Technologies to Achieve Future Emission Norms: A critical Review

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Abstract

The growing number of vehicle on the road in the country like India where existing emission standards are lagging behind from ten years in comparison to European standards has played a manifold. The country, having cities like Delhi where vehicle pollutions are disturbing the scenario, the regulation to adopt BS VI by 2020 require technologies to get through with the regulations. The vehicular emissions mainly consist of the nitrogen oxides, carbon monoxides, particular matters and hydrocarbons emitted by the combustion of fuel. BS VI demands the nitrous oxides level to 30 percent low in comparison to BS IV standards. The research elucidates the use of electro-mechanical water pump to attain fewer emissions and optimize the engine life by flowing the optimized coolant flow. The pump is an up gradation of the only electrical or mechanical pump by improving the limitations. The electro mechanical pump works on the switch technology by the need of engine cooling system to optimize the engine temperature. The pump works on electrical energy at lower and sporadic rpm and works on mechanical system from crankshaft drive at higher and constant rpm. The EGR cooler is also upgraded by the use of electro mechanical by providing the optimized flow of coolant for cooling the exhaust gases so that it can provide the optimum composition of harmful hydro carbons, carbon monoxide and nitrous oxide. Exhaust gas recirculation reduces nitrous oxides by circulating a portion of an engine exhaust gas again to engine cylinders. The recirculation dilutes oxygen to acts as an absorbent to attain high inert temperature. The EGR reduces nitrous oxides and improves engine life through reduced cycle temperature.

Keywords- Emissions, BS VI, pollutants, catalysts, toxic

Introduction

In the era of globalization and modernization, with the increase in automobiles on the road, the pollution level has reached to the dangerous level. The government authorities are regulating the emission issues to the next step. The future emission norms and regulations are tighter than ever, and the automobile companies are also matching the need and standards. India is the country with lighter emission standards and sixty million vehicles on the road. The Indian government is also tightening the laws and has targeted to achieve Bharat Stage VI emission standards like Euro VI by 2020. Bharat Stage VI is the most upgraded norm and has many benefits regarding environmental protection. Vehicles need most upgraded technologies to achieve future emission norms. The automobiles

majors are preparing to meet the norms, which require the optimised technology. The technologies like Selective catalytic reduction, diesel particulate filter, diesel oxidation catalysts require additional path which can help to attain the standards. The engine coolant system and its flow regulates the emissions attributions and enhances engine life. The research mainly consists of electro mechanical water pump to improve the cooling efficiency and limitation of only electrical and mechanical pump. The electro mechanical pump optimises the coolant flow according to engine RPM, warmup chamber temperature and warm up time. The engine coolant mechanism is very important for efficient functioning of engine which requires coolant flow according to different loads and chamber temperature. [7-10] The electro mechanical attains zero monoxide, nitrogen oxides, hydrocarbons and particulate matters which are the gaseous exhaust produced by the combustion of gasoline or diesel fuel. [11-12]

Electro Mechanical water pump

The engine cooling system articulates the entire cooling procedure of engine. The coolant flow is essential for functioning of engine. The temperature of engine and its gases reaches to 800 degrees Celsius, and there the need of an exemplary system comes into play. The water pump is a device which regulates the flow of coolant. The technology is advancing with every pulse. Similarly, the usage of old mechanical water pumps and new electronic pumps have provided a mechanism of cooling. The research elucidates the use of optimized technology to attain the best results. The electro mechanical pump provides the best minimize the emissions along with up-gradation of engine life. [1-6] The pump also optimizes the exhaust gas recirculation cooler temperature by varying the coolant flow in response to different cooler temperature. The diesel vehicle attains more toughness to meet the norms. The electro mechanical pump helps to reduce emissions, brake specific fuel consumption and enhances engine life. The electro mechanical reduces the flow strategy or optimised flow strategy at the warm up time to provide stable combustion. The pump flow varies with engine rpm conditions, like when engine rpm changes sporadically, electrical pump guides the coolant flow and at constant, high rpm mechanical pump guides the coolant flow. The mentioned technology helps to reduce the emission levels by restricting the pollutant levels like carbon mechanism to drive the coolant, and the attached data empowers the study. The efficient flow is necessary for cooling of engine cylinder which leads to better combustion along with; it increases the engine life. The better combustion is very important for exhaust gases and brakes specific fuel consumption.

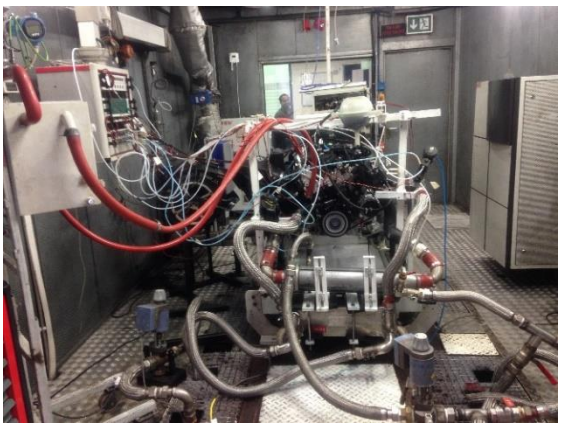

Figure 1: **Engine Setup**

Mechanical Pump

The efficient coolant flow guides for cleaner exhaust, engine life, and fuel consumption. The mechanical water pump is guided by the crankshaft drive belt mechanism which is directly proportional to speed of the engine. The engine during warm up time requires minimum coolant flow or zero flow strategy to attain optimized and required cylinder temperature. The mechanical pump does not understand the need and flow conventional 100% flow even during warm up time. The non-zero flow strategy at the warm up time leads to unstable combustion. The unstable combustion ahead more harmful emissions, less power, and more brake specific fuel consumption. The mechanical pump as driven by crankshaft belt drive is directly proportional to engine revolutions per minute which provide extra and unnecessary coolant flow inside the engine. The pump does not provide optimized flow. The efficient flow can provide minimum BSFC, better engine life, and fewer emissions. The coolant flow is necessary for engine life as it contains additives which act as rust inhibitors, corrosion inhibitors, and scale inhibitors. The mechanical flow sometimes does not provide the maximum flow which is needed to dissipate heat. The inefficiency of mechanical water pump leads to higher nitrous oxides when the cooling flow does not reach to the necessary flow and more CO, HC when they have less flow in comparison to the needed flow.

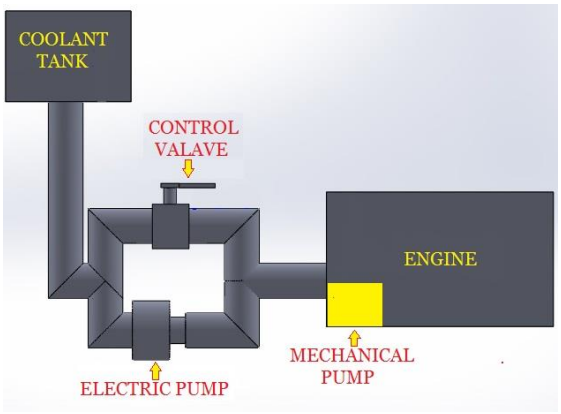

Figure 2: Electro Mechanical Pump Circuit

Electrical Pump

The electrical water pump regulates the limitations of the mechanical water pump, but the reliability factor raises the concerns. The electrical consumption at higher coolant flow rate increases which leads to draw back of electrical water pump. The electrical water pumps are less reliable because of the electronic circuits and any damage in the cooling pump system will lead to damage of engine. The electrical pump works in a streamlined manner, but at higher temperatures where large coolant flow is required, the pump faces constraints like high charge is needed to provide the flow, which draws more energy from battery. Sometimes, the battery is not able to provide the required amount of charge which affects the coolant flow, leading the inefficient cooling system. Sometimes electrical pumps are not able to provide high flow of coolant in comparison to mechanical pump.

Electro Mechanical Pump

The electro mechanical pump is the need of hour as it removes the limitation of mechanical and electrical water pumps. The electro mechanical consists of two drive mechanism to regulate the flow of coolant in the engine. The mechanical system functioning consists of belt drive

from the crankshaft pulley to empower the pump. The electrical water pump gets the energy from battery to drive the flow of coolant. The electro mechanical pump work on the electromagnetic clutch mechanism to switch from mechanical to electrical system or vice versa. The electro-mechanical water pump works according to need of the coolant flow for enhancing engine life, reducing brake specific fuel consumption and reduction in emissions. The electro mechanical pump consists of control valve which is mapped by ECU, when the electrical pump stops operating, the valve which is placed in the parallel path open and coolant flows from the tank to mechanical pump.

Coolant flow strategy during warm up time

The engine needs zero flow strategy or minimum flow strategy during warm up time, and the electro mechanical pump empowers this capability. The engine cooling system works on electrical system at the warm up time and at infrequent intervals where the variable flow is needed to optimize for best results. The use of electrical pump at initial phase and when the temperature is not high in the cylinder provides optimized coolant flow by managing the voltage of water pump. The movement of coolant is easily accomplished by regulating the speed of the electrical pump. The K-type thermocouples are used to take the cylinder temperatures which guides the type of pump needed for operation. The electrical pumps are used at low temperature of cylinder as less amount pf coolant is required to dissipate heat. The electrical pump is mapped by ECU which operates on the input of cylinder temperature and engine rpm. The electrical pump is suitable for lower rpm, and sporadic rpm as varying coolant flow is required to dissipate the heat inside engine. The coolant flow strategy wholly depends on the engine revolutions per minute, warmup time, chamber temperature during warm up. The engine requires zero flow or optimised during warm up time. The warmup time varies with the ambient temperature, like for the country like with the average temperature around 30 degrees Celsius, the warm up reduce to 60 seconds. The warm up time in colder regions reaches to around 8 minutes. The coolant flow must vary according to warm up time and warmup temperature. The electro mechanical pump empowers the engine cooling system to lead zero strategy and provides stable combustion. The engine does not need coolant flow during warm up time as it reduces the amount of required heat for better combustions and leads to unstable combustion. The engine easily gets warmup in less time in country like India, the engine chamber requires cooling at chamber inline.

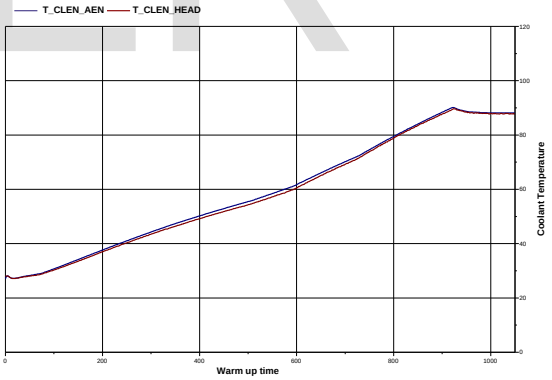

Figure 3: Effect of optimised coolant temperature during warm up time

The electro mechanical pump which is empowered by ECU mapping, takes the chamber temperature data and provides optimised flow of coolant. The optimised provides better combustion, reduces brake specific fuel consumption and also reduces emissions. The electrical pump optimizes its flow and uses only 60% of conventional flow to optimize and increase engine life,

reduce exhaust emissions and improve BSFC. The 60% coolant provides stable combustion by not flowing unnecessarily at the warm up time. The vehicle in city drive where the engine cylinder temperature changes continuously, the mechanical pump provides the same type of coolant flow which provides optimized cooling. The mechanical water pump provides adequate coolant flow for dissipating the heat produced at high temperature, as crankshaft belt driven mechanism drives it. The mechanical water pump provides required flow of coolant to enhance the cooling functioning. The electrical system issues are also removed by the mechanical pump, which helps at the time of breakdown of electrical pump. The ECU mapping empowers to switch the pumps according to need.

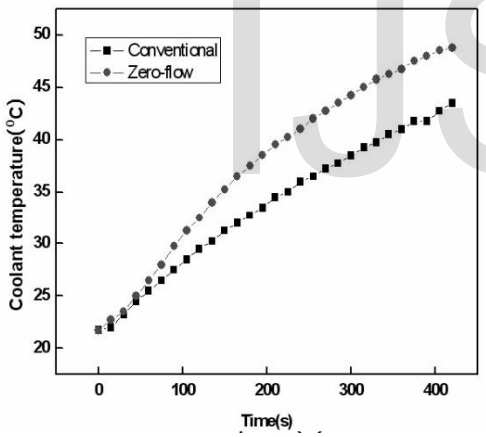

Figure 4: Effect of the zero-flow strategy on an increase of coolant temperature.

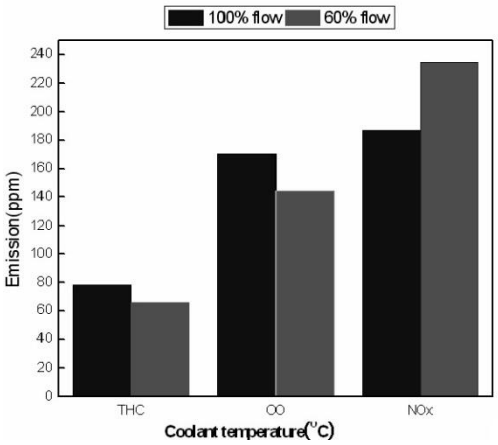

Figure 5: Effect of water pump speed on exhaust emission.

Coolant flow v/s engine rpm

The engine cooling system mainly depends on the engine rpm. The coolant flow is mapped according to engine revolutions per minute. The increase in engine rpm, leads to increase in engine temperature which requires more coolant flow to provide efficient cooling. The better coolant flow helps to dissipate heat efficiently, lead to better engine life. The electro mechanical pump provides the efficient cooling strategy by proving the optimised flow according to different rpm and load factors. The electro mechanical pump is a pair of electrical and mechanical pump which is connected through electromagnetic clutch mechanism. The electrical pump provides coolant flow at sporadic rpm and when low coolant flow is required. The electrical system provides optimised coolant which vary by the change in engine rpm or even at the chamber temperature. The pump is responsive for best cooling mechanisms, which drives the coolant to dissipate heat to the maximum level. The mechanical pump is helpful at high engine rpm and constant rpm where high flow of coolant is required. The electrical pump has limitations of high coolant flow which is eliminated by mechanical pump. The mechanical pump is connected by belt

which is driven by engine crank shaft to flow maximum coolant in comparison to electrical pump which have limitations to its maximum voltage. The mechanical pump overcomes the problem of electrical pump, whose electrical circuit issues can sometime effect the engine cooling system. The usage of electro-mechanical empowers the engine cooling system to provide optimized coolant to increase engine life, along with less BSFC and emissions. The research elucidates the difference of reduced emissions and BSFC.

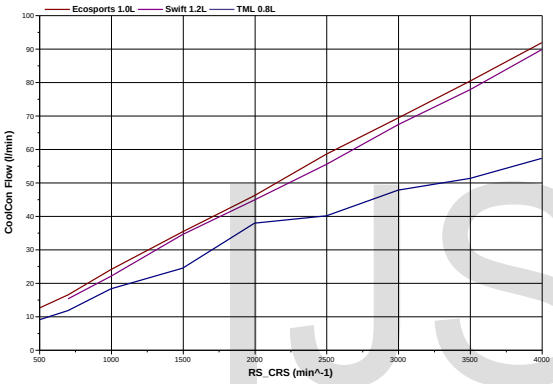

Figure 6: Change in coolant flow with engine RPM.

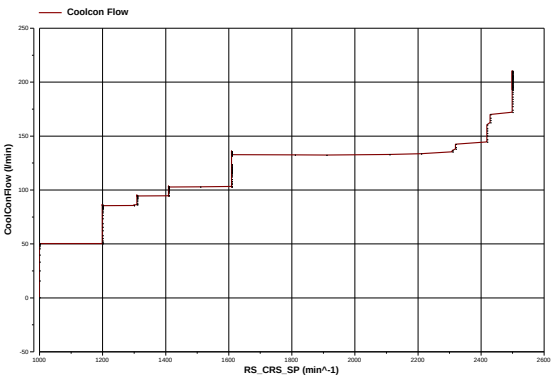

Figure 7: Coolant flow with change in RPM.

Coolant flow v/s brake specific fuel consumption

The brake specific fuel consumption is an important parameter for each and every automobile concern. The BSFC depends on the engine cooling system. The chamber temperature is very important for better and stable combustion. The electro mechanical pump takes the input from chamber temperature and varies its flow according to temperature and engine rpm. The efficient flow helps to obtain and maintain chamber temperature which lead to less brake specific fuel consumption. The efficient flow regulates the temperature which leads to better atomisation, vaporisation and mixing of fuel along with better mixing temperature of air. The optimised chamber temperature leads to better mixing, demanding less fuel, leading to less brake specific fuel consumption.

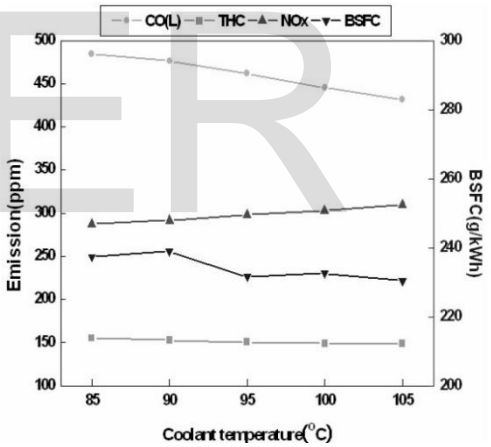

Figure 8: Effect of coolant temperature on emission characteristics and BSFC.

Coolant flow v/s emissions

The engine cooling system controls the emissions same like it controls the brake specific fuel consumption. The electro mechanical is helpful to reduce emission levels and to reach BS VI standards. The efficient coolant flow or zero flow at the time of warmup leads to fast heating of chamber. The fast heating helps to reduce total hydro carbons and carbon monoxide. The total hydro carbons are reduced by

10% which is really significant to achieve future emission norms and carbon monoxides are reduced by 14%. The stable combustion because of efficient cooling mechanism leads to better and less harmful exhaust. The optimised coolant flow leads to better mixing of fuel and air, lead to better combustion and in reduction of THC, Co and particulate matters. The particulate matter is also reduced by 3% as less carbon deposits are formed. The faster heating of combustion chamber leads to more nitrous oxides by 15% but that is resolved by the help of exhaust gas recirculation process. The EGR cooling procedure is also improved by the electro mechanical water pump. The flow improvement helps to provide inlet exhaust temperature of around 105 degrees Celsius. The exhaust temperature condensed down by the help of EGR cooler and it enters intake manifold to react with oxygen to provides diatomic nitrogen from harmful nitrous oxides.

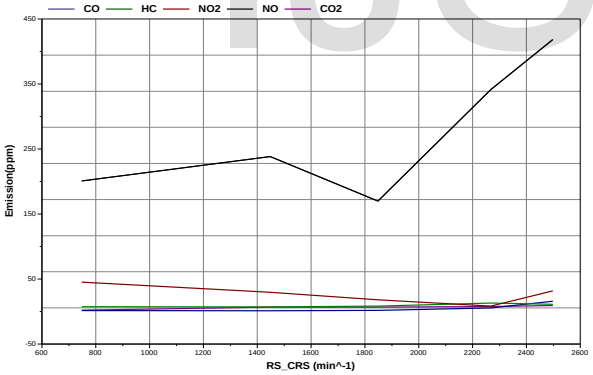

Figure 9: Change in emissions with coolant flow.

Exhaust Gas Recirculation

Exhaust gas recirculation help to reduce nitrous oxide emissions in gasoline or diesel engine by recirculating some amount of engine's exhaust gas back to the engine cylinder. The following process reduces the amount of diatomic oxygen in the incoming air stream and produces gasses inert to combustion to perform as absorbents of combustion heat to reduce peak in- cylinder temperatures. The exhaust gas temperature is lowered by a heat exchanger to permit the introduction of a greater amount of recirculated gas. The exhaust gas recirculation technique reduces half of the nitrous oxides emissions. The EGR improves throttling loss on spark ignition engines at part load. In diesel engines, the gas recirculated by the EGR system is considerably hot. So, an EGR cooler is employed to reduce the temperature of the exhaust gasses before they enter the engine. The cooler helps the EGR system to facilitate its prime function of decreasing cylinder temperatures and NOx emissions. An EGR cooler is a device that cools the exhaust gasses much in the same way as the radiator using fins, engine coolant, and ambient air. The engine improves through the reduced cylinder temperature which leads to the better combustion process. The chemical disassociation also reduces as the lower maximum temperatures result in more of the released energy remaining as sensible energy near top dead center. EGR cooler plays a vital role in reducing the temperature of exhaust gases and leading to fewer nitrous oxides formation. The EGR cooler is a chamber where the gases are cooled down by the help of flowing coolant at cooler outside jackets. The coolant helps to lower the temperature and provide the exhaust gases at less temperature to intake which prevents less formation of nitrous oxides during combustion. The water pump manages the EGR coolant flow. The electro-mechanical water pump helps to optimize flow which lowers the exhaust gas to the best-needed temperature because unwanted lower temperature will also bring problems during combustion. The exhaust gas temperature varies with the engine speed, combustion development, fuel and valve

timing and that is why the role of the electro-mechanical pump is crucial. The electro mechanical pump varies the flow of coolant according to the need. The time when EGR cooler requires high cooling capabilities and that too for a long time, the mechanical pump will do the functioning. The time when variable coolant flow is necessary, and at irregular intervals electro-pump will come into play by switching from mechanical system by the electromagnetic clutch system. The electrical pump provides variable flow as its speed can be varied according to need, and the valve control also provides the exact amount of coolant flow required inside the EGR cooler chamber.

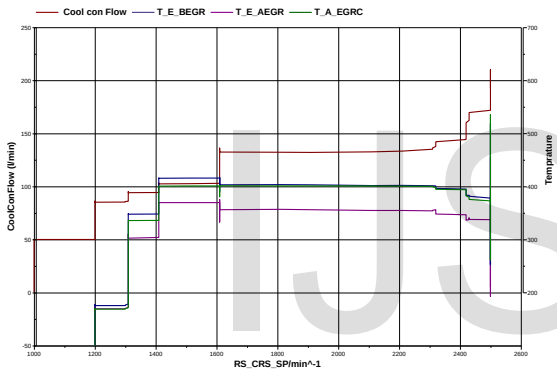

Figure 10: Effect of optimised coolant flow on EGR

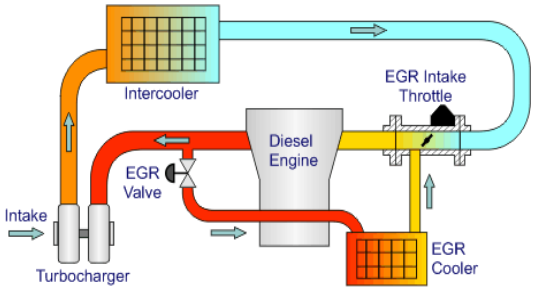

Figure 9: Engine Gas Recirculation

Conclusion

The electro mechanical pump provides the best path to reduce emissions, brake specific fuel consumption, unstable combustion along with increases engine life. The optimised coolant flow helps to attain future emission norms easily. The mentioned technology is inexpensive in comparison to other technologies like DPF, DOC, SCR and more suitable in terms of ergonomics of the vehicle. The other techniques require more space to adjust in the vehicles, but on boarding electro mechanical pump is comparatively easy. The engine life is also increased a lot as the optimised coolant flow along with better heat dissipation, also help to remove scaling, corrosion and rust. The engine cooling system is transformed by the help of electro mechanical pump as it regulates coolant flow with engine rpm, warmup temperature and warm up time. The ability to reduce the level of hydrocarbons, nitrous oxides, particulate matters and carbon monoxide is boon for the society.

References

[1] John B. Heywood, Internal Combustion Engine Fundamentals, McGraw-Hill International Editions.

[2] P. Revereault, B. Gessier and M. Chanfreau, Intelligent vehicle system thermal management in a mild hybrid-diesel vehicle, IMechE 2003, 545-560.

[3] M. Chanfreau, A. Joseph, D. Butler and R. Swiatek, Advanced Engine Cooling Thermal Management System on a Dual Voltage 42V-14V Minivan, VTMS5 SAE 2001-01-1742.

[4] John R. Wagner, Venkat Srinivasan and Darren M. Dawson, Smart Thermostat and Coolant Pump Control for Engine Thermal Management Systems, SAE technical paper 2003-01-0272.

[5] Franz W. Koch and Frank G. Haubner, Cooling system Development and Optimization for DI Engines, SAE 2000-01-0283.

[6] Ngy-Srun Ap, Philippe Jouanny, Michel Potier, Jerome Genoist, Ultimate Cooling System for New Generation of Vehicle, SAE 2005-01-2005.

[7] D. J. Allen and M. P. Lasecki, Thermal Management Evolution and Controlled Coolant Flow, SAE Paper 2001-01-1732, 2001.

[8] E. Cortona, C. H. Onder and L. Guzzella, Engine Thermomanagement with Electrical Components for Fuel Consumption Reduction, International Journal of Engine Research, 3 (3) September 2002.

[9] J. R. Wagner, V. Srinivasan and D. M. Dawson, Smart Thermostat and Coolant Pump Control for Engine Thermal Management Systems, SAE Paper 2003-01-0272, 2003.

[10] R. D. Chalgren, Development and Verification of a Heavy Duty 42/14V Electric Powertrain Cooling System, SAE Paper 2003-01-3416.

[11] Robert D. Chalgren Jr., Thermal Comfort and Engine Warm-Up Optimization of a Low-Flow Advanced Thermal Management System, SAE Paper 2004-01-0047.

[12] N.-S. AP, P. Guerrero, P. Jouanny, M. Potier, J. Genoist and J. L. Thuez., Ultimate Cooling new cooling system concept using the same coolant to cool all vehicle fluids, IMechE 2003 661-674.