Significance of the Ratio of Exhaust Temperature to Coolant Temperature and Its Effect on Various Engine Working Parameters

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Abstract-**Engine gets its power due to combustion of the fuel in its cylinder. Due to the combustion process the temperature of the cylinder wall is increased to a very high degree and here the coolant temperature comes to rescue by taking the heat from the cylinder wall to the outside atmosphere. Temperature of the exhaust plays an important role by giving an idea of the functioning of various engine parts and engine as a whole. With increase in the load the exhaust temperature increases and hence coolant temperature. Here the ratio of the exhaust temperature to the coolant temperature gives idea of the ability of coolant to take away heat from the cylinder wall at increases load. Higher the ratio means less effective cooling of the cylinder wall and hence decreased life of engine.**

Index Terms- **Coolant Temperature, Cylinder Wall, Engine, Exhaust Temperature and Heat Transfer**.

I. INTRODUCTION

Engine works by burning fuel and thereby giving out power for running the system. The combustion of the fuel increases the temperature of the cylinder to a very high degree. Of this 30% of heat is lost in the exhaust gas while 35% heat is used in doing work and rest 35% is lost as heat through the cylinder walls **[1].** This heat transfer through the cylinder wall to the atmosphere is helped by the coolant which is generally water or oil **[2]** or their mixtures with additional additives respectively. Coolant which is circulating about the cylindrical wall externally takes the heat from the cylindrical wall and disposes it to the atmosphere. Now with the increase in the external load (current or weight) on the engine, the amount of power required to do the same work increases. This leads to more working of the engine and therefore more combustion of the fuel per unit time. This in turn leads to rapid increase in the temperature of the cylinder. The increase in cylinder temperature is reflected in the increase of exhaust temperature **(E),** which is rapid compared to that of the coolant which is slow and constant. This in turn leads to ineffective heat transfer from the cylinder wall to the atmosphere. In this paper we will discuss the significance of the exhaust temperature to the coolant temperature **(C)** and how this ratio can help in distinguishing between effective and ineffective coolant and safe working load.

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II. SIGNIFICANCE OF E/C RATIO

As said the engine works by combustion of fuel. The engine cylinder remains at constant temperature at specific constant load and engine speed. The constant working is also helped by constant rate of heat transfer by the coolant. With the increase in external load on the engine, the power required to give the same work out put increases. As the engine load is increased the exhaust temperature increases, this is due to decreased rate of heat transfer through the cylinder wall at higher load. The increase in the external load also results in increase of coolant temperature. This can be explained as; more amount of heat is generated per unit time and hence increased rate heat transfer of the cylinder wall to the atmosphere by the coolant. At no load condition the exhaust temperature as well as the coolant temperature is minimum and the engine working is best at this point. The Exhaust temperature/Coolant temperature ratio **(E/C)** gives an idea about the amount of heat generated in the cylinder wall to the amount heat carried away by coolant. E/C ratio equal to one means the amount of heat transferred to the cylinder wall is equal to amount of heat dissipated or carried away by coolant. Ratio more than one shows that coolant is unable to carry away all the heat thats being transferred to the cylinder wall by the combustion of fuel. The ratio at no load condition gives an idea about the amount of heat that is being transferred to the cylindrical wall by combustion of fuel and the amount of heat that is taken away by the coolant when the external load is 0. This ratio is ideal for long and optimum performance of the engine.

As the load on the engine increases the ratio increases and hence it shows increased inability of the coolant to transfer heat from the cylinder wall to atmosphere. Thus larger is the difference between E/C ratio and no load E/C ratio line, the greater is inefficient working of coolant in the engine. Beside greater gap also affects the lubricating oil adversely and also leads to increased exhaust emission. Therefore it is of utmost importance to understand the significance of E/C ratio and make sure the coolant used is efficient enough to take away the heat even at high load.

III. EXPERIMENTAL APPARATUS AND TEST PROCEDURE

The engine used is of type TVL, series: 1, B.H.P =5, speed = 1500 r.p.m, bore =80mm, stroke= 110 mm, swept volume= 558 cc, diesel operated and single cylinder.

The exhaust and coolant temperature is measured by firstly starting the engine by cranking manually. Then with the help of stop watch, time taken for the consumption of a particular volume (20cc) of fuel (diesel in this case) at no load is noted. The speed of the engine is to be kept constant for the experiment. The rpm is measured with tachometer to check for the consistency of the speed. Then the coolant temperature of the water (which is coolant in this case) from the engine cylinder jacket, exhaust temperature and rise of water level in the tank is measured at no load condition. After this the load is increased in steps of 3amps with the help of electrical dynamometer and again the exhaust temperature, coolant temperature, rise of water level is measured and time for 20cc fuel consumption is noted.

Table 1 shows the reading of coolant temperature and exhaust gas temperature for constant variation of load. In addition it also gives the time for consumption of 20cc of fuel.

Table 1: Measurement of coolant and exhaust temperature with the increase in load

External current	Power (VI) in watts	Time taken for 20cc fuel consumption	Coolant temperature (in °C)	Exhaust gas Temperature (in °C)
0	0	2min 33sec	94	170
3	600	2min 13 sec	98	195
6	1200	1min 49 sec	105	237
9	1800	1min 31 sec	109	270
12	2400	1min 15 sec	115	320

IV. RESULT AND DISCUSSION

From the performed experiment and observation table above it can be seen, with increase in load the exhaust temperature increases rapidly whereas the coolant temperature increases slowly and by almost constant amount. **Figure 1** shows the variation of exhaust gas temperature with the external load in amperes. It can be seen from the graph the temperature of the exhaust gas increases non-uniformly with increase in the external load by equal amount.

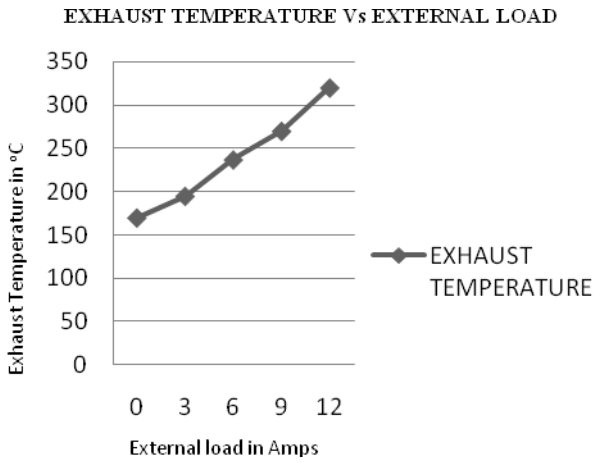

Figure 1: Plot between exhaust temperature and external load.

From **Figure 2** we see the variation of the coolant temperature with external load in amperes. It can be seen the variation of coolant temperature with external load is uniform, increasing by almost constant amount with constant increase in the load.

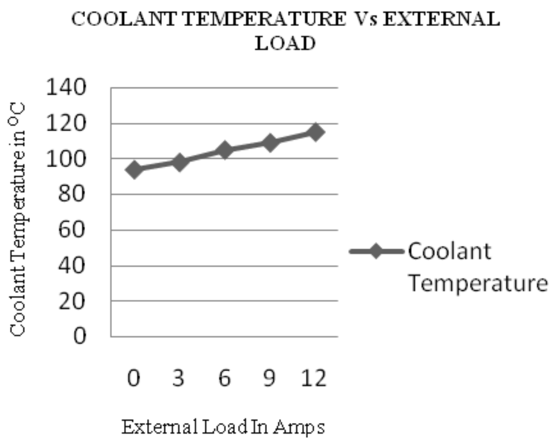

Figure 2: plot between coolant temperature and external load

Figure 3 compares the exhaust temperature and coolant temperature for the external load applied. It shows the variation of exhaust temperature compared to the coolant temperature.

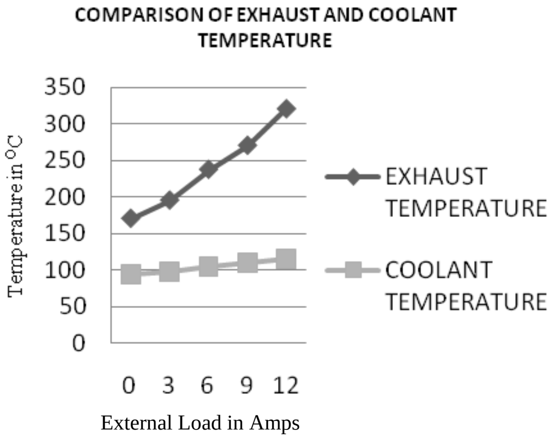

Figure3: comparison of exhaust temperature and coolant temperature.

Figure 4 gives a plot of ratio of exhaust temperature and coolant temperature versus external load in amperes. It can be deduced from the plot, with increase in the external load, the E/C ratio increases and deviates more from the no load line.

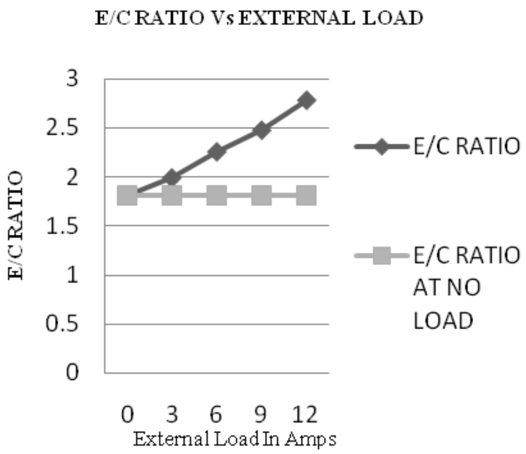

Figure 4: plot of E/C ratio against external load

From the figures above it can be noticed that the ratio of the exhaust temperature to the coolant temperature increases as the load on the engine increases, being the lowest for no load and highest for 12 amp load (in this case).Now the coolant performance will be best when the engine is running at the no load condition. And its effectiveness goes on decreasing with the increase in engine load. In other words the coolant will take the maximum amount of heat of the cylindrical walls for the no load condition and the amount of heat absorption and transfer capacity will goes on decreasing with the increasing load. This is because the amount of heat produced per unit time increases more rapidly relative to amount of heat transferred by the coolant. So if we take the ratio of the exhaust temperature to the coolant temperature and analyse it, then from the graph shown in the figure 4 we can notice, that more the blue line deviates from the red line the severe is the effect on the engine and hence on its life.

V. EFFECT OF E/C RATIO ON ENGINE WORKING PARAMETERS

With the increase in external load the diesel engine load is increased to make the engine work more effectively.
But this increase in the load leads to the increase in the E/C ratio, thus making the coolant ineffective to carry away the heat of the cylinder wall and hence helping in the cylinder wall temperature increase.
The effect of the cylinder wall temperature of various parameters **[3][9]** is illustrated below: **Figure 5** concentrates on the main chamber maximum temperature of cylinder for the examined load change. As expected, the (maximum) gas temperatures increase with an increase in the cylinder wall temperature due to the lower heat losses.

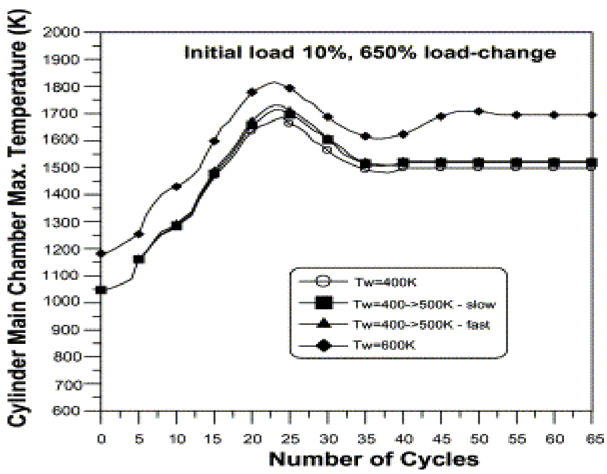

Figure 5: The effect of cylinder wall temperature on the maximum cylinder gas temperatures **[4][10]**

Similarly, **Figure 6** shows the response of the main chamber heat loss to the cylinder walls. It can be seen the heat loss to the cylinder wall decreases with increase in the load.

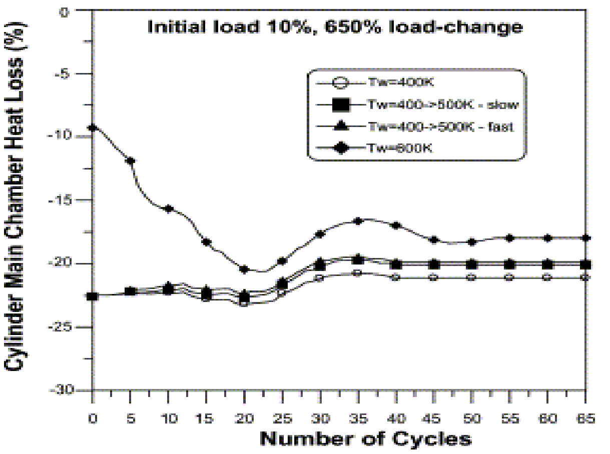

Figure 6: The effect of cylinder wall temperature schedule on the main chamber heat loss to the cylinder walls reduce to the incoming fuel energy after a ramp increase in load **[4][10].**

The same remarks hold for all the other important properties of the engine such as fuel pump rack position and engine torque. This is again depicted in the **Figure 7 and Figure 8**.

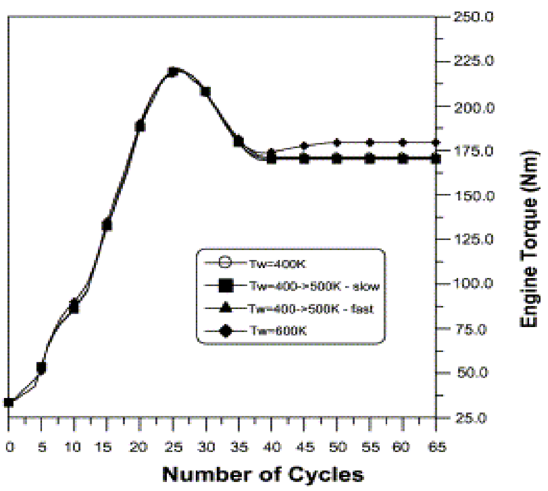

Figure 7: The effect of cylinder wall temperature on engine torque with increase in load **[4][10].**

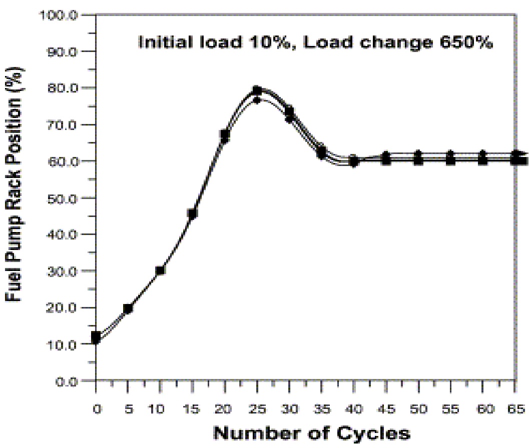

Figure 8: The effect of cylinder wall temperature on the fuel pump rack position[4][10].

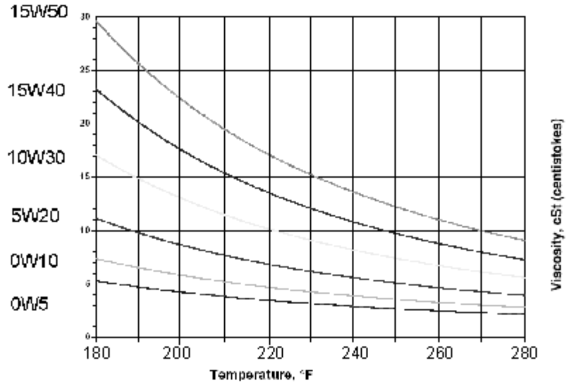

Figure 9: cylindrical temperature effects on the viscosity of lubricating oil **[5]**

Figure 9 shows the effect of the high cylinder temperature on the viscosity of the lubricating oil in the cylinder. It can be seen the viscosity of all the oil samples taken decreases markedly. This can have disastrous effect on the engines working as with the increase in temperature the oil film thickness reduces which can then lead to the metal- metal contact and hence rough working.

As from **Figure 1**, exhaust temperature have direct relation with load, therefore increase in load leads to exhaust temperature rise **[6]** and hence exhaust emission increase **[7]. Figure 10, Figure 11 and Figure 12** indicate the variation of exhaust emission with load. It can be noticed various pollutants increases with increase in the load, which in turn reflects the emission behaviour with temperature.

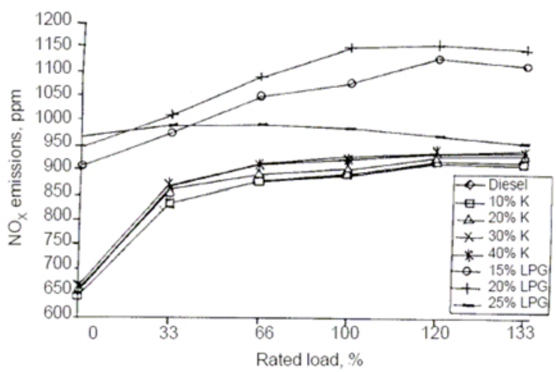

Figure 10: NOx emission vs. load in diesel engine **[8]**

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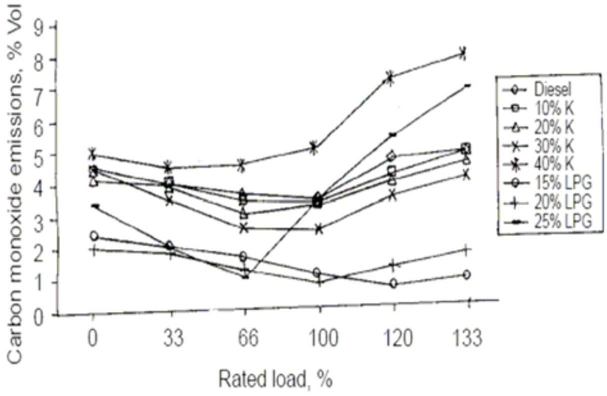

Figure 11: plot of CO emission Vs load **[8]**

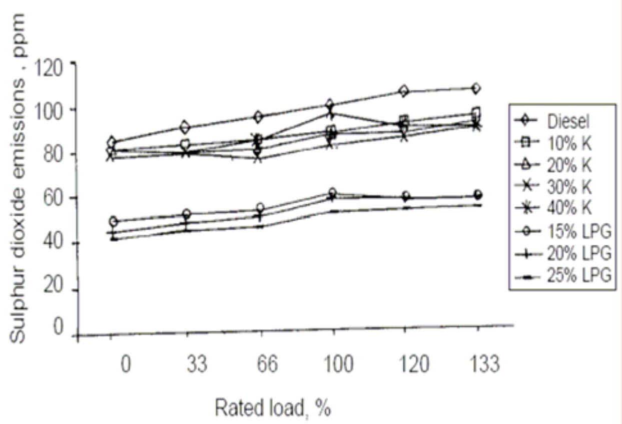

Figure 12: plot of sulphur dioxide emission Vs Load **[8]**

VI. CONCLUSION

From the above discussion it can be concluded:

a) The E/C ratio plays an important role in affecting the performance of the engine.
b) The E/C ratio predicts the effectiveness of coolant.
c) The more the E/C ratio line deviates from the no load coolant temperature line the more severely performance of the engine will be affected.
d) Increased E/C ratio predicts the increase in exhaust emission.
e) E/C ratio predicts the behaviour of lubricating oil in the cylinder.
f) E/C ratio predicts the effect on various engine parameters.
g) E/C ratio can be applied on S.I engine as well as diesel engine and using any fuel.

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