Experimental Investigation on The Electromagnetic Clutch Water pump and Pneumatic Compressor for Improving the Efficiency of an Engine

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Abstract - Considering the fuel crises today many work and research were conducted to reduce the fuel consumption of the internal combustion engine. The fuel consumption of an internal combustion engine can be relatively reduced by use of the electromagnetic clutch water pump and pneumatic compressor. Normally in an engine, the water pump is driven by the crankshaft, with an aid of belt, for the circulation of the water for the cooling process. The circulation of coolant is resisted by the thermostat valve, while the temperature inside the coolant jacket of the engine is below 375K the thermostat is closed only above 375K it tends to open. But water pump run continuously even when thermostat is closed. In pneumatic braking system, pneumatic or air compressor purpose is to compress the air and stored into the storage tank for the brake operation. When the air pressure of the storage tanks gets increases above its storage capacity pressure is regulated by governor, by passing them to atmosphere. Such unnecessary work of this water pump and air compressor can be minimized by use of the electromagnetic clutch water pump and air compressor. The European Driving Cycle is used to evaluate the performance of this water pump and air compressor when used in an engine. The result shows that the fuel economy of the engine while using electromagnetic water pump and pneumatic compressor were improved by 8.0% compared with conventional types which already exist. The application of these electromagnetic water pump and pneumatic compressor are expected to contribute for the improvement of engine performance because of their effect in reduction of the rate of fuel consumption.

Keywords - New European driving cycle test; Electromagnetic clutch; Water pump; Air compressor

1. Introduction
The role of the internal combustion engine is to provide tractive power to the driving wheels via drive train. The most commercial fuel used in internal combustion engine are petrol, diesel, CNG, LPG, biodiesel etc. Nowadays, alternate and hybrid technologies are used to reduce the emission from combustion of fossil fuel and also as an alternate source of energy for the internal combustion engine. Normally the combustion efficiency of an internal combustion engine are optimized, approximately 98% of the energy contained by combustion of the diesel fuel and 95-98% of the energy from the gasoline. However it may be, but only less than 40% of energy is transfer to drive the wheels and the fraction of energy are been used by ancillaries such as water pump, alternator, and air compressor [4]. The inability to convert all the chemical energy into brake power energy is termed as gross indicated thermal efficiency. From the definition of the engine fuel conversion efficiency is expressed as

Fuel conversion efficiency = Combustion efficiency \times Gross indicated thermal efficiency
For the improvement of the energy efficiency, electric and hybrid techniques, which can enhance the efficiency of the internal combustion engine, these technologies have been considered valuable in recent years of development. The advancement in science and technology, which have contributed to improvement in the efficiency of heavy-duty engines. High-efficiency technology like reduction in weight, air resistance, improving thermal efficiency, and energy optimization have been used to reduce fuel consumption in conventional vehicles. In most commercial engines, the cooling system consists of a water jacket which is the outer cover of the engine, thermostat, and radiator. Generally, the water pump is operated proportionally to the engine speed to circulate the coolant throughout the water jacket of the engine block and radiator. In this configuration of direct connection of the engine crankshaft and the water pump results in excessive mass flow rate of coolant at cold start and partial load condition; the flow is regulated by a thermostat. To optimize the coolant pump effect and meet the efficiency of the coolant, alternative methods have been proposed by electrification of coolant components.

As per the effect, the electromagnetic water pump and intelligent thermostat have been used in the vehicle cooling system. The mass flow rate of coolant in heavy-duty diesel engines is relatively high at low engine speed [6], which can be optimized by this technique. In our current study, we have suggested a method for the efficiency improvement technique, which not only can be applied to the water pump but also to the air compressor of the pneumatic brake system. In the pneumatic brake system, air compressor process is to compress the air for the brake operation and store it in the storage tank. The air pressure of the storage tank is regulated by the pressure relief valve. When the brake pedal is pressed, the pressurized air from the storage tank is flow through the hose to the brake cylinder which pushes out connecting rod of the brake cylinder to actuate the s-cam and pushes the brake shoe outward. The air compressor, purpose is to pressurize the air and store it in the storage tank when the pressure accumulation reaches beyond the capacity of the storage tank, pressure is regulated by pressure relief valve [2]. The electromagnetic clutch type air compressor is used for the energy optimization technique as an alternative of the conventional type.

From our study, we suggest a methodology which improves fuel economy of internal combustion by using electromagnetic clutch type water pump and air compressor. The performance of these water pump and compressor results in decrease in fuel consumption and CO₂ emission were demonstrated by the experimental mean results.

Figure 1. Layout of the coolant system with electromagnetic water pump

The Figure-1 gives the complete layout of the coolant system in an engine and with the electromagnetic water pump. The engine specification is given in the table 1.
Table 1. Specification of the Engine

| Items            | Value                              |
|------------------|------------------------------------|
| Engine type      | Water cooled type                  |
| Displacement     | 796 cc                             |
| Bore dia. X stroke | 68.5 X 72.5 mm                       |
| length           | 37 KW @ 5000rpm                    |
| Max power        | 15 Nm @ 2500 rpm                   |
| Max torque       | Petrol                             |
| Fuel used        | Solex carburetor                   |
| Fuel system      |                                    |

From the layout it is clearly illustrated the process of the coolant from the cylinder jacket to the radiator, the red arrows indicates high temperature coolant and blue arrows indicates the low temperature coolant. Figure-2 indicates the complete layout of pneumatic braking system, it consist of an air dryer, storage tanks, dual operated brake valve and brake cylinder. The air dryer purpose is to remove the moisture and water content in the compressed air and storage tanks is to store the pressurized into it. The dual valve used for control the air flow from storage tanks to the brake cylinder. The brake cylinder is to transfer kinetic energy of the pressurized air into mechanical energy by piston, connecting rod which connect the s-cam or wedge type for expanding the brake shoe inside the wheel drum.

![Figure 2. Layout of pneumatic braking system with electromagnetic clutch compressor](image)

![Figure 3. Flow Chart of Water Pump](image)
The belt connects the pulley of the water pump as well as the air compressor to the crankshaft for transfer of the rotation motion for the necessary operational process. However, with the electromagnetic clutch the rotation speed is controlled by disengage and engage of the clutch and to transfer the crankshaft rotational motion to the water pump and the air compressor. The consumption of the electromagnetic clutch is 20 W under all operating condition. And the temperature sensor is installed near the cylinder water jacket for monitoring the temperature output of coolant. For evaluation of fuel consumption we use the New European Driving Cycle test.

![Flow chart of Air Compressor](image1)

**Figure 4.** Flow chart of Air Compressor

Figure-5 shows about the schematic layout of the NEDC test process. In NEDC test [1], it consists of constant volume sample, dynamometer, etc. The constant volume purpose is to collect the exhaust for the measuring the emission parameters by gas analyzer method. The figure-3 shows the electromagnetic clutch type compressor. The figure-4 shows the model of the experimental setup of the engine with the electromagnetic clutch type water pump and Air compressor and the storage tank with relief valve.

![Schematic layout of testing process](image2)

**Figure 5.** Schematic layout of testing process
2. Results And Discussions

*The New European Driving Cycle Test (NEDC)*

The NEDC is a driving cycle designed to access the fuel consumption of the engine. The driving cycle used for emission type - approval of all light-duty vehicle models and Euro 3 in Europe. The emission limits (expressed as mass of pollutant emitted per kilometer driven) refer to the emissions over NEDC. From the NEDC evaluation test we obtained the results for fuel consumption and emission levels. We had conducted experiments on medium sized petrol engines to compare the performance of the clutch type water pump and pneumatic compressor with conventional types, the experimental setup consist of dynamometer for performance testing and CO2 emission parameter in the exhaust is determined from constant sampling process and gas analyzer test in NEDC. Figure shows about the difference between conventional and electromagnetic water pump at cold start phase, the reduction in fuel consumption is due to the optimization of the water pump, the unnecessary work is reduced at this phase. From the figure-5 it is clearly illustrated that reduction in CO2 and fuel consumption level when compared with conventional type. The level of CO2 and fuel consumption has been decreased because at cruising phase the application of the brake is very less due that air pressure is maintained constant inside storage tank.
Graph – 3 BP vs SFC

Graph – 4 Torque vs BP

Graph – 5 Brake thermal efficiency ($\eta_{bth}$) vs Brake Power (BP)
3. Conclusion
The paper study is to develop electromagnetic clutch water pump and air compressor to reduce the fuel consumption and CO$_2$ emission. The electromagnetic pulleys are installed and performance evaluation test were conducted using NEDC. From this test varies output results like fuel consumption, brake thermal efficiency and mechanical efficiency were obtained. New finding from the results are the decrease in the fuel consumption is upto 2.8% with electromagnetic water pump and upto 7.7% with electromagnetic air compressor when compared with the conventional type water pump and air compressor. By this method, the unnecessary work of the water pump and air compressor can be avoided from this we can expect considerable improvement in fuel consumption.

References
[1] Augusto F. Pacheco, Mario E.S. Martins New European Drive Cycle (NEDC) simulation of a passenger car with a HCCI engine: Emissions and fuel consumption results. Paper No.111 (2013) 733-739.
[2] Automotive and Off-Highway Air Brake Reservoir Performance and Identification Requirements, Truck and Bus SAE; Paper No.10 (2013)12.
[3] Christos Dardiotis, Georgios Fontaras, Alessandro Marotta, Giorgio Martini, Urbano Manfredi, Emissions of modern light duty ethanol flex-fuel vehicles over different operating and environmental conditions, Fuel 140 (2015) 531–540
[4] Heywood J. Internal combustion engine fundamentals. McGraw-Hill; 1988. ISBN 0-07-1004998.
[5] Krafft R, Faller W, Wolf A. Electromagnetic water pump clutch: working principle, design strategies and applications for heavy-duty vehicles. SAE;Paper No. 2007-01-4260.
[6]. R. Suarez-Bertoa, A.A. Zardini, C. Astorga; Ammonia exhaust emissions from spark ignition vehicles over the New European Driving Cycle, Paper No. 97 (2014) 043-053.
[7] Torregrosa AJ, Broatch A, Olmeda P, Romero C. Assessment of the influence of different cooling system configurations on engine warm-up, emissions and fuel consumption. Automotive Technology; Paper No. 9(2008) 447-58.
[8] Use of electromagnetic clutch water pumps in vehicle engine cooling systems to reduce fuel consumption 2013. Paper No. (2013)-04-073.
[9] Vicente Bermudez, José Manuel Luján, Santiago Ruiz, Daniel Campos, New European Driving Cycle assessment by means of particle size distributions in a light-duty diesel engine fuelled with different fuel formulations. Paper No.15 (2014) 649-659.