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# Friction Reduction Using Electrical Water Pump in I C Gasoline Engine

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## ABSTRACT

This paper illustrates the differences between mechanical and electrical water pumps of internal combustion engine. Literature have been studied regarding engine cooling with the water pumps. Main design features of the mechanical and electrical water pumps have been illustrated.
The traditional cooling system is not suitable for a high efficiency performance in terms of fuel economy and exhaust emission. Therefore, it is necessary to develop a new technology for engine cooling systems. These days, the electronic water pump is spotlighted as the new cooling system of an engine. The new cooling system can provide more flexible control of the coolant flow rate and the engine temperature, which used to be strongly relied on the engine driving conditions such as load and speed.

**Keywords:** Power; Torque; Electrical Water Pump; Mechanical Water Pump; Oil Temperature; Water Temperature, Cylinder Wall Temperature,

## I. INTRODUCTION

Since the invention of internal combustion engine in 1883, the process of combustion unfortunately produces an abundance of waste heat energy which needs to be removed in a systematic manner via a cooling system to prevent damage to any mechanical components. The output of the energy as a percentage of the energy generated by the fuel in the combustion process is shown in Figure 1 for a modern passenger car engine when tested through a “NEDC ECE 15 EUDC” European drive cycle. Specifically, the energy generated has 33% exhaust heat losses to the wall and wall heat losses which needs to be removed by a transfer mechanism to lower the engine’s temperature. Hence in this case the heat transfer medium is the coolant fluid circulated by a water pump in the engine’s cooling system. When the engine power output is substantially increased, the large amount of heat generated needs to be removed in a timely manner to prevent damage to the engine components.
To comply with these laws the emissions control systems are rapidly developing in the market aimed at providing products that meet future emissions standards, but savings in fuel consumption and greater durability

and competitiveness in international markets, improving cost-benefit ratio. In this context, it is performed a design and analysis of a control system for cooling the diesel engine, aiming to control the engine water temperature accurately, to save fuel and reduce emissions. The system under study consists of an electric water pump, electronic controller a control algorithm. This system is intended to provide precise control in water temperature of the diesel engine, thereby reducing pollutant emissions and fuel consumption, allowing also a rapid response to heating in cold start.

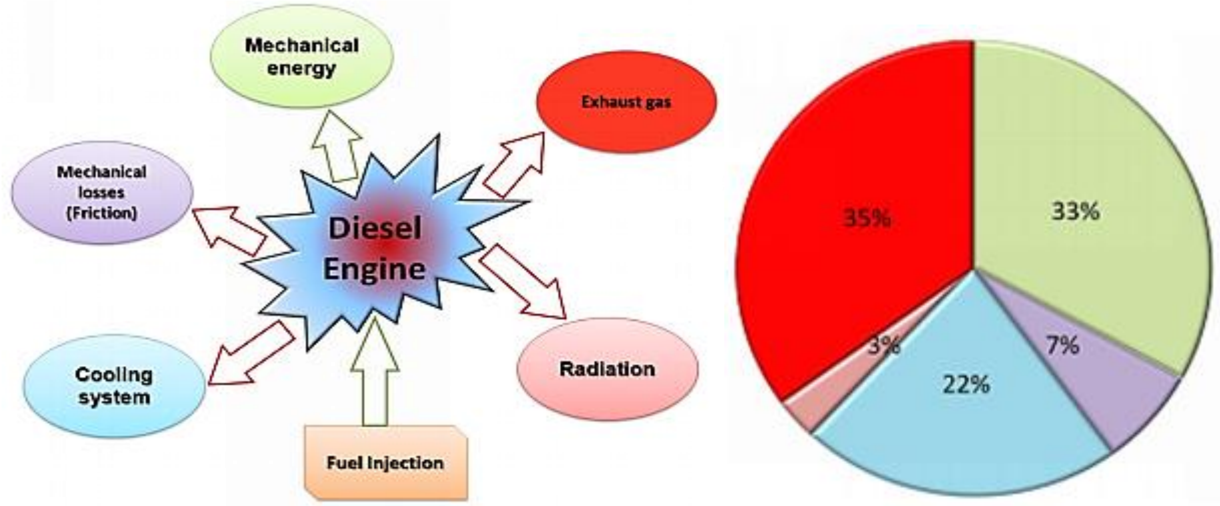



Figure 1: The heat generated by burning fuel is converted into mechanical energy

The coolant fluid, marked in a blue color as shown in Figure 2, is required to circulate around an engine to sufficiently carry the heat away, not only from the combustion chamber but also other critical areas of the engine such as the engine block, the cylinder head, the radiator and the heater core. It is this movement and circulation of the coolant fluid that is studied in this paper. Hence, the water pump can be either mechanically or electrically driven to circulate the coolant fluid around the engine in this cooling system. Instead of use of water, the coolant is often mixed with water in modern vehicle engines, which prevents the coolant fluid from either freezing or boiling, because the freezing or boiling water will significantly reduce the effectiveness of heat removal.

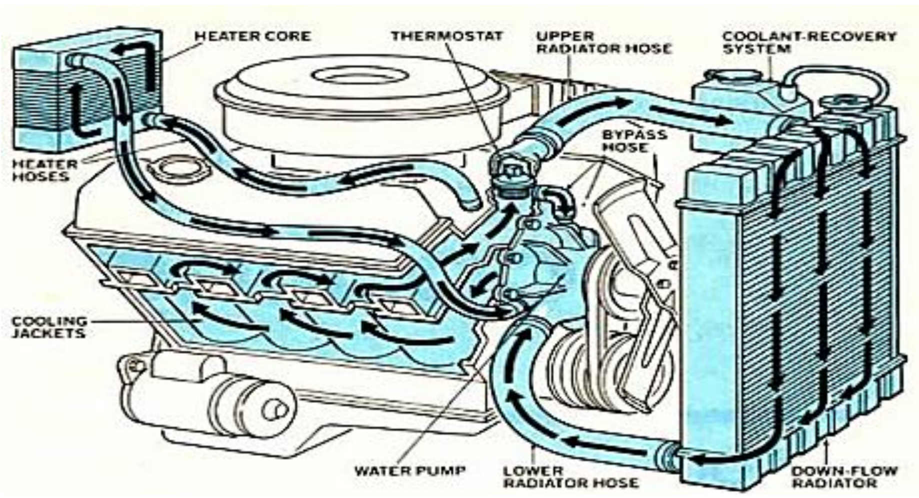



Figure 2: Coolant circulation in diesel engine

Conventional systems for cooling the engine are simply designed to keep the engine temperature acceptable for a wide range of operation and operating conditions. With the introduction of mechatronic technology conventional mechanical systems are being replaced by electronically controlled systems. A cooling system of electronically controlled diesel engine should provide improvements in performance through their effects on the engine, improved friction loss, improvement in fuel economy, reduced emissions and increased durability. The basic design of automotive cooling system has remained essentially unchanged for a long time; for example, drive the pump water from the cooling system of the motor is accomplished by rotating the engine. Thus, the coolant flow rate is determined by engine speed, which is not ideal for most cases. A conventional, mechanically driven water pump can cause unnecessary and parasitic losses. A water pump with electronic control would control the flow of water from the cooling system regardless of engine speed, providing a further reduction of parasitic losses. Another potential advantage of the electric pump is the possibility of reducing the size of the radiator, which is an important issue in the development of engine cooling systems. Increasing control possibilities provides a better choice of operating points of the diesel engine.

## II. COMPONENTS OF ENGINE COOLINGSYSTEM

The purpose of the Engine Cooling System is to prevent the overheating of your vehicle's engine. With engine combustion reaching extremely high temperatures, the resulting heat needs to be dissipated. An efficient cooling system is essential to prevent the engine from burning!! Another function of the cooling system is to regulate the temperature inside the passenger compartment, insuring your comfort and that of your passengers.

- Main Components of the Engine Cooling System
- Radiator and radiator cap
- Cooling Fluid - Coolant
- Radiator Fan & Hoses
- Water Pump
- Heater Core & fan
- Temperature Knob,valves,Thermostat & sensors
- Reservoir or Reserve Tank

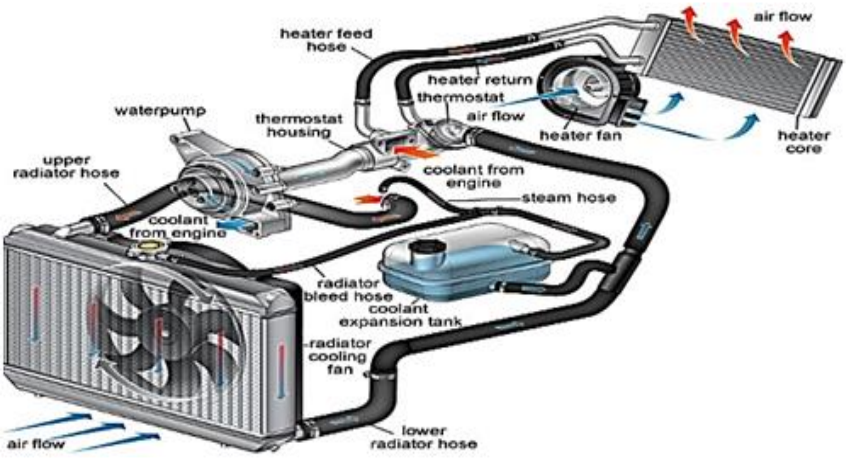



Figure 3: Main components of engine cooling system

### A. Mechanical Water pump:

As shown in figure 4, a typical mechanical water pump consists of an impeller located inside spiral housing and sealed via an axial face seal. The spiral housing is mounted against the engine block with channels leading in and out of the coolant fluid channels within the engine block. The mechanical power arrives via the hub with pulley. The channels on the pulley indicate the interface for the guides on the serpentine belt which transmits power from the crankshaft. Either driven by an accessory drive belt or meshing gears, the mechanical water pump is designed to circulate the coolant fluid through the engine based on the engine speeds.

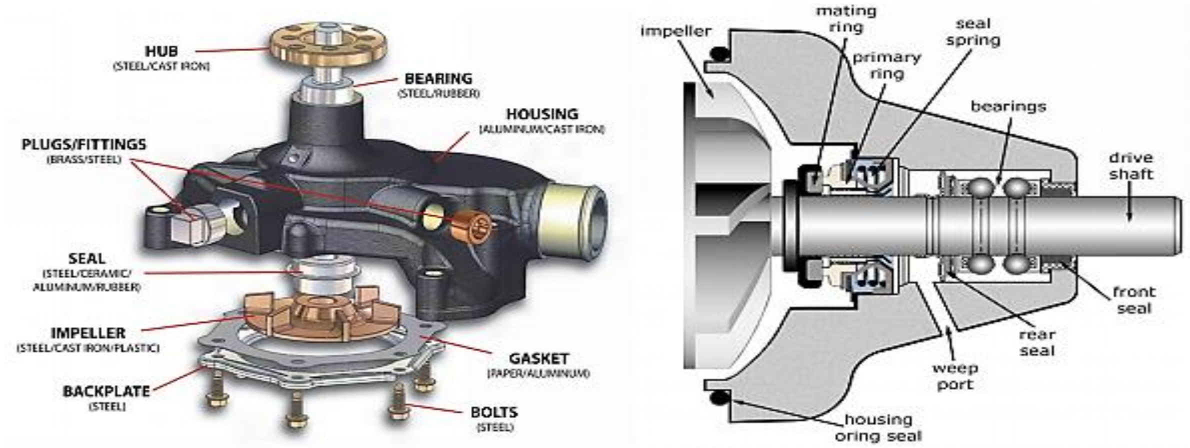



Figure 4 : Conventional(Mechanical) water circulation pump used in engines

### B. Electronic Water pump

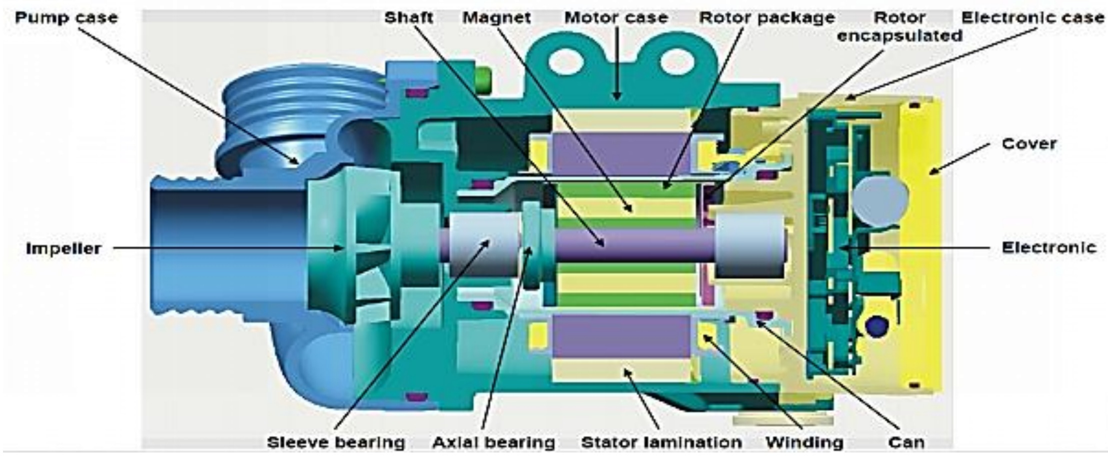



Fig 5 : Cross section view of electrical water pump

As the automotive industry strives to develop cleaner burning and more fuel-efficient engines, an electric water pump is becoming a sensible alternative to its mechanical counterpart. Modern vehicles the hybrid electric vehicles, have adopted advanced electronically control systems and sensors which have impacts on the engine cooling system, because negative aspects of the mechanically driven water pump is possible to be avoided. Since the coolant flow rates of the mechanical water pumps are elated to the engine speeds the thermal control using the mechanical water pumps is generally not effective in electric water pump shall be a good alternative to the current mechanical water pump, as the electric water pump may have an opportunity to remove a source of parasitic loss from the internal combustion engine and provide a better control of the engine temperature according to the engine heating and cooling requirements. Since an electric pump offers an effective flow control capability which is totally independent of engine speeds, this can lower the system operating requirement with a reduced pump flow rate at high engine speeds. This allows the engine to run at a steadier temperature, as there is no sudden fluctuation in the coolant flow rate. Some advantages of an electric water pump used in internal combustion engines are discussed as below

Design Losses – mechanical water pumps must be mounted where the power to drive them is available. The power is usually at the front of the engine where belts or gear-train can be used to provide the drive power. In some instances, this package constraint can limit the ability to design a pump system and result in a reduced head flow. Furthermore, the mechanical pump design has performance limiting characteristics such as fluid cavitation and. An electric pump can be remotely mounted, allowing the flow characteristics to be hydraulically optimized while not impacting on the design constraint of both the overall engine installation package and the cooling system effectiveness

Drive Losses – the gear drives of the mechanical water pump place large accelerations into the pump shaft due to the gear teeth mesh which generates high cyclic side loads on the pump bearings. The belt driven water pumps do not have the same accelerations as the gear driven ones, but the belt driven water pumps can experience larger side loads due to the drive belt tension. Both 'driving' factors require the mechanical water pumps to have large bearings and the physical design to support the bearing loads.

Operating Losses - mechanical water pumps deliver the coolant flow and pressure directly proportionally to engine speed, the only means of adjusting the coolant flow rate and pressure is through use of the restriction valves. On the other hand, an electric pump can operate as a function of the engine cooling requirement(s) which can adjust coolant flow rate based on 'need', not engine speed

Eliminate Hot Soak after Shutdown - an electric pump can circulate coolant fluid throughout the engine post shutdown which enables one to control the engine's thermal mass to prevent the overheat of critical components. This feature may also allow for design of engines operating at higher temperatures considering that the hot soak design limits will be eliminated

## III. COMPARISON OF ELECTRICAL AND MECHANICAL WATER PUMPS

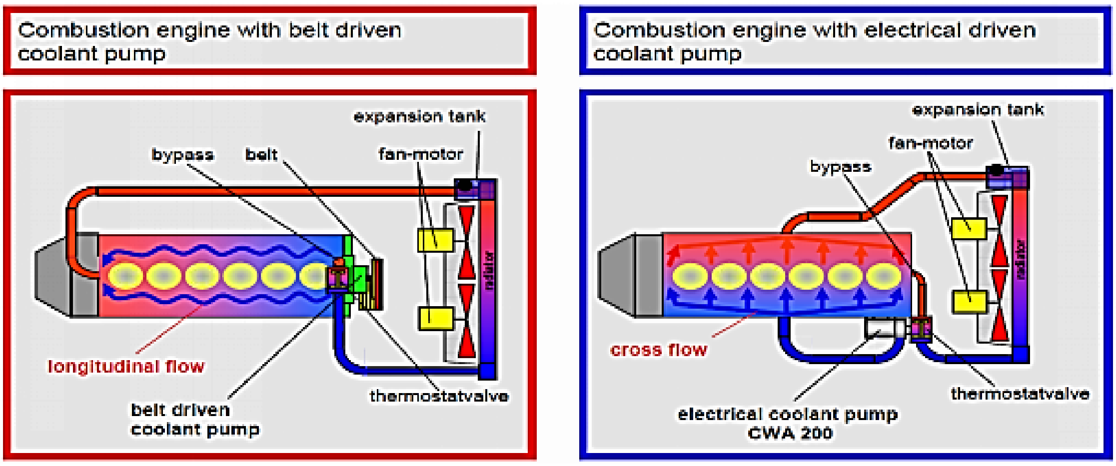



Figure 6 : Layout and energy conservation of electrical water pump

| Feature | mechanical waterpump | clutched mech. waterpump | variable mech waterpump | electrical waterpump |
|---|---|---|---|---|
| zero flow at cold start | no | yes | no | yes |
| variable speed of pump | no | no | limited | yes |
| after running function | no | no | no | yes |
| compatible for start / stop | no | no | no | yes |
| compatible for hybrid appl. | no | no | no | yes |
| maintenance free | no | no | no | yes |
| improved efficiency | possible | possible | possible | yes |
| high coolant flow at low engine speed | no | no | no | yes |

There are many benefits of the EWP:

- Increased Power and Torque
- Increased cooling capability
- Eliminating Heat Soak
- Better control of engine temperature
- Flexible options for pump control

## IV. SELECTION OF SUITABLE ELECTRIC WATER PUMP FOR ENGINE

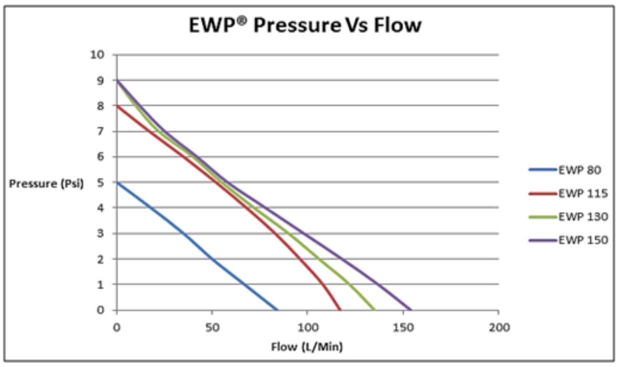
Pump performance maps were used in order to calculate pump power consumption. Pump performance maps consist of pressure rise, flow rate, pump speeds, and efficiency. Based on these map data, the pump power consumption was calculated using the following equation.

Ppump = Qp X  X P

Where: P: pump power consumption, η: pump efficiency, Qp : Volumetric flow rate,

ΔP: pressure rise across the pump.

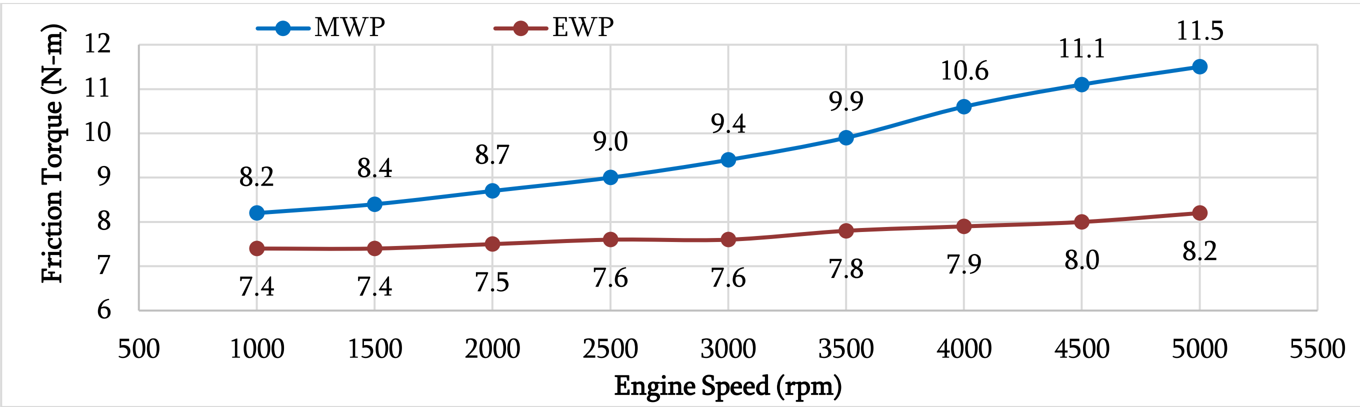
The coolant mass flow rate for a centrifugal water pump depends on the coolant density, shaft speed, system geometry, and pump configuration, the mass flow rate may be computed as:mc = ρc x (2 x rp x b x v) mass flow rate = density of fluid X volume of flow region X velocity of pump as v = p x rp x tan , Velocity of pump is a function of blade speed, blade radius and blade angle.



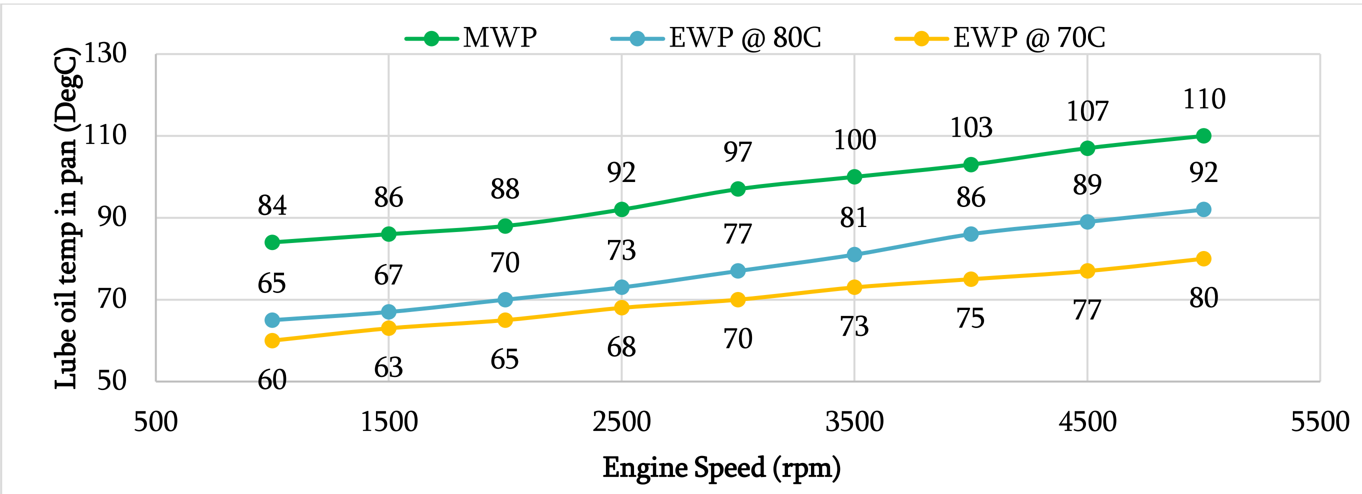
## V. TESTING OF ENGINE USING ELECTRICAL WATER PUMP

In order to verify the effectiveness of an electrical pump over a standard mechanical pump, engine dynamometer tests have been conducted where the engine fitted with the mechanical and electric water pumps was run back-to-back. In order to verify if the benefits are available for use of the electric water pump, it is necessary to adequately size the electric water pump and control its use via a proper understanding of the engine's optimum operation temperatures and then implement an ECU to manage the water pump switching to adequately control the engine temperature.

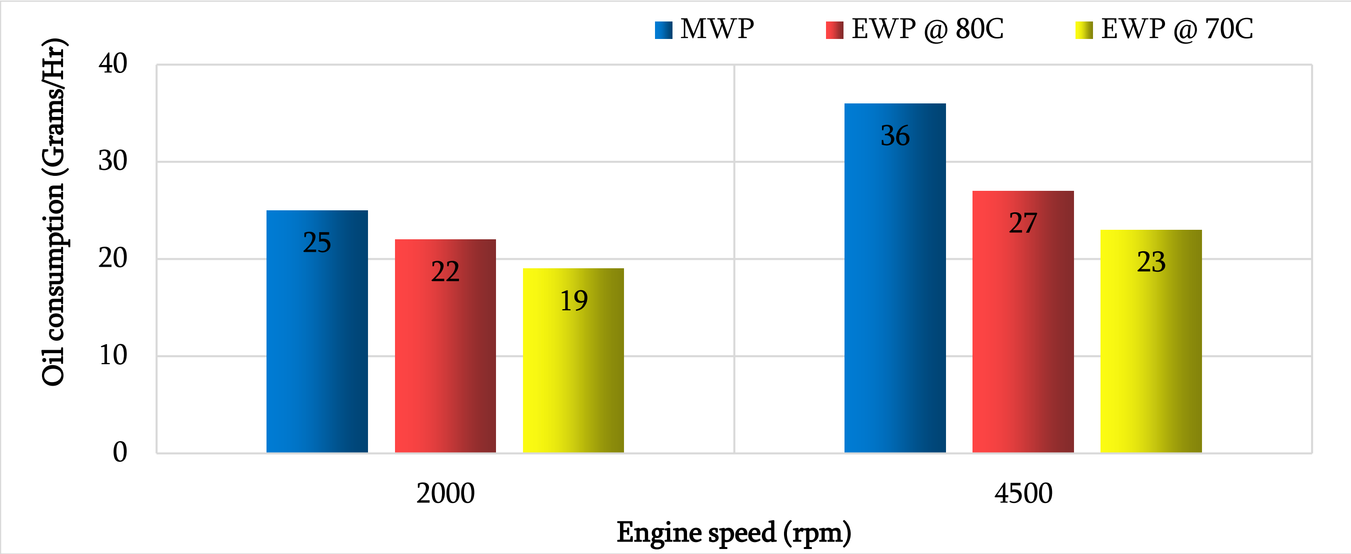
Following graph shows the details of engine torque with mechanical water pump (MWP) and electrical water pump tested under different engine rpm ranging from 1000 to 5000. As mechanical water pump is driven by the belt attached to the crankshaft pulley the power consumption (frictional torque) is higher from the engine compared to the electrical water pump (EWP) which is nowhere connected to running parts of the engine as it is mounted independently on the test bed. This non dependency of the drive saves the engine power for better output drive ability (used as useful power to the wheels)




To evaluate the oil temperature engine is tested with mechanical water pump with thermostat and electrical water pump without thermostat (Thermostat is not necessary for electrical water pump). The water limiting temperature is set at 80C and 70C for the electrical water pump through the ECU.



As shown in the above plots lube oil temperature can be controlled, we within the limits as per the design standards with electrical water pump by setting the engine water outlet temperature limit. Controlling oil temperature with mechanical water pump is limited by the thermostat of the engine which is difficult to control over the long duration running. Electrical water pump is beneficial compared to mechanical water pump in regulating oil temperature by setting water temperature rise limit.Rise in oil temperature over period during engine running will lead to evaporation of oil through the crankcases and reduces the viscosity of oil which in turn will affect the lubrication property of engine parts. To evaluate the effect of oil temperature on lubrication oil consumption engine is tested at 2000 rpm and 4500 rpm for about 8 hours in each rpm and based on the result obtained following bar chart is created to show the comparison of mechanical water pump and electrical water pump.




## VI. CONCLUSIONS

1. Elimination of mechanical commutation system leaves the durability of the rotor bearings as practically the only limiting factor of service life of engine. Using electrical water pump will improve the overall engine life as well as reduces periodic maintenance problems.
2. Reducing the number of rotating parts significantly reduces the engine noise as well as frictional losses in the engine as shown in the test results. The reduction in frictional torque is 3.3 N-m at 5000 rpm which constitutes about 1.7 kW of power in engine, which is very significant when we are using small power engines. Reducing frictional power improves the fuel efficiency of the engine.
3. Matching the electrical coolant pump out put to the actual cooling requirements of the engine can reduce the fuel consumption and exhaust emissions. Instead of the approximately 6.0 kW rated input for conventional mechanical pumps, an electric pump with 4.2 kW electric water pump can be used to automotive engines up to 55 kW rating engine. So effective power saving using electrical water pump is around 1.8 kW
4. It is possible to run the electrical water pump (EWP)after switching off the engines to avoid hot spots (localized overheating of parts) but this is not possible in mechanical water pump (MWP). With electrical

water pump we can keep circulating the hot water through the engine because the EWP is independent of the engine operation as it is controlled by the battery of the vehicle

5. The use of the electrically driven water pump is a design of future, such as those using hybrid or fuel technology is inevitable and most of the vehicles will use this technology in upcoming days in India. As hybrid technology uses most of the battery power so, the electrical water pump can be operated through battery in all speeds of the engine running
6. As the emission norms are getting stringent, in upcoming years with BS6 and above the particulate matter emission reduction is one of the biggest challenges. Lubrication oil consumption contributes a considerably amount in particulate matter formation. With the use of electrical water pump the oil consumption can be reduced by properly controlling the oil temperature by setting the engine out water temperature at the desired limit using electrical water pump. The experimental result shows there will be around 35% oil consumption reduction using electrical water pump in 8 hours testing.

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