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Effects of Temperature on Noise Reduction in Diesel Particulate Filters (DPFs)

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Abstract

The temperature of exhaust gasses plays a significant role in the DPFs' performance. DPF is a device that is responsible (in addition to exhaust emissions reduction) for making noise reduction (which is usually measured by noise reduction factor (NRF)) of noise resulted from engines. Temperature of exhaust gases has a considerable effect on such filters performance. Temperatures' effects on the performance of those filters is studied and investigated here, and a relation between noise reduction factor and temperature will be constructed. Analytical or/and numerical techniques will be used here to execute the study to construct the mentioned relation.

Introduction

Temperature has a considerable effects on NRF, the temperature of exhaust gases effects the performance of the DPF. As the temperature of gases increases the frequency of the propagate sound inside the DPF is increased. For filter regeneration to work effectively, exhaust temperatures need to exceed about 500° C for non-catalyzed systems, and 250° to 300° C for catalyzed systems. Some diesel particulate filters use a "passive" approach, and do not require an external or active control system to dispose of the accumulated soot. Passive filters are installed in place of the muffler. At idle or low power operations, particulate matter is collected on the filter. As the engine exhaust temperatures increase, the collected material is then burned or oxidized by the exhaust gas, thus cleaning or regenerating the filter.

Allam and Abom (2002) build up theoretical models to predict the acoustic 2-port (4-pole) of a diesel particulate filter (DPF) unit. In the first model the steady flow resistance was used to calculate an equivalent lumped resistance. In this model the wave propagation in the DPF monolith was neglected and was a low frequency approximation. To include wave propagation effects the monolith was described using a coupled wave guide model, where the coupling was via the porous walls of the monolith. Darcy´s law was used to describe the pressure drop in the porous walls. Based on this an improved theoretical model was obtained. Both models were compared to measured data from a test rig with clean air operating at 20 C. The agreement for the 1-D wave propagation model was quite good but for low frequencies (< 300 Hz) the lumped resistance model also seems satisfactory.[3]

Allam (2005) studied the acoustic modeling and testing of DPF and considered it as an eigenvalue 1D problem. This paper presented a first attempt to describe the acoustic behavior of DPFs and to present models which allow the acoustic two-port to be calculated. The simplest model neglected wave propagation and treated the filter as an equivalent acoustic resistance modeled via a lumped impedance element. This simple model gave a constant frequency independent transmission loss and agreed within 1 dB with measured data on a typical filter (length 250 mm) up to 200–300 Hz (at 20 C). In the second model, the ceramic filter monolith is described as a system of coupled porous channels carrying plane waves. The coupling between the channels through the porous walls is described via

Darcy's law. This model gave a frequency-dependent transmission loss and agreed well with measured data in the entire plane wave range.[8].

Transmission losses of the DPF depending on [1] can be given as:

$$\begin{aligned}TL_{DPF} &= 10\log_{10}(\Big| (1/16)T_{11} + (1/8)iY_1NT_{21} + (1/8)NT_{21}Z_{IN}M_{IN}(1/m_{IN}^2 - 1) + \\ &(1/4)T_{11}Z_{OUT}M_{OUT}(1 - 1/m_{OUT}) + (1/2)iY_1NT21 + 0.5NT_{21}Z_{IN}M_{IN}(1/m_{IN}^2 - 1) + \\ &Z_{OUT}M_{OUT}(1 - 1/m_{OUT}) + (1/8)iY_3T_{11} - 0.25Y_3Y_1NT_{21} + 0.25iY_3NT_{21}Z_{IN}M_{IN}(1/m_{IN}^2 - 1) + \\ &(1/16)T_{12}NiY_3 - (1/8)Y_1Y_3T_{22} + (1/8)iY_3T_{22}Z_{IN}M_{IN}(1/m_{IN}^2 - 1) + (1/16)NT_{21} + \\ &0.25NT_{21}Z_{OUT}M_{OUT}(1 - 1/m_{OUT}) + (1/8)NT_{21}iY_3 + (1/16)T_{22} \Big|)\end{aligned} \tag{1}$$

Noise reduction factor is given as

$$NRF = TL + 10\log\frac{\alpha}{A} \tag{2}$$

The noise reduction factor-temperature relation can be formulated depending on analysis made by [1] it is found that as temperature rises the noise reduction will increase by 60%, so:

$$NRF_t = 1.6(NRF = TL + 10\log\frac{\alpha}{A}) \tag{3}$$

Equation (3) shows that the noise reduction of the DPF increases about 60% by increasing the temperature because the filter regeneration increases as the gases temperature increases. In addition and depending on results of [1] it can notice that transmission losses increases with temperature and hence noise reduction increases.

Results and discussion

The figure below shows that the noise reduction factor increases as the temperature increases.

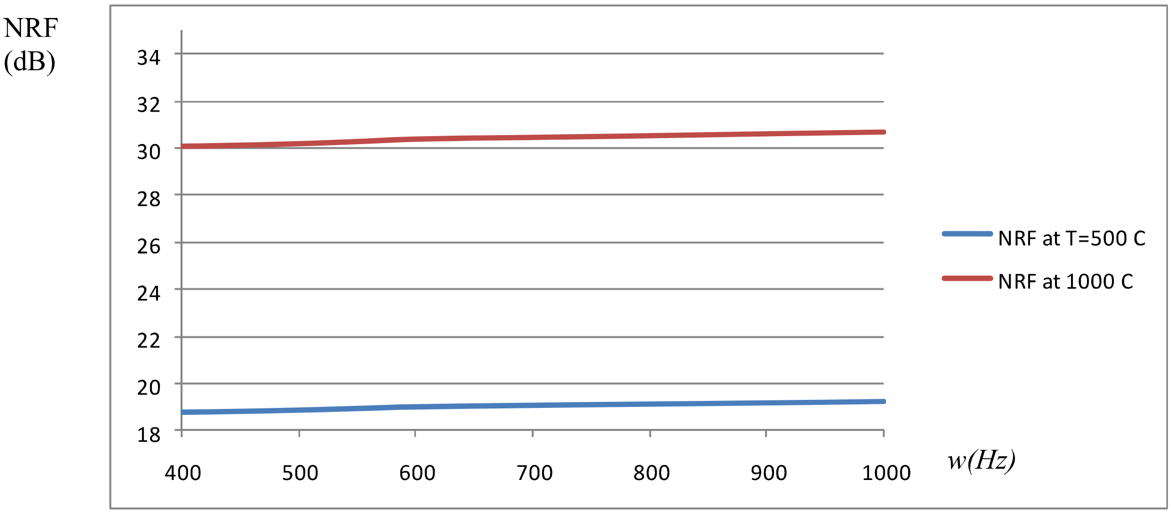

Figure (1) NRF vs. frequency.

Conclusions

The temperature of exhaust gases has an important role in DPF operation, since as this temperature increases the noise reduction increases, also the regeneration for the DPF becomes easier and so more transmission losses occur and hence more noise reduction.

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