Contribution of fan and water pump drives to energy efficiency and reduction of emissions for commercial vehicles

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ABSTRACT

The adoption of the Proconve P8 regulation, which further restricts the emissions of the Brazilian fleet, raises the discussion and the need for more efficient energy control in vehicles. The fan and the water pump are elements of the thermal management system and the activation of these components has a direct influence on the energy efficiency of the vehicle.

Focused on fuel economy and emissions reduction of vehicles equipped with an internal combustion engine, new technologies were developed for the forced ventilation and water pump systems, so that they are activated only when necessary, among these technologies, the visco clutches electronically controlled have the advantage of having greater precision in the actuation control.

For electric and hybrid commercial vehicle applications, the use of electric motors as fan and pump drivers is a necessity. In this case, the High Voltage Fan and High Voltage Coolant Pump can work with high voltages, without the need for converters, eliminating electrical losses.

This work evaluates the contribution of drives for fans and water pumps in reducing emissions and improving energy efficiency for commercial vehicles with internal combustion engines, electric and hybrid.

INTRODUCTION

The growing demand for reducing emissions brought the need for new, even more restrictive legislation regarding greenhouse gas emissions, in the case of Brazil, the new Proconve P8 legislation, equivalent to the European legislation Euro VI, was introduced in January 2023.

In this context, thermal management in engines assumes great importance, since the technical solutions to keep up with the requirements of the new emission laws will demand cooling systems with greater thermal dissipation which will require more powerful fans and pumps.

Another technology that the automotive industry has also used in this context is the electrification of vehicles, thus, electric power trains are also being developed for commercial vehicles in order to reduce dependence on fossil fuels.

The thermal management system of vehicles equipped with an internal combustion engine ECI or electric engine plays an important role in energy management, and can contribute significantly to reducing fuel consumption and/or battery energy conservation.

The fan and the water pump are two components of the thermal management system that demand power in their activation, the evolution of the controls and modularization during operation bring great energy savings to the vehicles.

In the case of electric vehicles, the fan and water pump actuators are electric motors, nomally controlled by PWM, while for internal combustion vehicles, the applied technology is the electronically controlled viscous clutch with variable activation for fan and water pump.

E-VISCO – PRINCÍPLE AND STRUCTURE

The most advanced system for commercial vehicles with an internal combustion engine is the electronically controlled clutch, E-Visco. By this principle, torque is transferred from the engine's crankshaft or a remote pulley to the fan through the shear friction of a specific fluid found inside the clutch.

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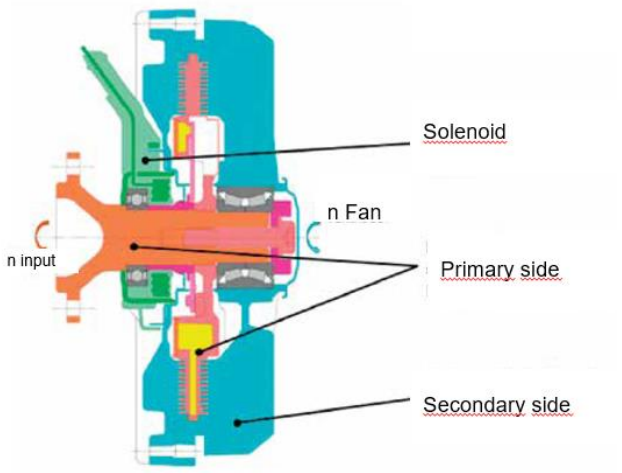
In figure 1, the input side of rotation is called the primary, in which the primary disc and shaft are rigidly connected, it is powered by the rotation of the pulley or directly from the engine crankshaft. The drag side, secondary, is made up of the casing that surrounds the primary disk and has the fan connected to it.



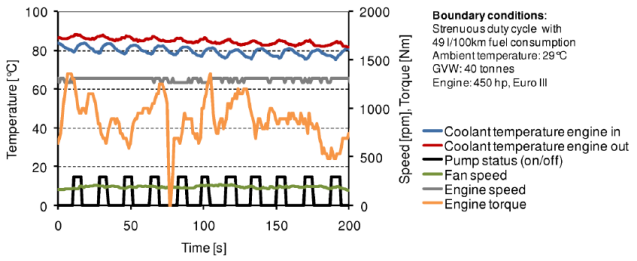
Picture 1. Visco Clutch section [MAHLE] [3] [4]

WATER PUMP DRIVER

The water pump is one of the biggest consumers of engine power among auxiliary systems, it is usually connected to the engine shaft by a set of pulleys and without drive control, which results in an unnecessary fluid flow in many conditions of operation. Thus, controlling the required coolant demand at each stage represents an important energy saving opportunity.

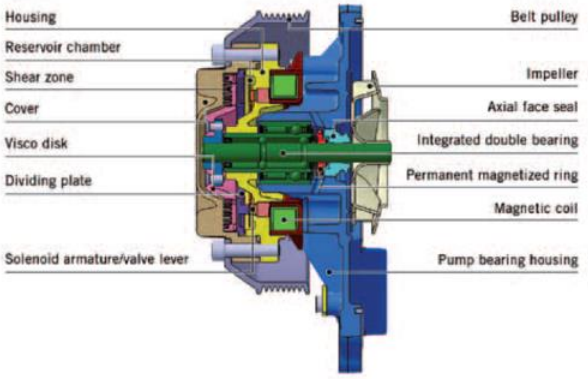
One of the possible technologies for activating the pump on demand is the intermittent electric clutch, also known as on-off.

In a measurement carried out in a vehicle with an internal combustion engine, the water pump with on-off actuation control showed savings of 480W, when compared to a pump without actuation control, in energy consumption, which may represent up to 0.5% fuel savings in long distance.



Picture 2. Graph with cooling fluid temperature behavior and on-off pump activation [MAHLE] [2]

The continuous variable control is possible with the application of the electronically controlled visco clutch in the water pump, the so-called E-Visco Water Pump.



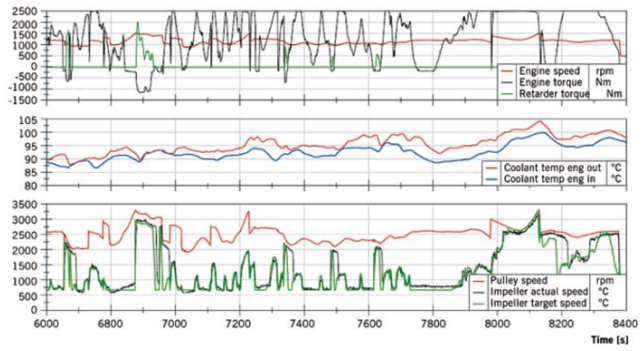
Picture 3. E-visco Water Pump Section [2]

The water pump controlled by the visco clutch has advantages over the on-off intermittent control because it is possible to modulate the pump rotation speed according to the demand.

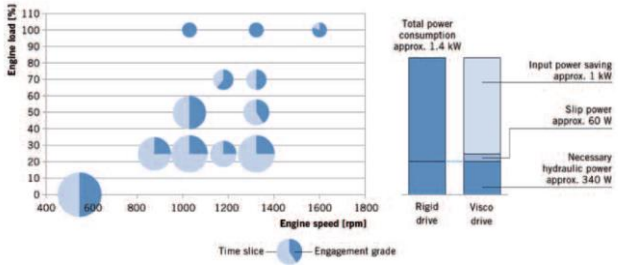
For an engine with EGR, compared to an engine without EGR, pump speed control is of particular interest, since the fluid flow required is greater to meet the thermal rejection of the engine.

Assuming a long-distance application, a reduction in average drive power from 1.4 to 0.4kW can be calculated. Extra heavy 40-ton trucks use 100kW of power to overcome resistance such as air and friction with the asphalt at a speed of 80km/h on a flat track.

Reducing the energy expenditure of the engine to drive the water pump by 1kW would correspond to a 1% reduction in fuel consumption. These values are totally dependent on the driving conditions of the vehicle.



Picture 4. E-visco variable drive pump power graph [MAHLE] [3] [5]



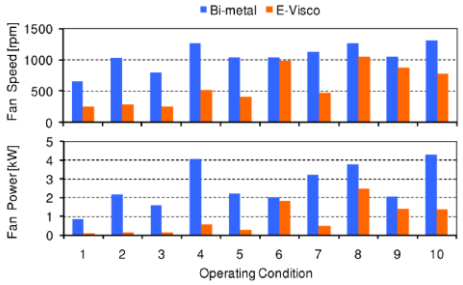
Picture 5. Calculation of fuel consumption reduction when loading in the WHSC profile. [MAHLE] [3] [5]

For electric vehicles, the water pump must be driven by an electric motor, as commercial vehicles, due to the need for high torque, use high voltages (800 Vdc), high voltage drivers were developed, the so-called High Power Electric Coolant Pump, which dispenses DC/DC converter and eliminates electric losses from the vehicle.

FAN DRIVERS

The electronically controlled clutch makes an efficient contribution to reduce the load on the engine caused by the fan during operation, especially when a high-power fan is required.

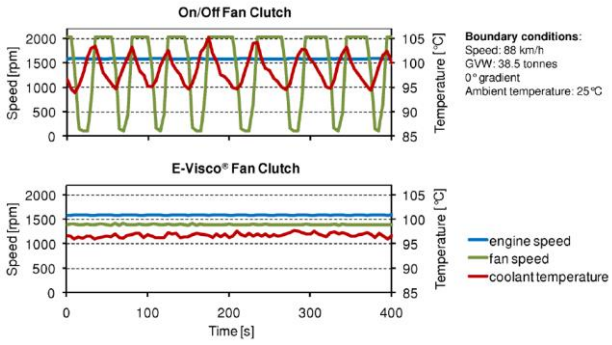
The bimetal visco does not measure the coolant inlet temperature in the radiator, instead, the actuation is done indirectly through the temperature behind the radiator. Thus, to avoid overheating, the bimetallic visco clutch must be activated, even with the coolant at lower temperatures.



Picture 7. Comparison graph of power in application between bimetallic clutch and E-visco [MAHLE] [2]

In comparison with the bimetal, the electronic visco, E-visco, presents reduction of 2% of fuel consumption, since many operating points can be fulfilled with lower air flow at lower fan speed.

Another clutch available on the market to drive the fan is the intermittent drive, also known as on-off.



Picture 7. Comparison graph of power in application between bimetallic clutch and E-visco [MAHLE] [3] [5]

Compared to the intermittent actuation clutch, the electronically controlled visco clutch has some advantages and it is able to reach 48% reduction in actuation power and 2,8% in fuel consumption, due to the possibility of modulation of fan rotation in intermediates speeds.

The new family of electronically controlled viscous clutches presents some evolutions, one of them is the greater control range from 0.1 to 0.95 of the fan input speed, which contributes to fuel saving and brings greater comfort to the driver since the fan starts operating more smoothly but quickly.

The drag rotation also decreased, reaching values close to those achieved by intermittent drive clutches, in the range of 120 to 160 RPM.

For electric commercial vehicles, the application of the High voltage Fan, similarly to the High Power Coolant Pump, eliminates the need for an on-board DC/DC converter. Offered in a modular design covering a performance range from 5 to 15kW and with diameters

from 500 to 650mm, it is possible to use it as a dual fan concept for higher power demand applications.

Motor	8-blade Ø500mm	13-blade Ø500mm	8-blade Ø650mm	13-blade Ø500mm
5 kW	x			
10 kW		x	x	x
15 kW		x	x	x

Picture 8. Fan size and power available for High Voltage applications [MAHLE]

CONCLUSION

The use of variable drives for fans and water pumps represents an important contribution in terms of reducing fuel consumption for vehicles with internal combustion engines.

The evolution from the bimetallic visco to the electronically controlled E-visco is a further contribution to the gain over rigid drive.

Intermittent actuation, on-off, also present gains in relation to the rigid actuation, however they do not present the same modulation performance as the E-visco.

Thus, E-visco as a driver of pumps and fans are the greatest contribution to reducing fuel consumption, from 1 to 2,8%, and consequently reducing emissions for commercial vehicles with internal combustion engines.

For electric commercial vehicles, the advantage of using high voltage and high power fans and water pumps is to eliminate DC/DC converters what also contribute to decrease thermal demand of the vehicle.

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