Heat losses in Ceramic Coated Diesel Engine

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Abstract
The energy produced due to combustion of fuel in an engine is partly converted into work and the rest is lost. The knowledge of how the energy is lost will help in finding means to reduce the same to improve the performance of the engine in terms of efficiency and power output. The elimination of, in cylinder heat transfer to either the coolant or the environment does not violet the second law of the thermodynamics and moreover according to the first law, has the potential of producing more work. Another advantage of this concept is that great reduction losses in parasitic losses due to the simplicity of the cooling system, thus increasing the brake power of the engine. The main purposes of the study are to calculate the heat losses at different engine loads and speeds with and without ceramic coated diesel engine. The result showed a reduction in heat losses to the coolant and increases in exhaust energy at all the loads levels.

Keywords: Ceramic coating, Diesel engine, Heat losses

1. Introduction

A small increase in brake horse horsepower can be gained by decreasing the heat losses from the engine cylinder. Approximately 30% of the available energy is converted to useful work (thermal efficiency), and this is done near the TDC during the combustion and the following expansion stroke, which encompasses approximately one fourth of the total engine cycle. On the other hand heat transfer occurs over the entire 720˚ of the cycle. Therefore only one fourth of the saved energy is available when output work is being generated and only 30% of this is utilized. Most of the reduced heat loss energy ends up in the enthalpy of the exhaust. There would be a higher steady state temperature of internal components [1].

A new trend in the field of internal combustion engine is to insulate the heat transfer surfaces as combustion chamber, cylinder wall, cylinder head piston and valve by ceramic insulating material for the improvement of the engine performance and simplicity of the cooling system [2].

2. Theoretical and experimental works

The engine under test is considered to be enclosed with in an imaginary boundary. When the engine runs for certain period, the condition becomes stabilized for a particular load. When this state is reached the rate at which energy enters the boundary becomes equal to the rate at which energy goes out of it. The energy enters the boundary as, heat energy of the fuel, sensible heat of air, sensible heat of circulating water entering the jacket, and sensible heat of surrounding air entering the boundary by radiation. The energy leaves the boundary as, brake power, sensible heat of exhaust leaving the engine cylinder, sensible heat of circulating water leaving the jacket and sensible heat of surrounding air leaving the boundary. The rate of heat carried away by cooling water is given by

$Qw = Mw * Cpw(Two - Twi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$ Heat carried away by the exhaust gases is given by

$Qg = Mg * Cpg(Tge - Ta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

By equating the rate at which the energy enters the imaginary boundary to the rate at which the energy goes out of the boundary, we get

$Qs = (Pb + Qw + Qg + Qun) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$

Where , $Mw =$ Rate of mass of water
$Cpw =$, specific heat of water,
$Two =$ Outlet temperature of water,
$Twi =$ inlet temperature of water,
$Cpg =$ specific heat of exhust gases,
$Mg =$ Brake power mass of exhust
$Tge =$ temperature of exhust gases leaving the exhust valve,
$Ta =$ ambient temperature,

Qs = heat supplied by the fuel,
Pb = brake power,
Qun = heat rejected to the oil plus convection and radiation from engine external surface [3].

A four stroke, direct injected, water-cooled, three cylinder, diesel engine is used for this investigation. Detail of engine specification is given in table 1 [4]. The schematic experimental set-up is shown in Fig. 1. Engine torque is measured by a hydraulic dynamometer. The instantaneous speed is read through a digital counter and the exhaust temperature is measured using a thermocouple located downstream of the exhaust valve. The intake airflow rate measurement system consists of a damping box of, a laminar flow element and interchangeable orifice plates. The damping box volume is about 100 times the swept volume of the engine and is fitted downstream of the laminar flow element. Fuel, air inlet, engine coolant inlet and outlet, lubricating oil temperatures were measured by thermocouples. All the measurements were collected and recorded by a high-speed digital data acquisition system. First, standard engine (without coating) was fully instrumented and connected to the dynamometer. A water-cooled intercooler was mounted to cool the inlet air of the turbocharger. The first stage tests are performed at different engine speeds and loads. The experiments are conducted at the three load levels, low, medium and high. The required engine load percentage is adjusted by using the hydraulic dynamometer. These procedures are repeated to cover the engine speed range at the specified load percentage. The second stage concerned an investigation of heat losses when combustion chamber insulation is applied. Stock aluminum pistons, cylinder head and valves are modified for coating with ceramic material. The engine is insulated and tested at baseline conditions to see the effect of insulated surfaces on engine heat losses.

The indicated power is the sum of the brake power and friction power. A substantial part of frictional power (about half is dissipated) between the piston and piston rings and cylinder wall and transferred as thermal energy to the cooling medium. The remainders of the friction power is dissipated in the bearing, valve mechanism, or drive auxiliary devices, and is transferred as thermal energy to the oil or surrounding environment (inQun) [5].

A four stroke, direct injected, three cylinder, intercooled, turbocharged diesel engine is used for this investigation. First, standard engine is fully instrumented and connected to the dynamometer. A Water- cooled inter cooler is mounted to cool the inlet air of turbocharger. The first stage tests are performed with different engine speeds and loads. The second stage test is performed with ceramic coated engine. The engine is insulated and tested at baseline conditions to see the effect of insulated surfaces on the engine heat losses.

3. Result and discussions

The result of standard engine and ceramic coated engine tests are shown in figures 2-7. Figures 2-4 represents the variation of heat flow rate to the exhaust as a function of engine speed for standard engine (SE) and ceramic coated engine (CCE) at 25Ċ at low, medium and high loads, respectively. The result shows an increase in heat flow rate to the exhaust (Q_{ex}) with increase in speed and loads. At all the load levels and engine speed, the result shows a (5-12%) increase in heat flow rate to the exhaust for ceramic coated engine in comparison to the standard engine (without coating). This is explained by the high temperature reached in the combustion chamber which results in the better combustion efficiency and high exhaust temperature.

Figures 5, 6 and 7 represents the heat flow rate to the coolant as a function of engine speed for standard engine and ceramic coated engine at 25Ċat low, medium and high loads. The result show an increase in heat flow rate to the coolant (Q_c) with increase in speed and load. In the entire cases ceramic coated engine shows a5-25% decrease in heat flow rate in comparison to the standard engine.

4. Conclusions

The following conclusions are drawn from this investigation:

1. By application of the insulation coating the reduction in heat loss to the coolant is found to be nearly 5-15%.
2. Using insulation to reduce the heat loss to the cooling system of the engine causes the cylinder walls to become hotter and increase the exhaust gas energy.
3. The extra gas energy resulting from insulation may partly used to aid the engine power via compounding.
4. Ceramic coated engine have the potential to offer the simplified and cheaper vehicle cooling system.

References

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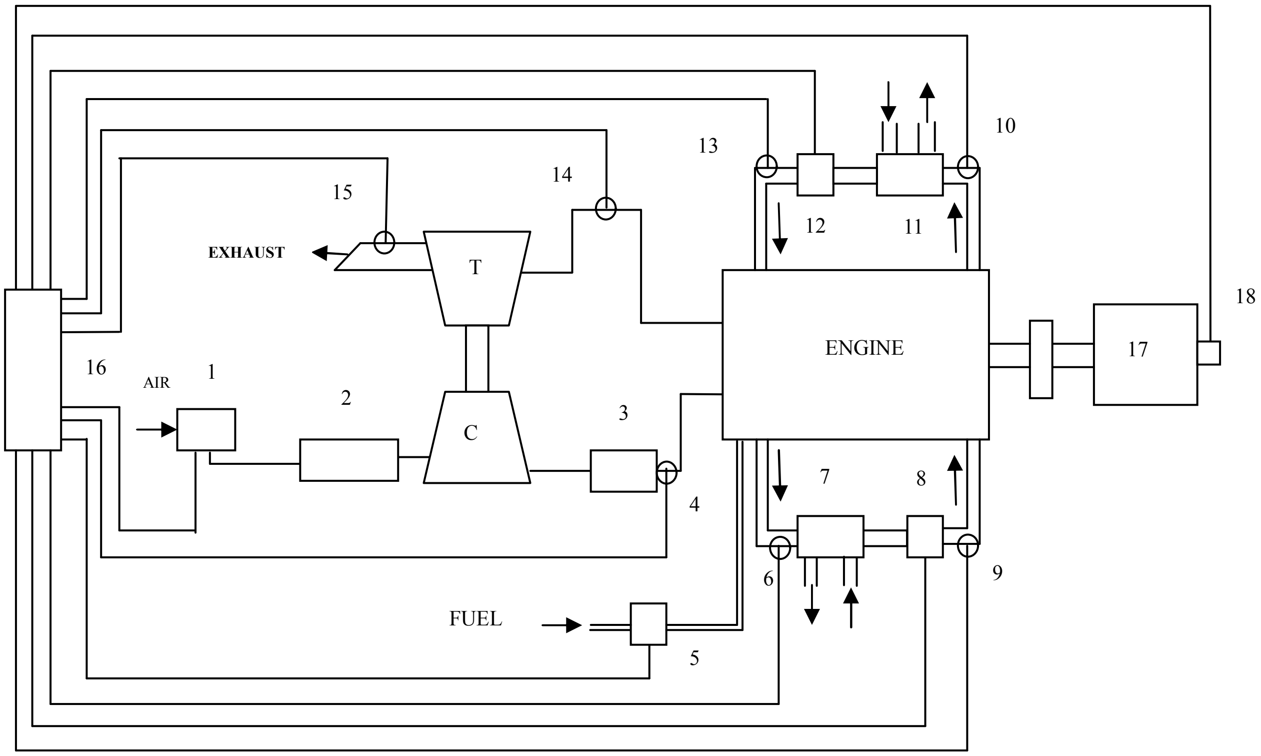
Table1. Engine specifications:

Engine type	Direct injected ,water cooled
Stroke number	4
Cylinder	3
Bore(mm)	100
Stroke(mm)	118
Compression ratio	18.4:1
Maximum power(kw)	30.53(at 2100rpm)
Cubic capacity	2780cc



1 –Air flowmeter
2- Air damping device
3- Intercooler
4- Air temperature sensor
5- Fuel supply meter
6- Oil outlet temperature sensor
7- Oil heat exchanger
8- Oil flow meter
9- Oil inlet temperature sensor
10- Outlet temperature water for engine cooling water
11- Heat exchanger for engine cooling water
12- Water flow meter
13- Inlet temperature sensor for engine cooling water
14- Exhaust temperature sensor before turbine
15- Exhaust temperature sensor after turbine
16- Control panel
17- Dynamometer
18- Speed sensor

Figure1. (Schematic layout of experimental set up)

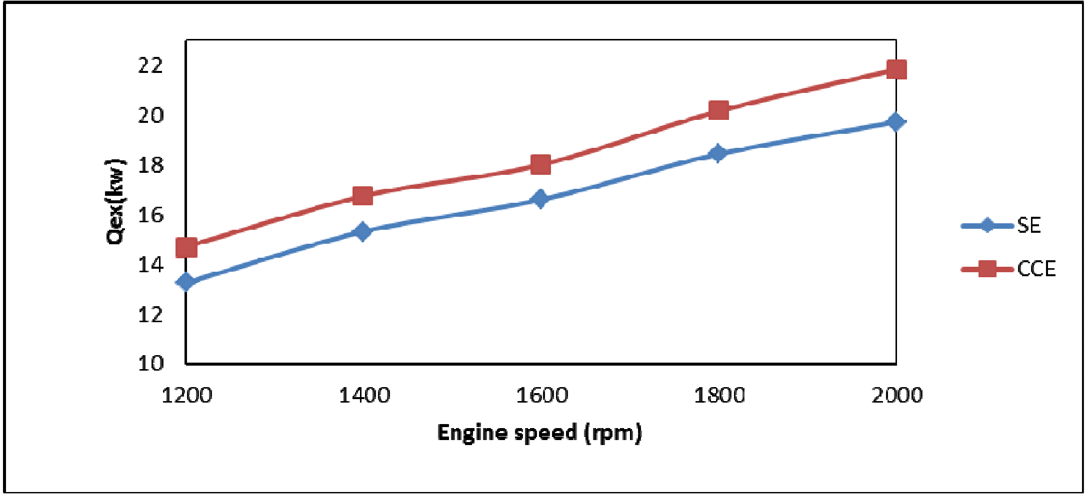


Figure 2. The heat flow rate to the exhaust as a function of engine speed at low load.
[SE=Standard Engine, CCE= Ceramic Coated Engine)

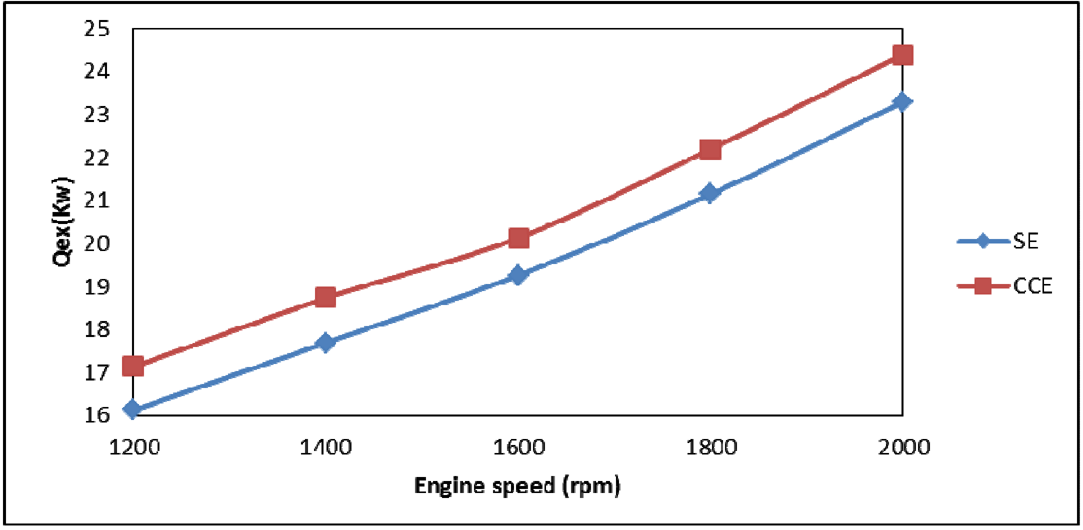


Figure 3. The heat flow rate to the exhaust as a function of engine speed at medium load.

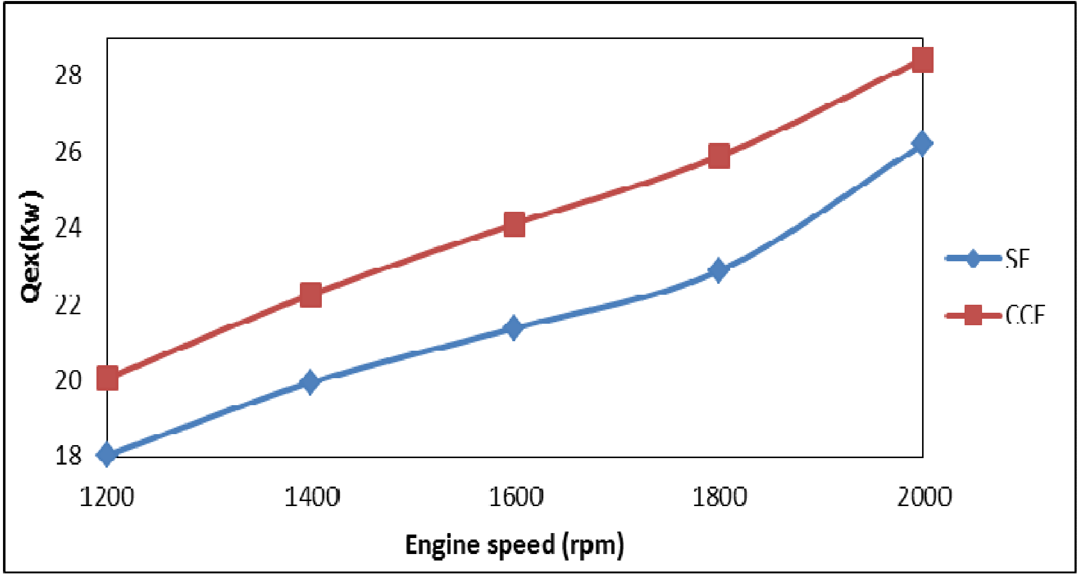


Figure 4. The heat flow rate to the exhaust as a function of engine speed at high load

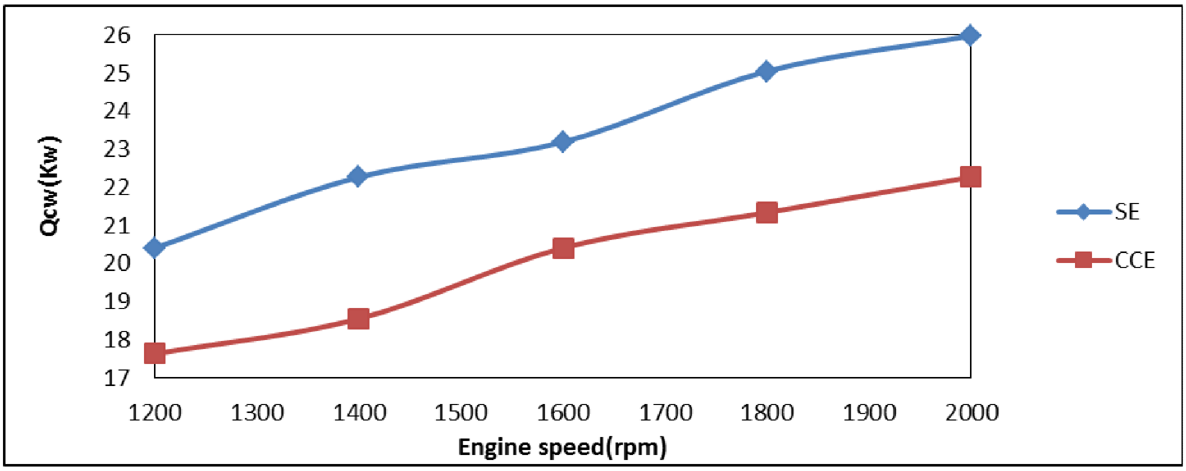


Figure 5. The heat flow rate to the coolant as a function of engine speed at low load.

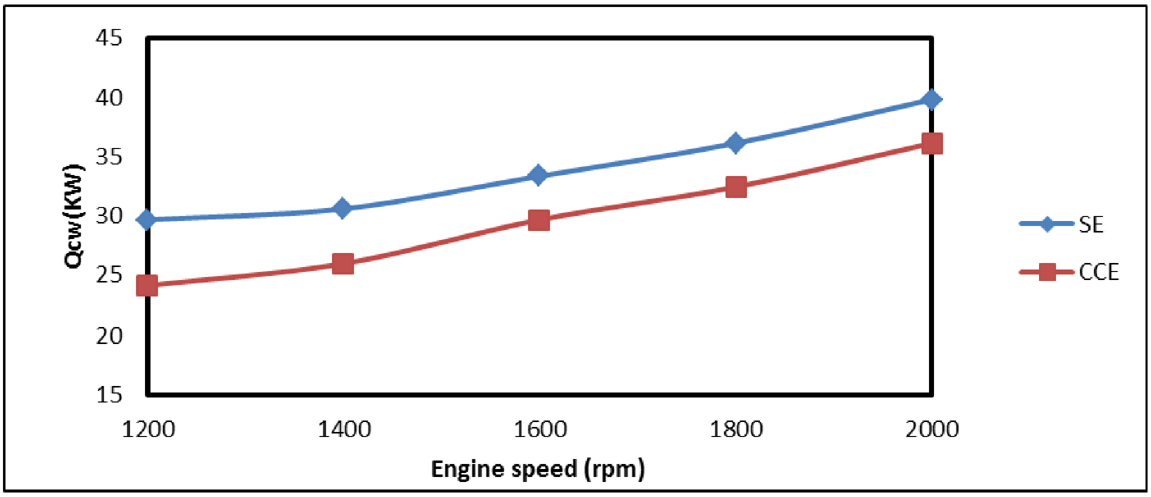


Figure 6. The heat flow rate to the coolant as a function of engine speed at medium load.

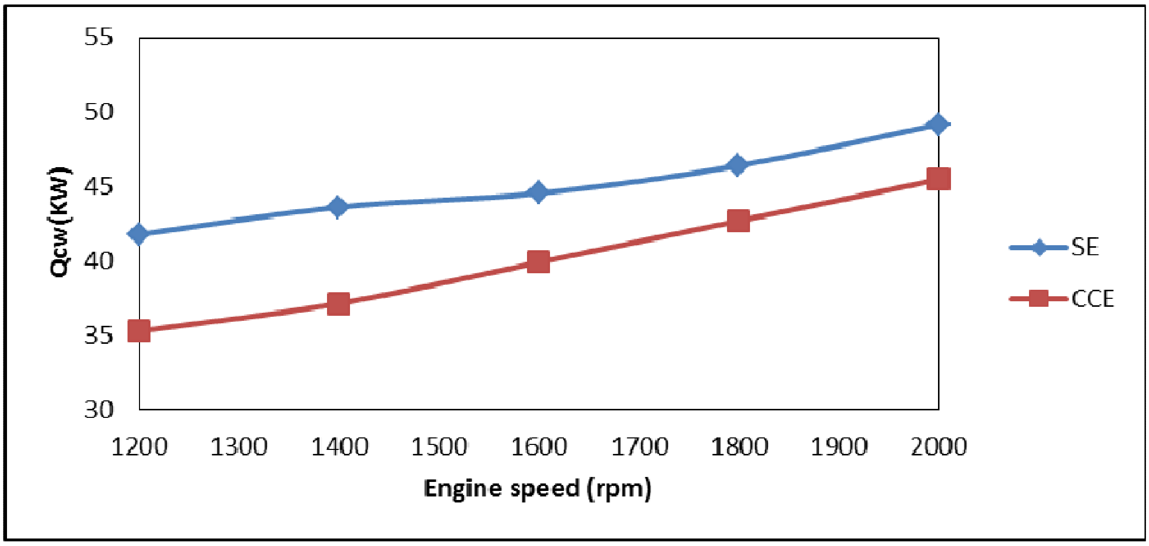


Figure 7. The heat flow rate to the coolant as a function of engine speed at high load.