A STUDY OF THE AIR FILTERS' MAINTENANCE FOR AUTOMOTIVE INTERNAL COMBUSTION ENGINES

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The internal combustion engines' wear, of a motor vehicle, is influenced by the dust from the atmosphere, which passes through the air filter. The air filters have a reduced initial efficiency of filtration. They are designed to increase their efficiency over their life, due to sedimentation of the dust layers. The paper analyses the technical state of the air filter, for Renault K7M engines, which are prevent replaced, according to the maintenance schedule, recommended by the producer, without taking into account their real estate. The paper proves that the replacement of air strainers is both uneconomical and disadvantageous due to technical state evolution of the engines.

Keywords: air filters, restriction, maintenance.

1. Introduction

The air contains lots of impurities, of different sizes, minerals, very rough and with rugged shapes [1]. Lots of them are invisible for the human eye, which has the minimum visibility dimension of 20μm. By entering into the engine they will mix with the lubricant and will cause the reduction of engine's life [8].

In average, an engine consumes around 30,000 to 60,000m^3 of air per year. For that amount of air, in normal conditions, a weight of 0.3 to 0.6kg consists of impurities, which represents an average concentration of 10mg/m^3 [9].

The air which reaches the combustion chamber has to be filtered, in order to protect engine kinematic couples.

The main criteria of air filtration are:

- high efficacy;
- low filter's gaso-dynamic resistance all over its life;
- high heap capacity of impurity.

The filtering efficiency characterizes the quantity and the dimensions of dust particles that pass through the filter. It mainly influences the engine's wear.

The air filters are designed to increase their efficiency while they are loaded with dust layers. Even in small quantity, the dust from the air significant improves the filter efficiency.

Depending on material type and other design and functional characteristics, a new filter has an initial efficiency of 94% to 99%. At the

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moment of reaching the pressure drop limit (between 1,000 to 2,500Pa – depending on authors), the efficiency exceeds 99% and can reach 99.9% of filtration [2],[10],[11]. It must be highlighted that the filters are replaced at a value, too low of pressure drop limit, thing that is demonstrated by the author's determinations.

From paper [3], a truck filter made of cellulose filtering material, has a penetration ratio 16 times higher than the average of the entire lifecycle, in the first exploitation period (immediate after the beginning of exploitation, as new, until it collects $10.8 g/m^2$ of dust).

Defining the air filter maintenance range that fits out an internal combustion engine is a complex operation which must take into account the vehicle functional – constructive particularities. The most utilised criterion of the filters replacement is the distance travelled by the motor vehicle.

Mostly, the air filters are unnecessary replaced when they appear to be dirty after a subjective visual inspection, without knowing and understanding the high efficiency of functioning, even if they are in the useful life [5],[7].

Another criterion of air filters replacement is the reaching point of the pressure restriction of the used filter compared with the new one.

The pressure restriction (static pressure measured downstream the tested air filter) assesses the air flow resistances, which appear at the entrance into the engine, and which are generated by the air filter, its case and by the pipes upstream the air filter's case.

The maxim restriction's growth at the replacement moment compared with the new filter must be between 1 and 2.5kPa [4]. For high power motor vehicles low values of grow are adopted. Some papers [2],[5],[6],[7],[10] recommend the air filter replacement for values of pressure restriction over 2.5kPa. Those advisories are valid for normal conditions of usage, specific in 97% of normal motor vehicles situations [7].

To apply this criterion of air filter replacement, the motor vehicles must be equipped with a special sensor. A small number of nowadays motor vehicles have that kind of sensor.

2. The preparation and deploy of the experimental researches

The experimental research presented in this paper was made on air filters of Renault K7M gasoline engines with a cylinder capacity of $1,598\ cm^3$.

This type of motor vehicle is in exploitation in high number of private persons and at institutions. In the air filter case can be installed filters from many different producers.

In laboratory, the air filters are tested on a special designed and manufactured testing bench. It is conform to SAE J726/ISO 5011 standards, and its architecture is presented in figure 1.

Using this test bench it is possible to measure the air flow, differential pressure (static pressure upstream and downstream the air filter), pressure restriction generated by the filter (static pressure generated downstream the filter).

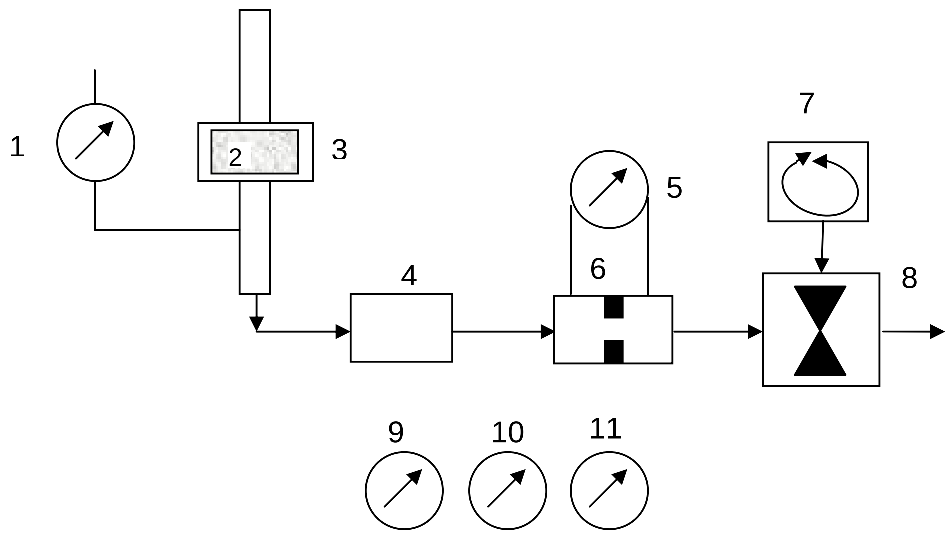


Fig.1. The test bench measuring the pressure restriction
1. pressure gauge M I, 2.air filter, 3.special case for fitting up the air filter, 4.absolut filter, 5.pressure gauge M II, 6.measuring device of air flow, 7.the adjusting air flow device, 8.exhaustor, 9.thermometer, 10.barometer, 11.humidometer.

The working parameters are the values of the air flow and the generated restriction by the air filter.

As a reference value, the maximum air flow consumed by Renault K7M engine running at full load is considered. To measure the maxim consumed air flow, the motor vehicle Dacia Logan was tested on the dynamo-meter test bench. A maximum air flow value of 208m^3/h was determined, at a driving regime at 110km/h in the 3rd gear with the throttle valve completely opened.

The MAHA AIP-ECDM 48L dynamo-meter is placed since 2009 inside a laboratory of Automotive Department within the Faculty of Transports of University Politehnica from Bucharest.

Due to constructive limitations of the testing air filter bench (exhauster system and air flow measuring) an air flow up to 200m^3/h can be repeatedly generated and precise measured. The filters were tested for different values of air flow (see table 1). With the aim of emphasizing their influence over the pressure restriction produced by the air filters.

Table 1

Values of air flow during the tests

Notation	Value [m^3/h]
Q1	103
Q2	155
Q3	180
Q4	200

To make possible a comparison between values of restriction pressure obtained inside the laboratory, the values of this parameter must be set to standard conditions [14],[15] (a pressure of 1,013kPa, a temperature of 20^0C).

The value of pressure restriction referred to the standard conditions is given by the equation 1 [26]:

—— —— . (1)

where: Δp_{r0} – pressure restriction for standard conditions,

Δp_r – pressure restriction measured for laboratory conditions of ambient temperature, t, and pressure, p.

The tested air filters are classified by:

- their condition: new “N”; used “U”;
- their manufacturer: type “A” and type “B”.

The tested can be tested in different combinations:

- type A new filters – “NA” (fig.2);
- type B new filters – “NB” (fig.2);
- type A used filters – “UA” (fig.3);
- type B used filters – “UB” (fig.4).

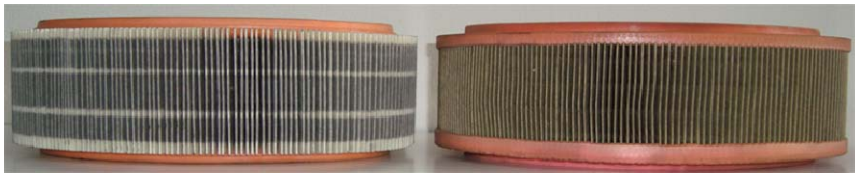
type A **type B**

Fig.2. New air filters

The used filters delivered by car services were obtained during the preventive maintenance from motor cars still in use.

The air filters are replaced according to the prevent maintenance schedule, specified by the producer (for 2007 Dacia Logan they were replaced every 15,000km or an year of use; for a 2009 model they were replaced at 20,000km or two years of use [12][13]).

They were drawn directly from the air filter case and they were immediately deposited in plastic bags to prevent water absorption from the atmosphere. In this way over 60 pieces were collected. From that number only 49 were kept, of both types of air filters.



type A **type B**

Fig.3. Used air filters

A number of 11 type B filters were incorrect installed during the maintenance activities (fig.4). Their wrong installation leads to the deterioration of gasket, thus allowing the direct entrance of atmospheric air, with impurities, inside the engine cylinder with severe consequences over the engine's aging.

For a part of the collected filters some information concerning the usage period and the zone where the motor vehicle was driven were taken directly from the motor vehicles users.

Fig.4. Type B deteriorated filter – the consequence of incorrect installation of it

The tests were made for 10 type A filters and 10 type B filters that seemed to be clogged and for which other information were known (tab.2, tab.3).

Table 2

Type A used filters (UA)

Nr.	Exploitation conditions		
	distance [km]	usage period	driving area
1	15,000	1 year	urban
2	<15,000	1 year	mixt *
3	<10,000	1 year	mixt *
4	10,000	1 year	mixt *
5	<10,000	1 year	mixt *
6	<10,000	1 year	mixt *
7	<10,000	1 year	mixt *
8	<10,000	1 year	mixt *
9	10,000	1 year	urban
10	15,000	1 year	urban

*driven inside and outside cities

Table 3

Type B used filters (UB)

Nr.	Exploitation conditions		
	distance [km]	usage period	driving area
1	15,000	1 year	urban
2	15,000	1 year	urban
3	15,000	1 year	urban
4	15,000	1 year	urban
5	>15,000	> 1 year	mixt *
6	15,000	-	-
7	15,000	1 year	extraurban
8	20,000		mixt *
9	15,000	1 year	urban
10	15,000	1 year	urban

*driven inside and outside cities

3. Results and interpretation

New filter testing

Figure 5 presents the domain between the minimum and the maximum values of the measured restriction for every type of filter at the established air flows (NAQ1: N – new, A – type of the filter, Q1 – air flow for which the measure is made). It must be observed that both types of filters have a similar behaviour and produce the same restrictions (comparable) at the same value of the air flow.

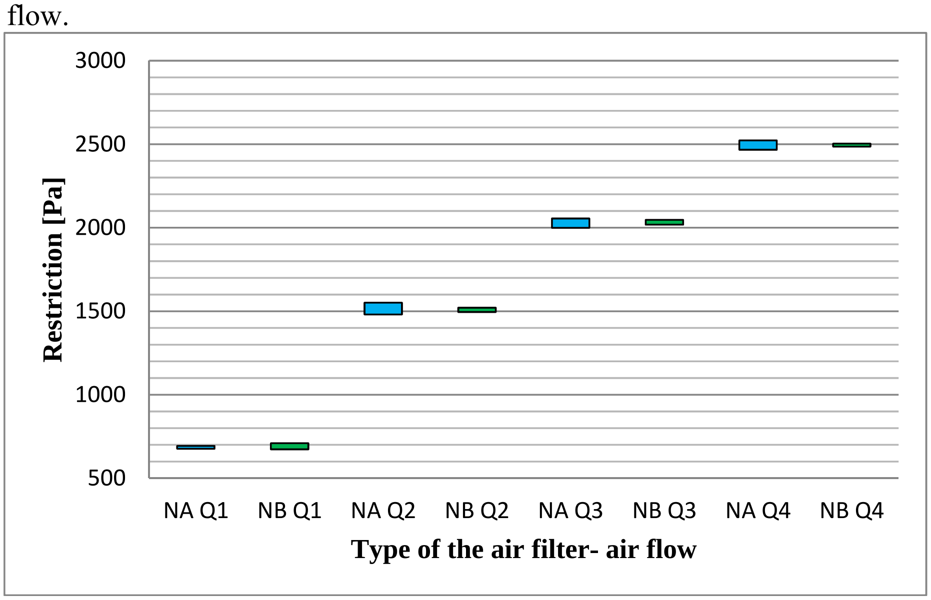


Fig.5. The measured restriction for type A and B new filters (NA, NB)

A high uniformity of filter behaviour was obtained during testing the new filter. For different types of air filters the variation domain of restriction is reduced at 70 Pa for type A filters and 37 Pa for type B filters. Those restrictions are comparable with the ones presented in the specialised literature [7].

Used filters testing

The used filters were installed on the test bench in random order and the restriction Δp_{r0} was measured.

The figure 6 presents the minimum and maximum restriction domain for used filters.

From table 2 and 3 it can be seen the tested filters were obtained from motor vehicles which run 10,000 to 20,000km, inside and/or outside the city, which means different exploitation conditions.

The difference between the restriction of the clean one and the most clogged type UA filter is about 122.5Pa for a Q4 air flow.

For the type UB filters the difference is 262.5Pa in the same conditions.

The type UA filters equipped, from the beginning, the new cars and they came mainly from private motor vehicles that run less than 10,000km/year in a mixed areal (tab.2).

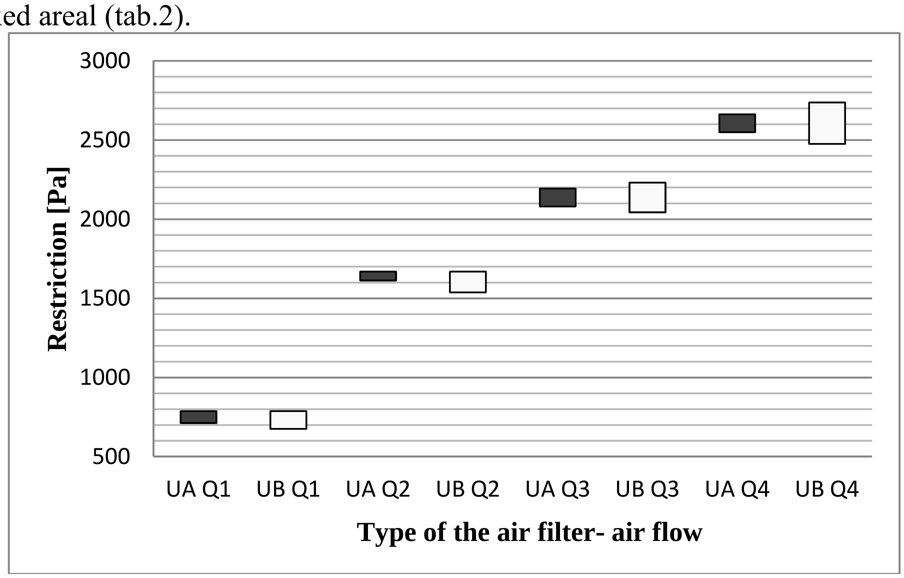


Fig.6. The measured resistance for type UA and UB used filters

The type UB filters came from the state institutions that run at least 15,000km/year (table 3). The generated restriction by those filters is comparable with the one of the type UA filters and shows a larger variation interval (the type UB filters are used for long distances and the areal of movement is: mixed urban and extra urban). Both types of filters have comparable levels of restrictions, so, they have an appropriate load of impurities.

A comparison between the measured restriction of the new and the used type A filters is presented in figure 7.

The used filters have a bigger restriction than the new ones for all the loading regimes but the maximum value of the rise is about 138Pa.

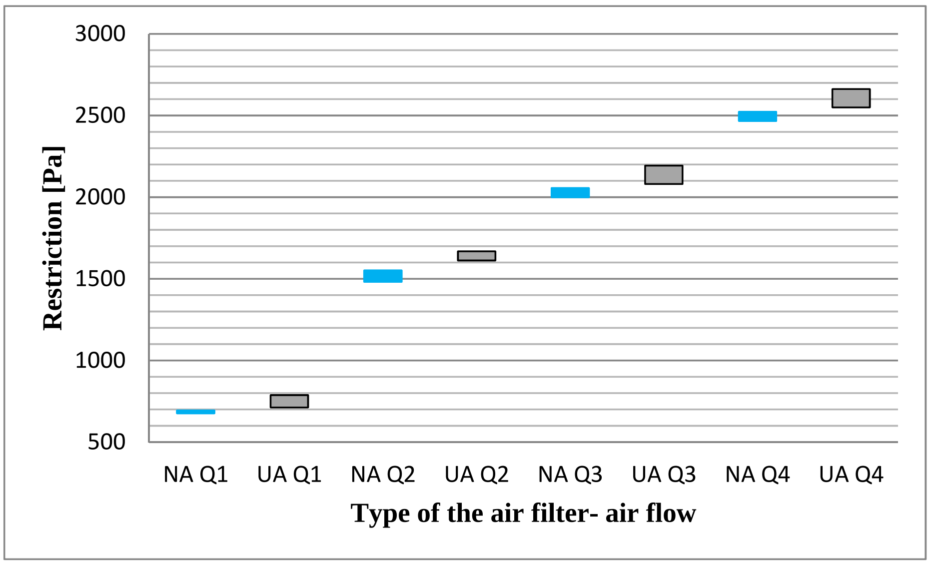


Fig.7. The measured restrictions of the new and used filters of type A

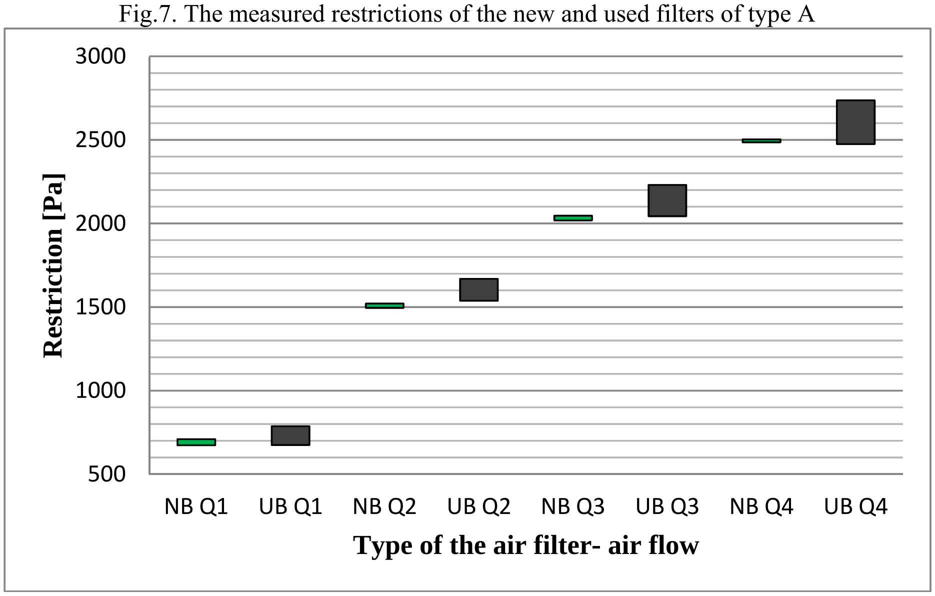


Fig.8. The measured restrictions of the new and used filters of type B

Figure 8 presents a comparison between the measured restriction for the new and used filters of type B. The maximum rise of the restriction for the type B used filters is about 252Pa, higher than the values obtained for the new filters. There are used filters which have the same or even smaller value of the restriction compared with the new ones. This fact presumes a separate research over the structure of filtering material and the efficacy of filtration.

4. Conclusions

The 12 new filters had the same behaviour. Values of the measured restrictions for the new filters had differences under 100Pa (1 mbar) for all values of air flow, no meter the flow. This observation is valid for filters of the same type and even compared to the other type.

Thought all the used filters were changed by the standard schedule, the measured values of restrictions have recorded insignificant growth in comparison witch the same type of the new ones. The type A used filters have a maximum growth of the restriction of 138Pa compared to the new ones. In the case of the type B filters, the growth is about 252Pa. Compared to the literature recommendation (rise about 1,000 to 2,500Pa) those values are extremely reduced.

It has been proved by several authors [2], [10], [11] that the maximum filtering efficiency of over 99% is reached when the restriction gets to its acceptable limit. Therefore it can be said that filters of both types were premature replaced, long before reaching their complete filtration capacity. This way the filter never reaches its full filtering capacity thus the protection of the engine is reduced. On the other side, the maintenance costs rise (a number of filters is changed in the same period as for a single complete filter's life cycle).

The cost of air filter replacement using original parts is 95 RON (80 RON air filter, 15 RON manual labour).

For K7M engines, the manufacturing company Renault specifies the period of replacement of the air filters between 15,000km to 20,000km, depending on the year of manufacture of the vehicle. For normal use conditions, the recommended replacement interval, in the literature, is 48,000km. Experimental/empirical records, presented in this paper, confirm the recommendations of the literature. Early/premature replacement according to Tables 2 and 3 leads to the increase of the cost of filters replacement between 2.4 ÷ 4.8 times and to an unjustified acceleration of the aging process of the engines.

Due to the special design of type B filters, they must be carefully installed in the filter's case.

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