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MEASURING THE PRESSION FIELD IN AN INVERTED AIR FILTER

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Abstract:
This article presents a concept regarding the design of an efficient air filter for internal combustion engines, and more precisely: the super-absorbing air filter. The collection effect is being described by measuring the pressure fields with a digital manometer under air flow action.
Keywords:
air filter, internal combustion engine, pressure fields

1. INTRODUCTION

The correct filtration of the air that circulates inside the cylinders of the internal combustion engine is essential for preserving the good functioning of the engine over time. The obstruction of the admission of various impurities from the atmospheric air significantly lowers the wearing out of the moving parts of the engine.

Unfortunately, in addition to its air filtration function, the air filter displays a significant gas-dynamic resistance of the absorbed air. If the air filter is not periodically cleaned and the car circulates frequently in a dusty area, both the absorption pressure p_a and the filling coefficient η_V are dramatically decreased.

There are currently on the market several constructive variants of air filters, which differ according to the filtering principle:

- filters with filtering cell,
- inertia filters,
- combined filters.

These air filters have the following *disadvantages*:

- the presence of the filtering element inside the box induces an enhanced gas-dynamic resistance of the absorbed air (generating the phenomenon of insufficient absorption);
- storage of impurities inside the filter affects the self - cleaning feature of the filtering element;
- the filtering element can not be visualized and it has to be dismantled for the impurity level to be checked;
- incapacity of the air filter to significantly increase the speed of the absorbed air;
- incapacity of the air filter to cool the absorbed air;
- impossibility of the air filter to create a slight effect of overfeeding during the functioning of the engine.

2. THE INVERTED SUPER ABSORBING FILTER

The inverted super absorbing filter consists of a cylindrical filtering element, bordered at its anterior part by an internal diffuser fused to a joint cylinder. At its posterior part, the cylindrical filtering element is embedded concentric-axially (2/3 of its length) in a mono-block complex, which consists of an external diffuser for air collection, followed by a direction-invertor (figure 1).

For an optimum air collection and absorption yield, the inverted super absorbing filter is set along the geometrical axis of the car.

Due to its geometry, the external diffuser (figure 2) with direction-invertor (figure 3) ensures a very good collection, causing the inversion of the absorbed air flux by 180°, which is thus directed through the filtering element towards the internal diffuser (towards the exit of the filter).

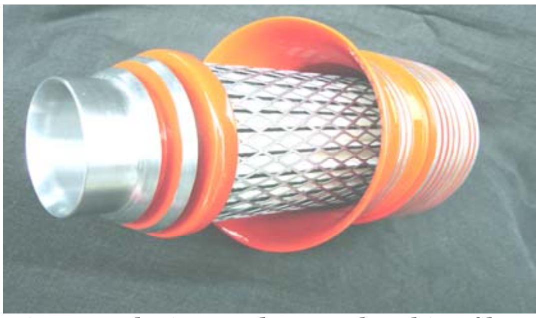

Figure 1. The inverted super absorbing filter

The external diffuser with direction-invertor covers the filtering element (for 2/3 of its length) up to a very precise distance from the exterior of the element, which ensures the collection and inversion of the air flux. Cooling radiators are located on the outside of the direction-invertor.

2.1. The external diffuser for air collection with direction-invertor

The cooling radiators consist of external wings, which cover 80% of the external surface of the direction-invertor. They maintain a low temperature of the direction-invertor and generate, consequently, a thermal equilibrium between the surface of the wall and the absorbed air. As a result, the temperature of the air is significantly decreased before it enters the air filter.

Figure 2. The external diffuser for air collection

Figure 3. The direction-invertor

2.2. The filtering element

The filtering element (figure 4) has a cylindrical shape. It consists of a micron size cardboard, which forms the lateral surface of the filtering element (in a radial section, the micron size cardboard has a W shape).

Figure 4. The filtering element

Figure 5. The internal diffuser and joint cylinder

The cardboard ensures a micron size filtration and is covered on the outside with a millimetric sieve, which allows a rough millimeter size filtration of the air. The micron size cardboard and the millimetric sieve are fixed at the two open ends by silicone rings, for an optimum sealing and concentric – symmetrical alignment with both the internal diffuser of the anterior part and the mono-block complex of the posterior part.

2.3. The internal diffuser for air acceleration

The internal diffuser for air acceleration has a taper shape and ensures the connection between the contact surface and the joint cylinder (figure 5). Due to its constructive geometry, the internal diffuser has the capacity of increasing the speed of the absorbed air. Taper-shaped cooling radiators are located on the outside of the internal diffuser. Because of their taper shape, they redirect the air flux towards the external diffuser, which allows a concentrated flow of the air and a minimum gas-dynamic resistance. They maintain a low temperature of the diffuser and generate, consequently, a thermal equilibrium between the surface of the wall and the absorbed air. As a result, the temperature of the air is significantly decreased before it leaves the inverted filter.

The purpose of the joint cylinder is to link the air filter to the admission gallery of the engine.

The internal diffuser for air acceleration, the filtering element and the mono-block complex (the external diffuser for air collection with direction-invertor) have varying dimensions according to the swept volume of the engine, so that the bigger the swept volume, the larger the dimensions of the diffuser and vice-versa.

The inverted super absorbing filter improves the filling coefficient and is useful for engines that employ air filters set in the opposite direction of the flow of the absorbed air (filters set up at the rear of the Bugatti, Ferrari, Lamborghini engines).

2.4. Conclusion regarding the inverted super absorbing filter

The inverted super absorbing filter has the following *advantages*:

- being in direct contact with the air, the filtering element ensures a minimal gas- dynamic resistance of the absorbed air, increasing therefore the level of absorption and collection of the air, and consequently boosting the air filling coefficient of the engine cylinders;
- possibility of self-cleaning of the filtering element;
- the level of impurities on the filter can be readily evaluated: the filtering element can be easily visualized without previously dismantling the filter;
- the speed of the absorbed air both at the entrance and the exit of the filter is considerably increased;
- significant capacity of the air filter to cool the absorbed air;
- the air filter creates a slight effect of overfeeding during the functioning of the engine, which is proportional with the speed of the car;
- this air filter fulfils new tasks, in addition to its classical function of air filtration: increases the degree of absorption and collection, the speed of the absorbed air, cools down the absorbed air and inverts the air flux by 180°

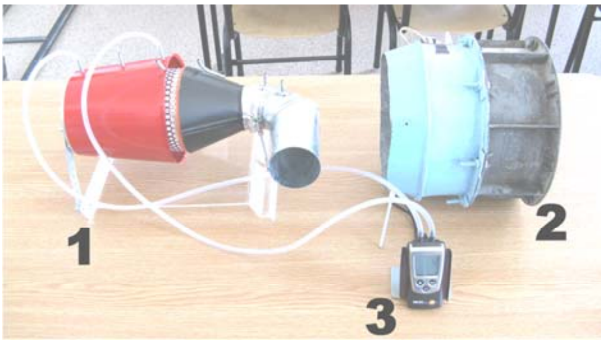

Figure 6. General view of the experimental setup: 1- inverted super-absorbing filter; 2- constant flow ventilator; 3- digital manometer

3. THE EXPERIMENTAL SETUP. DESCRIPTION

3.1. The inverted super-absorbing filter

The inverted super-absorbing filter consists of a cylindrical filtering element (C), bordered internally by a diffuser (D) fused to a joint cylinder (E). The cylindrical filtering element is embedded concentric-axially (90 % of its length) in an external air collector (A), bordered at its posterior part by an internal cone (B) (Figure 7). For an optimum air collection and absorption yield, the inverted super aspirant filter is set longitudinally with respect to the geometrical axis of the car.

Figure 7. Inverted super-absorbing filter. Constituting elements

3.2. The external axial collector with the internal cone

Due to its geometry, the axial external collector A with the internal cone B (Figure 7, 8 and 9) ensures a very good air collection. It causes the inversion of the absorbed air flux by 180°, which is therefore directed through the filtering element towards the internal diffuser (towards the exit of the filter).

Figure 8. The external axial collector with the internal cone (longitudinal view)

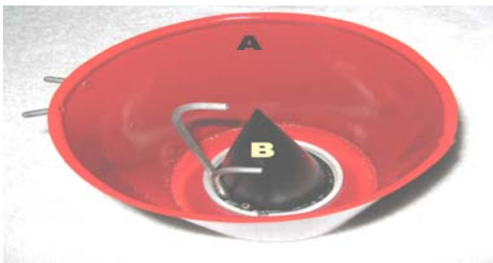

Figure 9. The external axial collector with the internal cone (radial view)

The axial external collector with internal cone covers the filtering element (for 90 % of its length) up to a very precise distance from the exterior of the element, which allows an optimal collection and inversion of the air flux. There are 4 pressure plugs on the outside of the axial external collector and 3 pressure plugs around the internal cone.

3.3. The cylindrical filtering element

The filtering element is cylindrically shaped (Figure 10). It consists of a piece of cardboard with micron-size pores, which forms the lateral surface of the filtering element (in a radial section, the cardboard piece has a W shape).

Figure 10. The filtering element

The cardboard ensures a micron-size filtration and is covered on the outside with a sieve with millimetre-size pores, which allows a rough millimeter-size filtration of the air. The cardboard and the sieve are fixed at their open ends by silicone rings, for an optimum sealing and concentric – symmetrical alignment with both the internal diffuser at the anterior part and the mono-block complex at the posterior part.

3.4. The internal diffuser for air speed acceleration

The internal diffuser for air acceleration D (figure 11) has a taper shape and ensures the connection between the filtering element C and the joint cylinder E (Fig. 7). Due to its geometry, the internal diffuser has the property of increasing the speed of the expelled air. Its taper shape directs the air flux towards the external axial collector, which allows a concentrated air flow and a minimum gas-dynamic resistance.

Figure 11. The internal diffuser

4. MEASURING METHODOLOGY

The static pressure is measured in the external axial collector via the pressure plugs 1, 2, 3, 4, inside the filtering element (at ½ its length) via plug 5, at the entrance of the internal diffuser via plug 6 and inside the joint cylinder via plug 7 (figure 12). All these pressure plugs were designed perpendicular to the air flow.

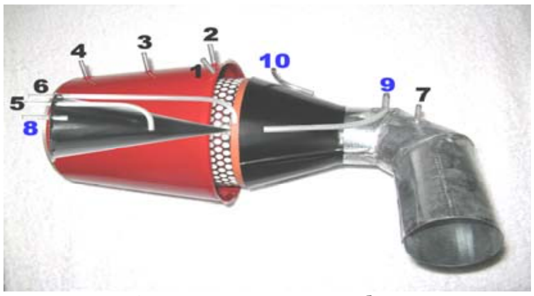

Figure 12. Pressure plugs

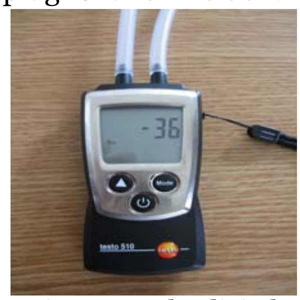
Figure 13. The digital manometer TESTO 510

The dynamic pressure is measured at the basis of the internal cone via plug 8, at the exit of the internal diffuser via plug 9 and at the external surface of the internal diffuser via plug 10 (figure 12). These pressure plugs were designed axial to the air flow.

The measurements were performed with the digital manometer TESTO 510 (0-100hPa) described in Figure 13. Pressure measurements relative to the atmospheric pressure were carried out at each pressure plug, at various distances.


Figure14. Filter with the internal cone


Figure15. Filter without the internal cone

5. ANALYSIS OF RESULTS AND CONCLUSIONS

A significantly higher collection yield is observed in the presence of the internal cone (figure 14, Tabel 1) compared to when the internal cone is missing (Figure 15 and Tabel 2). The following graphs show the effect of the presence or absence of the cone on the pressure fields recorded at various distances from the ventilator: 0, 20, 40 cm.

Table 1. Static Pressure values (with internal cone)

distance	Plug 1	Plug 2	Plug 3	Plug 4	Plug 5	Plug 6	Plug 7
0	44	28	33	50	26	14	8
5	38	25	30	42	22	11	7
10	33	23	28	36	20	11	10
15	31	23	28	34	21	13	10
20	32	26	30	37	22	13	13
30	32	26	33	39	27	20	14
40	32	27	34	40	28	20	16
50	29	24	29	32	23	17	14

Table 2. Static Pressure values (without internal cone)

distance	Plug 1	Plug 2	Plug 3	Plug 4	Plug 5	Plug 6	Plug 7
0	39	26	35	50	20	8	3.5
5	30	19	25	36	15	4.5	2
10	20	15	20	29	13.5	3	1
15	16	13	19	21	13	3	1
20	17	14	19	22	11.5	2	1
30	15	13	18	22	12	2	2
40	15	13	19	22	12	3	2

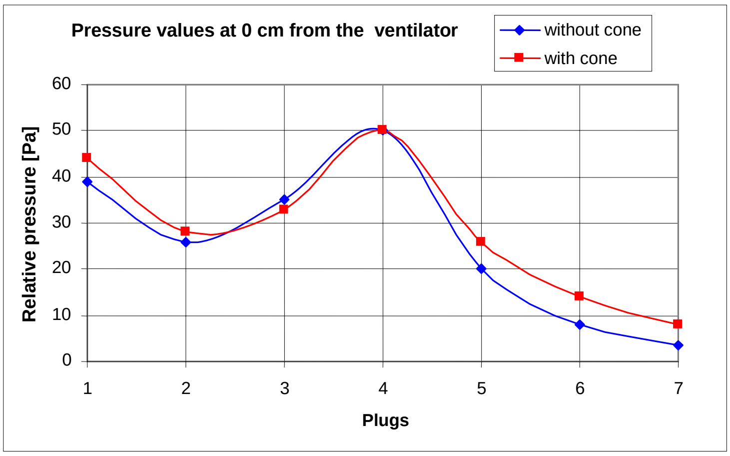

Figure 16. Comparative pressure values in the filter at 0 cm form the ventilator

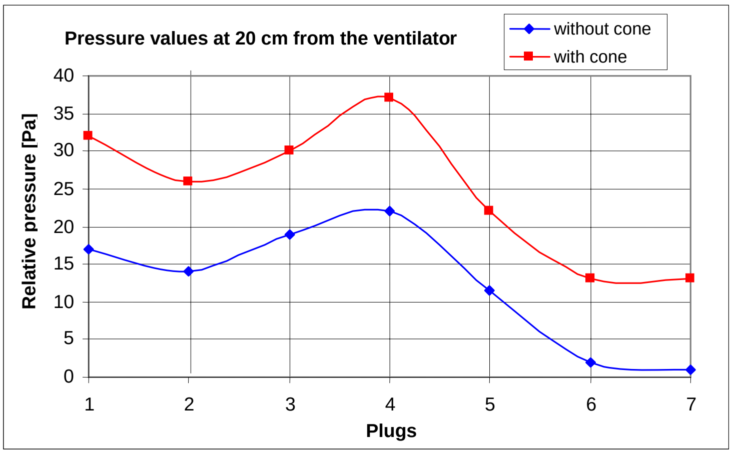

Figure 17. Comparative pressure values in the filter at 20 cm form the ventilator

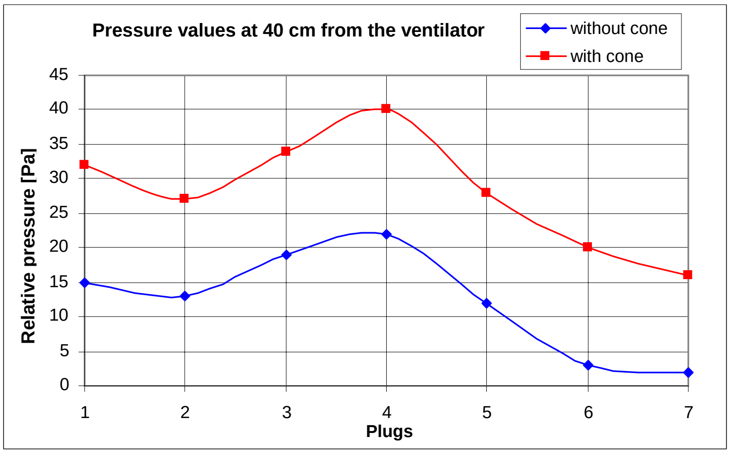

Figure 18. Comparative pressure values in the filter at 40 cm form the ventilator

The following graphs display the relative pressure fields measured at each plug vs the distance between the filter and the ventilator (Fig. 19-20). The inverted super-absorbing filter improves the filling coefficient and is useful for engines that employ air filters set in the opposite direction of the flow of the absorbed air (filters set up at the rear of the Bugatti, Ferrari, Lamborghini engines).

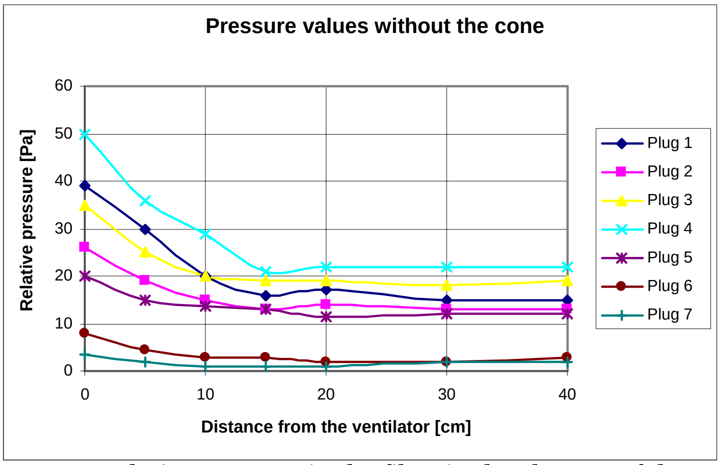

Figure 19. Relative pressure in the filter in the absence of the cone

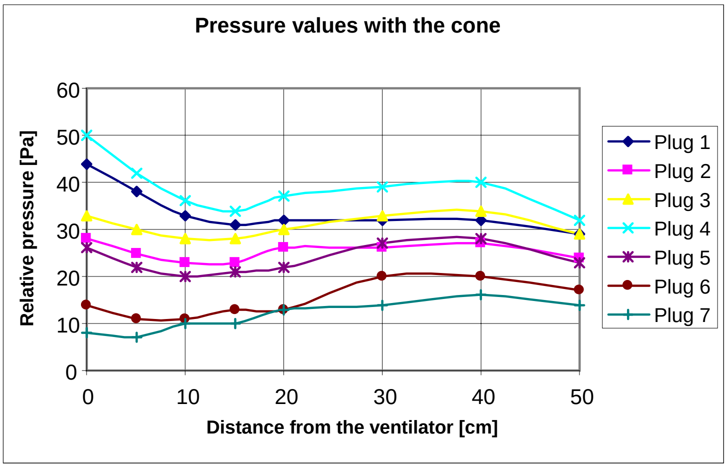

Figure 20. Relative pressure in the filter in the presence of the cone

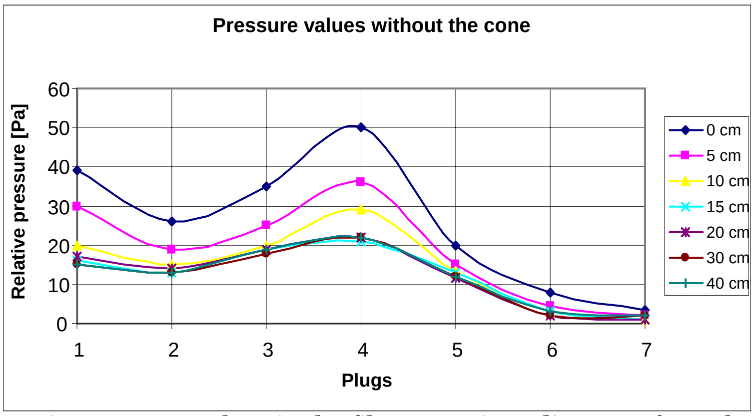

Figure 21. Comparative pressure values in the filter at various distances form the ventilator in the absence of the cone

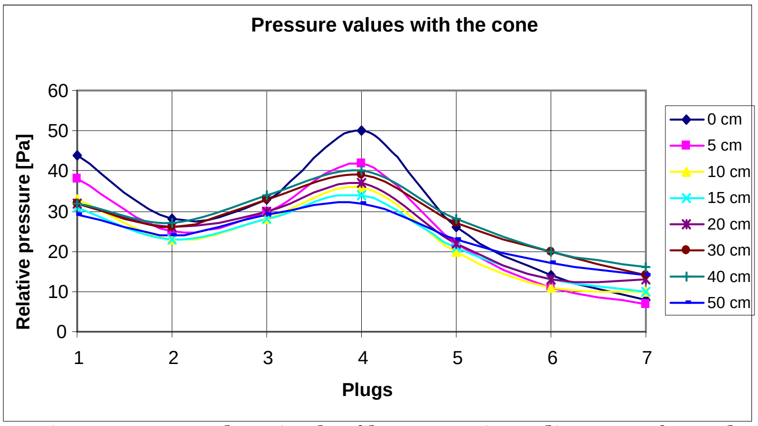

Figure 22. Comparative pressure values in the filter at various distances form the ventilator in the presence of the cone

6. CONCLUSIONS REGARDING THE INVERTED SUPER-ABSORBING FILTER

The inverted super aspirant filter has the following advantages:

- being in direct contact with the air, the filtering element ensures a minimal gas-dynamic resistance of the absorbed air, increasing therefore the level of absorption and collection of the air;
- possibility of self-cleaning of the filtering element;
- the level of impurities on the filter can be readily evaluated: the filtering element can be easily visualized without having to dismantle the filter;
- the speed of the absorbed air both at the entrance and the exit of the filter is considerably increased;
- the air filter creates a slight effect of overfeeding during the functioning of the engine, which is proportional with the speed of the car;
- this air filter fulfils new tasks, in addition to its classical function of air filtration: increases the degree of absorption and collection, the speed of the absorbed air, cools down the absorbed air and inverts the air flux by 180°.

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