EFFECTS OF USING CRT PARTICULATE MATTER FILTERS FOR SELF IGNITION ENGINES

Particulate matter emission, next to that of nitrogen oxides, belongs to the most serious ecological threats posed by combustion engines. This is particularly dangerous in great urban agglomerations. One of the most significant sources of particulate matter emission in the urban centres are self ignition engines of lorries and urban buses. Most effective ways of lowering particulate matter emission are particulate matter filters. This paper presents studies results on the influence of using self regenerating CRT filter on their emission, from the bus engine. The tests were conducted in the static and dynamic conditions.

Keywords: self ignition engines, pollutants emission, particulate matter filters.

1. Introduction

Particulate matter emission is one of the most serious ecological threats posed by motorism. It is well known that particulate matter – PM10 concentration limits are one of the most frequently exceeded acceptable air pollutants concentration limits in the urban agglomerations [5, 11, 12]. Harmfulness of particulate matter to health is also known [5, 11, 12].

Figure 1 shows photography of particulate matter emitted from the self ignition engine.

![Particulate matter in agglomerates, emitted from the self ignition engine](image)


![Particulate matter content diagram: SOF – organic fraction dissolvable in methylene chloride CH₂Cl₂, INSOL – fraction insolvable in methylene chloride CH₂Cl₂ (most often non–organic)](image)

Carbon part – PMₐ of particulate matter consists of soot (C₅₀₋₇₀). Non–organic fraction consists of: water, metal salts, (sulfates and nitrates) as well as other none organic substances, like heavy metals. Particulate matter organic fraction consists of hydrocarbons HCₐ from fuel (PMₖ₉) and from diesel oil (PM₉₋₁₀). Hydrocarbons contained in the particulate matter form part of the hydrocarbons emitted from the engine – their remaining part is in the volatile state. Most dangerous to health particulate matter components are: organic compounds, particularly heavy ones (coming first of all from oil fraction) and heavy metals. Particulate matter acts in a very harmful way on human organisms, mechanically affecting the air passages [11, 12].

The main source of particulate matter emission in the transport sector are self ignition engines. Because of that, the methods of lowering particulate matter emission from self ignition engines are being sought as well as those to replace these engines with other types in the vehicles used in the areas most ecologically endangered. There are several possibilities of lowering particulate matter emission from the vehicle engines. Classic methods being perfecting engine design solutions and developing new generations of diesel oil [5, 7]. Other work on catalytic fuel additives is also being conducted, providing decrease of pollutants emission, including particulate matter [10]. The use of biofuels to supply self ignition engines is an effective solution. Biofuels containing vegetable oil esters enable effective limitation of particulate matter emission [9, 10]. Particularly good effects can be obtained in this field using E95 fuel (of over 90 percent bioethanol content) to supply self ignition engines of special design (Scania DS9E 01) [6]. Using natural gas as a fuel is also an effective solution [7]. Usually natural gas is used to supply spark ignition engines, which are modified self ignition engines powering heavy duty vehicles [7].

A classic method to decrease the emission of particulate matter is the use of particulate matter filters– DPF (Diesel Particulate Filter) [1 – 5, 7, 13 – 27]. These filters enable even 10 – fold reduction of particulate matter emission. The basic operational problem of these particulate matter filters is the necessity of regenerating them due to pollutants being collected in the filter pack. The solution, which in the recent years revolutionised limiting particulate matter emission, is the use of self regenerating particulate matter filters – CRT (Continuously Regenerating Trap). System CRT consists of two modules: oxidising catalytic converter OXICAT and particulate matter filter DPF [3, 13, 15, 17, 20, 21]. CRT filter diagram and the way it works is shown on the figure 3.
In the oxidising catalytic converter, oxidation of the following substances takes place: organic compounds into carbon dioxide and water, carbon monoxide to carbon dioxide and nitrogen oxide to nitrogen dioxide. Thanks to significant affinity of nitrogen dioxide with carbon it is possible to effectively oxidise soot, forming a matrix of particulate matter, already in the temperature just above 200ºC, while oxidising soot by an oxygen contained in the exhaust gasses takes place at sufficiently high speed, only at the temperature above 550ºC [2, 17, 25]. Since, the oxidisation of soot contained in the filter effectively takes place already from 200ºC, the filter constantly undergoes the process of regenerating itself during engine operation [2, 17, 25].

2. Results of CRT filter efficiency studies

CRT filter efficiency studies have been carried out using British system Eminox and self ignition 6CT107 Andoria Mot engine in the following tests [5]:
- static ESC test (European Stationary Cycle) to study pollutants emission – with a start up of a warm engine,
- dynamic ETC test (European Transient Cycle) to study pollutants emission – with a start up of a warm engine
- dynamic HDDTT test (Heavy Duty Diesel Transient Test) to study pollutants emission – with a start up of a cold engine – HDDTT–c with a start up of a warm engine
- HDDTT–h,
- dynamic ELR test (European Load Response) to smoke test of the exhaust – with a start up of a warm engine.

They were the first CRT system tests in Poland in the dynamic conditions, also for the first time in Poland, the engine studies were carried out using American HDDTT dynamic test.

The equipment used complied with the type approval procedures requirements. In the dynamic tests, the values measured were being recorded constantly with a 10 Hz frequency.

Figures 4 – 8 show specific brake pollutants emission and specific brake fuel consumption in the research tests – ETC, HDDTT and ESC, while figure 9 – shows light absorption coefficient for the exhaust gasses in the ELR test. For comparison the results shown are for the engine: without the filter and with the filter.
As a result of using CRT filter, a significant reduction of particulate matter emission has been obtained in all tests. The greatest efficiency was achieved in the static conditions (ESC) – over 90%, but even in the dynamic test HDDTT with a start up of a cold engine, the efficiency of almost 70–percent should be regarded as very good. The use of CRT filter also caused significant reduction of carbon monoxide and hydrocarbons emission. It is important, that an increase of nitrogen oxides emission did not occur, but instead, even their small reduction took place. Specific brake fuel consumption remained practically at the unchanged level. This confirms effectiveness of the filter self regeneration process during operation. It is worth noting the fact, that an average exhaust counterpressure, due to using CRT filter was small, being about 3 kPa – figure 10.

Slight increase in the exhaust temperature was noted, due to using CRT filter – by an average umpteen degrees centigrade (figure 11).

CRT filter tests in the static and dynamic conditions confirmed great effectiveness of this method of reducing particulate matter emission.

3. Final remarks

CRT filter effectiveness tests were conducted in the tests, complying with type approval procedures in Europe and United States. In reality of vehicles operation, particularly urban buses, there are big discrepancies between combustion engines operating conditions and type approval tests conditions. First off all, during normal operation, engine loads are smaller, resulting in lower exhaust temperature. This can cause insufficient effectiveness of the filter regeneration during operation – practice of using CRT filters in urban busses confirms these worries [24, 25]. Therefore it is advisable to conduct operational tests of CRT filter in the urban busses as well as bench tests, simulating bus engine operating condition. Such tests would be expected to reveal sensitive points of the effectiveness of lowering the particulate matter emission and filter self regenerating, in relation to the engine thermal state. Such knowledge could be used to work out indications and guidelines to: on one hand – the conditions of the filter installation, and on the other – optimising engine operating conditions with regards the efficiency of lowering particulate matter emission, under the conditions of small loading of the combustion engine.
4. References


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