Experimental studies regarding the influence of the intake manifold material on the thermodynamics processes in the internal combustion engines

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Abstract. The paper presents an experimental stand designed to study the influence of the intake manifold material on the thermal transfer process during intake of air into the engine. For this purpose, the stand allows temperature measurements at different characteristic points for two geometrically identical intake manifolds, but made of different materials. It was taken into consideration the Aluminum alloy intake manifold of the Ford Puma 1.7i and the polyamide intake manifold of the Ford Puma 1.4i. The experimental results were presented in a comparative study where conclusions were drawn regarding the influence of the intake manifold material on the internal combustion engine processes.

1. Introduction

The tightening of global emissions standards and mandated minimum fuel economy requirements for automobile manufacturers have become the primary impetus behind internal combustion engine (ICE) research and development. Gasoline direct injection (GDI), multiple injection, gasoline-electric and plug-in hybrids, and common-rail (CR) diesel engines with sophisticated emissions-reducing after-treatment technology have all recently found their way onto public roads. These environmental constraints, along with the rapid advance of embedded computing power and advanced sensors, are pushing engine research into advanced combustion modes. Various low temperature combustion concepts, including homogeneous charge compression ignition (HCCI) and its variants, are being researched as viable future options for efficient internal combustion engines. The High-Efficiency Dilute Gasoline Engine (HEDGE) research currently focuses on knock-resistant combustion chambers, high-energy ignition approaches, and increases in high brake mean effective pressure (BMEP).[1]

Proper maintenance can help vehicles perform as designed, positively affecting fuel economy, emissions, and the overall driving. This effort investigates the effect of one maintenance factor, intake air filter replacement, with primary focus on vehicle fuel economy, but also examining emissions and performance.[2]

The engine behavior in engine performance, fuel consumption and exhaust emissions aspects are influenced by the magnitude of air intake pressure. It needs to form leaner air fuel mixture to extract more energy from the combustion process. The large amount of air increases the potentiality of fuel chemical elements to be burned with oxygen. As a result, the engine performance and fuel economy are increased while the unburned exhaust emissions components are reduced.[3]
The intake manifold of the Ford Puma, (Figure 1) is located behind the cooling radiator, which leads to a substation heating process resulting in raising the intake air temperature in direct connection with the thermodynamic losses.

**Figure 1.** The thermal field in the engine compartment captured with a thermal imaging chamber

### 2. Experimental setup. Equipment and procedures

Resource intake manifolds stand (R.I.M.S.) (Figure 2) designed for the thermodynamic study of the influence of the intake manifold material on the heat transfer and gas-dynamic process during intake of air into the engine.

**Figure 2.** General view of experimental setup

For this purpose, the stand allows for temperature and pressure measurements at different characteristic points for identical or geometrically different intake manifolds made of various materials (aluminum alloy, polyamide, fiberglass, carbon fiber, etc.).

The R.I.M.S. (Figure 2) is composed of the following parts:
1 – air blower;
2 - throttle valve;
3 - intake manifold;
4 - straight pipe region;
5 - heating source;
6 - digital temperature indicator;
T1, T2, T3 - NiCr-Ni thermocouple sensors (T1 - outside heating air temperature, T2 – inside intake wall temperature, T3 – outlet air temperature).[4]
Figure 3. Intake manifold configuration: a - Ford Puma 1.7i, b - Ford Puma 1.4i, c – virtual model Catia V5
An important factor is that the intake manifold subject to the comparative experimental study respects the mounting positions of the propulsion group (Figure 3).

It was taken into consideration the aluminium alloy intake manifold of the Ford Puma 1.7i (Figure 4.a) and the polyamide intake manifold of Ford Puma 1.4i (Figure 4.b).[4]

![Intake manifolds: a – aluminium alloy intake manifold Ford Puma 1.7i, b – polyamide (PA) intake manifold Ford Puma 1.4i](image)

**Figure 4.** Intake manifolds: a – aluminium alloy intake manifold Ford Puma 1.7i, b – polyamide (PA) intake manifold Ford Puma 1.4i

The program used to acquire the data is Cassy Lab2 software (Figure 5), the temperature was recorded for 40 minutes, second by second.[5]
3. Results and conclusions
In the case of a gallery made of aluminum due to the relatively high heat transfer coefficient, the difference in temperature outside (T1) and the inside (T2) of the wall is negligible, unlike the polyamide in which case the difference is much higher (Figure 7), in the conditions where the thermal source generates the same value of temperature for both cases.

Figure 8 shows that the temperature values indicated by T1 at the outside of the intake manifolds are much higher for the polyamide (PA) than for the aluminium alloy (Al). The explanation: due to the low thermal transfer coefficient of the polyamide, it acts as a thermal barrier resulting in local temperature increase.

From Figure 9 it can be seen that the air temperature inside the aluminium intake manifold is much higher than the air inside the intake manifold of the polyamide with negative consequences on the cylinder filling efficiency.
Figure 7. The evolution of temperatures for polyamide (PA) intake manifold.

Figure 8. Comparative values for outside the intake manifold heated region (T1).
On the other hand, also in Figure 9, we notice that the air intake heating rate is higher for the aluminium alloy, which is an advantage when starting the cold engine.

Figure 10 shows the evolution of air temperature when leaving the intake manifolds. It is noticeable that the temperature of the inlet air to the engine cylinders is higher in the case of the intake manifold made by aluminium alloy.

The analysis of the recorded data shows that the temperature variation in the case of the polyamide intake manifold is between (52-33) °C. In terms of thermal losses, the polyamide is a material that has the subunit heat transfer coefficient, which it recommends for the manufacture of thermally required components.
References

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