The Influence of Engine Speed on Exhaust Emission of Four Stroke Spark Ignition Multi Cylinder Engine

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Abstract- An experimental study is carried out to investigate engine performance parameters and methods of reducing emissions from spark ignition engine. Fuel efficiency is one of the major concerns for the users, the designers and the manufacturers of internal combustion (IC) engines, The effect of increasing the temperature of cylinder liner has the advantage of reducing the specific fuel consumption but it increases thermal stresses on piston head, challenges material properties such as high temperature yield strength, creep and high temperature fatigue, increases chances of knocking and pre ignition and decreases the volumetric efficiency. Coolants with specified fluid properties are circulated through inner channels in the cylinder blocks to maintain an optimum temperature.

The present investigation reports the experimental study carried out by using three cylinders, four stroke petrol carburetor of Maruti 800 engine. The engine is connected to eddy current type dynamometer to provide suitable loading with provisions for measuring and control of fuel flow to maintain fuel –air mixture ratio. It is found that exhaust emission is a dependent parameter on decrease even at higher loads which confirming that engine perform better upon optimal load condition rather than part load condition.

Keywords: Exhaust emission, spark ignition engine, optimization, and engine speed.

I. INTRODUCTION

The methods and techniques used to reduce emissions from spark ignition engines have some impact effects on engine performance. So, many researches directed their researches to increase spark ignition engine efficiency. For spark ignition engine a reasonable solution for reducing emissions is by controlling some combustion parameters, in such way engine performance is kept unaltered. Two types of internal combustion engines, the spark ignition, SI, and the compression ignition, CI exist. Both have their merits. The SI engine is a rather simple product and hence has a lower first cost. The problem with the SI engine is its poor part-load efficiency (as opposed to full load efficiency) due to large losses during gas exchange and low combustion and thermodynamics efficiency. [8-9]

The effect of increasing the liner temperature i.e., engine temperature, has an advantage of reducing the exhaust emission , however, high head temperature increases thermal stresses in the top of the piston crown which , increases chance of knocking and pre ignition and reduces volumetric efficiency.

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Heat transfer to the air flow in the intake manifold lowers the volumetric efficiency as the density of the intake air is decreased. In addition to above, optimum engine temperature is required for a number of other important reasons, including material temperature limits, lubricant performance limits, and emissions. [23-24] since the combustion process in an internal combustion engine is not continuous, in contrast to that of an external combustion engine, the average component temperatures are lower than the peak combustion temperatures. The engine temperature is maintained by transfer of heat to a circulating coolant. [21]

There are two types of engine cooling systems used for heat transfer from the engine block and the head viz. (a) liquid cooling and (b) air cooling. In almost all multi cylinder passenger automobiles liquid coolant is used as the heat transfer fluid. With a liquid coolant, the heat is removed through the use of internal channels within the engine block. Liquid systems are much quieter than air systems, since the cooling channel also absorbs the sounds from the combustion process. However, liquid systems are subject to freezing, corrosion, and leakage problems that do not exist in air system. [1]

The heat transfer rate in an engine is dependent on the coolant temperature and the engine size, among other variables. Complex interactions exist between various operational parameters. For example, as the temperature of the engine coolant decreases, the heat transfer to the coolant will increase, and the combustion temperature will decrease. [2-4]

With increasingly compact engine design and higher specific power, the density of the waste heat (i.e., the heat necessary to be dessipitated) has increased significantly. Removing heat from an increasingly restricted space is of particular concern especially at vulnerable region, such as the ‘exhaust valve bridge’ area, as the risk of catastrophic failure in such regions is increased considerably even with minor failure in the cooling system. This heat rejection problem which is prominent at Wide Open Throttle (WOT) conditions is tackled by optimizing coolant gallery design for optimum heat transfer effectiveness by targeting this region with high coolant-flow velocities. Consequently, hydraulic losses in the engine cooling system is evident at ‘part-load’ conditions in convectional engine-cooling system because at the ‘part-load’ conditions the engine driven coolant pump, supplies more than that required coolant flow in the system[19-20]

Recent developments have seen thermal management features integrated into the engine management system to enable an optimized balance between engine warm-up, cabin conditions, electrical and electronic system, catalytic conversion and emission performance. Although the current engine-cooling system is a passive system, the engine management system controls the heat distribution in the engine and the vehicle by compensating engine controls, such as spark timing and air-fuel ratio to regulate engine power output, as well as heat production and distribution to each part of the engine. Although the integration of the vehicle and the engine thermal management into the engine-cooling system significantly improves engine performance, there are limitations to the overall benefits that can be achieved with a simplistic and passive engine-cooling system. The engine-cooling system can be improved significantly with the inclusion of advanced design and operating features, allowing the engine-cooling system to operate efficiently and effectively, indirectly improving fuel economy and lowering emission outpt. With greater emphasis placed on improving fuel economy are lowering emissions output from modern IC engines, engine downsizing & raising power density are the favored options. Through this route, modern engines can attain similar power outputs to larger convectional engines with reduced frictional losses.[15-16]

The SI engines being used in automotives in India are designed with cold weather conditions in consideration. As the coolant inlet temperatures are invariably the ambient temperatures, any large variation in ambient temperatures are expected to cause variation in engine temperatures during cold start, warm up as well as during continuous operation because heat transfer in radiator will be affected by ambient temperature. India is among those tropical countries where the variation in the temperature is large. Considering this, it is very difficult to predict and to maintain the optimal engine temperature of automobiles operating in India.[10-11].

This paper presents an experimental study in this demanding and evolving area which has not attracted the kind of attention it deserves. The present paper deals with the experimental studies conducted in this regard during which a three cylinder, four stroke, petrol, carburetor engine (Maruti 800) connected to eddy current type dynamometer for simulating loading was adopted to study the effect of varying coolant temperatures (hence engine temperature) of 45 to 85°C with varying engine rotational speed of 1500 to 2400 rpm on the exhaust emission.

II. EXPERIMENTAL DETAILS

The experimental study was carried out on a test rig which mainly consisted of a three cylinders, four stroke, water cooled, engine (Maruti 800) coupled with an eddy current type, dynamometer.. The facility also existed for control of once through cooling water (no radiator) and also for measuring the inlet and outlet temperature of the cooling water. The set up is also provided with necessary instruments for measurements of combustion pressure and crank-angle. These signals are interfaced to an IBM computer through engine indicator for PΘ/PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurements. The setup has standalone panel box consisting of air box, fuel tank, exhaust gas analyzer, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator, load indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of engine performance for Exhaust emissions, brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, air-fuel ratio and heat balance.

Fig.1 Computerized Test rig of 3 Cylinder 4 Stroke Water Cooled SI Engine

The above test rig was used to examine exhaust emissions, with varying engine speed of 1800 to 2400 rpm with respect to simulated engine loading of 5 to 14 kg.

Engine temperature has been controlled by controlling cooling water flow rate. No coolant and/or additives were added in the water. The cooling water flow rate for engine is measured manually by rotameter. The values of engine performance parameter are directly obtained by using "Engine Soft" software

III. RESULTS & DISCUSSIONS

The results have been shown by various graphs in figure 2 to figure 5 & from fig.6 to fig.9 and trends of variation of Hydrocarbon (HC) against engine temperature, engine speed & engine load are shown.

3.1 Effect of engine speed on HC emission:

The graphs below delineate the trend in Hydrocarbon (HC) as a function of engine speed.

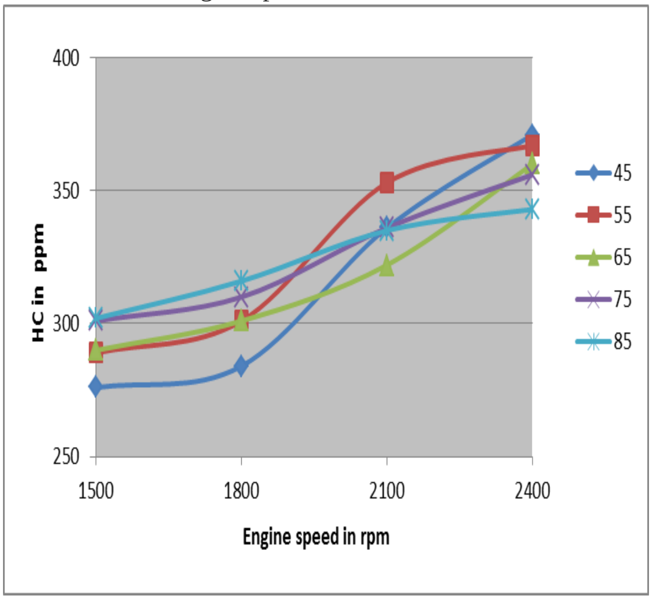

Fig. 2 Effect of engine speed on HC with varying engine temperature at 5 kg engine load

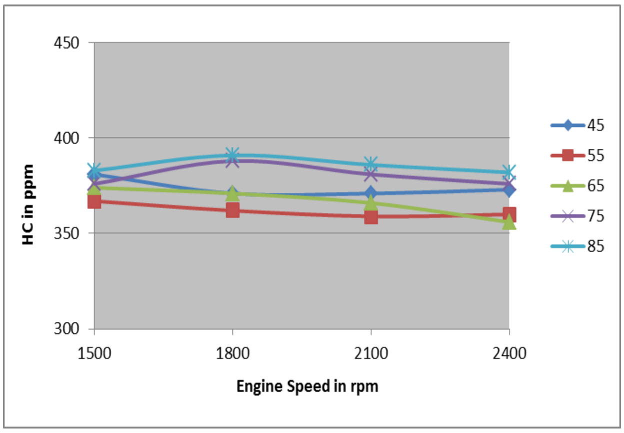

Fig.3 Effect of engine speed on HC with varying engine temperature at 8 kg engine load

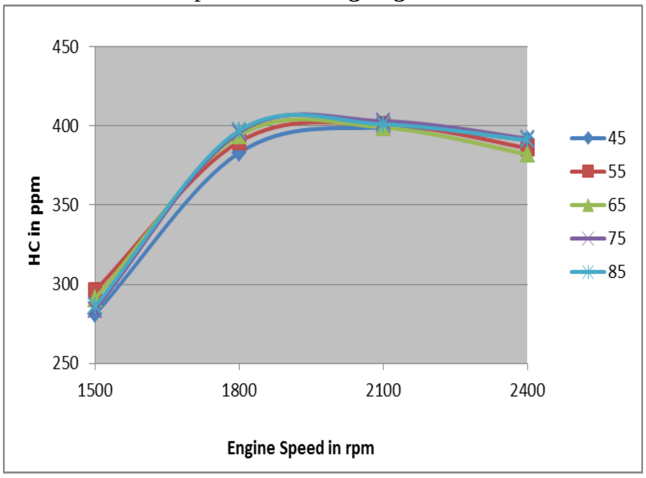

Fig. 4 Effect of engine speed on HC with varying engine temperature at 11 kg engine load

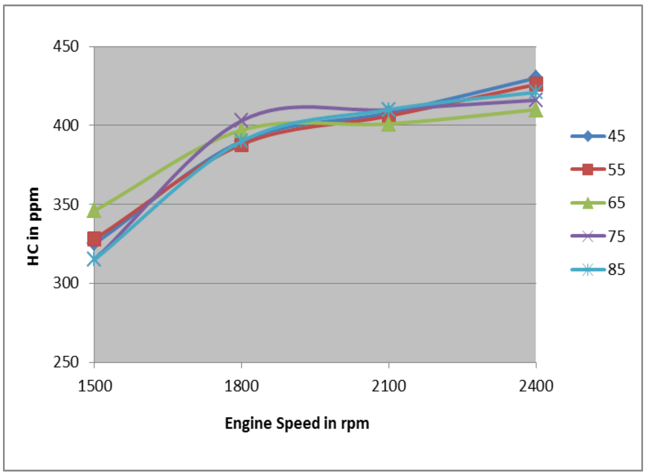

Fig. 5 Effect of engine speed on HC with varying engine temperature at 14 kg engine load

The analysis of the graphs reveals trends which is similar to that obtained in case of HC emission versus engine temperature. HC emissions shows decreasing trends when engine speed varies from 2100 rpm to 2400 rpm at 11 kg engine load.

The results have been shown by various graphs in fig. 6 to fig. 9 trends of variation of oxides of Nitrogen (NOx) against engine temperature, engine speed & engine load are shown.

3.2 Effect of engine speed on NOx emission:

The graphs below delineate the trend in oxides of nitrogen as a function of engine speed.

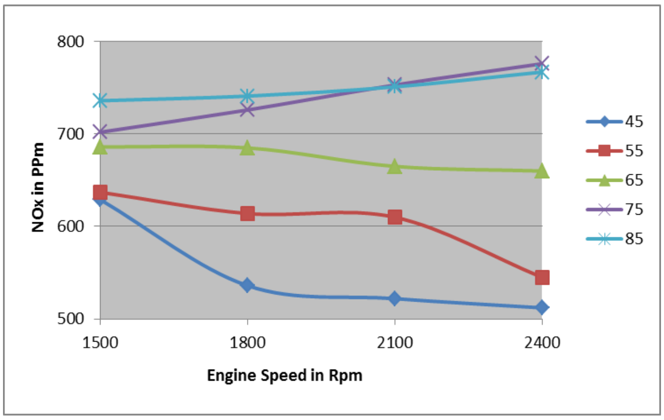

Fig. 6 Effect of engine speed on NOx with varying engine temperature at 5 kg engine load

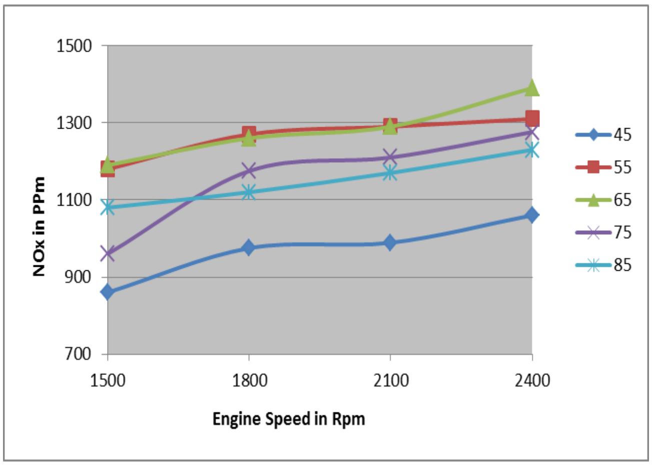

Fig. 7 Effect of engine speed on NOx with varying engine temperature at 8 kg engine load

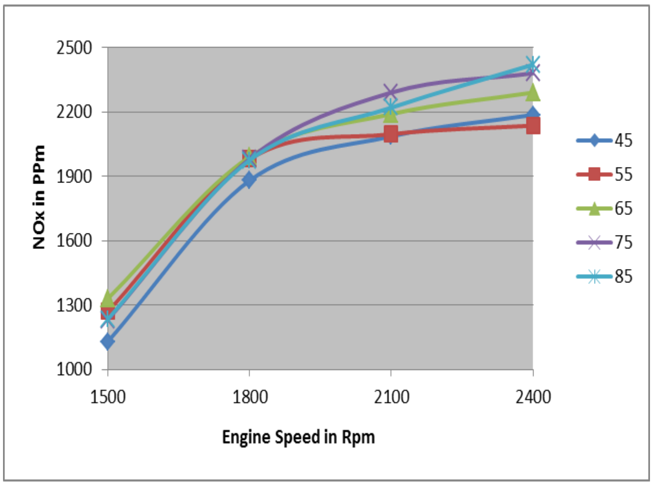

Fig. 8 Effect of engine speed on NOx with varying engine temperature at 11 kg engine load

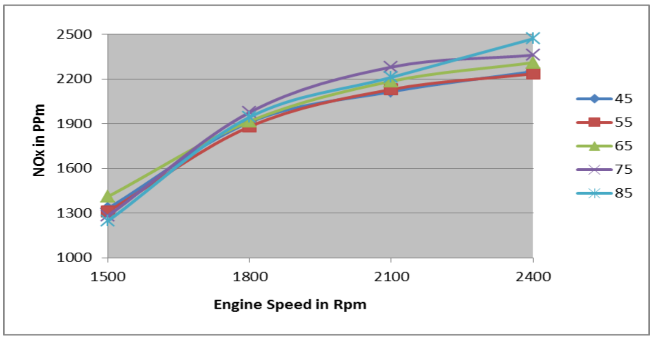

Fig. 9 Effect of engine speed on NOx with varying engine temperature at 14 kg engine load

The analysis of the graphs reveals that increasing trends in NOx emissions when engine speed varies from 1500 rpm to 2400 rpm at 11 to 14 kg engine load but it shows decreasing trends at 5 to 8 kg engine load.

IV. CONCLUSION

The following conclusions can be drawn from the experiments on spark ignition engine:-

1. The study confirms that exhaust emission is a dependent parameter on the engine speed.
2. Hydrocarbon (HC) emission shows decreasing trends when engine speed varies from 2100 rpm to 2400 rpm at 11 kg to 14 kg engine load.
3. Oxides of Nitrogen (NOx) emission shows increasing trends when engine speed varies from 1500 rpm to 2400 rpm at 11kg to 14 kg engine load but it shows decreasing trends at 5 kg to 11 kg engine load.
4. Exhaust emission is reduced with low load confirming that engine performs better in optimal load condition than on part load condition.

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