Study case regarding the measurement of an intake gallery airflow

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Abstract. This paper is a scientific approach designed to highlight the importance and relevance of developing and optimizing intake galleries for cars and high-performance vehicles. It is of major importance to get a low fuel consumption and a lower pollution index. It is desirable to get cleaner, recyclable products. Several individual tests, such as computer simulations and prototype testing are being implemented to produce a new product, thus gaining valuable insight into the characteristics of the new product. Also, a major challenge for engineers is the cost and time of getting assemblies and subassemblies done. That is why we are continuously looking for faster production methods in step with technology.

1. Introduction
Intake manifold should provide a uniform fresh charge for each cylinder of the engine, which is an important factor affecting the quality of engine combustion. Intake manifold is one of the main parts of the engine. Its main role is to provide uniform and stable intake air for the engine so as to ensure the intake uniformity of each cylinder. Uneven intake will produce unstable torque output, engine vibration, emissions increase and other problems [1].

The rational design of the intake manifold not only can reduce the inlet pressure loss and increase the intake air quantity, but also can ensure the intake uniformity of each cylinder. Therefore, designing the intake manifold is one of the key technologies of ensuring the engine power, economy, and reliability and emission quality. By comparing the many types of intake galleries, due to construction and dynamic performances and by analysing the operating parameters of a spark ignition engine, a final model for the CBR600 engine was developed. The new intake model has achieved the highest possible performance in a 600 cm³ engine [2].

It has included all the auxiliary elements to be considered such as the fatigue strength of the material, the pressures to which the gallery is subjected, the chemical properties of the substances it will come into contact with. So, we have succeeded in building a prototype stand for testing intake manifold models that aims to real-time simulate air flow through the inlet geometry. It is equipped with various sensors and measuring equipment.
2. Intake manifold testing stand

2.1. Testing approach
The intake manifold test stand aims to measure the air flow, its temperature or, in special cases, the pressure in the intake manifold. This is possible with the help of simple components such as: a stable and modular support, an electric motor attached to a propeller, an air-heating resistor, and sensors for checking the input and output parameters. The support table is made of wood, because it is not a good thermal conductor which makes the measurement of air temperature accurate. The engine that propels the air through the intake pipe is a simple electric motor, with a rated power of 1800 W, this is particularly important because a high air flow is required. The engine can deliver at a maximum power a flow of air at 7.1 m/s. The air-heating resistance can produce 95 degrees Celsius heating over ambient air. This aspect is meant to simulate the air in areas with extremely hot climate, but also the convection heating of the air from the engine heat.

![Figure 1. Working schematics of intake airflow measurement](image)

Based on study of the material properties, it was chosen for the construction of the intake manifold to be used materials as: 7075 aluminium and carbon fibre. Aluminium 7075 is an aluminium alloy, with zinc as the main alloying element. It has excellent mechanical properties and has good ductility, high strength, hardness and good fatigue resistance [3].

Carbon fibre, due to its high strength and low density (low weight), is ideal for the intake manifold that must withstand both pressure variations in positive and negative values. Thornel MAT VST has a tensile strength 1.4 e015 N/m2, density of 2000 kg/m3 [4].

The pipe between the manifold and the intake area of the engine will be made of 7075 aluminium because, first of all, it has to withstand the heat released by the engine without deforming and, secondly, it is a structural part that has to support the rest of the elements.

The technical parameters used in the simulations were: pressure, air flow, flow diagram of the fluid and resistance of the material chosen for the intake manifold. Based on calculus the mass airflow and the density were determined [5].

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\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{const.}, \quad \rho_{\text{air}} = \frac{p}{R \cdot T}
\]

From the simulations performed on the inlet pipe at a positive pressure, it turned out that only the aluminium has a good resistance to stress. Unfortunately, the other materials, plastic and carbon fibre, do not have the strength required to withstand the pressure existing in the inlet pipe, especially if you opt for an air overload model. After the comparison of the different types of materials, it will be chosen for the present application, that the intake pipe be made of Aluminium 7075 SS. The main characteristic considered, besides the particularly good result to the resistance, is the need of the...
material to withstand the temperature released by the engine. For this reason, aluminium is very good for this application. The operating principle of the stand (see Fig. 1) is represented by the introduction of a known air flow in the intake manifold and its measurement at the exit of the gallery. This procedure checks both the leakage losses in the intake manifold and its attachments, as well as the veracity of the design of the effective manifold, because it can be observed when the air flow is evenly proportional on each intake pipe of the cylinder. This equalized air diffusion on each branch is crucial to the smooth running of the engine and high performance.

![Figure 1](image1)

**Figure 2.** Positive/negative pressure of intake manifold table

From the simulations performed on the inlet pipe at a negative pressure, it turned out that only aluminium has a good resistance to stress. Unfortunately, the other materials, plastic and carbon fibre, do not have the strength required to withstand the pressure existing in the inlet pipe, at the vacuum point that the piston inlet stroke can develop, especially in the engine brake. After the comparison of the different types of materials, it will be chosen for the present application, that the intake pipe be made of Aluminium 7075 SS. The main characteristic taken into account, besides the very good result to the resistance, is the need of the material to withstand the temperature released by the engine. For this reason, aluminium is very good for this application [6].

Another advantage presented by the test stand of the intake manifolds is that related to the possibility of dynamic modification of the input parameters. The temperature of the air and / or the introduction of substances into the inlet pipe (such as oil vapours, flue gases) can be controlled and thus data are obtained in accordance with these factors.

3. **Study case**

The air flow measurement is performed using a digital anemometer which determines the air velocity very precisely. The temperature was validated by using an infrared thermometer that calculates the temperature of a portion of the thermal radiation sometimes called the black body radiation emitted by the measured object. These are sometimes called laser thermometers, because a laser is used to help direct the thermometer, non-contact thermometers or temperature guns, to describe the device's ability to measure the temperature at a distance. Temperature measured with the anemometer was similar with the initial temperature, so we determined it by the infra-red thermometer.

In the current application were used two type of intake manifolds (see Fig.3) with different shape and geometry which can accomplished initial requirements.
The test has been made in series of 5 minutes starting from $t_0 = 44^\circ C$ and $v_0 = 3.3$ m/s. The data presented in figure 4 were measured with the infrared thermometer on the intake manifold wall. Can observed that the evolution of the temperature is almost uniform.

**Figure. 3.** Types of intake manifolds (first type a / second type b)

The inside temperature for the two-intake manifold vary in time with 40% for type a and 10% for the type b, measured with a temperature probe.

**Figure. 4.** Evolution of the temperature in the intake manifolds

Explanation between these two factors is that type a gallery has a much larger volume. In this case the air has more surface area to radiate heat through the intake walls. For the type b gallery, the geometry forces the air to have a more direct output through the gallery exhaust ports shortening the time the air is kept inside the gallery reducing the possibility for the heat to pass by the intake walls. Concerning the speed for the two types of intake manifolds, there is a difference of 20%. This fact is due to the simple geometry of type b.

Because values are converging to a similar value (see Fig.5), the in-take manifold testing stand fitted with measuring equipment accomplished the initial requirement for valid result and constant parameters.
4. Conclusions and perspectives

Creating a prototype for the intake manifold test stand was a real challenge. The development of this test system was necessary because the current market did not offer this type of equipment. The stand has the role of relieving the producers of high costs, related to the purchase of the classic dynamometric stands for engines. The booth also aims to simulate real-time air flow through the intake geometry, being equipped with sensors and specialized measuring equipment such as anemometers, pressure and temperature readers. The obtaining of the stand was done at low costs, namely at one quarter compared to the cost of acquiring a classic dynamometric stand, and the measurement procedure is a simple one that can be performed and those who do not have a good training in the field.

Starting from the operating parameters of a spark ignition engine, the flow scenarios were simulated through the different types of intake manifolds proposed. The new intake stand achieved the highest possible performance from a 600 cm³ engine, given the restrictions imposed by the competition and included all the auxiliary elements to be taken into account such as: fatigue resistance of the material, pressures to which the gallery is subjected, chemical properties of the substances it will come into contact with.

Using materials with a high degree of resistance, which also have a low density, was the key factor for a successful product that met customer expectations. By conducting simulations of resistance, but also of flow, we could get a very close idea of reality of the developed product.

The construction of a prototype stand for the effective testing of the intake manifold models was a big challenge, but in the same time the development of this testing system was necessary because there was no such means of testing. This stand aims to simulate real-time air flow through the intake geometry, being equipped with numerous sensors and specialized measuring equipment. The obtaining of the stand was realized with reduced costs per quarter compared to those necessary to purchase a dynamometric stand for engines [7].
By the information presented in this paper it can be concluded that the improvement of the admission system to a vehicle can be achieved by testing the reused in-take manifolds which can be done with a stand obtained at low costs.

The testing stand was developed by modules to be fitted with compressed air for measuring a new set of data, useful in supercharged or turbocharged applications.

In future, this type of application can be implemented in Industry 4.0 scenarios through interconnection (devices, sensors), information transparency (collect immense amounts of data and information), technical assistance.

Space considerations
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5. References

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