carbon monoxide, hydrocarbon, and unused oxygen emissions were recorded with 2.5 % ethanol blend. The smoke of the biodiesel was reduced by 20 % when blended with 7.5 % of ethanol. The maximum reduction of smoke was 27.47 % with 2.5 % ethanol blending. It was concluded that the 2.5 % ethanol blended with biodiesel could improve the performance and reduce the emissions of the diesel engine.

Michael et al. (1999) studied the effects of common errors on the calculated gross heat release rate data obtained when analyzing simulated and experimental pressure diagram of a direct injection diesel engine using a traditional single zone first-law heat release rate model. They revealed that the greatest uncertainty in most cases would be caused by assuming the wrong rate of heat transfer between cylinder charge and combustion chamber walls. To overcome this limitation, they proposed an alternative heat release model to give superior results over a wide range of operating conditions. This heat release model used a variable polytropic index to cater for the heat transfer. They reported that the new polytropic index model was found to produce comparable results to the traditional gross first law model in general and was much superior in performance compared to the adiabatic first law model. They concluded that the polytropic index model is well suited for the diesel engine development applications where consistent results are required.

Samuel and Arvind (1997) concluded an experimental analysis of the heat release rate from experimental data obtained on a Detroit, six cylinders 12.7-litre turbocharged diesel engine. Two separate concepts obtained the overall gross heat release rate and net apparent heat release rate. The gross heat release rate was determined by exhaust gas concentration measurements using an exhaust gas analyzer. The net apparent heat release rate was determined from the in-cylinder pressure measurements for each of the six cylinders arranged over 80 cycles. They suggested that these techniques could be used to validate steady-state heat transfer models and investigate the steady-state effects of insulated ceramic coatings in the cylinder.

Shehata and Abdelrazek (2008) reported that air injection in the exhaust manifold is the simplest method for reducing HC and CO concentrations due to increased oxygen concentration after exhaust valve opening which is used to oxidize HC and CO to CO2 and H2O at high exhaust temperatures. The temperature decreases with the increase of mass of air injection due to increasing AFR to very lean conditions which overcome heat release effects with air injection. Engine cycle to cycle variation is found to increase with an increase in engine speed due to increase in the variation of AFR, fuel burning rate, heat release rate, turbulence intensity, mean effective pressure, volumetric efficiency, and engine cylinder pressure.

Randolph (1990) studied the three feasible mounting schemes of piezoelectric pressure transducers namely flush mount, remote mount via a single passage and remote mount via multiple slots. This study reviews the theoretical principles dictating the performance of transducers and examines the influence of the mounting scheme on pressure data quality. He reported that a fourth mounting scheme namely remote mount via a sintered porous metal interface was not possible because of excessive pressure drop across the porous metal. The multiple slot-mounting adopters performed the best. When properly designed, this adopter can maintain data accuracy while considerably reducing transducer induced variability relative to flush mounting.

Shrinath Potul et al., (2014) have considered engine performance individuality such as braking torque, brake power, brake mean effective pressure and specific fuel consumption in their simulation software. Lotus engine simulation was used to estimate the effects of the deviation in the length of intake plenum on these parameters. The engine performance can be improved using an intake plenum length that can frequently be mixed.

Miqdam Tariq Chaichan et al.,(2016) have conducted a study to expand basic understanding of the differences in performance and behaviour that result from the use of alternative fuels (methanol) and their blends in conjunction with recirculated exhaust gas in a diesel engine. The experimental results obtained provide a basis to optimize engine operating points with methanol. The conclusions in his study mention that (i) adding methanol with a rate of 10% to diesel fuel presented better specifications on brake specific fuel consumption and brake power basis compared with neat diesel; (ii) Adding methanol reduces the harm effects of EGR on engine performance by increasing available oxygen inside combustion chamber; (iii) At constant engine speed (1500 rpm) increasing the load increased the thermal efficiency. Introducing EGR beyond a limit caused the thermal efficiency to decline and (iv) At constant engine speed the use of cool EGR may be favorable in terms of less reduction in thermal efficiency.

The revival of two-stroke petrol engines is felt necessary to retain the best advantages, and such engines are utilized for environmental safety and energy conservation because of their performance.

The literature review shows that research work has been carried out using various methods to produce turbulence flow aspects of modified manifold mainly for four-stroke engines. Few research works were conducted using a modified valve and a piston in spark ignition engine. The literature review reveals that research on two-wheeler two-stroke engines has not been reported with possible improvements by way of cooled EGR and orifice suction control. This research attempts to study the same.

In the present investigation, attempts have been made to use a modified manifold to obtain a solution for optimum mixing of air-fuel mixture with exhaust gas in two-stroke gasoline under varying operating conditions. Both performance and emission characteristics of a spark ignition two-stroke gasoline engine operated with modified manifold using orifice and EGR have been analysed and reported.