Simulation of Thermal Transfer Through the Polyamide Intake Manifold

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The aim of the present study is to model the steady heat transfer of the engine polyamide intake manifold. Under the condition of a steady flow, the intake manifold wall temperature and the intake air temperature were measured to examine the effect of the thermal boundary layer on the heat transfer. Experimental data is used to generate the numerical model of airflow simulation through the intake manifold.

Keywords: intake manifold, intake air, polyamide, numerical simulation

Increasing the use of plastics in designing and revitalizing vehicles in vehicle production will increase the demand for the automotive industry in plastic. Plastic helps car manufacturers reduce their production and assembly costs and produce more attractive and appealing functional designs. The rising demand for vehicles from emerging economies such as China, India and Latin American countries is expected to boost industry. Volatile raw material prices and huge investments in new material research are the major challenges facing industry specialists. Biodegradable plastics such as PHA, PCL and PBS provide a better opportunity for major manufacturers in the machine industry [1, 2].

Composites are any combination of polymer matrix and fibrous reinforcement. Glass, carbon, aramid and other fibers provide strength and rigidity, while the polymer matrix (or resin) made of polyester, polyurethane, epoxy, polypropylene, nylon or other resin protects and transfers loads between fibers [3- 7]. This creates a material with attributes superior to the polymer or fiber itself. In recent years, carbon fiber reinforced composites have applied to light vehicles.

The plastics and polymer components were essential for a wide range of advances in today's safety and performance. Today's plastics generally account for 50% of the volume of a new lightweight vehicle, but less than 10% of its weight, which makes vehicles lighter and more fuel efficient, which leads to low greenhouse gas emissions. Durable, modern components and polymer composites also help improve passenger safety, and car designers rely on the versatility of plastic materials and polymer composites and the aesthetic possibilities of vehicle design. In addition, many plastic resins are recyclable [3, 5, 8].

Modern automobile engines' fuel efficiency improvement and reduction of hazardous exhaust gases are becoming more demanding. In regard to those strict regulations, the previous studies [9- 12] developed the technology to reduce the combustion fluctuation and maintain the constant air-to-fuel ratio.

However, the previous studies [2, 13-16] stated that the combustion fluctuation was increased by increasing the variation in the air-to-fuel ratio due to the heat transfer phenomenon of the intake system, in direct connection with the material (PA66, Al alloy) of the intake manifold (fig. 1).

Fig..1. Polyamide intake manifold

Experimental part

The data required for the numerical simulation model of the thermodynamic processes taking place in the air flow through the intake manifold were obtained with the experimental laboratory equipment specifically designed for this purpose.

The positioning of the experimental stand elements respects the actual intake manifold configuration in the engine compartment relative to the heating source (fig. 2). The stand allows temperature measurements to be made at various points for a Ford Puma 1.4 engine intake manifold made of polyamide (PA 66).

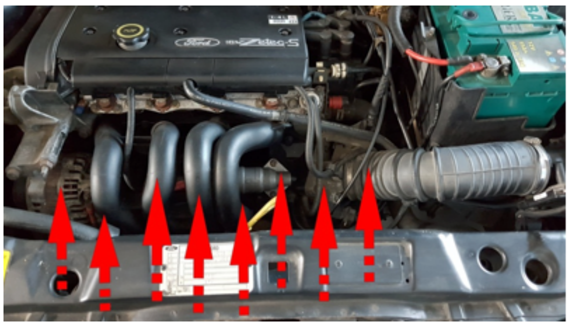

Fig.. 2. Ford Puma 1.4 engine compartment

The experimental stand (fig. 3) contains, a blower (1) and a throttle valve (2) were placed, followed by the intake manifold (3) and a straight pipe region (4). The blower was used to direct intake air into the intake manifold, simulating the supercharging process. Three NiCr-Ni thermocouple sensors were used for temperatures measurements as follows: T1 - outside the intake manifold heated region, measuring the temperature of the air coming from the heat source, T2 - inside of the intake manifold,

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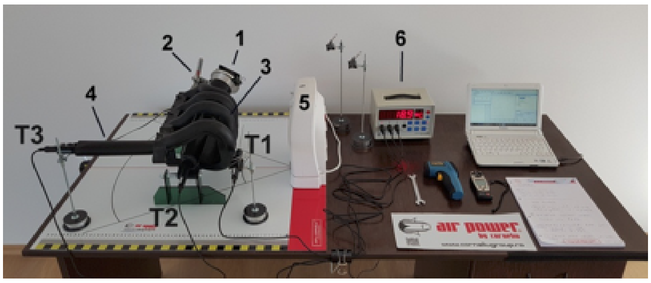

Fig.. 3. General view of experimental setup

measuring the interior wall temperature, T3 - inside the straight pipe region, measuring the temperature of the air that exit the intake manifold. The stand also contains a heating source (5) and a digital temperature indicator (6). Experimental data was acquired with the help of Cassy Lab2 software. The interface of this software is presented in figure 4.a.

The temperature values were taken from second by second to 2500 s until thermal equilibrium was established (fig. 4.b).

After this time the thermal transfer can be considered as a steady state one. In this case, the data necessary for the realization of the numerical simulation model were presented in table 1.

Table 1
EXPERIMENTAL DATA USED FOR THE NUMERICAL SIMULATION MODEL

Intake air velocity through throttle valve [m/s]	1.7
Heating air velocity [m/s]	1.4
Initial temperature of the intake air [°C]	22
Heating air temperature [°C]	50
Thermal conductivity of PA 66 [w/m·k]	0.22

In order to simplify the numerical model, only a part of the intake manifold in the form of a pipe that transports the air to one of the engine cylinders was considered. Thus, the domain of analysis becomes the one shown in figure 5.

The numerical model was developed with ANSYS Multiphysics [17], which is a multi-purpose analysis tool that allows the user to combine the effect of two or more physical phenomena (structural, thermal, electrical, magnetic, electromagnetic, electrostatic, fluid flow).

The following modules were used in the ANSYS package:

- ANSYS Design Modeler (fig. 6.a) that provides modeling tools specific to simulation requirements, including: the ability to modify existing geometry and tools to create the geometric model.

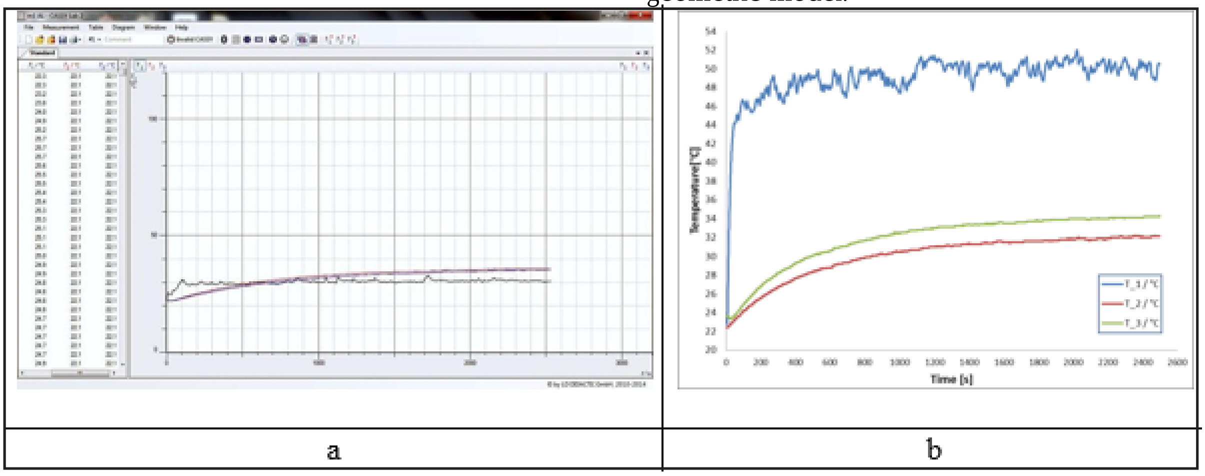

Fig.. 4 CASSY LAB 2 software: a - the interface of the CASSY LAB 2 software; b - the evolution of temperatures

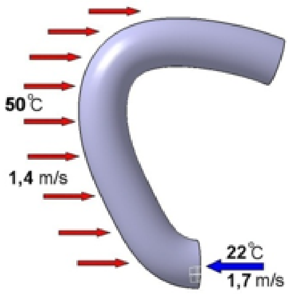

Fig.. 5. The domain of analysis with boundary conditions

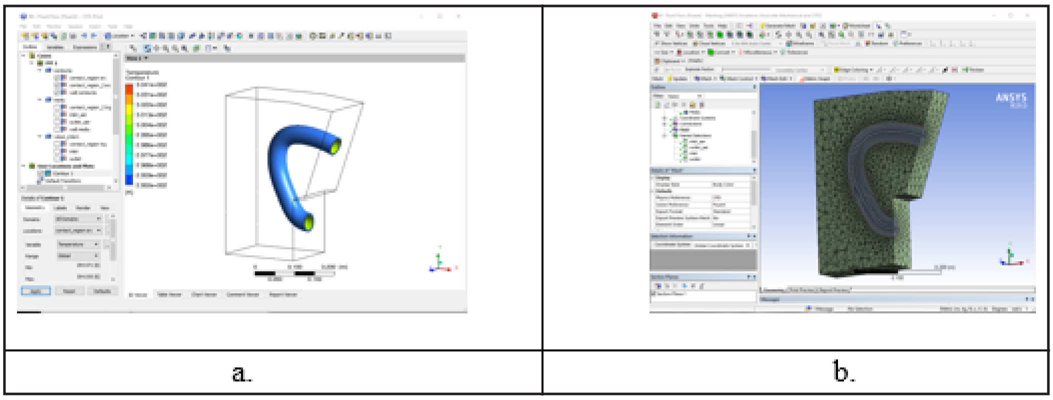

Fig.. 6. ANSYS module interfaces: a - ANSYS Design Modeler, b - ANSYS Meshing

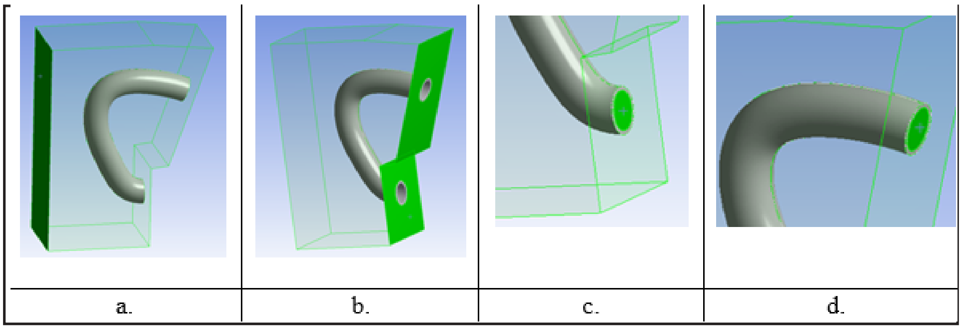

Fig.. 7. Surfaces for data input: a - Surface 1, b - Surface 2, c - Surface 3, d - Surface 4

- ANSYS Meshing (fig. 6.b) provides very complex preprocessing tools with direct connection to solvers. Makes meshing in finite volumes of the domain to be analyzed, depending on the application goal.

- FLUENT is a flexible CFD module, belonging to the ANSYS Multiphysics platform, used for simulations of any complexity. It offers a complete range of physical models that can be used for a wide range of applications across industries.

- CFD Post allows the results to be highlighted both as values and as graphical and imaging [17].

In order to input the data has been defined two surfaces:

Surface 1 - heating air inlet (fig. 7.a); Surface 2 - heating air outlet (fig. 7.b);

Surface 3 - Pipe air inlet (fig. 7.c); Surface 4 - Pipe air outlet (fig. 7.d).

Results and discussions

After running the simulation, the results in CFD Post were:

-temperature field on a median section plane (fig. 8.a);

-current lines depending on temperature (fig. 8.b);

-velocity vectors (fig. 9);

-distribution of temperatures on the surfaces (fig. 10).

Analyzing the temperature difference (approx. 3 ° C) of the incoming air or the exiting pipe, in the case of the stationary thermal regime, we can conclude that the heating of the air entering the engine cylinder is insignificant due to the material from which the pipe is made.

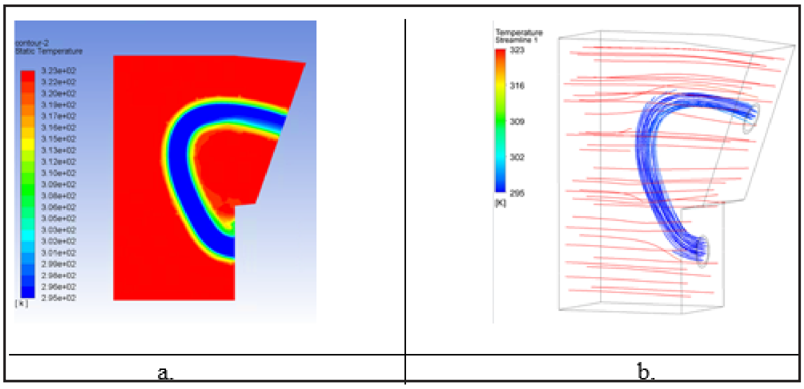

Fig.e. 8. Temperature field on a median section plane (a) and current lines color-coded depending on temperature (b)

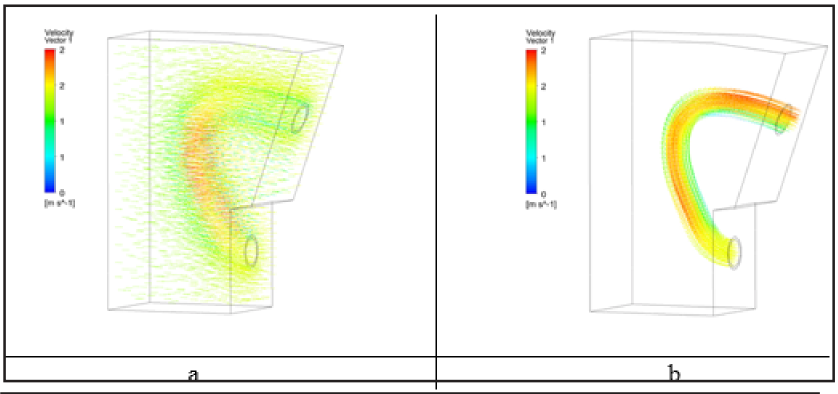

Fig.. 9. Velocity vectors in the outside (a) and inside of the pipe (b)

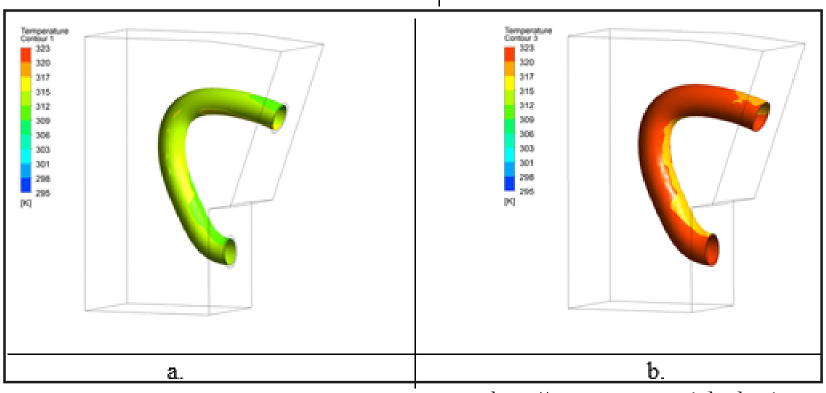

Fig.. 10. Distribution of temperatures on the inner (a) and outer (b) surface of the pipe

Research into the influence of air intake temperature on fuel consumption reveals that a highest value of brake specific fuel consumption (BSFC) was 380 g/kW.hr at higher air intake temperature 30°C, which was 4 % higher than the lowest air intake temperature 20°C at the same engine speed of 1500 rpm. The higher air intake temperature resulted in lower oxygen concentration will lead to a small negative effect on the combustion rate and BSFC [18].

Conclusions

The objective of the present study was to model the steady state heat transfer of the engine intake system through the temperature and flow rate measurements in the intake manifold model. The important conclusions obtained from this study were summarized below.

The numerical model developed in ANSYS allows the study of the heat transfer regime taking into account the characteristics of the material of the intake manifold in particular by the specific heat transfer coefficient.

The data obtained allows new solutions to be found for the thermal optimization of air interaction with the intake manifold walls, in particular to reduce its heating over the intake path.

The low thermal conductivity coefficient of PA 66 keeps the temperature of the intake air relatively constant, with positive consequences on the cylinder filling efficiency. It can also be seen that the difference in temperature between the inner and outer surface of the pipe wall differs greatly, due to the fact that PA 66 is a good thermal insulator.

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