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Development of a Sliding Vane Rotary Pump for Engine Cooling

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Abstract

The efficiency of a pump for engine cooling system in automotive sector can be very low (15%-20%) during the homologation cycle which is more oriented to medium and low engine loads. Actual pump technology makes reference always to centrifugal pumps, which suffer in terms of efficiency when the speed changes as well as when head and flow rate delivered. In order to reduce the power absorbed by the pump, a different type is needed.
A sliding vane rotary pump (SVRP) is a serious alternative having all the characteristics to fulfil the engine cooling circuit with high efficiency and reliability. In this work, a SVRP has been designed, built and tested for an existing engine cooling circuit: its performances were compared to the traditional (centrifugal) pump which today is mounted on that engine. The benefits over the homologation cycle in terms of mechanical energy and CO_2 saving have been emulated thanks to a comprehensive mathematical model.

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Keywords: engine cooling; sliding vane rotary pump

1. Introduction

As part of a policy aimed at reducing air pollution and optimizing fuel consumption, over the years, regulations governing the automotive industry have become increasingly stringent. In response to these needs, the research has therefore stepped up its efforts in the direction of several technological options which can participate to an overall energy consumption and emission reduction of the vehicle (Fig. 1).

In Fig. 1, "thermal management" is referenced as the plurality of the technologies which are referred to the engine cooling and vehicle thermal needs.

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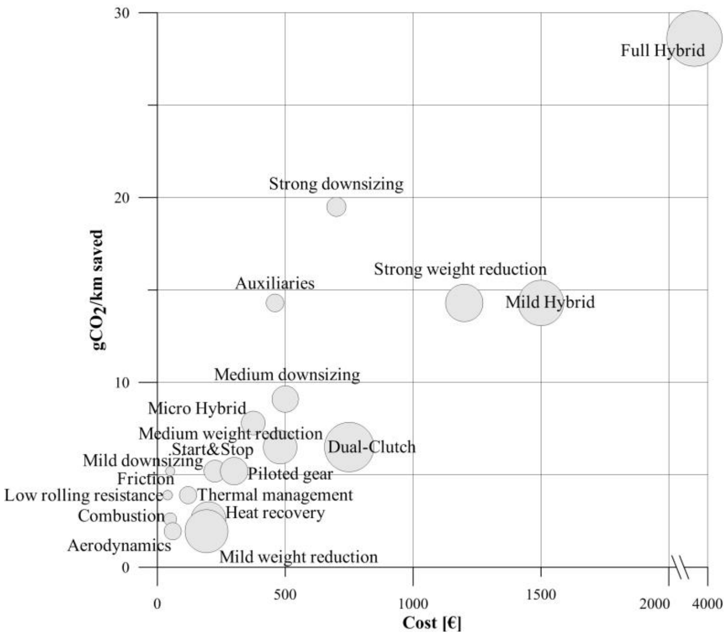

Fig. 1: vehicle cost increase expected and potential CO_2 saving for automotive technological options. Ball size represents specific costs [1]

Among the different options available, engine cooling system, which have remained almost unchanged in last decades, could produce significant fuel and CO_2 savings with a very low expected cost increase if revised. Fig. 1 shows that a cost of 25 €/gCO_2 is acceptable. In addition to the fundamental purpose of removing heat and maintaining the mechanical parts of the engine at a temperature compatible with the proper functioning and strength of materials, during last years other important functions have been added to the cooling systems. For example, exhaust gas recirculation and compressed air cooling as well as integrating important thermal needs of the vehicle (cabin heating and cooling) which progressively increase the overall complexity and specifications (radiator size, heated thermostat).

The fundamental component in the engine cooling system is the pump: it must fulfill the circuit requests in terms of coolant flow rate and pressure rise, which depends on fluid dynamic flow passages and layouts. Typically, a centrifugal pump driven by the engine is used in such system, with a significant low efficiency especially at off-design conditions, as they usually are in an internal combustion engine in the transportation sector due to its speed variations and to the head and flow rate requested by the engine.

In recent years, cooling fluid circulation control was the main aspect: electrical water pumps or electromagnetically or mechanically switchable water pumps have been proposed [2, 3, 4] and put on the market. New pump arrangements were proposed including devices to stop the flow or to reduce it according to controlled variables [5, 6, 7]. All of these were mainly directed to the reduction of the engine warm up time, this phase being responsible of 60% of the overall harmful emissions during a homologation cycle [8]. A faster warm up, also, participates in a positive way to the CO_2 emission reduction, thanks to the benefits on the mechanical efficiency due to friction reduction. A system view of all the thermal needs on board (engine & vehicle) is expressed by other cooling technologies which introduce multiple cooling circuits (operating in parallel) at different temperature levels [9, 10, 11], rearranging engine thermal needs with those of the vehicles [12, 13]. Other studies are focused on the benefits of phase changing coolant to seriously decrease the flow rate delivered [14] or insuring different cooling temperature levels between head and engine block [15, 16, 17]. All these technologies are mature but, for cost reasons, they are struggling to reach a wide application: some of them were also conceived to improve traditional engine performances and component size.