Combined effect of compression ratio & diffuser at exhaust on performance of Single cylinder CI engine, fuelled with blends of Waste Plastic Oil and diesel-A review study

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ABSTRACT

Environmental degradation due to pollution with depletion of oil reserves is a big problem around the globe. Developing countries like India heavily depends on crude oil import. Diesel is the main transportation fuel in India so, finding a suitable fuel alternative to diesel is very much needed. Waste plastic oil is potential alternative for CI engines and more attention is focused in India because of its potential to generate largescale employment generation and relatively low environmental degradation. Back pressure, having a strong influence on engine efficiency and need to be minimized by using diffuser. Present study focuses on improving performance of diesel engine fuelled with waste plastic oil by using diffuser at exhaust and varying compression ratio. Taguchi optimization method will be used to get optimum combination of diffuser angle and compression ratio which give higher performance.

Keyword: *Engine performance, Waste Plastic Oil, compression ratio, Tapered pipes, Diffuser, Exhaust manifold.*

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1. Introduction

Disposal of waste plastic creates large problems for the environment. Waste plastics do not biodegrade on landfills, they also don't get easily recycle. In place of biodegrading, plastics waste goes to photo-degradation which results in plastic dusts which can enter in food chain and can be a reason behind complex health issues to living organism. The literature shows that the waste plastic oil and diesel have similar properties so it can be used in place of diesel. The diesel fuel use and waste plastic oil disposal problems are simultaneously solved by using waste plastic oil as an alternate to diesel fuel.

To fulfill the consumer requirement of more power, improvement in exhaust system is needed. For this reason, adequate design of exhaust manifold geometry becomes necessary. Exhaust manifolds which are too large in diameter cause exhaust gas to expand and slow down which makes it difficult to exit, reducing the scavenging effect and exhaust manifold that are too small in diameter will increase exhaust gas flow resistance resulting in reduction power and dilution the incoming intake charge.

One of the operating parameters affecting the performance and emissions of a Diesel engine is the compression ratio. By increasing compression ratio the air temperature increases resulting in proper combustion of fuels that have high self ignition temperature. Due to this, the thermal efficiency of the engine increases. Most of the compression ratio effects studies have been performed with direct injection (DI) Diesel engines. But no studies have been reported yet on combined effect of compression ratio and diffuser at exhaust on diesel engine fuelled with waste plastic oil.

The main objective of this study is to investigate the effect of compression ratio and diffuser angle on performance characteristics of the engine fueled with waste plastic oil.

2. Literature review

2.1 Literature on Exhaust System

Patil et al. (2014) Worked on Design and construction of the diffuser type exhaust manifold having different half cone angle i.e. V_1=22.5°, V_2=25°, V_3=30°, V_4=45°, V_5=60°, V_6=75°, V_7=90°. Experimental set up of the new diffuser type exhaust manifold and suitable instrument for measuring different parameters like pressure, temperature and mass of exhaust gas. In this work, throughout the complete trials conducted engine jacket cooling water was kept constant at 0.1666 litters /sec, which provides easiness in comparison with different parameters. Diffuser with different angles was used as a test piece for pressure variations. [1]

Experimental work was carried out at engine output condition of 5 kg load and 1500 rpm constant speed and found out that the result of fuel consumption rate was inversely proportional to the volume of the diffuser at exhaust manifold. Pressure at outlet of diffuser type exhaust manifold was directly proportional to the volume of the diffuser at exhaust manifold, which reduces the back pressure. Performance of different exhaust manifold having half cone angle from V_1 to V_7, Brake thermal efficiency and fuel consumption rate variation shown below in Figure 1.

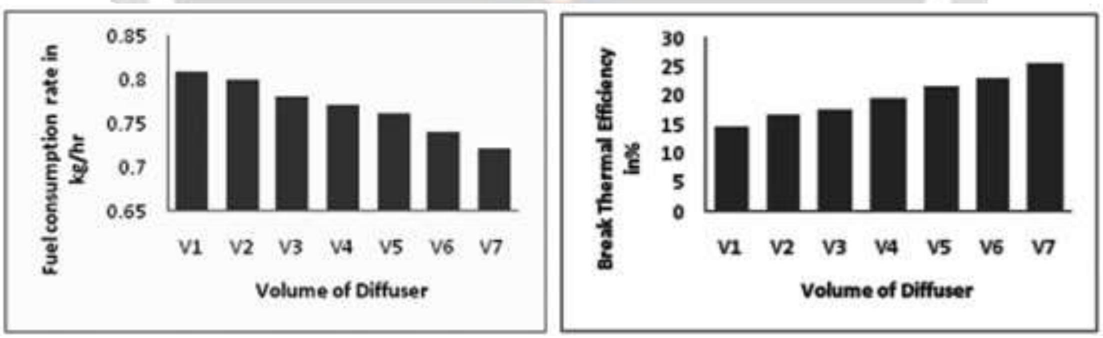

Figure 1: FC v/s Volume of Diffuser and BTE v/s Volume of Diffuser

Payri, et al. (2004) carried out experiments in which different taper pipe configuration was constructed in order to see the mass conservation at steady flow conditions through the tapered ducts. A tapered pipe having different cone angle values of 3°, 6.3° and 9° was tested. An impulse test rig was there as experimental facility that generate impulse flow which help to analyze fluid dynamic behaviour of different element against the pulsating flow. That facility consisted of a reservoir, an electro-valve, two very long ducts and a data acquisition system. The pressure pulses reflected and transmitted by a tapered duct has been also analyzed at a steady flow process. It is known that the tapered duct calculation has mass conservation problems, which could be increased with the consideration of a pulsating flow, typical in automobile engine. Mass conservation problem was improved in 9°

convergent divergent pipe when compared to other tapered duct. Calculated and measured pressure at different section of duct is approximately same. Mass conservation in 6.3° Divergent duct is shown below in Figure 2. [2]

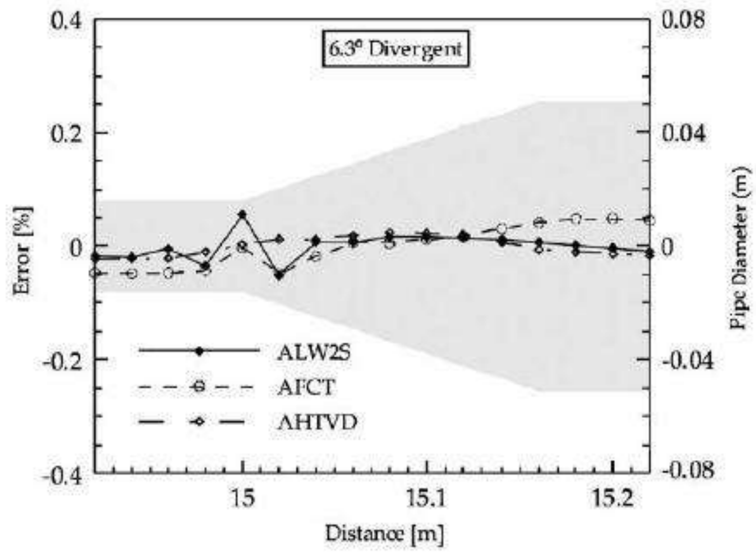

Figure 2: Mass conservation with Impulsive flow

Kanazaki et al. (2003) Divided exhaust manifold equally into three segments. In their work pipe radius of exhaust manifold was designed, in first case, radius of exhaust pipe varied from 83% to 122% of the original radius from first segment to third segment of exhaust manifold. Their result achieved increased in charging efficiency (that indicates power) than the conventional exhaust manifold. In second case, The pipe radius of exhaust manifold varied from 90% to 120% of the initial radius from first part to third part of exhaust manifold. First part radius, second part radius is increasing by factor will vary from 1.06 to 1.18 and third part radius is increasing by factor b will vary from 1.35 to 1.45. Their result suggests that less gas interaction and the larger charging efficiency achieved in second case compared to first case. [3]

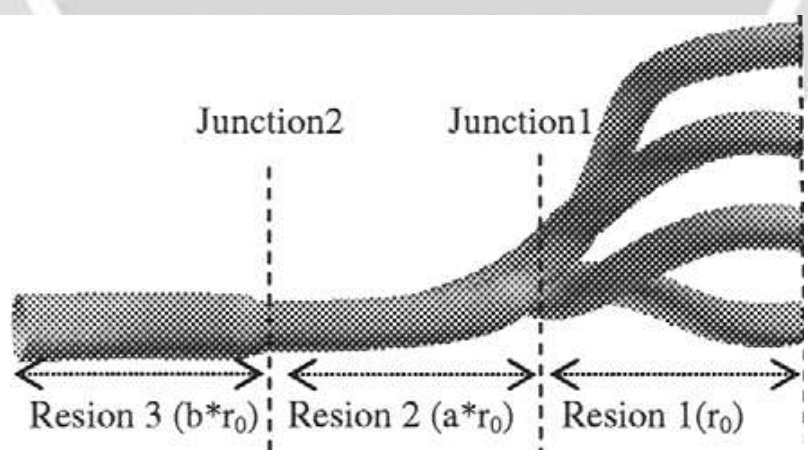

Figure 3: Geometry Definition for tapered pipe

Galindo et al. (2004) performed experimental work on dual-wall air-gap exhaust manifold and a conventional exhaust manifold. They compared two exhaust manifolds with the same shape, the only difference was their thermal inertia of walls. Thermal inertia value of Grey cast iron is 375 (kJ/W m) and Stainless steel is 575.6 (kJ/W m). In that test, they had taken exhaust manifold which had higher thermal inertia (stainless steel) or lower thermal inertia (cast iron) with insulation for measuring engine performance. [4]

The result of mass flow rate in lower thermal inertia material and higher thermal inertia material is shown in Figure 4. Engine torque in lower thermal inertia material and higher thermal inertia material is shown in below Figure 4. Non-insulated, lower thermal inertia material manifold delivered 1.7% higher energy compared to the higher thermal inertia material manifold.

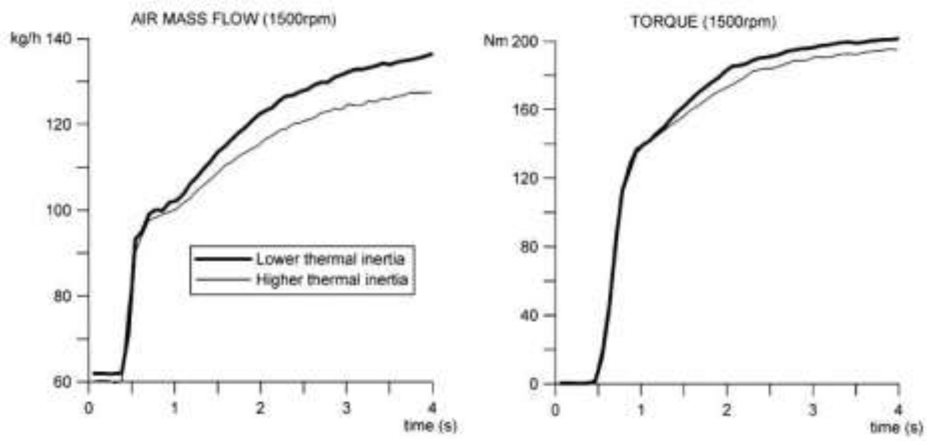

Figure 4: Air mass flow rate and Torque vs. Time

Finally they had concluded that dual wall air gap exhaust manifold improve transient performance of engine by saving exhaust energy due to reduction in heat loss to increase catalyst temperature by 50°C, increase in torque was 6.6 %. [4]

Qudais, (1997) investigated a new analytical model for prediction of instantaneous exhaust gas temperature & velocity of a single cylinder CI engine. He includes modelling of variable specific heat, heat transfer and non instantaneous combustion to get continuous change in the state of gas throughout the cycle. Also, the cylinder volume, charge mass and the internal energy of gas was found out at any instant of cycle. [5]

Experimental measurement of the instantaneous exhaust gas velocities and temperatures were obtained from a single-cylinder, indirect injection diesel engine. The engine operated at 1800 rpm and F/A ratio of 0.03. The instantaneous exhaust gas velocity was measured by using fast response dynamic pressure transducer which measures the instantaneous dynamic pressure at the exit of the exhaust port. [5]

Finally, they stated that experimental results were approximately same to results obtained from modeling, and is shown in below Figure 5. Based on this conclusion, we can use the model to predict the instantaneous exhaust gas velocity and temperature of many engine over a wide ranges of operating condition. [5]

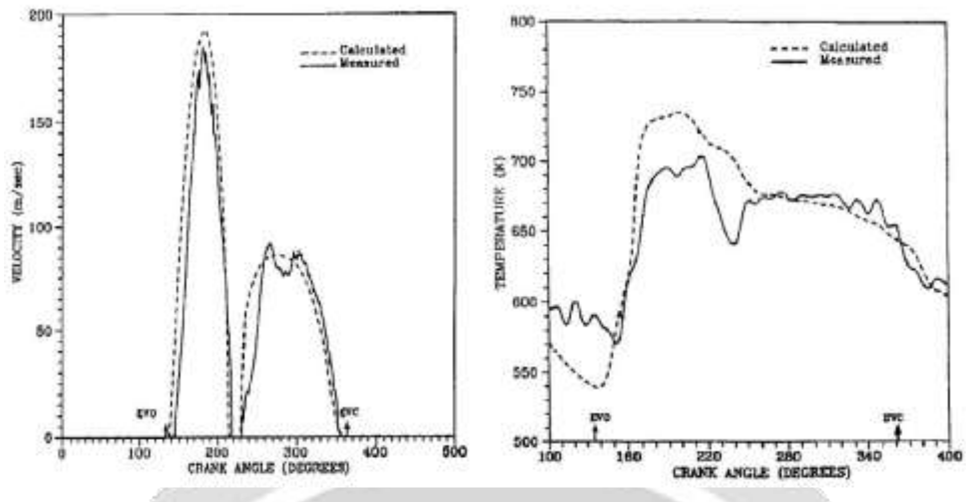

Figure 5: Velocity and Temperature Vs Crank angle

2.2 **Literature on effect of compression ratio on blends of diesel and biodiesel:**

Kassaby et al. (2013) carried out experiments to check effect of compression ratio on emission with engine fueled with biodiesel made by transesterification of waste cooking oil. [6]

They conclude that the engine torque for all blends increase as the compression ratio increase. The bsfc of all blends decrease as the compression ratio increase.At all compression ratios, bsfc remains higher for the larger blend ratio as the biodiesel percent increase. The compression ratio cahnge from 14 to 18 resulted in 18.39%, 27.48%, 18.5%, and 19.82% increase in brake thermal efficiency in case of B10, B20, B30, and B50 respectively. Although having slightly higher viscosity and lower volatility of biodiesel, the ignition delay was lower for biodiesel than for diesel. On average, the delay period decreased by 13.95% when compression ratio was increased from 14 to 18.

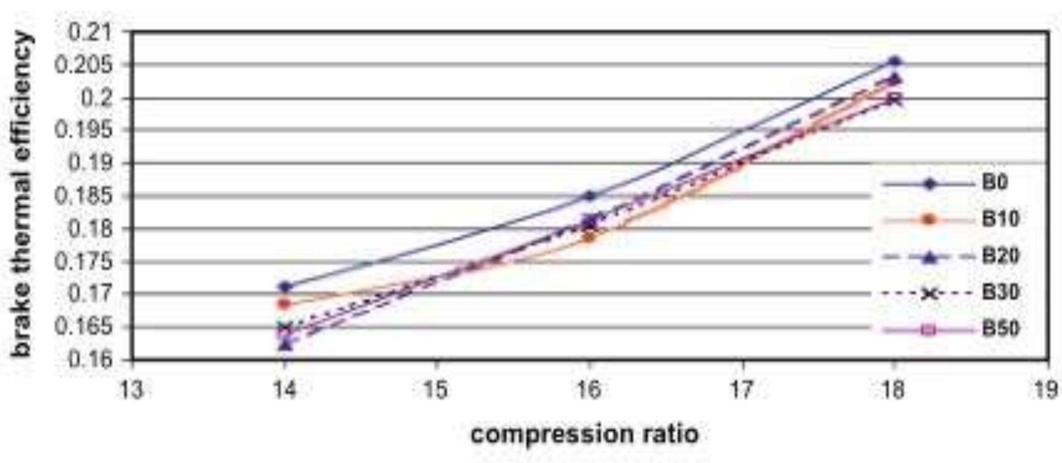

Figure 6: variation of brake thermal efficiency with compression ratio

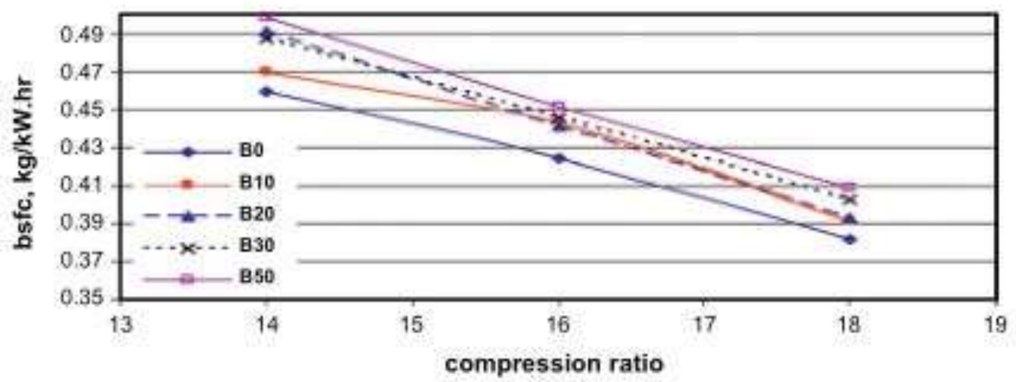

Figure 7: Variation of brake specific fuel consumption with compression ratio for all blends at 1500 rpm and full load condition

Ganji et al (2016) used CONVERGE tool for CFD analysis to optimize parameters such as Compression Ratio (CR), Start of Injection (SOI) and Exhaust Gas Recirculation (EGR) to reduce emission.

VCR engine run for 100 % load for testing its performance and it was validated for standard configuration. They performed the simulation by varying the design or operating parameters such as CR (18–14), SOI (17–26 degree bTDC) and EGR (0–15 %) at constant fuel injection pressure of 230 bar and speed of 1500 rpm. The effect of this parameter on oxides of nitrogen, pressure and soot were presented. [7]

Their result showed that the NOx emission and soot emission have shown reverse trend. Early injection increases NOx emission and decreases the soot. While, lowering the CR results in reduction in NOx and increase in soot emission. So, a trade off could be made between soot emission and NOx emissions by selecting appropriate SOI & CR. The optimized set of CR 18, SOI 21.5 degree BTDC and EGR 2 % was obtained which reduce soot by 40 % while marginal reduction in NOx was observed. [7]

Sayin et al. (2011) carried out experiments to find out influence of compression ratio (CR) and injection parameters such as injection timing (IT) and injection pressure (IP) on the performance and emissions of a diesel engine using biodiesel (%5, %20, %50, and %100) blended diesel fuel. Tests were performed using different CRs (17/1, 18/1, and 19/1), ITs (15,20,and 25 degree CA BTDC) and IPs (18,20and 22 MPa) at 20 Nm engine load and 2200 rpm [8]

The tests were conducted at 20 Nm engine torque and 2200 rpm. First test was conducted with pure diesel fuel to obtain the basic data of the engine for comparison purpose. The ratios of the test values of the engine performance parameters and exhaust emissions obtained with the fuel blends by those with pure diesel fuel were found out. [8]

They come to a conclusion that BSFC, BTE are improved considerably with increase in CR as compared to the original and decreased CRs. Increasing CR improves density of air charge in the cylinder. The higher the density, the higher angles of spray cone which results in increase of amount of air contact in the spray. Enough air in the fuel spray results in the complete combustion. For all CR, the emissions of HC, OP and CO with biodiesel blend were lower than that of pure diesel fuel. With the rise in CR, the temperature was also high and so less OP, CO and HC emission were found at the exhaust. But, this effect raised NOx emission. [8]

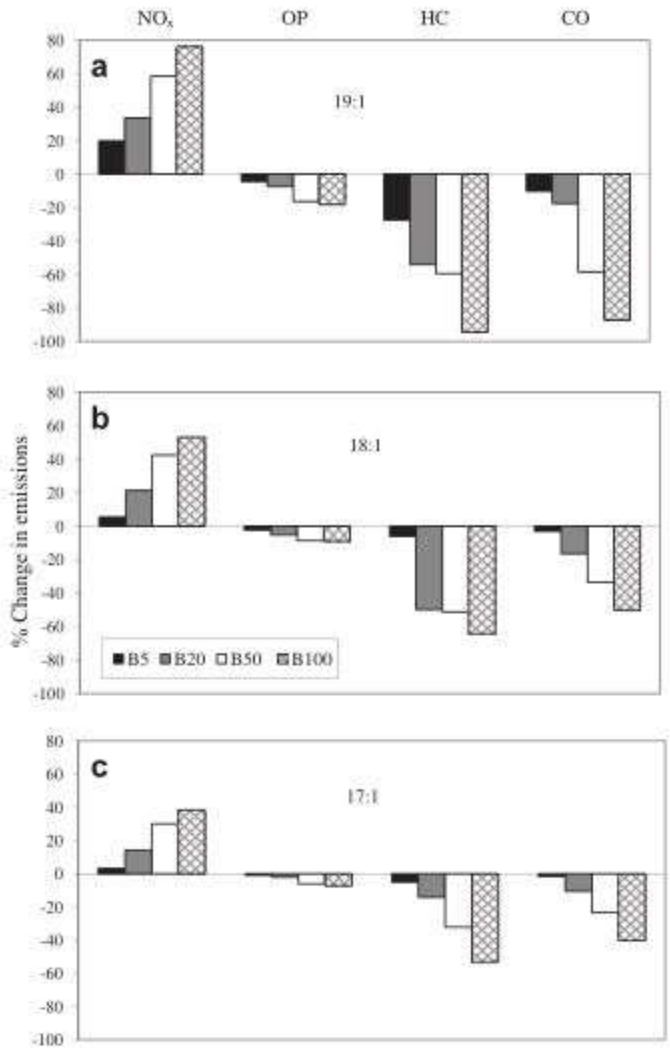

Figure 8: The changes within the emissions with the blends compared to diesel fuel for different Compression ratio

2.2 **Literature on performance of WPO and its blends:**

Kumar et al. (2013) have collected waste HDPE (from used mobil oil containers) from the National Institute of Technology Rourkela, Orissa, India campus waste yard and used in their experiment. The plastic was cut into small pieces (approx. $1cm^2$) and was used in pyrolysis reaction. [9]

They have found that BTHE at all load condition were lower than compared to that of pure diesel fuel because of the lower CV of waste plastic oil, exhaust temperature increased by increasing the engine load. The NOx emission increased with increase in percentage of waste plastic oil in blends and decrease with increase in the engine load. The UBHC emission was decreased with increase in engine load and increased with increase in percentage of waste plastic oil in the blends. [9]

Kaimal et al.(2015) performed experimental investigation to analyze the effects of using plastic oil in diesel engine. Plastic oil was made from plastic waste, collected from municipal landfill areas, by pyrolysis process. PO25 (25 % plastic oil and 75 % diesel by volume), PO 50 and PO75 blends were made using plastic oil and the diesel fuel. [10]

Their result suggests, in comparison to blends and pure plastic oil, ignition delay for diesel was less. Due to lower cetane number and higher viscosity of the blends, poor atomization happened which in turn affected the proper mixing of air and fuel increasing the delay period. Although the engine was able to run on pure plastic oil, blend PO25 showed good and compatible results than other blend when compared with pure diesel fuel. So 25 % plastic oil diesel blend can be considered as an effective replacement for diesel in CI engines without any modification. [10]

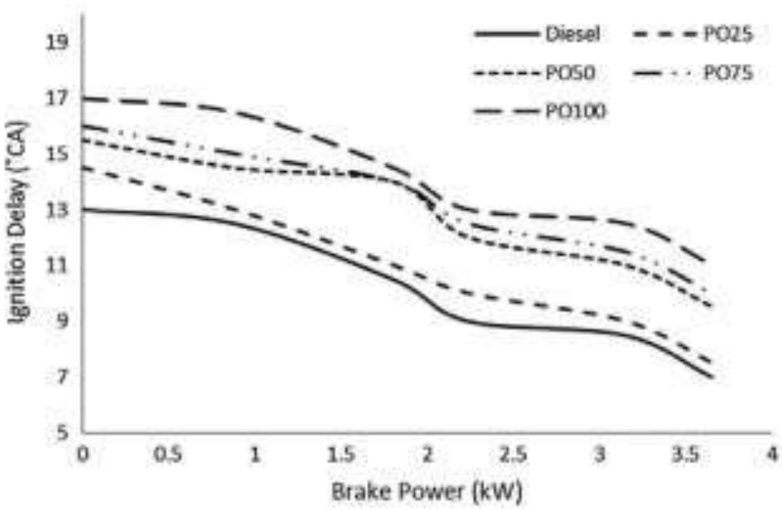

Figure 9: Variation in ignition delay with brake power

Ananthakumar et al.(2016) obtained waste plastic oil from pyrolysis process as shown below Figure 10. Plastic oil obtained from the plastic waste was used as a fuel in diesel engine without engine alteration. The performance and the emissions of the plastic oil, plastic oil blend were compared to results of pure diesel. Waste plastic mainly consists of polyethylene terephthalate, high density polyethylene, low density polyethylene, polystyrene, polypropylene and polyvinyl chloride etc. These waste plastic were crushed into small pieces and fed to the reactor for thermal degradation. In the absence of air, these waste plastics were heated to the range of 300–900 °C where plastic vapor was formed. The outlet gas (plastic vapour) from the pyrolysis reactor was condensed into a series of water cooled condenser and the oil after condensation was taken as fuel for the experiment. The other uncondensable gases were sent out into the atmosphere. [11]

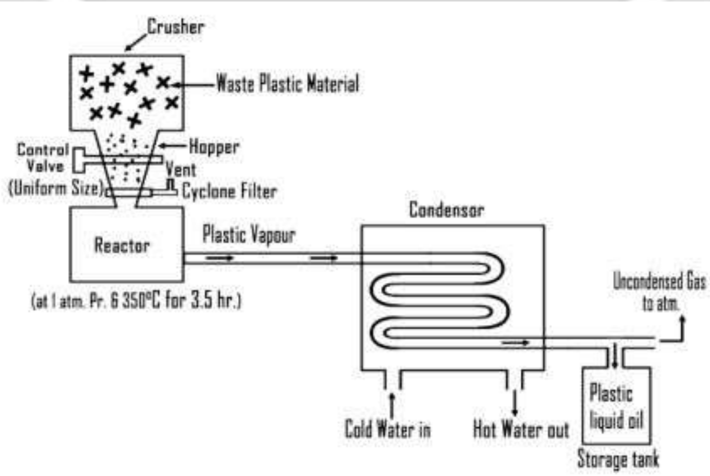

Figure 10: Schematic of Pyrolysis of waste plastic

VCR engine was allowed to run with diesel for 15 min to maintain actual steady state of the engine so it gets stabilised. The coolant water flow at constant rate of 60 ml/s. Before changing any fuel blends, the engine was operated 7–10 min to stabilize, as a standard procedure. The fuel was fed by a fuel injection pump starting at 23° before TDC and injection pressure was maintained constant at 200 bar. The data was noted for the compression ratio of 16 at rated speed of 1500 rpm with pure diesel. The data recorded were used as datum for comparison with plastic oil and its blends. The compression ratio was changed to 12,16 and 20 by changing clearance volume of VCR engine. A lever was provided to change the compression ratio in the VCR. An eddy current dynamometer with a load cell was used to impart load the engine. [11]

Their results state that Waste plastic oil can be used as an alternative to diesel at higher compression ratio without any alteration in diesel engine. Blending waste plastic oil and diesel with the additive diethyl ether(DEE) gives parallel result as diesel. Specific fuel consumption was higher to diesel in all the cases.

3. CONCLUSIONS

Following conclusion can be drawn from the literature-

- Tapered pipe design consideration is very effective to maximise charging efficiency
- This result suggests that the variable pipe radius definition is an important design specification to improve design objectives
- Increasing CR increases density of air charge in cylinder. The higher the density, the higher angles of spray cone which results in increase of amount of air contact in the spray. Enough air in the fuel spray contributes to the complete combustion
- Specific fuel consumption and thermal efficiency are considerably improved with the increase in Compression ratio.
- Fuel consumption is inversely proportional to volume of the diffuser at exhaust manifold
- Pressure at outlet of diffuser type exhaust manifold is directly proportional to the volume of the diffuser at exhaust manifold, which reduces the back pressure
- The in cylinder pressure and peak pressure of engine while using Waste plastic oil and its blends are higher than pure diesel. The reason behind this is the higher viscosity of waste plastic oil increases the ignition delay causing more peak pressure.

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