

# Reducing emissions by using special air filters for internal combustion engines

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**Abstract.** This paper presents the experimental methodology to carry out functional performance tests for an air filter with a particular design of its housing, generically named *Super absorbing YXV „Air by Corneliu”*, patented and homologated by the Romanian Automotive Registry, to which numerous prizes and medals were awarded at national and international innovations salons. The tests were carried out in the Internal Combustion Engines Laboratory, within the specialization "Road vehicles" belonging to the Faculty of Engineering Hunedoara, component of Politehnica University of Timisoara. The scope of the study is to optimise the air intake into the engine cylinders by reducing the gas-dynamic resistances caused by the air filter and, therefore, to achieve higher energy efficiency, i.e. fuel consumption reduction and engine performance increase. We present some comparative values of various operating parameters of the engine fitted, in the first measuring session, with the original filter, and then with the studied filter. The data collected shows a reduction in fuel consumption by using this type of filter, which leads to lower emissions.

## 1. Introduction

Motor vehicles are significant sources of pollution that can damage the environment and pose public health issues. Everyone has a stake in limiting pollution. Carbon monoxide, nitrogen oxides, and hydrocarbons are released when fuel is burned in an internal combustion engine and when air/fuel residuals are emitted through the vehicle tailpipe. Gasoline vapors also escape into the atmosphere during refueling and when fuel vaporizes from engines and fuel systems caused by vehicle operation or hot weather. The pollutants in vehicle emissions are known to damage lung tissue, and can lead to and aggravate respiratory diseases, such as asthma. Motor vehicle pollution also contributes to the formation of acid rain and adds to the greenhouse gases that cause climate change [1-3].

Pollutants emitted directly from vehicles are not the only cause for concern. On warm, sunny days, hydrocarbons react with oxides of nitrogen to create a secondary pollutant, ozone. In many urban areas, motor vehicles are the single largest contributor to ground-level ozone which is a common component of smog. Ozone causes coughing, wheezing and shortness of breath, and can bring on permanent lung damage, making it a cause of crucial public health problems.

Proper maintenance of car and truck emission control systems not only limits harmful emissions, but also can improve fuel efficiency and vehicle performance extending the life of the vehicle. Care in storing and handling gasoline and other solvents also reduces evaporative losses to the atmosphere [4].



The fuel mixture is flowing through the intake system under the effect of the depression created by the downward movement of the piston from TDC to BDC, in conjunction with the inertial flow effect and the undulating effect of the pressure waves created by the opening and closing valves. The size of depression in the sucked engine cylinder depends primarily on the gas-dynamic resistances that oppose the fresh load passing through the intake system components. In general, the depression created by the engine depends on many factors, among which the constructive factors are the most important. In practice, it has been found that the depression increases with increasing rotational speed. This depression is directly influencing the quantity of air retained in the engine cylinders during an operation cycle [5].

The air filter is the inlet system component which makes the connection between the gases acting inside the engine and the outside environment [6]. Its main role is to prevent the access of impurities from outside to inside the cylinders. Constructively, it has also the role to reduce the noise produced during the filling process. The air filter should ensure the supply with an air flow rate higher than the maximum one required by the engine. To do not worsen the cylinder filling with fresh charge (by decreasing the air mass actually retained in the engine cylinders), the filter gas-dynamic resistance must be as low as possible. Unfortunately, due to its design, the air filter introduces pressure loss into the system caused by the gas-dynamic resistances generated by its geometric form and the filtration material nature [6].

The air mass found in cylinders after closing the intake valve is the decisive factor in relation to the mechanical work produced by cyclically burning of the fresh load, with direct influence on the engine torque. Consequently, the measures to increase the maximum torque and the maximum power almost always involve creating the conditions for obtaining a maximum possible filling ratio [5].

The scope of the study is to optimise the air intake into the engine cylinders by reducing the gas-dynamic resistances caused by the air filter and, therefore, to achieve higher energy efficiency, i.e. fuel consumption reduction and engine performance increase. We note that this study does not cover the material of the air filter element, which is standardised, but only its housing optimisation for improving the flow conditions.

The novelty of this study is the development of our own air filter concept, as a method of reducing the gas-dynamic losses along the intake route of the internal combustion engines and thereby reducing fuel consumption, with direct implications on emissions. This new concept leads to the multiplication of air filter functions, i.e. the increase of the air capture and intake capacity regardless of the mounting position in the engine compartment [7].

This study is based on our own concept of super absorbing air filter, named *Super absorbing YXV „Air by Corneliu”*, patented and homologated by the Romanian Automotive Registry, to which numerous prizes and medals were awarded at national and international innovations salons.

The concept underlying the initiation of this study is subject to the Patent no. 126019 / 28.12.2012 “Super absorbing air filter”. This product, along with the related solutions for the optimisation of air intake processes occurring inside the internal combustion engines (the own solutions developed by some of the research team members) were appreciated and honoured with countless awards at the innovations salons at home and abroad (21 gold medals, 4 silver medals, 2 bronze medals and 19 special prizes).

## 2. Experimental

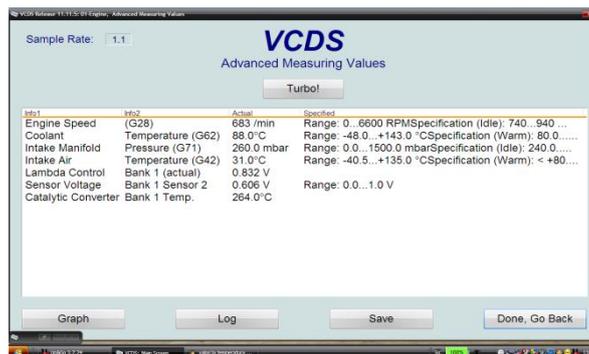
For performing the experimental measurements, we had an engine test stand, produced by Christiani, consisting of a multi-point fuel injection engine, brand VW, 1.4 MPI, used by the Golf VI 5K1 models, cylinder capacity: 1390 cm<sup>3</sup>, power: 59 KW/80 CP, 4 cylinders in line, manufacturing years: 2009-2012 (Figure 1).



**Figure 1.** Overview of the test stand

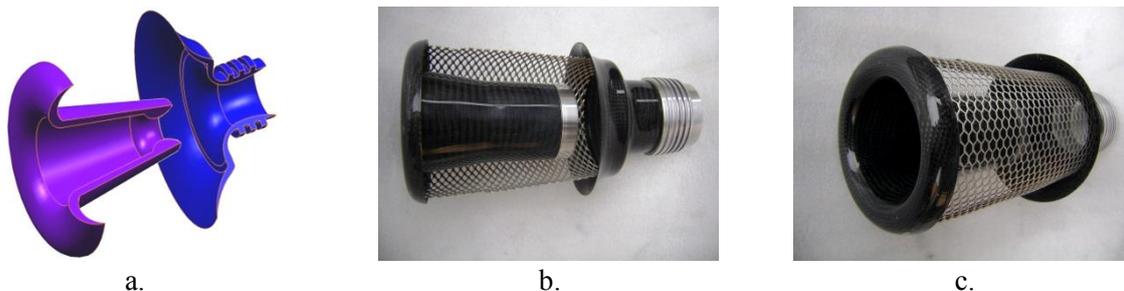
The stand offers the possibility to monitor the engine during its operation. It enables the connection to the OBD port of all the testers usually found in garages, and the measurement of signals and electrical quantities, with the possibility of assessing the obtained parameters.

The related software contains a professional interface that allows the PC to be transformed, via an USB port, into a device to be used for diagnostics and visualization of the functional parameters (Figure 2). Also, it enables the visualization and simultaneous storing of three measuring blocks, and can graphically display the essential features of the engine.

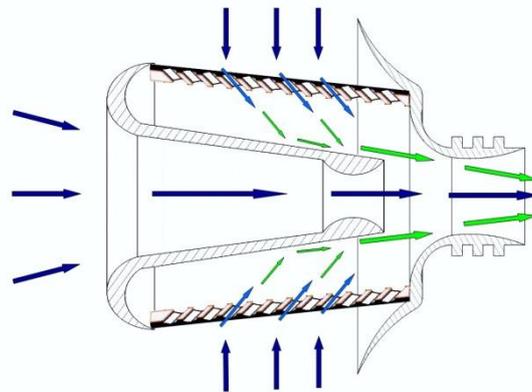


**Figure 2.** Monitoring the engine parameters

The tested super absorbing YXV filter [8] has the additional function of accelerating the air speed at the output of the filter. Due to the constructive geometry, it provides a significant increase in the air-filling coefficient of the engine cylinders. The filter (Figure 3) is provided with a frontal diffuser, lateral surface with the guiding cells and external diffuser – internal diffuser unit.



**Figure 3.** Super absorbing filter YXV „Air by Corneliu”: exploded virtual model, realised in AutoDesk Inventor (a); physical models (b and c) [8]



**Figure 4.** Illustration of the operating principle [8]

The tests consisted in determining the key operational parameters of the engine, at various speeds at idle, the engine being equipped, at a time, with the original filter or with YXV. The measuring sessions were repeated to confirm the results, and the test conditions for the two variants (engine equipped with original filter and with YXV) were maintained strictly constant. The filtering element is the same for both filters.

For the first measuring session, the experimental engine was equipped with the original filter (Figure 5.a). The data acquisition was made at various engine speeds at idle, beginning with the idling speed and continuing with 1500, 2000, 2500, 3000, 3500 and 4000 rpm. We measured: engine speed; throttle position; manifold air pressure; coolant temperature; manifold air temperature; hourly fuel consumption; ambient temperature and atmospheric pressure.



a.



b.

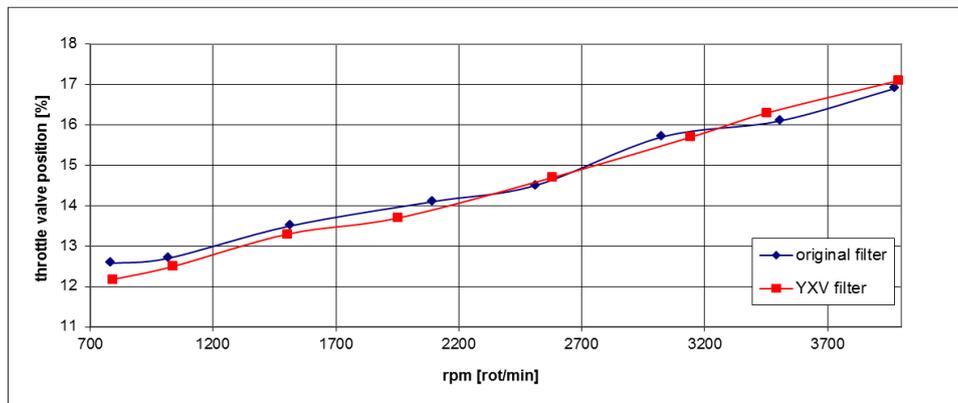
**Figure 5.** Engine equipped with original filter (a) and engine equipped with YXV filter (b)

The next session of measurements was carried out with the engine equipped with YXV filter (Figure 5.b). The same above-specified parameters have been determined, under the same conditions. We mention that the measuring sessions were conducted inside the laboratory, where the temperature and pressure remained strictly constant [9].

### 3. Results

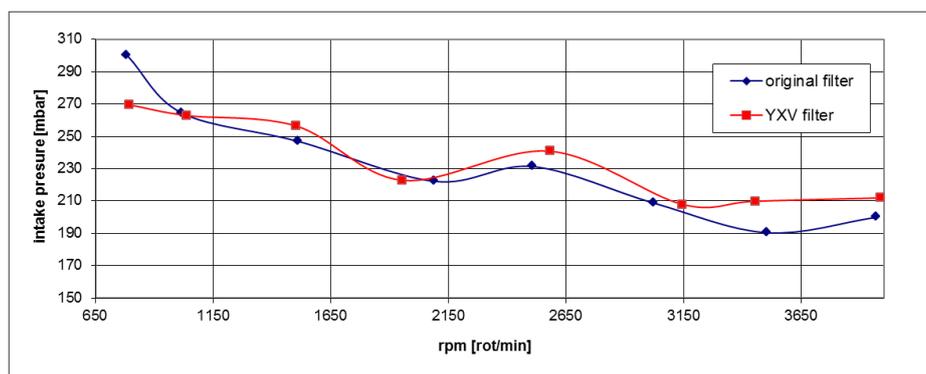
We present below the comparative values of the above-specified parameters on the performance of the engine equipped with original filter and YXV filter, respectively.

The chart presented in Fig. 6 shows that, at engine speeds below 2250 rpm, when using the YXV filter, the throttle valve opens less, which means less gas-dynamic resistance due to this filter installation, situation beneficial for the process of filling the engine cylinder with fresh load. At higher speed values, it can be seen that the throttle valve position is approximately identical in both cases.

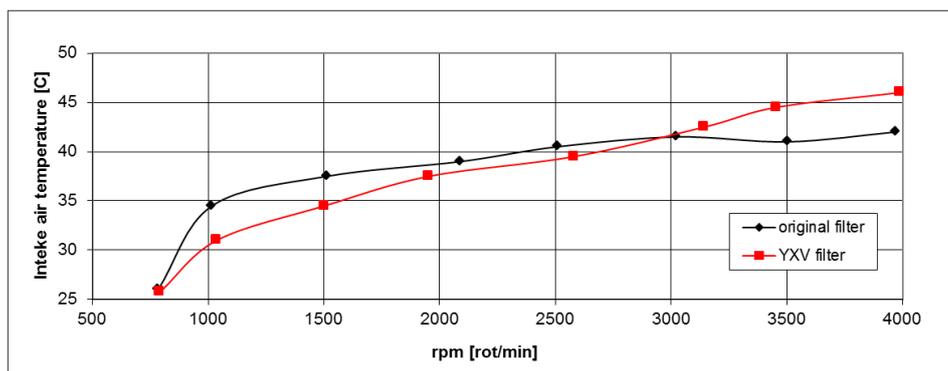


**Figure 6.** Position of the throttle valve versus engine speed at idle

From Figure 7, we can deduce that, throughout the range of speeds at which the tests have been performed, the pressure in the intake manifold is higher when using YXV than when using the original filter, situation beneficial for the process of filling the engine cylinder with fresh load.

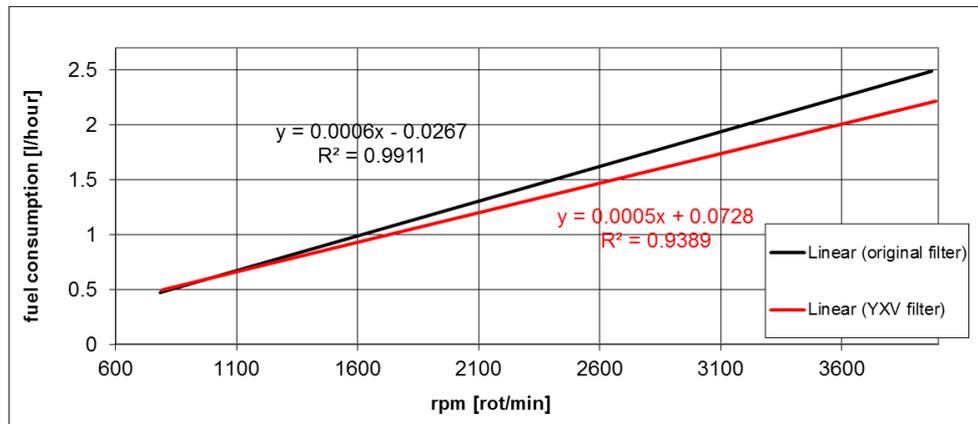


**Figure 7.** Pressure in the intake manifold versus engine idle speed

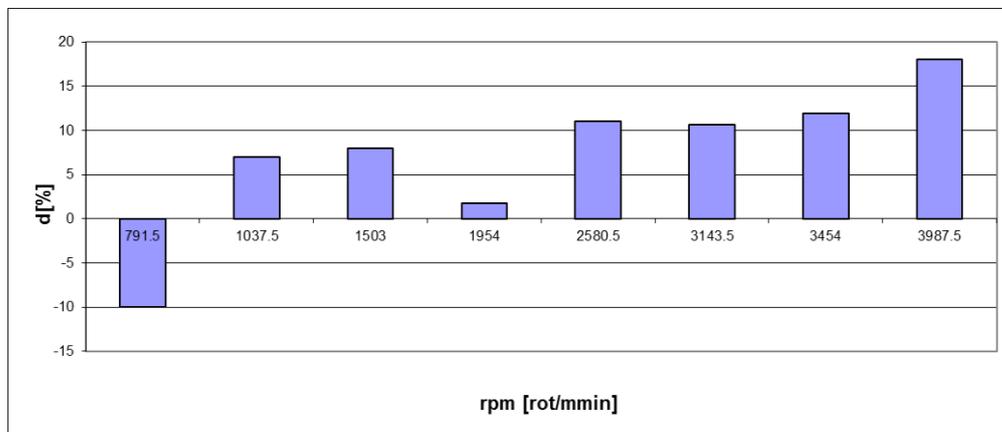


**Figure 8.** Air temperature in the intake manifold versus engine idle speed

From Figure 8, it can be concluded that, up to a speed of 3100 rpm, the air temperature in the intake manifold, when using the YXV, is lower than that obtained when using the original filter, situation beneficial for the cylinder filling process, because a lower air temperature when entering the engine means a higher density, and therefore a larger amount introduced into the cylinders, with beneficial consequences for the engine power.



**Figure 9.** Hourly fuel consumption versus engine idle speed



**Figure 10.** The percentage consumption difference

The most important parameter monitored during the tests was the hourly fuel consumption, in litres/hour. In Figure 9, we can see the variation of the hourly fuel consumption with the engine speed, for the cases when the engine is running equipped with the original filter and with YXV filter, respectively. It appears that, from speed values around 1600 rpm, the fuel consumption begins to decrease considerably when using the YXV filter.

The percentage difference ( $d$ ) between the hourly consumption with original filter ( $Ch_{original.filter}$ ) and the hourly consumption with YXV ( $Ch_{YXV.filter}$ ) is calculated using the relation (Eq. 1):

$$d = 100 - \frac{Ch_{YXV.filter}}{Ch_{original.filter}} \cdot 100 \quad [ \% ] \tag{1}$$

In Figure 10, we can see that the percentage difference is positive at all the engine speeds, with the exception of idle (more precisely: 791.5 rpm). The positive values show lower fuel consumption than in case of the original filter.

Throughout the speed range used for conducting the tests, the reduction of fuel consumption by using the super absorbing YXV filter is 7.2%.

#### 4. Conclusions

Following the conducted researches and monitoring of the behaviour when installing the filter on various types of engines, we concluded that this one has a number of advantages, such as:

- being in contact with the air, the filter element ensures a minimum gas-dynamic resistance to the absorbed air, increasing thereby the absorption and capture rates;
- the self-cleaning possibility of the filter element;
- visualisation of the filter element, without the prior removal of the filter, for checking its *pollutant loading level*;
- the capacity of air filter housing to significantly increase the speed of absorbed air, both at the input and output of the filter;
- the ability to create a slightly boost, which increases proportionally to the vehicle movement speed.

All these advantages lead to improved performance and thereby reduce fuel consumption, with direct implications in reducing emissions.

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