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PERFORMANCE APPRAISAL OF A STATIONARY DIESEL ENGINE WITH DIFFERENT PISTONS

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Abstract

In this era of industrialization, due to rapid growth in energy sector, energy requirements for transportation and agricultural needs is ever increasing. At the same time due to depletion in fossil fuel sources, there is an urgent need to research for alternatives. Before the alternative sources are identified, there is a need towards improving the performance of existing engines. An attempt is made here to study the behaviour of a single cylinder, four stroke diesel engines with cast iron, cast iron coated with nickel chromium and aluminium pistons. The very aim of this experimentation is to find the suitability of different materials for piston towards better performance. Compared with the existing cast iron piston engine, brake thermal efficiency is increased by 9.12%, where brake specific fuel consumption, exhaust gas temperature, mechanical efficiency and volumetric efficiency are decreased by 8.3%, 2.05%, 5.24% and 0.75% respectively by using aluminium piston.

Keywords: Diesel engine, Cast iron piston, Aluminium piston, Coated piston, Performance

Introduction

The crown temperatures can be as high as 550K.The temperatures of piston and valves depend on their thermal conductivity. As the thermal conductivity increases, the conduction resistance decrease, resulting in lower surface temperatures. For the same speed and loading, aluminium pistons are about 40 to 80°C cooler than cast iron piston (8). The main cooling paths for the piston are conduction through piston rings to the cylinder wall and conduction through piston by to the air-mist on the outer side of the piston.

Ekrem Buyukkaya et.al. (2) carried out tests on a six cylinder, direct injection, turbocharged Diesel engine whose pistons were coated with a 350 μm thickness of $MgZrO_3$ over a 150 μm thickness of NiCrAl bond coat. $CaZrO_3$ was employed as the coating material for the cylinder head and valves. The working conditions for the standard engine (uncovered) and low heat rejection (LHR) engine were kept exactly the same to ensure a realistic comparison between the two configurations of the engine. Comparisons between the standard engine and its LHR version were made based on engine performance, exhaust gas emissions, injection timing and valve adjustment. The results showed that 1–8% reduction in brake specific fuel consumption could be achieved by the combined effect of the thermal barrier coating (TBC) and injection timing. On the other hand, NOx emissions were obtained below those of the base engine by 11% for 18° BTDC injection timing.

Ciniviz et.al. (7) studied, the effect of thermal-barrier coated piston and combustion chamber surfaces on turbocharged diesel engine performance was experimentally investigated. Satisfactory performance was obtained with TBC_1 (with coated cylinder head and valves) and TBC_2 (with coated cylinder head, piston top and valves). Compared with a standard diesel engine, engine power was increased by 2%, the engine torque was increased by 1.5 to 2.5% and brake specific fuel consumption was decreased by 4.5 to 9%. The NO_x emissions were increased by 10% in diesel engine with TBC coatings compared with a standard diesel engine. Experimental studies have shown that there is a reduction in smoke emissions of up to 18% as a result of TBC application.

Etsion and E.Sher (3) presented an experimental study to evaluate the effect of partially laser surface textured piston rings on the fuel consumption and exhaust gas composition of a compression–ignition IC engine. Dynamometer tests were performed with a Ford Transit naturally aspirated 2500 cm^3 engine at a wide range of engine speeds under near-half-load conditions. A comparison was made between the performance of reference non-textured conventional barrel-shaped rings and optimum partial laser surface texturing (LST) cylindrical-shape rings. It was found that the partial LST piston rings exhibited up to 4% lower fuel consumption, while no traceable change in the exhaust gas composition or smoke level was observed.

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Adnan Parlak et.al (1) studied, the effect of insulated combustion chamber surfaces on the turbocharged, direct injection Diesel engine performance. Satisfactory performance was obtained with the low heat rejection (LHR) engine. In comparison to a standard Diesel engine, specific fuel consumption was decreased by 6%, and brake thermal efficiency was increased by 2%. It was concluded that the exhaust gas process was the most important source of available energy, which must be recovered via secondary heat recovery devices. The available exhaust gas energy of the LHR engine was 3–27% higher for the LHR engine compared to the standard (STD) Diesel engine. However, it is impossible to recover all the exhaust gas energy in useful work. It is found that the maximum extractable power is less than 47% of the exhaust power.

Krzysztof Z. Mendera(5) carried experimentation on effects of plasma sprayed zirconia coatings on diesel engine performance. They presented comparative analysis of heat release in baseline and insulated piston crown with plasma sprayed zirconia coatings diesel engine.

K. Funatani et.al(6) carried works on application NCC coatings in two stroke motor cycle and diesel engines. They found benefits with the use of NCC coatings like elimination of cast iron line, lowering of oil consumption, improved fuel economy, reduced cylinder wall temperature, engine weight and increased power, reduction in emissions, friction reduction, improved scuff and wear resistance on cylinder bores, pistons and piston rings, thermal barrier protection on diesel piston domes, reduction in carbon deposition on piston domes, reduced noise from piston slap, ability to operate in corrosive environment.

Imdat Taymaz (4) studied the effect of insulated heat transfer surfaces on diesel engine energy balance system. The research engine was a four-stroke, direct injected, six cylinder, turbocharged and inter-cooled diesel engine. This engine was tested at different speeds and load conditions without coating. Then, combustion chamber surfaces, cylinder head, valves and piston crown faces were coated with ceramic materials. Ceramic layers were made of $CaZrO_3$ and $MgZrO_3$and plasma coated onto base of the NiCrAl bond coat. The ceramic-coated research engine was tested at the same operation conditions as the standard (without coating) engine. The results indicate a reduction in fuel consumption and heat losses to engine cooling system of the ceramic-coated engine.

Testing and Performance

Experiments are carried out on a four stroke, single cylinder diesel engine with different pistons in two stages. The first stage involves determination of optimum cooling water flow rate/temperature at full load with cast iron piston. The second stage involves carrying load test on the engine with cast iron piston, cast iron piston coated with nickel chromium and aluminium piston. The experimental set up consists of the engine mounted on a sturdy frame with rope brake dynamometer coupled. The tests are carried out to find various performance parameters like specific fuel consumption, Cooling water flow rate, brake power, frictional power, air flow rate etc. This test setup is shown in plate 1. The specifications of the engine are shown in table 1.

Plate 1. Engine setup

Table 1. Specifications of the engine test setup

S#	Description	
1	Make	Texvel
2	Type	4-stroke,Single cylinder, Water cooled, Vertical engine
3	Rated speed	650 rpm
4	Bore X Stroke	114.3mm X 139.7mm
5	Loading	Rope Brake Dynamometer

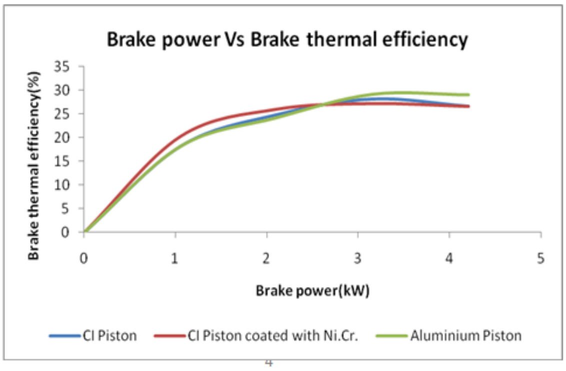
Results and Discussion

The experiments are carried out at maintaining optimum cooling water temperature, obtained by carrying out tests on the engine at full load with different cooling water flow rates with cast iron piston. It is found that the specific fuel consumption is 0.281kg/kW-h at 70°C, which is less among specific fuel consumptions obtained at other temperatures. The lower specific fuel consumption at this cooling water temperature can be attributed to the reduced frictional losses, hence better running of the engine.

Variation in brake thermal efficiency with brake power for different pistons

From fig.1, it can be found that at full load the maximum brake thermal efficiency is obtained with aluminium piston while there is not much difference in brake thermal efficiency obtained with cast iron and cast iron piston coated with nickel chromium pistons. This 9.12% rise in brake thermal efficiency obtained with aluminium piston over cast iron piston can lead to significant improvement in overall performance of the engine.

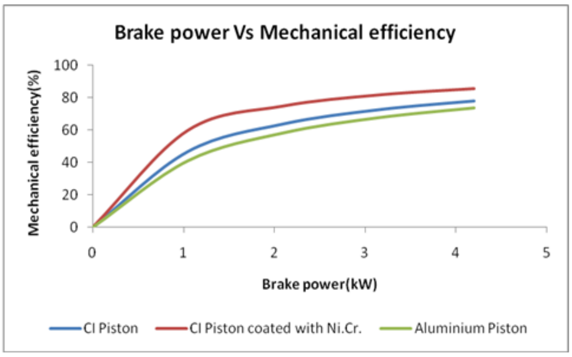
Fig 1. Variation of brake thermal efficiency with brake power for different pistons



Variation in mechanical efficiency with brake power for different pistons

It can be observed from fig. 2, that the maximum mechanical efficiency at full load is observed with cast iron coated with nickel chromium. At full load the mechanical efficiency with cast iron piston is found to be 77.78%, with aluminium piston it is 73.7% while the same is 85.72% with cast iron piston coated with nickel chromium. The drop in mechanical efficiency with aluminium piston can be attributed to the higher coefficient of thermal expansion of aluminium which results in increase friction at elevated temperatures and hence at high loads. By coating the cast iron piston with nickel chromium, the mechanical efficiency is found to be raised by 10.2%.

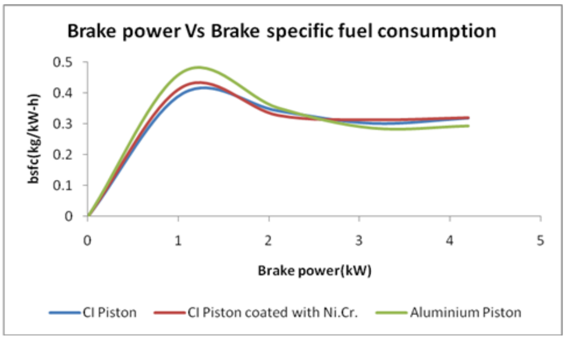
Fig. 2. Variation of mechanical efficiency with brake power for different pistons



Variation in brake specific fuel consumption with brake power for different pistons

From fig. 3, it can be shown that lesser brake specific fuel consumption at full loads is obtained by using aluminium piston. It is also evident from the fact that higher brake thermal efficiency is obtained with aluminium piston. The reduction in brake specific fuel consumption with aluminium piston can be attributed to the lesser weight and hence inertia of aluminium piston when compared to the cast iron make. There is a reduction of 8.35% brake specific fuel consumption with aluminium piston.

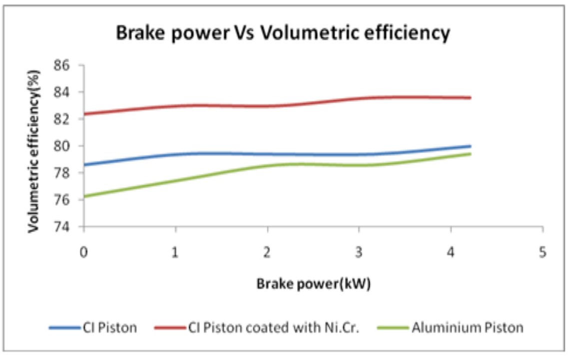
Fig. 3. Variation of brake specific fuel consumption with brake power for different pistons



Variation in volumetric efficiency with brake power for different pistons

From fig. 4, it can be found that at full load the maximum volumetric efficiency is obtained with cast iron piston coated with nickel chromium while there is not much difference in volumetric efficiency obtained with cast iron and aluminium pistons. At full load the volumetric efficiencies are found to be 80%, 83.6% and 79.4% with cast iron, cast iron coated with nickel chromium and aluminium pistons respectively. Thus volumetric efficiency is more with cast iron piston coated with nickel chromium at full load.

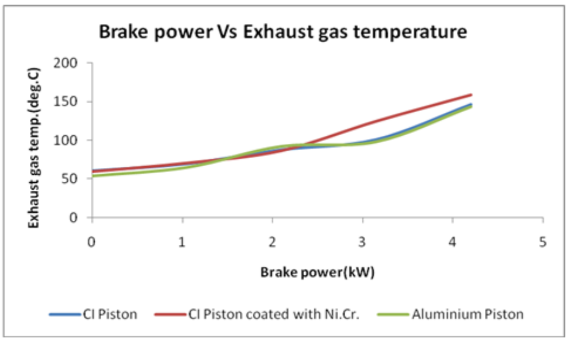
Fig. 4. Variation of Volumetric efficiency with Brake power for different Pistons



Variation in exhaust gas temperature with brake power for different pistons

From fig. 5 it can be seen that the exhaust gas temperatures at full load is 146°C, 159°C and 143°C with cast iron, cast iron piston coated with nickel chromium and aluminium pistons respectively. When compared to cast iron pistons the reduction in exhaust gas temperatures with aluminium piston is found to be 2.05%, when compared to cast iron piston coated with nickel chromium the reduction in exhaust gas temperature is 10.06% which is very significant.

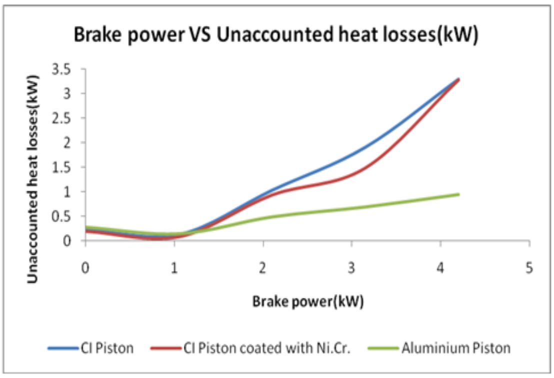
Fig. 5. Variation of exhaust gas temperature with brake power for different pistons



Variation of unaccounted heat losses with brake power for different pistons

It can be seen from the fig. 6 that at full load the unaccounted heat losses from the engine with aluminium piston is much less when compared to their counter parts .At full load the unaccounted heat losses are found to be 3.29kW, 3.28kW and 0.94kW with cast iron, cast iron coated with nickel chromium and aluminium pistons respectively. This reduction in unaccounted heat losses with aluminium piston is evident from the fact that brake thermal efficiency is more with aluminium pistons.

Fig. 6. Variation of unaccounted losses with Brake power for different pistons



Conclusions

- The brake thermal efficiency of the engine is increased by using aluminium piston and is about 9.12% compared to cast iron piston at an optimum cooling water exit temperature of 70°C.
- The mechanical efficiency is better with nickel chromium coated cast iron piston compared to cast iron piston. The increase in mechanical efficiency is about 10.2% at full load.
- By using aluminium piston brake specific fuel consumption is reduced compare to cast iron piston and is about 8.3%.
- At an optimum cooling water exit temperature of 70°C, the exhaust gas temperatures are found to be less with aluminium piston. There is a reduction in 2.05% when compared to cast iron piston.
- The unaccounted heat losses are found to be much less with aluminium piston. There is a reduction in unaccounted heat losses by 71.4%as compared to cast iron piston.
- The volumetric efficiency of cast iron piston coated with nickel chromium is increased by 4.3% compared with existing cast iron piston at full load with an optimum cooling water exit temperature of 70°C.

In this work, increase in brake thermal efficiency and decrease in fuel consumption, exhaust gas temperatures & unaccounted heat losses are predominant in case of aluminium piston. Hence for this setup, it is proposed that cast iron piston may be replaced with aluminium piston.

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