Review of Electrically Operated Water Pump

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Abstract

Radiator water pump holds an important aspect as far as engine cooling system is concerned. Conventional mechanically driven water pump accounts for 10-12% of total mechanical losses as referred in the literature. Reduction in this loss would therefore result in the increase in efficiency of engine. Instead of crankshaft driven water pump, electrically driven water pump holds key in achieving better efficiency.an electric motor is used to drive the centrifugal water pump. Motor gets its power from the battery which continuously gets charged by an alternator. Then the experiment had been conducted to verify the effectiveness of electric pump over the mechanical one.

Keywords: Arduino, Centrifugal Water Pump, Radiator, Relay, Thermistor, Thermostat

I. INTRODUCTION

Since the invention of the internal combustion engine in 1883, combustion process produces an unavoidable waste heat which is hazardous. In order to prevent the various engine components to get damaged, an effective cooling system should be there to carry this heat away in systematic manner. Energy generation by fuel combustion process on basis of percentage is shown in FIG.1. Specifically, the energy generated has 13% exhaust heat losses to the wall and 18% wall heat losses which needs to be removed by a transfer mechanism to lower the engine's temperature (Zoz et al.,2001). 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. Hence, to push the coolant through the engine block, radiator and hoses for getting the heat away; a water pump is required. After passing through the pump, coolant goes through engine carrying the heat away, and ultimately through the radiator where this heat exits in atmosphere. This pump can either be mechanical or electrical.

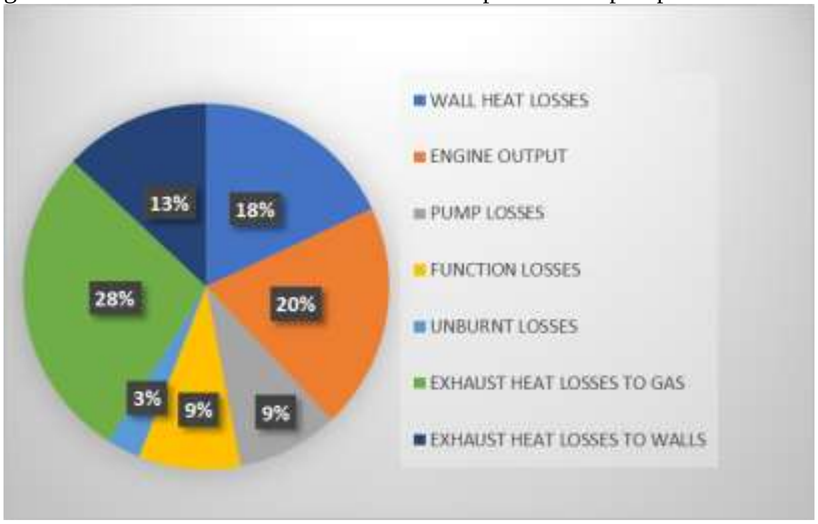

Fig. 1: Pie diagram of Overall losses in engine

A pump is a device that moves fluids (liquids and gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps. Pumps operate by some mechanism (typically reciprocating or rotary) and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines or wind powers.

A. Types of Pump

1) Mechanically Operated Pump

Presently, single stage radial centrifugal pumps are used in the vast majority of motor vehicle cooling circuits (Van Basshuysen and Schafer,2007). The speed of the pump and coolant flow rate are linked directly to the engine speed, through a serpentine belt or meshing gear running directly off the engine's crankshaft, running at a specific transmission ratio.

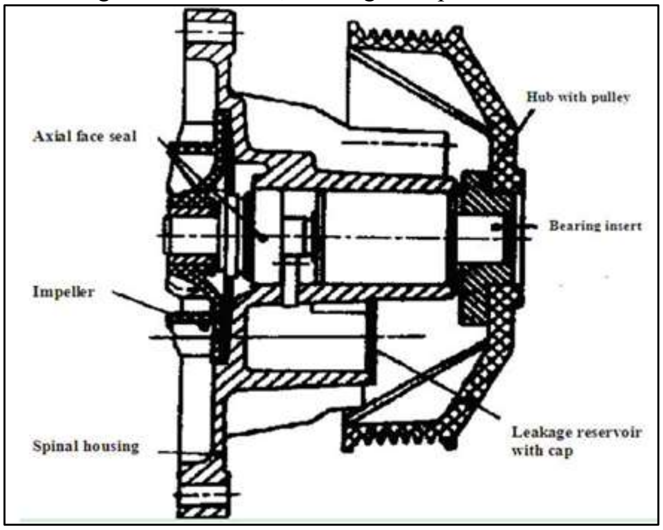

Fig. 2: Mechanical Water Pump

As seen in Figure 2, 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.

2) Electrically Operated Pump

A centrifugal electrical water pump consists of an impeller located in spiral housing which is driven with the help of an electric motor. Electric motor is in-line with the impeller. The motor receives the power from a battery other than the vehicles electrical source.

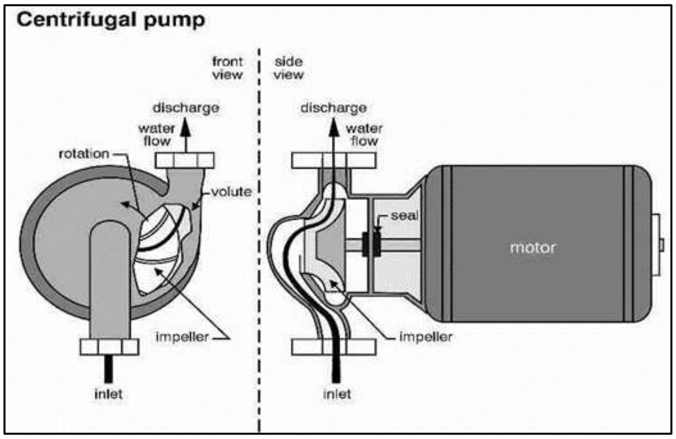

Fig. 3: Centrifugal type electric water pump

B. Drawbacks of the Conventional System:

The conventional system works on the following principle, the coolant absorbs heat given out during combustion from the engine which leads to rise in temperature of the ccolant. When the coolant temperature exceeds 85oC the thermostat valve opens and the coolant flow through the radiator and engine. At this time the water pump keeps on running as it is attached to the crankshaft of the engine which leads to increase the load on the engine. About 10-12% of the power from the engine is transferred to the water pump which is not necessary.

The conventional water pump continuously receives power from the engine due to which the engine performance is decreased. It has to overcome the load of the water pump therefore it uses more fuel due to which it increases fuel consumption. This results in the decreased efficiency of the engine and increased load.

C. *Advantages of Electrical over Mechanical Water Pump*

1) *Removes the losses from I.C. engine*
In case of mechanical pump, there is direct connection between crankshaft and pump pulley. This creates friction loss due to belt or gear mechanism. Where in case of electrical one there is no direct contact.

2) *Better control of Engine Temperature according To the Requirement*
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.

3) *It can be Remotely Mounted*
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. 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.

4) *Large Bearing Support is not Required*
Gear driven or belt driven water pump generates large amount of cyclic side loads on the pump bearing. This requires larger bearing. Electrical pumps feature a drive motor in line with the impeller eliminating the need for large bearings and in some cases seals depending on the type of coupling used between the motor and pump which further reduces the pump drag friction loss.

5) *Eliminate Heat Soak after Shutdown*
An electric pump is able to 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.

6) *The Manufacturing Process is Much Simpler than Mechanical Water Pump*
The manufacturing techniques of the mechanical water pump include casting, forging, machining, assembly of the water pump and inspection. Machining the mechanical water pump involves CNC turning, pin boring, grinding the side face, milling of housing and machining impeller and pulley. An electric water pump is much simpler to manufacture than its mechanical counterpart, as the total number of parts of the electric water pump is much less. The pump housing can be made from thermal/injection moulding and machining processes, while the impeller can be made from casting and machining processes.

II. METHODOLOGY

A. *Conventional System*

The conventional system uses a mechanically operates water pump which runs on engine crankshaft. This increases the load on engine due to which we are replacing the conventional water pump with the electric water pump. At first we checked the engine performance with the conventional system. Note down the results of the following outcomes such as power, efficiency, cooling rate, coolant temperature, fuel intake. Check the stability of the engine.

B. *Electric Water Pump*

After taking into considerations of all requirements of water pump we selected the motor for the electric water pump. There was a need of a centrifugal type water pump. We designed a CAD model of water pump and manufactured it. The impeller used inside the water pump are open centrifugal type. The next step was to combine the water pump with the electric motor. The pump was mounted onto the motor by press fitting it. The material used for the water pump was cast iron alloy. After finishing that the design was ready to use and the only work remaining was the electrical circuit.

C. *Electronic System Used*

To build an electronic system for the water pump we required arduino, step down transformer, program to run the circuit. The battery was connected to a step down transformer which converts the 12V DC to 5V DC which is suitable for the arduino. The arduino is programmed to switch ON the circuit when the temperature of the coolant exceeds above 85o Celsius. The thermostat is replaced with the thermocouple to measure the temperature of the engine coolant. The water pump thus starts to operate when the temperature exceeds above 85o Celsius. Even when the engine is turned off, if the temperature of coolant is above the required temperature the water pump will be still operating.

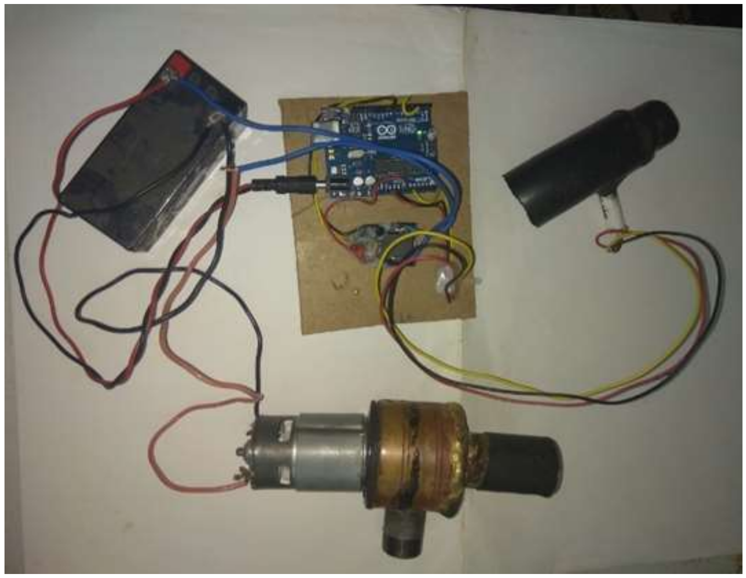

Fig. 4: Circuit diagram of electronic system

There are various electric component used in the electronic system to control the electric water pump and the radiator fan. The major components are as followed.

1) Step down IC 7805
2) Arduino
3) Thermocouple DS18B20

The components works as follows:

D. Arduino

Arduino is an open soure computer hardware and software company, project and user community that design and manufactures single-board microcontrollers and microcontroller kit for building digital devices and interactive objects that can sense and control object in physical and digital world. The project products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL).

Arduino microcontrollers are pre-programmed with boot loader that simplifies uploading of programs to the on-chip flash memory.

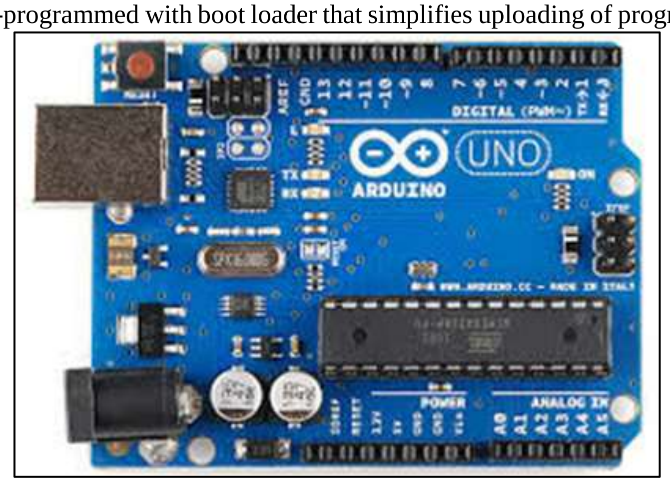

Fig. 5: Arduino UNO

E. Thermister LM35

A thermistor is a type of resistor whose resistance is dependent on temperature, more so than in standard resistors. The word is a portmanteau of thermal and resistor. Thermistors are widely used as inrush current limiters, temperature sensors (negative temperature coefficient or NTC type typically), self-resetting overcurrent protectors, and self-regulating heating elements (positive temperature coefficient or PTC type typically).

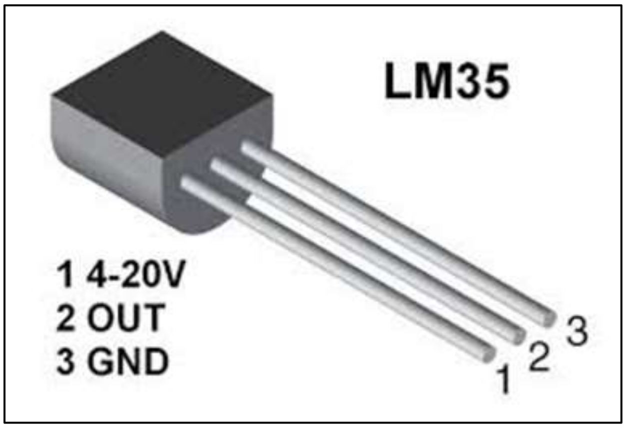

Fig. 6: Thermister LM35

F. *Working of the System:*

The system is designed to cool engine by using electric power and negotiating the mechanical drive coming from the engine crankshaft. When the engine starts running at high RPM the heat is transferred from cylinder of engine to the coolant inside the cooling jacket. When the temperature of the coolant reaches opto 85oC the DS18B20 thermocouple will sense the temperature and will provide information to the arduino. The arduino is so programmed to start the electric water pump and the radiator fan when the temperature reaches to 85oC. As the temperature is above 85oC the arduino will start the radiator fan and the electric water pump. When they both start the battery will be consumed by them so there is a battery loss.

But the power drawn from the engine during it's running condition is more than the power drawn by the electric system. The power drawn from our system is approximately 130W and it does not increase the engine load. This system will only function when the temperature of the coolant reaches 85oC otherwise it will not function. The system has its own advantage, when the engine is turned OFF and the temperature of the coolant is above 85oC the system will still keep functioning.

Fig. 7: Experimental set-up in the vehicle

G. *Algorithm of Processing*

When engine gets started, its temperature increases as the load on engine increases. When the temperature exceeds its allowable range; in our case it is 850C, arduino system comes into action. Temperature sensor mounted inside block senses the temperature. Arduino gets input from sensor and programme is so fed that after reaching the temperature, it gives command to the actuator i.e. electric pump. Coolant is then circulated throughout the engine and is allowed to go through radiator where it gets cooled.

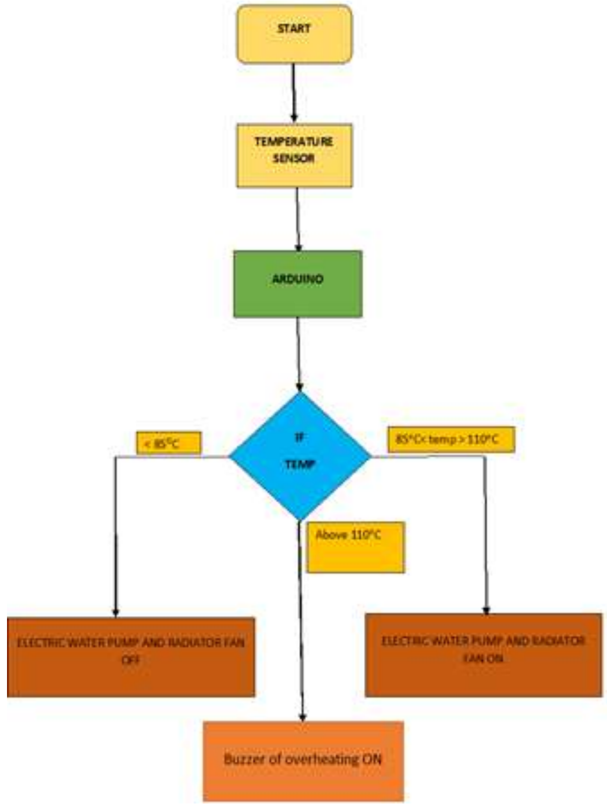

Fig. 8: Algorithm of the electronic circuit

III. RESULT

A. *Testing at No Load Condition*

After installing the system onto the vehicle, the timing belt was replaced with another timing belt which connects only to the crankshaft and the alternator. The system has to be tested for fuel consumption. For that purpose, the engine should heat up. For testing, the vehicle was accelerated in no load condition to measure the fuel consumption rate of the engine. In no load condition the conventional system used to intake 1 litre of petrol for 12min. When the system was installed onto the vehicle, the engine ran for 17min in 1 litre of petrol.

B. *Testing At Load Condition*

After testing for no load condition, the system was to be tested for load condition. In this test we kept 4 persons in the vehicle increasing the load of the vehicle. Then we tested the vehicle for its fuel consumption rate. We ran the vehicle at 30kmph-40kmph then we observed the fuel consumption, in 2 litres of petrol the vehicle drove about 23km. After that we installed our system into the vehicle and again tested for load condition at the same amount of speed, the vehicle travelled 29km in 2 litres of petrol.
CALCULATIONS: At load condition,
Mileage with conventional system = 23/2 Mileage with proposed system = 29/2
= 11.5 kmpl = 14.5 kmpl

C. *Results*

1) *At no Load Condition*

Table – 1
Results at no load condition of vehicle

Sr. No.	*System used*	*Time*	*Fuel consumption*
1.	*Conventional System*	*12 min*	*1 litre*
2.	*Proposed System*	*17 min*	*1 litre*

2) *At Load Condition*

Table – 2
Results at load condition of vehicle

Sr. No.	*System used*	*Distance travelled*	*Fuel consumption*	*Mileage*
1.	*Conventional System*	*23 km*	*2 litre*	*11.5 kmpl*
2.	*Proposed System*	*29 km*	*2 litre*	*14.5kmpl*

IV. CONCLUSION

After comparing the mechanical and electric water pump, we can see the difference between them. The results show clear variation between these two of them. The conventional water pump increases the load on the engine and shuts off, if the engine is turned off. The electric water pump reduces engine load providing an optimum cooling required by the engine. It also keeps operating when the temperature of engine is higher as it is independent of the engine drive.

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