

Advanced Dual Level Vehicle Heat Rejection System for Passenger Cars

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ABSTRACT

In perspective of the incoming CO₂ emission regulation, the on board heat management is becoming even more relevant to assure the engine performance improvement minimizing the impact on the vehicle lay out, cooling drag and cost. The paper highlights the benefit of dual level heat rejection system where the conventional front module is replaced by a two coolant-to-air exchangers and where the charge air cooler and condenser are liquid cooled. This approach allows to review the engine bay design allowing a deeper integration level: the charge air cooler can be integrated in the air intake manifold while the condenser can be placed near the compressor minimizing the tube lengths and refrigerant charge. In addition, the coolant thermal inertia reduces the temperature fluctuations of the engine intake air temperature. These effects compensate the introduction of an intermediate temperature level allowing to reduce the overall vehicle fuel consumption in real use and could enable the front aerodynamic improvement. The paper is focused on the system description and on the result acquired validating two B-segment prototypes one having a diesel engine and the other having a gasoline engine. The experimental results show that the approach allows to improve the vehicle performance, simplify the engine bay lay out and to reduce the fuel consumption of up to the 4% when the air conditioning is operating. These results complete the integrate the work presented in 2011 at the VTMS.

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INTRODUCTION

The European Commission is promoting the reduction of the CO₂ and CO₂-equivalent emissions of road transports thanks to and Integrated Approach mainly based on:

- a regulatory framework for reducing the CO₂ emissions of the average new fleets [1]
- the replacement of the air conditioning refrigerant with more environmental friendly alternatives [2]
- the technology development sustaining the research in the domain with the Green Car Initiative and other funding measures

In the overall effort to achieve sustainability, advanced technological solutions have to be developed to reduce fuel consumption and carbon dioxide emissions from vehicles. In the scenario towards more efficient road transports the improvement of the on board thermal management could play a relevant role enabling a finer subsystem control, more

compact engine and engine compartment packaging and the cooling drag reduction.

Following the state of the art approach, each subsystem (e.g. charge air cooler, condenser, engine coolant, oil cooler, ...) has its own cooling system where the fluid-to-be-cooled is brought on the front of the vehicle and then back in the engine compartment.

This approach implies that:

- the front end module changes according to the powertrain and to the optional equipment making more difficult to optimize the vehicle aerodynamics
- all the subsystems share the same fan and it is activated on a single system need; this implies higher energy demands
- the introduction of new subsystems (e.g. electronics, e-motor, batteries) will require a proper cooling system and any additional heat exchanger on the front has a negative impact on cooling drag and heat rejection





Figure 1. The Fiat Punto Evo- B segment car: wheel base 2510 mm, length 4030mm, width 1687 mm, height 1490 mm

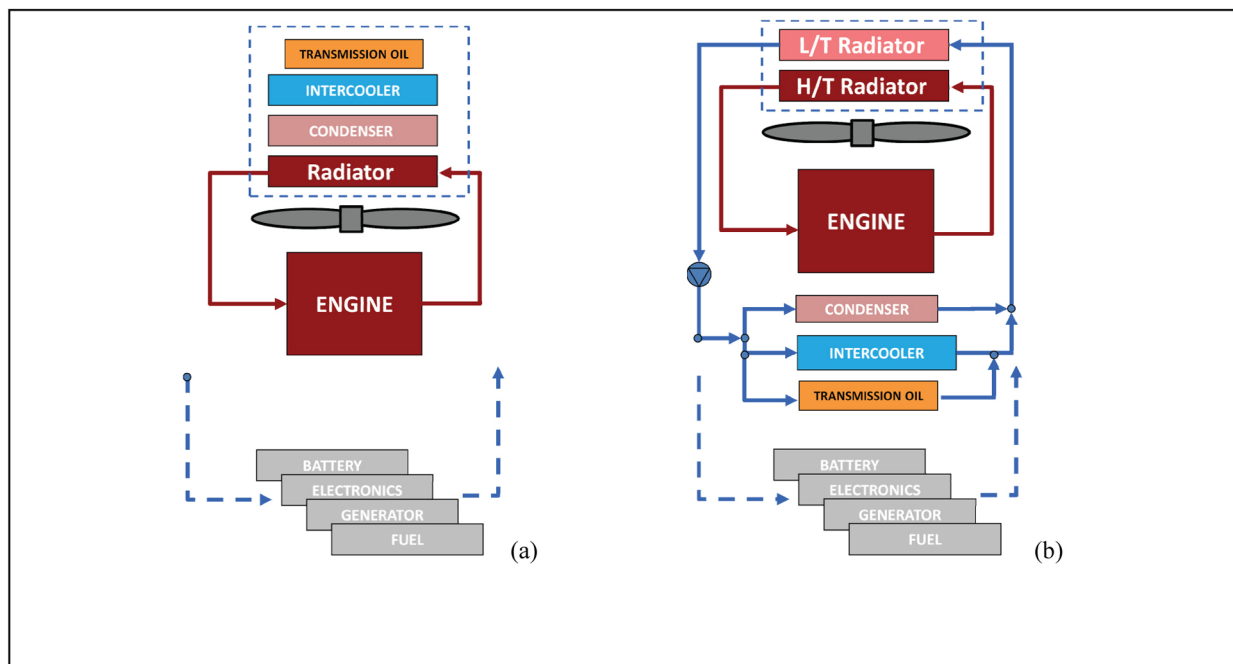


Figure 2. Standard System (a) and Two-levels heat rejection approach (b) allows to increase the modularity and standardization simplifying the thermal module and enabling the aerodynamic improvement of the overall vehicle

- in case of small accident the exchangers could be damaged and the fluids dispersed in the environment (refrigerant, oil, ...)

To overcome to these points and to enable the design review of the engine compartment and of the vehicle front it has been evaluated an approach based on a simplified version of what already presented by Valeo [3] in the recent past and where the coolant is brought in the subsystems-to-be-cooled, but the engine, and then to a radiator placed in the front of the vehicle (Figure 2). This concept enables to

- standardize the vehicle thermal module and optimize the front end aerodynamics;

- activate the fan only on the basis of the average needs: the thermal inertia of the shared coolant allow to buffer the heat rejection need;
- reduce the “fluid-to-be-cooled” amount (e.g. air conditioning refrigerant);
- integrate the fluid coolers in the subsystems (e.g. charge air cooler in the air intake manifold);
- share the cooling loop cost among the systems;
- limit the impact on the front end architecture and size (modularity) in case of an additional (e.g. electronics, e-motor, batteries) cooler is required;

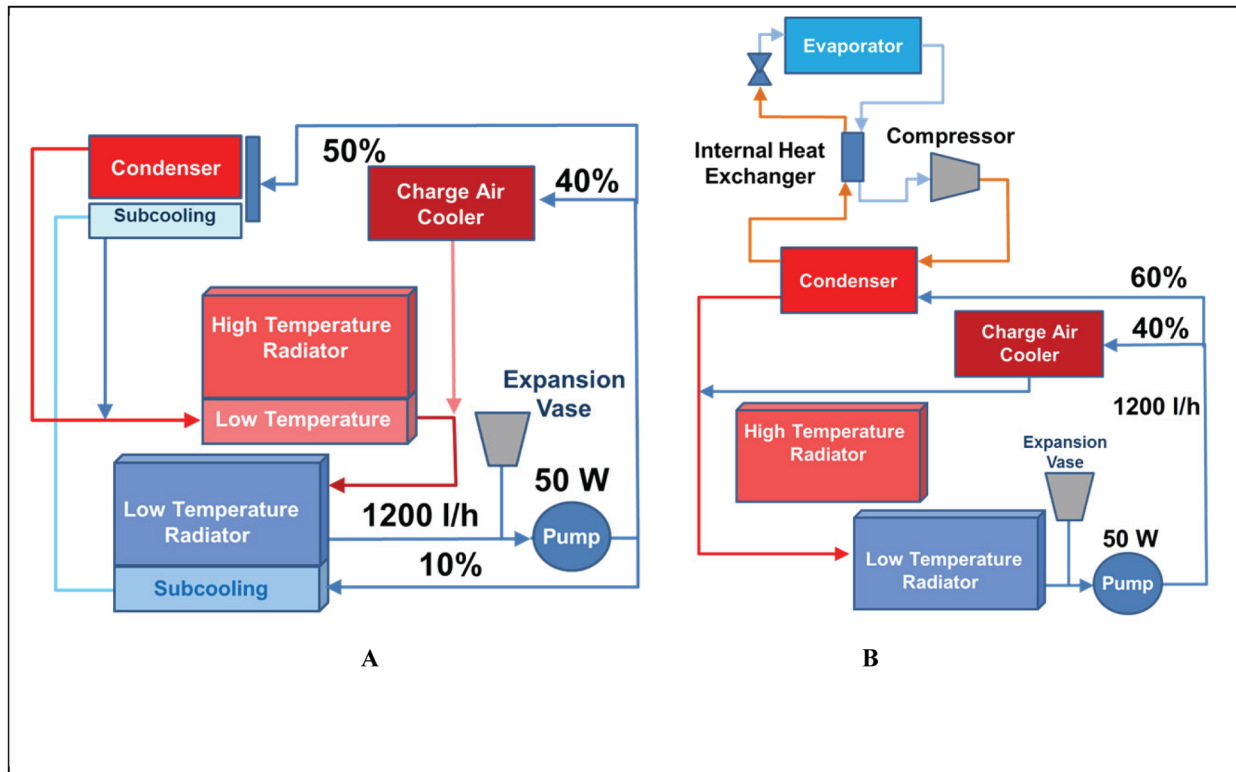


Figure 3. System architecture. (A) with subcooling branch - (B) without subcooling and with internal heat exchanger. The configuration A has been adopted as preferred in terms of performance and simpler layout and components

- limit damage and fluid dispersion (only water-glycol) in case of small accidents;
- reduce the refrigerant charge

PROTOTYPE SYSTEM

The adopted system scheme is shown in figure 3: the high temperature loop is almost unchanged while a low temperature loop is devoted to changer air cooler and condenser cooling. An electrical pump assures the coolant flow in the low temperature loop while, to keep the system simple, no valves have been integrated.

Two possible configuration have been evaluated one with subcooling loop and one without subcooling loop but with the adoption on an internal heat exchanger on the refrigeration loop.

This second has been preferred due to the simpler lay out and components and estimated better performance.

The system has been prototyped first on a Fiat 500 85 HP MultiAir (gasoline 2-cilynders turbocharged engine) with MTA and experimentally validated [3].

Then, after having collected good and promising results, to verify the effectiveness on b-segment the same approach has been adopted to design and realize two new prototypes based on the Fiat Punto EVO, one with the 1.3 MultiJet diesel engine and one with the 1.4 MultiAir gasoline engine.

Being very similar the results collected on both the systems, only the one on the diesel version are here reported.

The Figure 4 shows the impact on the system packaging and highlights how the replacement of the standard charge air cooler allows to simplify the thermal module that becomes constituted by only two heat exchanger and thinner in the lower part. To evaluate the highest integration level, the charge air cooler has been integrated in the air intake manifold and the condenser has been placed near the evaporator and compressor.

The air intake system becomes then more compact and the air ducts shorter, the air conditioning loop is more compact and the front end module is now constituted by only two heat exchangers of identical technology (air - coolant) instead of being constituted by three elements of different technology (i.e. air-to-air, air-to-coolant and air-to-refrigerant).

The higher compactness of air conditioning system enabled a refrigerant charge reduction of about the 20 % (from 450 g to 350 g), that in perspective of the adoption of the HFO-1234yf that is more expensive than the R-134a (e.g. 70 Euro/kg vs 5 Euro/kg), allows a relevant cost saving and eliminates any risk of release in case of small crashes.

The components of the system have been designed and realized in cooperation with leader tier one suppliers that for confidentiality reasons are not here mentioned, and then installed on the demonstrators and experimentally validated. The characteristics of the standard production and dual level cooling main components are reported in table 1 here below.