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EXPERIMENTAL RESEARCH CONCERNING THE VALIDATION OF A DPF CONSTRUCTIVE VARIANT FOR A C.I.E. MEANT FOR LIGHT DRIVE

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Abstract: *It is well known that the fitting of vehicles equipped with Diesel engines (also known as a compression-ignition engine) with EURO5 and EURO6 standards supposes special measures of depollution by using the post treatment exhaust gases system. In this case, the particle filter (DPF – diesel particulate filter) is an indispensable element; therefore, important researches are being done as to the particle forming mechanism, as well as to the constructive optimization of the PAF elements. Researches have also been made in relation to the regeneration of these filters and to the DPF architecture on a vehicle. The former part of our paper presents a synthesis of these preoccupations, and the latter proposes a way of validation of a constructive DPF variant by counting the drops in pressure in given working conditions of the engine, for different values of the gas flow in the ceramic monolith. One presents the curves experimentally obtained and the validation conditions.*

1. THE DIESEL PARTICULATE FILTER. CONSTRUCTIVE ELEMENTS. THE NEED OF USE WITHIN THE DEPOLLUTION SYSTEMS BY POST TREATING THE EXHAUST

The particle filter PAF is a filtration system used to eliminate the fine particles – the ceramic ones – contained by the exhaust gases of the Diesel engines. These soot particles are essentially made of carbon and have specific measures between 10 nm and a µm. Finer particles (nanoparticles) are not well retained by the existing filters.

The formation mechanism of these particles is rendered in figure 1, and its structure in figure 2:

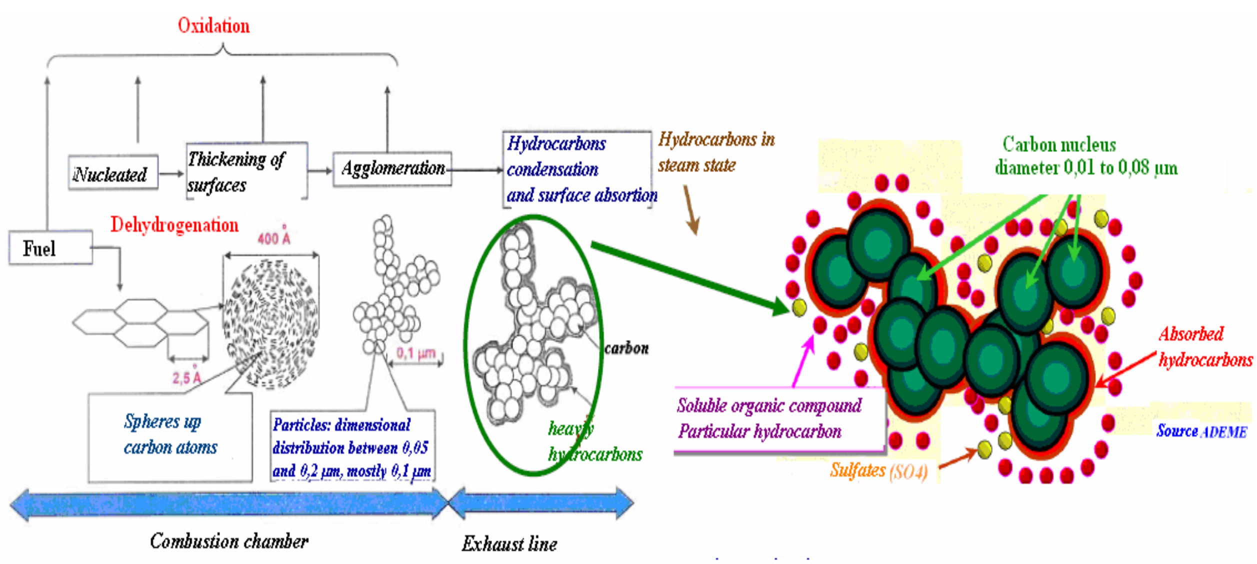
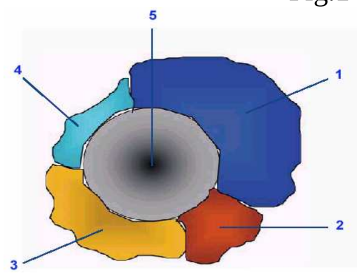


Fig.1



1 - Hydrocarbons
2 - Metals
3 - Sulphates
4 - Water
5 - Carbon

Fig.2

The composition of the mechanical particle depends on the perfection of the burning process (the organized movement in the combustion chamber, the supercharging, the air/fuel ratio), the quality of the Diesel fuel (the cetane number, the sulphur content), the post treatment temperatures of the catalyst system – the diesel particulate filter.

In the making of the diesel particulate filter (DPF) one uses ceramic porous materials such as the silicon carbide (fig. 3) or the cordierite (fig. 4).

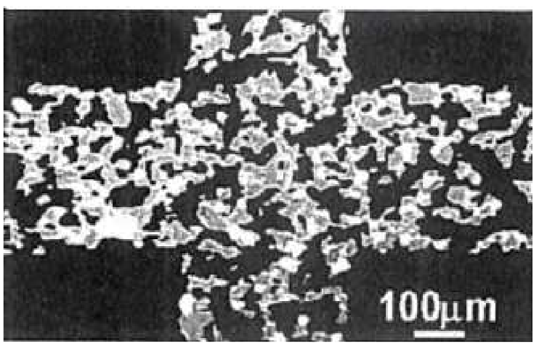


Fig. 3

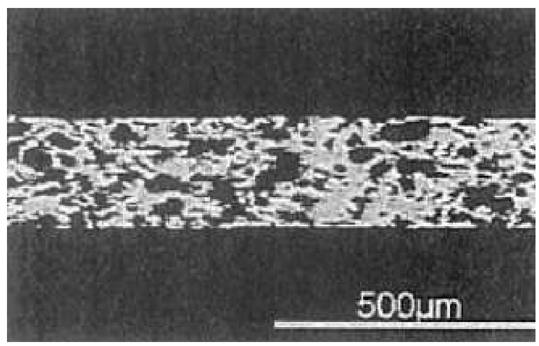


Fig. 4

Ceramic monoliths are permeable to gas and have a porosity of 52% (less than 9-10 µm). Generally, in the case of a 52% porosity, the monoliths have the following densities:

- for cordierite ceramic 490g/l
- for silicon carbide 720g/l

The major difference between the two kinds of monoliths used is represented by the melting temperature of about 1355°C for the cordierite ceramic, and for the silicon carbide this exceeds 2000°C. Figure 5 presents these monoliths,

Cordierite ceramic Silicon carbide

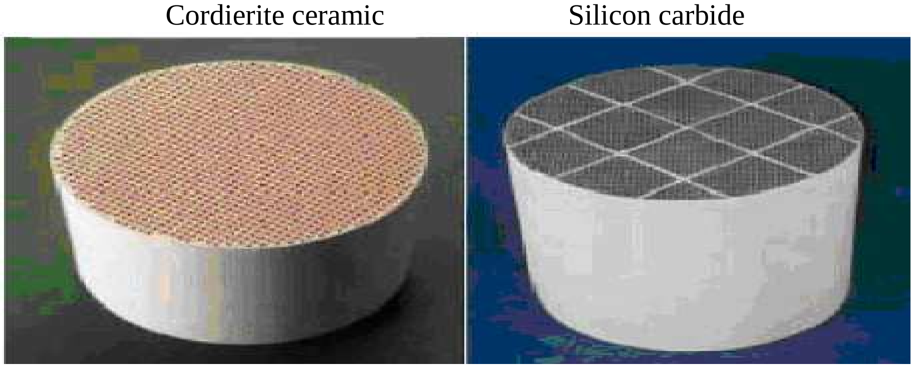


Fig.5

and figure 6 renders the interior structure of a used monolith in the making of a DPF, longitudinal section

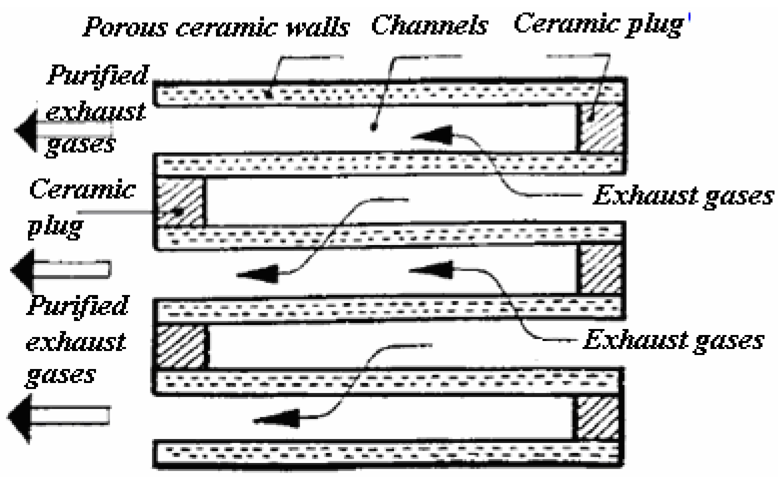


Fig. 6

The working principle of a DPF (fig. 7) resembles the one of a “sieve”, allows the gas molecules to pass and retains the mechanical particles. As these particles gather in the PAF one has to find a way to eliminate them. Therefore, the particle filter works in two steps:

- the particle charge
- the regeneration

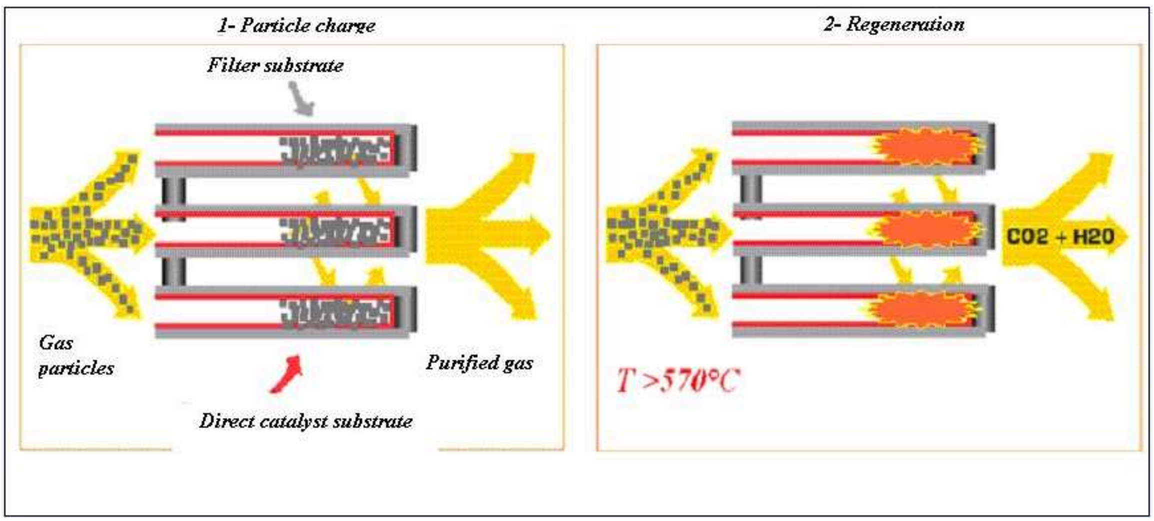
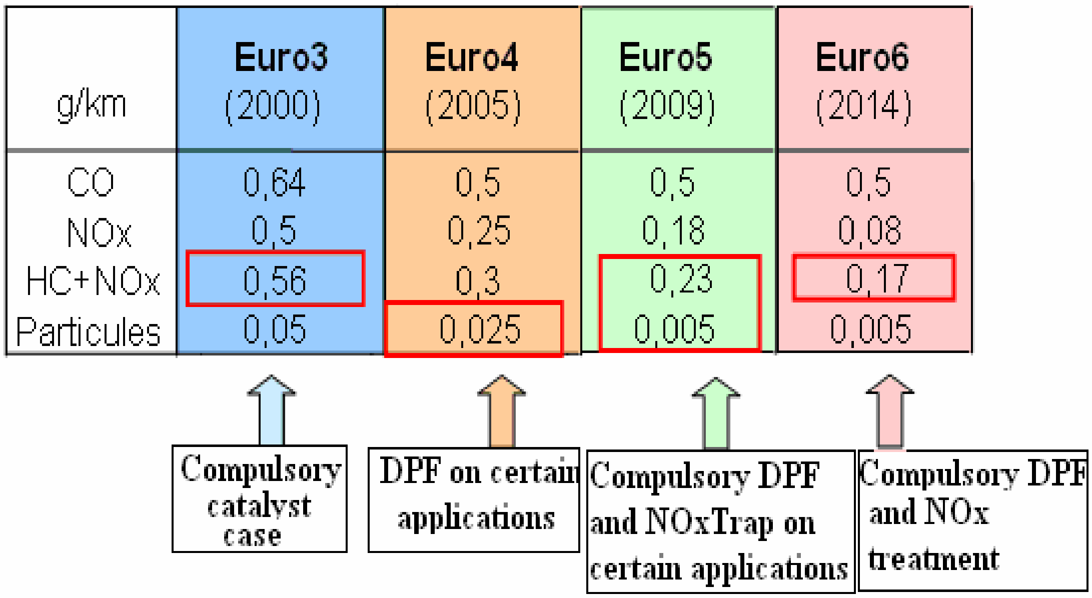


Fig.7

As one can notice in figure 7, in the first step the filter retains the particles all the time, and when a certain degree is reached the regeneration starts. This phenomenon lasts for about 20 minutes at each 300-500 km, depending on the running time.

Although there is the possibility of genesis depollution, this is not enough to observe the new pollution standards, which establish the maximum values which can be released in the atmosphere. Along time their severity has increased, so that today one already talks about EURO6. Figure 8 presents the evolution of the limits imposed by European standards.



g/km	Euro3 (2000)	Euro4 (2005)	Euro5 (2009)	Euro6 (2014)
CO	0,64	0,5	0,5	0,5
NOx	0,5	0,25	0,18	0,08
HC+NOx	0,56	0,3	0,23	0,17
Particules	0,05	0,025	0,005	0,005

Fig.8

Mechanical particles represent major problems for human health. One knows very well the effects on the respiratory system as well as the cancerigenic effects for the circulatory system. If nowadays the actual standards impose limits as to the particle mass, in the future the standards will have to provide for their dimensions, because it is well known that the smallest particles are the most toxic ones (the circled area in figure 9).

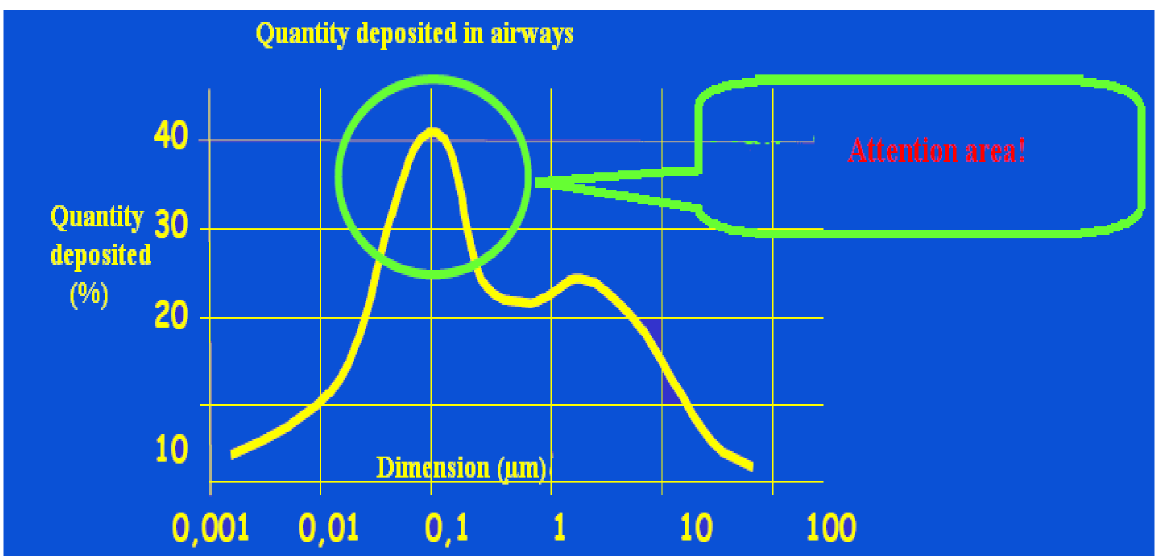


Fig.9

2. PROBLEMS REGARDING THE IMPLEMENTATION OF THE VEHICLE POST TREATMENT SYSTEMS

The main problems encountered with the PAF implementation are related to the old DPF' s recycling, their limited lifetime, constraints related to the vehicle's architecture. Figure 10 presents the main PAF implementation architecture of a vehicle

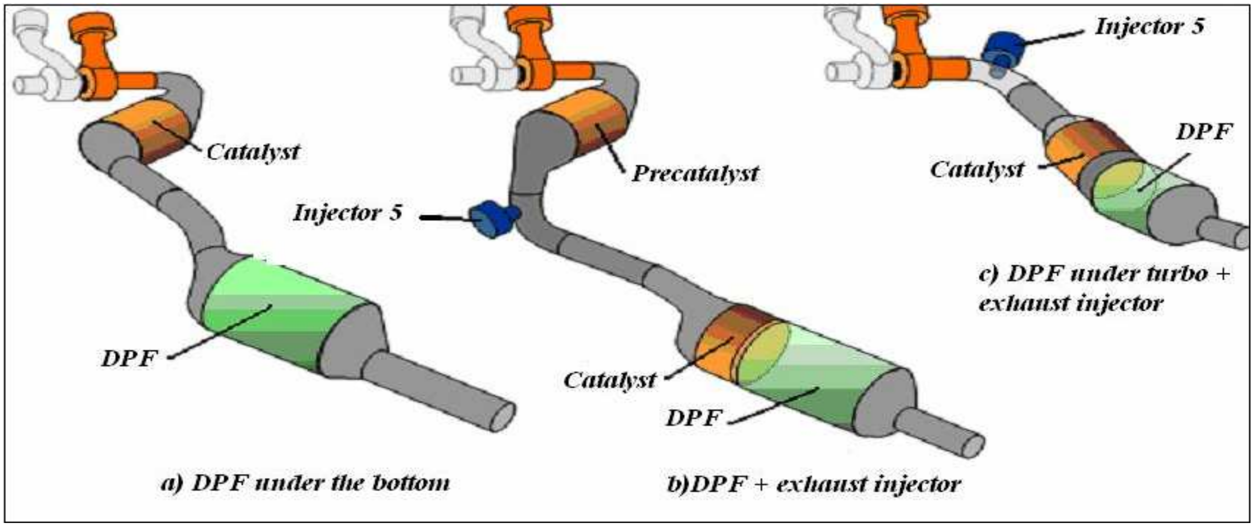


Fig.10

1. DPF under the bottom (fig 10a) realizes the regeneration by the saturation of the first precatalyst. It has as advantages a quick heating which leads to a quick kicking-off of the catalyst case. As to the main disadvantages, mention should be made of: the temperature necessary for the regeneration is reached hard (which makes the regeneration to be difficult); a high cost.

2. DPF + exhaust injector (fig 10b) has as advantage a good vaporization of the Diesel oil in the exhaust section. It has as disadvantages: a regeneration is needed at short time periods (almost 100 km), and the Diesel oil injection in the exhaust section leads to a fuel increase, on the whole.

3. DPF under turbo + exhaust injector (fig 10c) has as advantages minimal heat losses between the turbo supercharging system and the catalyst case. Therefore, regeneration is easier. It has as disadvantage the setting.

3. WAYS OF CONTROLLING REGENERATION

Two main conditions have to be satisfied to have an efficient regeneration: the entering DPF temperature has to vary between 550°C and 650°C and the oxygen percentage in the gas that passes through the filter has to be between 5% and 10%. Generally, two ways of PAF regeneration are known, namely:

- passive (natural) regeneration, occurring in the case of high rotation and charge degrees in the engine functioning (regeneration is the consequence of high temperatures reached by the gases in the exhaust section).
- active regeneration, which supposes either fuel injection in the upwards DPF, or late injection (post injection) in the combustion chamber, electronically controlled. Post injection adjusts to the temperature increase given by the oxidation catalyst reactions and the oxygen quantity controlled with the help of a shutter.

4. EXPERIMENTAL RESEARCH CONCERNING THE VALIDATION OF A DPF CONSTRUCTIVE VARIANT FOR A C.I.E. MEANT FOR LIGHT

The aim of the research is to notice the DPF behavior regarding the drop in pressure, function of the gas flow in two cases: new DPF (curve 4) and regenerated DPF (curve 5) fig. 13.

The attempts were made on an engine test stand, the obtained values for the drop pressure being showed in the graphic (fig 13). One had in view that both in the case of the new DPF and of the regenerated DPF the curves be between curves 1 and 2 in the admissible area. The inferior and superior limit curves are established according to some research on similar vehicles which fit in the EURO5 standards. The drop pressure curve represents the middle area of the range. One has in view that the new PAF have a drop pressure situated as much as possible as close as the reference curve 3. The used DPF was similarly set according to the way rendered in fig. 10c.

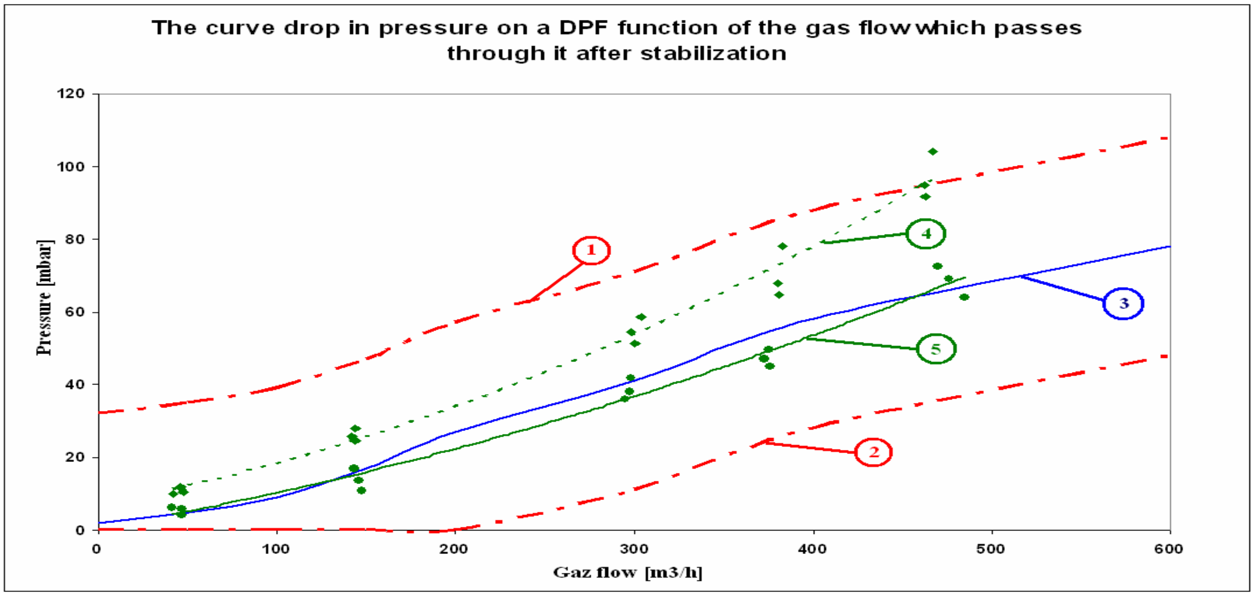


Fig. 13

The principle of this attempt is represented by the maintaining of the engine within working conditions at which the exhaust gases temperature is higher than 650°C when entering the DPF, to allow the oxidation of the mechanical particles of the DPF. In this case the level of the smoke emission has to be higher than 2FSN (filter smoke number) as there have to be particles to oxidize within the DPF all the time. If the particles are missing during the regeneration process there is the risk of the"Green Effect' phenomenon, which means exaggerated increase of the monolith temperature, leading to destruction. It results that the DPF solution has values of the drops in pressure near the reference curve both before and after the regeneration.

5. CONCLUSIONS

The fitting in the EURO5 and EURO6 European standards imposes well studied particle filters both in point of view of the setting and of the drop in pressure. The proposed testing method to validate the construction of a PAF proved to be efficient and necessary.

6. BIBLIOGRAPHY

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