EXPERIMENTAL ANALYSIS OF JACKET COOLING OF S I ENGINE AND STUDY OF OPERATING PARAMETERS AND EMISSIONS

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ABSTRACT

In Spark Ignition engines about excess energy in the form of heat needs to be removed by the Jacket cooling water to maintain the temperature of the engine within the optimum range so that the emissions and the losses are maintained to minimum. Very high temperature of the engine leads to increase in the emissions and friction power (losses). Low engine temperature leads to improper vaporization of the fuel and thus starting problems. The experimentation was carried out in order to analyse various operating parameters and emission characteristics so that an optimum range can be determined for the operation of the specified engine and After experimentation and overall analysis it was found that this range was between 50-55°C for both proper operating parameters (Mechanical Efficiency, BThE, BSFC, BMEP) and Emission reduction for the specified engine.

KEYWORDS: *Emission Characteristics, Engine temperature, Jacket cooling water, Operating Parameters Spark Ignition Engine.*

NOMENCLATURE:

BThE *Brake Thermal Efficiency*
BSFC *Brake Specific Fuel Consumption*
BMEP *Brake Mean Effective Pressure*
NO_x *Oxides of Nitrogen*
CO *Carbon Mono-oxide*
HC *Hydrocarbon*
FP *Friction Power (losses)*
BP *Brake Power*

I. INTRODUCTION

Energy input to an IC Engine is by combustion of gasoline in the Engine cylinder. This combustion in the engine results in the production of heat. The heat in the engine results in increase in temperature of the engine parts. Engine heat transfer and cooling is always been a crucial area of interest for improvement of engine performance as analyzed by Amit v. Paratwar et al [4]. If no cooling is provided, the average temperature attained by cylinder and piston will correspond to gas temperatures in the range of 2300-2500 ºC which will cause the overheating of engine components and increase in emissions. Out of the total heat 30-37% of energy is utilized for conversion into useful work, 30-35% of energy is carried away by the exhaust gases, 10-12% is lost by convection, conduction and radiation, 17-26% of energy flows from gases to cylinder walls. This results in raised temperature of piston and cylinder walls. Though these high temperatures will give higher thermal efficiency and reduced friction losses, however such high temperature will damage the certain vital parts of engine due to their mechanical expansion and distortion cause by thermal stresses. Also, the cylinder lubrication will be impossible at these high temperatures. Therefore it becomes necessary to provide cooling system to maintain the temperature within certain limits to obtain the maximum performance from the engine. In a water cooled engine, the heat is removed by forced convection through the water jacket A.ghasemian et al [5].

Also low temperature in the engine causes starting problems due to insufficient vaporization of fuel, this non-vaporized fuel will be wasted and at low temperature the viscosity of oil increases this in turn increases the frictional power and engine power losses. Hence it is important to maintain the engine cylinder temperature to optimum. The optimum temperature is the temperature at which NO_x, CO, HC, BSFC, friction power are less and BThE, Mechanical efficiency are as high as practically possible. Amit V.Paratwar et al [4] observed that the flow path of coolant across jacket significantly affects the heat transfer analysis and maximum temperature value of engine components. Water cooling was employed for engine cooling and the temperature of the water was maintained in certain range with the help of a cooling tower to find out the proper range of cooling water temperature.

II. EXPERIMENTAL APPARATUS

The present work was carried on a Maruti-800 engine. This is a four-stroke 3-cylinder spark ignition engine with a bore × stroke of 66.5 × 72 mm and a compression ratio of 9.2:1. All the work was carried at the Thermal Laboratory in the department of Mechanical Engineering at the D Y Patil College of Engineering, Akurdi. For the experimental purpose various attachments were added. The attachments include a water flow meter (Rotameter), Coolant Pump, Exhaust gas analyser for measuring CO, CO_2, NO_x, HC emissions and Engine-Soft software for temperature measurements, pressure measurements, power measurements and efficiency measurements. Cooling tower is the main part in cooling system. Its purpose is same as that of radiator i.e. to cool the water and supply it to engine at desired temperature. This temperature can be adjusted to required value by mixing it with cold water and then fed to cylinder jacket. It's another purpose is to save the water by circulating same water again and again through engine. This indirectly changes the engine efficiency, emission and also fuel consumption. As temperature of water circulating through cylinder increases, it results in decrease in the Friction Power of engine. Temperature indicators are the essential component to measure the temperature of water at inlet and outlet. It gives indication to maintain the temperature at desired level which required for calculation. It also gives the temperature at inlet and outlet water.

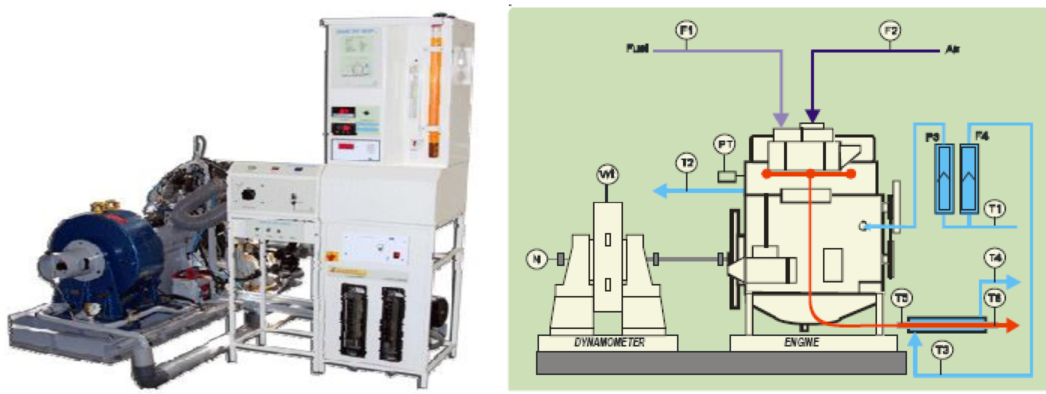

Figure 1. Experimental Setup

III. EXPERIMENTATION METHODOLOGY

From observed data it is found that engine running at high speed is not that much efficient to reduce the emissions and fuel consumption due to higher engine temperature, so one of the way to improve the performance of S.I. Engine is to maintain the temperature of water in cylinder jacket in the range of 50 to 90 ºC in order to maintain the optimum engine temperature. To adjust and maintain temperature at required value, a cooling system (cooling tower) is attached to the engine. Cooling tower has two inlets and two outlet ports. One of the inlet ports of cooling tower is connected to engine exhaust port and other inlet port is directly to pump which provide the cold water to cooling tower at high pressure. Out of two outlet port of cooling tower, one is connected to engine inlet and other is exhaust pipe to pass the overflow of water in order to maintain the cooling water temperature.

Initially engine run at some steady condition, after some time test is carried out at different engine speed (2000rpm to 3500rpm) when engine outlet water with higher temperature is dropped into cooling tower, its temperature is maintained in desired limit. If temperature of engine outlet water is higher (80ºC to 90ºC) then cold water is added to it to maintain water temperature (40ºC to 60ºC). This low temperature water is then recirculated in engine to increase its performance.

When the engine is run at 2500 rpm, exhaust water from engine at higher temperature can be cooled in cooling tower. The engine temperature directly affects the engine parameters such as FP which is continuously reduced from 2.82KW to 0.55KW as temperature of cooling water rises from 40ºC to 60ºC. It is observed that reducing FP reduces BSFC and increasing the BThE. It is observed that emission from engine is reduced significantly.

IV. LITERATURE SURVEY

The physical properties of concern in case of coolant are the density, specific heat at constant pressure and viscosity. The ideal coolant has low viscosity, high specific heat, is low cost and are non-toxic. A liquid with a high specific heat has more capacity to absorb heat than a liquid with a lower specific heat Efeovbokhan et al [3]. It is observed that high specific heat of water provides efficient thermal transition, avoids thermal overloads due to excessive temperatures on different engine components, it has low viscosity, is virtually available free of cost and is non-toxic qualifies it amongst the best for engine cooling . The purpose of the engine cooling system is that the engine temperature is maintained at the most efficient practical operating temperature Jong Pil et al [10]. Antifreeze, a solution of a suitable organic chemical (most often ethylene glycol, diethylene glycol, or propylene glycol) in water, is used when the water-based coolant has to withstand temperatures below 0 °C, or when its boiling point has to be raised.

The factors that can lead to adverse effects while operating outside this optimum range can be divided into high and low. Complete fuel vaporization is required for proper combustion, at lower engine temperatures improper combustion occurs due to incomplete vaporization thereby requiring more fuel for proper combustion. Improperly vaporized fuel can lead to cooling of engine parts and condensing of gases in the combustion chamber and water vapours on cylinder walls, dilution of lubricating oil, soot formation and removal of oil film on cylinder wall-which can lead to wear of cylinder bore. Moisture from combustion can also mix with unburnt hydrocarbon fuel and form acidic mixtures which can lead to acidic corrosion Tonye. K et al [1].

High temperature of coolant can lead to boiling of water, leading to oil film loss and restricted parts movement due to certain lubricant temperature is required for proper oil flow. High coolant temperature can also lead to damage to the engine and also cause pre-ignition and detonation. The maximum possible coolant temperature can be maintained by coolant boiling point and radiator Heat transfer capacity depending on the number of fins, radiator surface area, and thickness, and the number of coolant tubes Tonye. K et al [1]. The temperature of the gases in the engine after combustion is 2300-2500ºC, this high temperature need to be brought down to 150-200ºC for efficient operating of engine M. S. Shehata et al [9]. A proper flow management of coolant through the cooling jacket can reduce the severity due to temperature increment in the coolant side M.A. Hazrat et al [2].

A blend of 50/50 mix of water and ethylene glycol in which corrosion inhibitors have been incorporated is much more effective than using water and ethylene glycol alone. While water alone is good coolant but the enormous corrosion problems associated with it Efeovbokhan et al [3]. Increased engine temperatures will lead to reductions in fuel consumption and emissions Brace CJ et al [6]. S Palani et al [14] experimented for improvement in I C engine improving performance by reducing the cost and this was done by designing the proper coolant delivery system. Adding fins to the engine can transfer heat at a rapid rate. Vikash Kumar et al [15] observed that the shape and thickness along with the material of the fins plays an important role in amount of heat transfer from the fins. Mahesh Kumar et al [16] observed that a porous media can be used for the heat transfer from the engine cylinder to the water jacket with the use of a specified model.

V. RESULT AND DISCUSSION

5.1 FRICTION POWER

It is observed that maximum value of friction power for gasoline engine is 3.13 kW at 2500 rpm and 40^0C cooling water jacket temperature of engine. It reduces to 0.55 kW at 2500 rpm, as temperature of cooling water through cylinder jacket increases to 55^0C. Friction power is noted down for different constant speeds with varying temperature and it is observed that friction power continuously decreases with increase in cooling water temperature. The decrease in friction power can be attributed to higher mechanical efficiency and it reduces emission from engine.

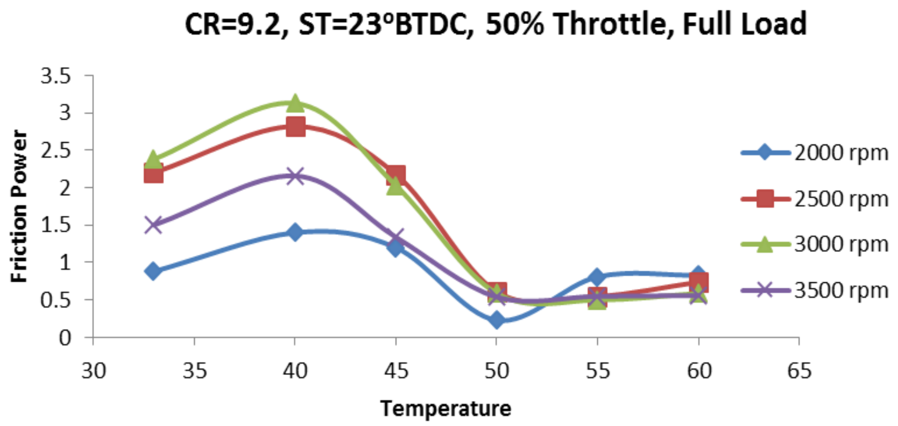

Figure 2. Friction Power, kW vs Temperature, °C

5.2 MECHANICAL EFFICIENCY

Mechanical efficiency is the ratio of brake power to indicated power. As temperature of cooling water increases, it decreases the friction power which in turns increases the mechanical efficiency of gasoline engine. It can observed from graph that it is maximum i.e. 96.17% at 3500 rpm and 60^0C cooling water temperature. And its minimum value is 79.19% at 2500rpm and 40^0C cooling water temperature. As the temperature increases from 40^0C-60^0C with different constant speeds, it is observed that mechanical efficiency goes on increasing.

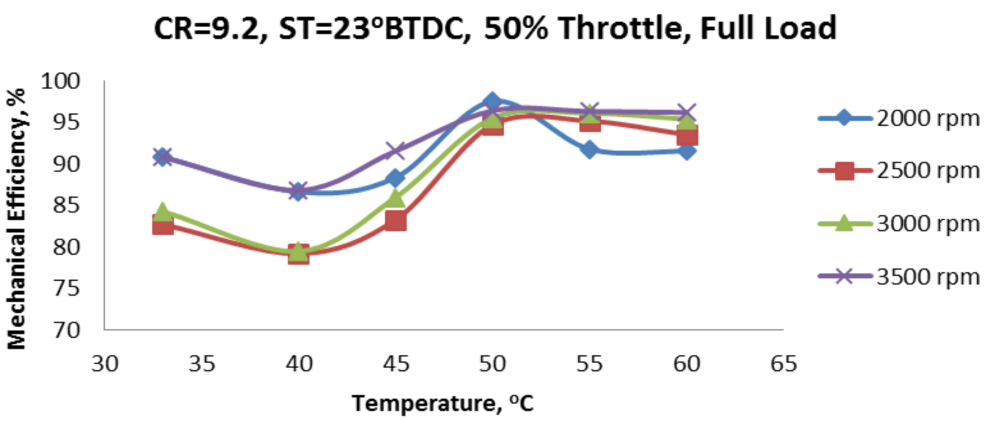

Figure 3. Mechanical Efficiency, % VS Temperature °C

5.3 BRAKE THERMAL EFFICIENCY

Brake thermal efficiency of an engine is the indicator of conversion of heat supplied into work energy. Also it can be defined as ratio of brake power to heat energy supplied by fuel. It is observed that maximum value of BThE for gasoline is 37.98% at 3000 rpm and 60^0C cooling water temperature and its minimum value is 25.70% at 40^{0}C and speed of 3000rpm. It results into an increase of 12.28% of BThE. The BThE is found to increase with the increase in the temperature of cooling water. The increase in Brake Thermal Efficiency can be attributed to better engine performance.

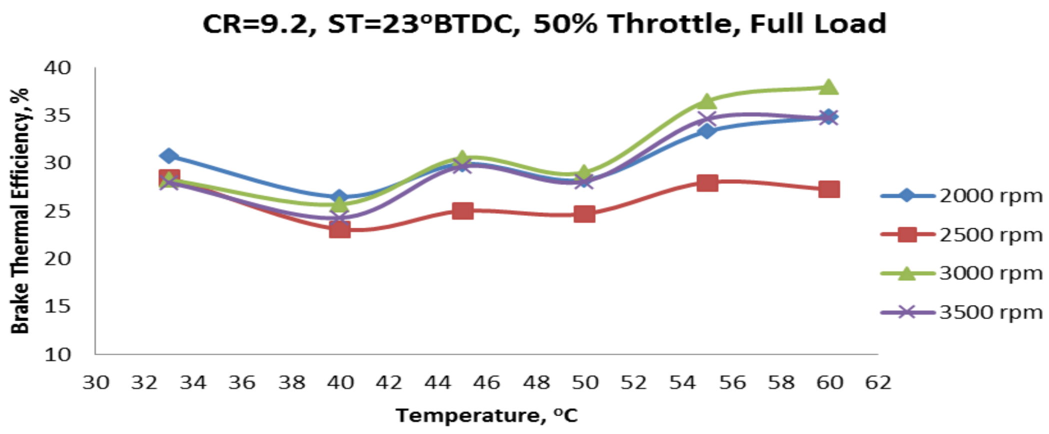

Figure 4. Brake Thermal Efficiency, % VS Temperature, ºC

5.4 BRAKE SPECIFIC FUEL CONSUMPTION

It is defined as amount of fuel required to be supplied to an engine to develop 1kW of power per hour. BSFC is mass flow rate of fuel w.r.t BP and therefore it is inversely proportional to BThE John B. Heywood [11]. Elevated water temperature must have reduced the heat losses to the cooling water which is conducted through the cylinder walls. As a result this produces some improvement in fuel consumption rate Mohammad mamun et al [8]. In the investigation it is observed that specific fuel consumption is lowest for 3000rpm at 60^{0}C cooling water temperature. As the temperatures increase BSFC at 3000 rpm reduces from 0.3183 kg/kW.hr at 40^{0}C to 0.2153 kg/kW.hr at 60^{0}C. BSFC decreases with increase in cooling water temperature as friction power (losses) reduce.

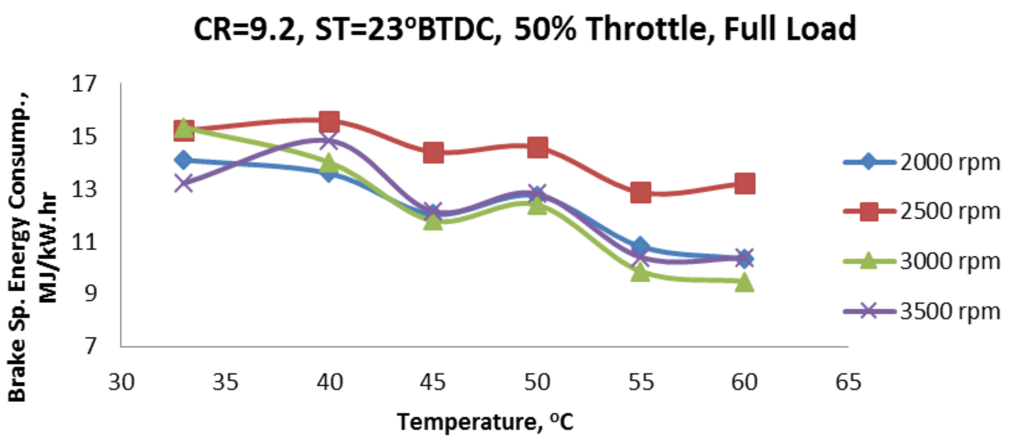

Figure 5. Brake Sp. Energy consumption. MJ/kW.hr VS Temperature, ºC

5.5 BRAKE MEAN EFFECTIVE PRESSURE

BMEP **is** the average (mean) pressure which, if imposed on the pistons uniformly from the top to the bottom of each power stroke, would produce the measured (brake) power output John B. Heywood [11]. It can be observed that the BMEP increases with the increase in the coolant temperature i.e. the engine temperature and further remains constant in the range of 50-60ºC and again decreases.

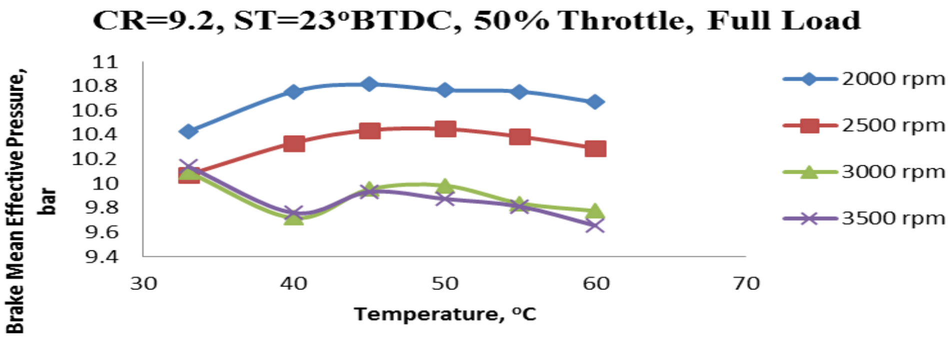

Figure 6. Brake Mean Effective Pressure, bar VS Temperature, °C

5.6 NOx EMISSIONS

NOx formation is the function of engine temperature; it increases with the increase in temperature. It also is a function of engine speed, as with increase in engine speed the temperature increases. At less engine speed localized combustion occurs which also leads to increase in NOx emissions. The reactions governing the NO_x emissions are time and temperature dependent L. M. Das et al [12]. The NO_x emissions are observed to be minimum in the range of engine cooling water temperature of 50 to 60 °C.

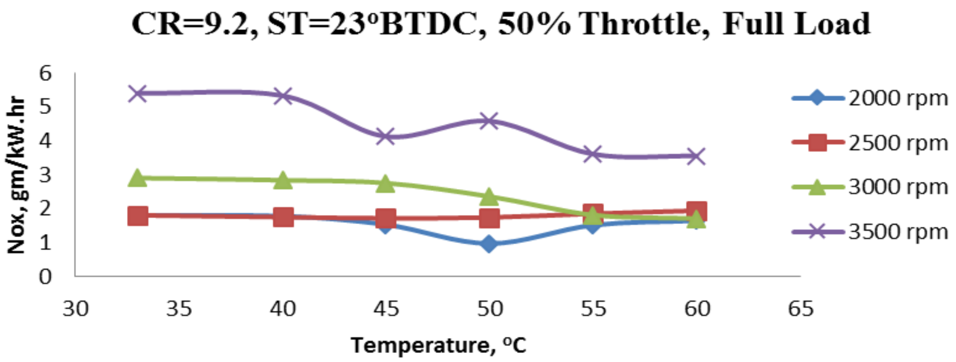

Figure 7. NOx, gm/kW.hr VS Temperature, °C

5.7 CARBON MONOXIDE

The carbon-monoxide emissions are due to incomplete combustion at richer mixtures as there is lack of oxygen. As the equivalence ratio increases the CO emissions increases. In gasoline the CO emissions are more as compared to gaseous fuels due heterogeneous mixtures. The CO emissions are less at lean mixtures increases sharply at rich mixtures as the air available is less. CO emissions increase from 103.89 gm/kW.hr -130.18 gm/kW.hr with increase in cooling water temperature. From the graph it can be seen that CO emissions are maximum at 3000 rpm.

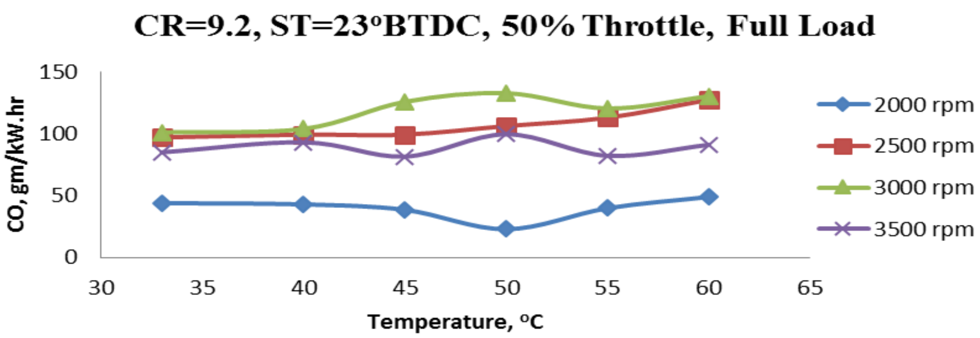

Figure 8. CO, gm/kW.hr VS Temperature, °C

5.8 HYDROCARBON EMISSIONS

HC's are mainly formed in the exhaust due to incomplete combustion. HC is included in unburned fuel, partially oxidized fuel and lubricating oils. They are formed in the quench zones of cylinder and due to patchy combustion. HC are also function of temperature and its emission decreases with increase in temperature of cylinder and hence increase in temperature of cooling water. The HC emissions are minimum at higher temperature of cooling water due to complete combustion. The emissions are high at low temperature of cooling water.

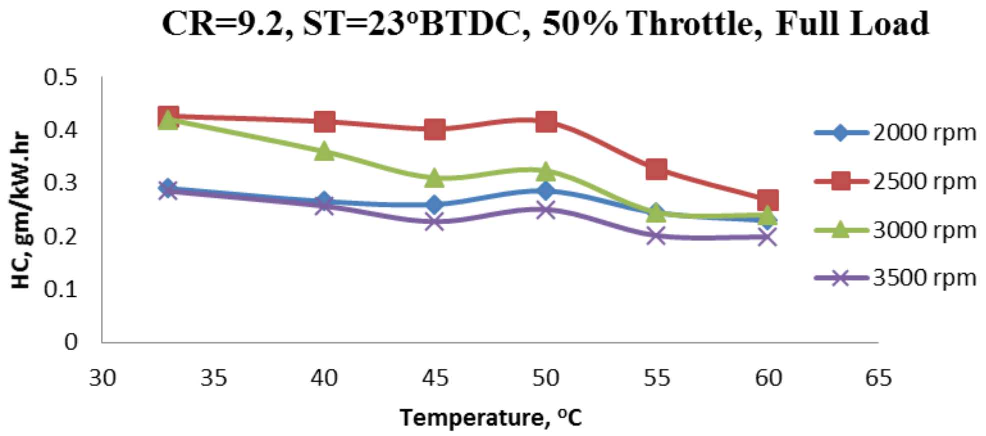

Figure 9. HC, gm/kW.hr VS Temperature

5.9 EXHAUST GAS TEMPERATURE

As the temperature of cooling water increases, the exhaust gas temperature also increases due to less cooling of engine cylinder. There is an increased exhaust gas temperature at higher engine speeds. At higher engine speeds, time available for combustion is less. Hence the amount of heat transfer would be less thus resulting in an increased exhaust temperature. Increasing the load will increase the exhaust temperature. Exhaust gas temperature increases from 300^{0}C to 450^{0}C with increase in speed.

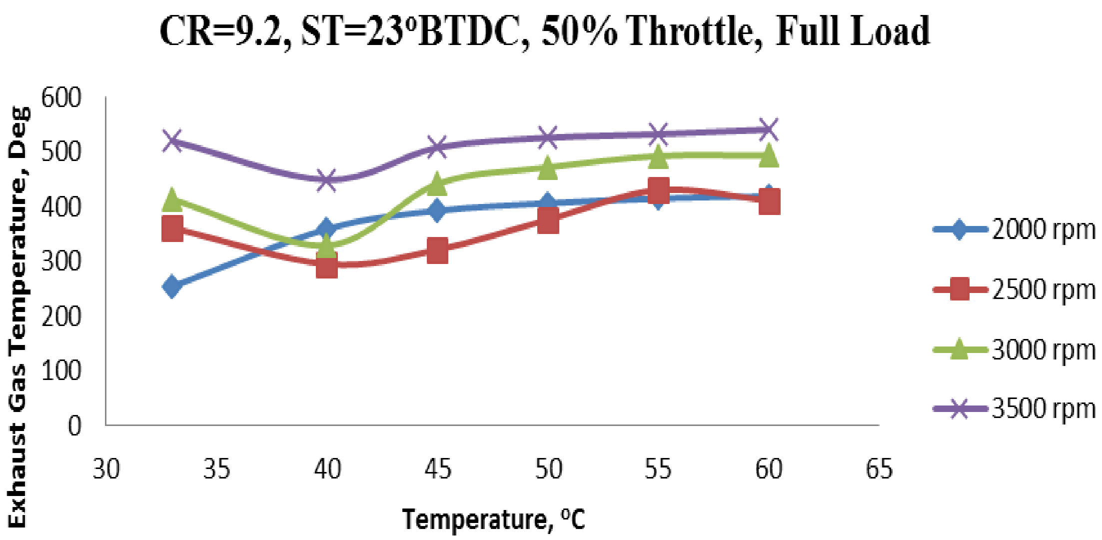

Figure 10. Exhaust Gas Temperature, °C VS Temperature, °C

VI. CONCLUSIONS

1. Maximum friction power for gasoline engine is found to be 3.13 kW at 3000 rpm and lowest cooling water temperature. The range was 3.13 to 0.59 kW at 3000 rpm.
2. Mechanical efficiency is found to be function of cooling water temperature with increase in cooling water temperature (up to 60^0C) it increases and attains a maximum value of 96.17% at 3500rpm.
3. BTHE at 3000rpm is 25.7% at 40^0C and 37.98% at 60^0C it is found to increase by an amount of 12.28%.
4. BSFC is found to decrease with increase in cooling water temperature and BMEP is found to have nearly constant behavior at constant speeds.
5. NO_x was found to increase with increase in speed and for the same speed the values were found to decrease with increase in cooling water temperatures.
6. CO emissions are lower at lower speeds and are found to increase at higher speeds as the time available for combustion is less.
7. The HC emissions are lower at higher temperature of cooling water due to complete combustion. The emissions increase at low temperature of cooling water due to incomplete and patchy combustion.
8. But the emission characteristics although showed a slight variation with coolant water temperature did not change significantly.
9. Exhaust gas temperature is found to increase with increase in speed and increase in cooling water temperature. It is found to increase to about 540 ^{0}C.
10. It is thus found from experimentation that the engine performance is enhanced and the emissions are minimum, if the jacket cooling water temperature is maintained between 50ºC to 55 ºC at 3000 rpm.

VII. FUTURE WORK

It can be seen that the proper operating temperature for the engine was found from the experimentation and analysis for better operating parameters and emission characteristics. The operating characteristics can be further improved by using a specific coolant for the required operation of the engine. The NOx emissions can be reduced by adding Exhaust Gas Recirculation to the Engine. The CFD (Computational Fluid Dynamics) analysis can be used for the analysis of coolant temperature distribution so that a profile can be established and changes can be made so that a required profile is obtained for proper cooling with minimum coolant circulation Xiao Xu Liu et al [13].

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