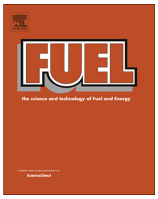
Fuel xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel



Full Length Article

Impact of high sulfur fuel and de-sulfation process on a close-coupled diesel oxidation catalyst and diesel particulate filter

Federico Millo [a,*], Mahsa Rafigh [a], Maurizio Andreata [a], Theodoros Vlachos [a], Pranav Arya [a], Paolo Miceli [b]

[a] *Energy Department, Politecnico di Torino, Italy*

[b] *Applied Science and Technology Department, Politecnico di Torino, Italy*

ARTICLE INFO

Article history:
Received 15 May 2016
Received in revised form 8 December 2016
Accepted 4 January 2017
Available online xxxx

Keywords:
High sulfur diesel fuel
Diesel oxidation catalyst
Catalyst sulfur poisoning
Catalyst light-off

ABSTRACT

The application of more stringent emission regulations for passenger cars in Asian and South American countries is challenging due to the presence of low-quality diesel fuel, which enhances the risk of deactivation of aftertreatment systems due to its higher sulfur content. In this context, the impact of high sulfur fuel on the performance of a close-coupled Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF) was experimentally tested for degreened, sulfated and de-sulfated real size aftertreatment components, through engine tests carried out on a highly-dynamic engine test rig, allowing to reproduce the transient operation of the engine and of the aftertreatment system during type approval driving cycles. In order to assess the impact of sulfur poisoning, a specific poisoning procedure was adopted which resulted in different sulfur poisoning levels. The impact of different space velocities on degreened, poisoned and de-sulfated system was examined and compared considering light-off curves for CO and HC. The poisoned system was found to be worst effected due to increasing space velocities. In addition, the ability to recover the performance of aftertreatment system after regeneration through a proper de-sulfation strategy was evaluated with respect to fresh, degreened, catalyst. The aftertreatment system recovered its efficiency almost completely after the de-sulfation procedure was carried out.

1. Introduction

The application of more stringent emission regulations for passenger cars in Asian and South American countries (see for instance [1] for future legislation trends in India) is challenging due to the presence of low quality diesel fuel with high sulfur content, which not only produces harmful emissions of SO_x and increases the sulfate fraction of Particulate Matter (PM) [2], but also enhances the risk of diesel catalyst deactivation [3].

Deactivation of the diesel catalyst causes gradual deterioration of its performance resulting in increased emission levels from the vehicle [4]. Catalyst poisoning, which can be originated from sulfur coming from either diesel fuel or lubricant oil, degrades the performance of aftertreatment devices. It is worth mentioning that sulfur poisoning is frequently reversible by exposure of the affected catalyst to high temperatures through which the sulfur compounds decompose and are released from the catalyst washcoat. During combustion sulfur compounds are oxidized and converted to SO_x and sulfate particulates which accumulate on the catalyst surface of aftertreatment devices and cause the temporary or permanent deactivation of the catalyst [5]. Previous studies revealed that traces of sulfur in the combustion products can poison the Diesel Oxidation Catalysts (DOCs) in the emission control system and reduce their effectiveness for the oxidation of harmful carbon monoxide (CO), hydrocarbons (HCs) and volatile organic matter [6–8]. During past researches [9,10], it was observed that the increase of the sulfur content of the fuel results in almost linear growth of PM (particularly sulfate particulates) which results in masking of sites and pores of the DOC and deteriorating its performance. Andersson et al. evaluated the degree of reversibility of the chemical deactivation by sulfur over a diesel oxidation catalyst [11]. Truex et al. [12] found out that poisoning is more crucial at low temperatures, while at higher temperatures adsorption of sulfur is negligible and sulfur species can desorb if a threshold value is reached. In another study, Phillips et al. [13] investigated the impact of high sulfur levels of the fuel on the DOC at low

---

Abbreviations: BMEP, Brake Mean Effective Pressure; DECSE, Diesel Emission Control–Sulfur Effects; DOC, Diesel Oxidation Catalyst; DPF, Diesel Particulate Filter; FTP, Federal Test Procedure; NEDC, New European Driving Cycle; PM, Particulate Matter; ULSD, Ultra Low Sulfur Diesel.

[*] Corresponding author.

E-mail address: federico.millo@polito.it (F. Millo).

http://dx.doi.org/10.1016/j.fuel.2017.01.006
0016-2361/

Please cite this article in press as: Millo F et al. Impact of high sulfur fuel and de-sulfation process on a close-coupled diesel oxidation catalyst and diesel particulate filter. Fuel (2017), http://dx.doi.org/10.1016/j.fuel.2017.01.006

temperatures through experimental analysis. The experiments conducted by Diesel Emission Control–Sulfur Effects (DECSE) program assessed the effects of various levels of sulfur and found out that a significant increase in the high-temperature HC emissions over DOC was observed during Federal Test Procedure (FTP) transient tests for high sulfur content, while CO emissions were almost unaffected in this case [6].

In this context, the aim of this study is, therefore, to experimentally investigate the decay trend of the oxidation performance of a full-size, close-coupled Diesel Oxidation Catalyst and Diesel Particulate Filter aftertreatment system due to sulfur poisoning and the capability to recover the catalyst efficiency using a proper de-sulfation process.

2. Experimental setup

Experimental investigations were performed on a Euro 5, 4-cylinder 2.0 l Common Rail Diesel engine for passenger car applications, the main characteristics of which are reported in Table 1. All experimental tests were carried out at Politecnico di Torino, on a highly-dynamic engine test bed, featuring an ELIN AVL APA 100 cradle-mounted dynamometer capable of realizing full four-quadrant operation with high speed and torque dynamics, including simulation of zero torque and gear-shifting oscillations in the drivetrain.

The instantaneous fuel consumption was measured through an AVL KMA 4000 system; exhaust gas were sampled at three different locations in the exhaust, at the engine outlet, at DOC outlet and at DPF outlet by means of an AVL AMA i60 gas analyzer and of a V&F AIRSENSE mass spectrometer, as reported in Fig. 1. The AMA i60 features two simultaneous sampling lines, thus allowing the measurement of pollutant species in two locations along the exhaust line, for instance at engine outlet and DPF outlet. Due to the presence of just two sampling lines, multiple tests were carried out performing emission measurements first at engine out and DOC out, and then at engine out and DPF out. The multiple tests were carried out accurately checking the repeatability of the data.

Moreover, gas temperatures and pressures in the most important locations of the exhaust and intake systems of the engine (i.e. upstream and downstream of the compressor and turbine, of air and EGR cooler, etc.) were measured by means of K-type thermocouples and piezo-resistive pressure transducers respectively. It is worth mentioning that all the temperatures measured in this study are the gas temperatures, not the monolith temperatures, although in previous activities it was proven that through proper numerical models the monolith temperatures can be estimated [15].

All of the above described measurement devices were controlled by an AVL PUMA Open 1.3.2 automation system, which also includes ISAC 400 software for the simulation of vehicle (road load, road gradient and moments of inertia of the driveline components that are not physically present on the test bed) and driver behavior (use of clutch, accelerator pedal and gear shifting), thus allowing the user to reproduce the driving cycles which are usually carried out on the whole vehicle on the chassis dynamometer for type approval. The New European Driving Cycle (NEDC) was selected to assess the impact of sulfur poisoning on the conversion efficiency of the aftertreatment devices, and the execution of each NEDC test was repeated at least three times, in order to assure the repeatability of the results [14].

Tested aftertreatment component was a close-coupled cc(DOC-DPF) catalyst. DOC and DPF were installed inside a dismountable canning, as shown in Fig. 1, allowing an easy switch between different components.

The main characteristics of tested aftertreatment components installed in the dismountable canning are listed in Table 2.

It is important to note that prior to each sulfur loading phase, after a de-sulfation procedure, which will be explained in following

Table 1
Main characteristics of the test engine [14].

Engine characteristics	
Engine type	Diesel 4 stroke
Displacement	1956 cm^3
Cylinders arrangement	4 in line
Firing order	1-3-4-2
Maximum torque	350 Nm @ 1750 rpm
Maximum power	115 kW @ 4000 rpm
Bore × stroke	83.0 mm × 90.4 mm
Compression ratio	16.5:1
Turbocharger	Single-stage with VGT
Fuel injection system	Common rail 2nd generation CRI2.2 – 1600 bar

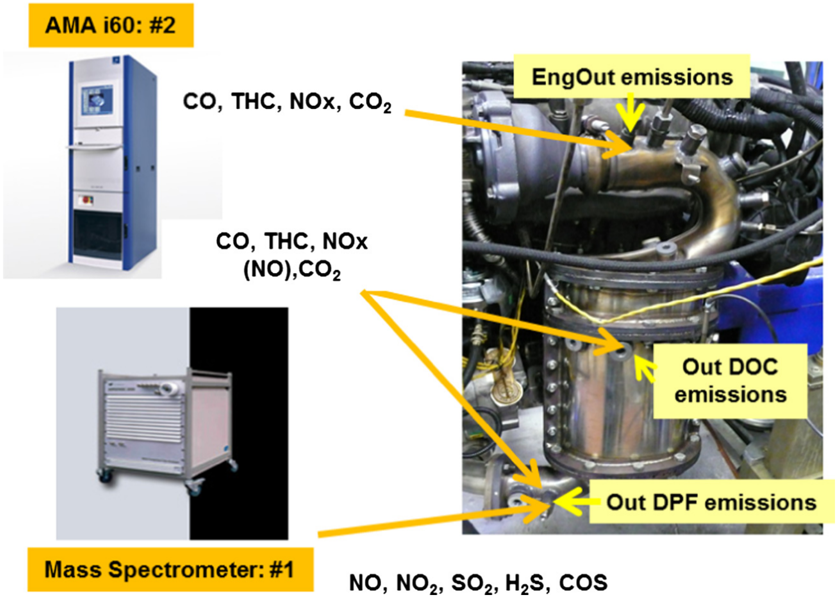


Fig. 1. Exhaust emission measurement layout [14].

Please cite this article in press as: Millo F et al. Impact of high sulfur fuel and de-sulfation process on a close-coupled diesel oxidation catalyst and diesel particulate filter. Fuel (2017), http://dx.doi.org/10.1016/j.fuel.2017.01.006