A Counter Flow Denuder for Engine Exhaust Conditioning: First Laboratory Experiments

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Introduction

The European emission standards limit the number of solid particles per kilometer emitted by vehicles. In order to measure this regulated quantity correctly it is necessary to:

- Remove volatile particles
- Inhibit the growth of sub-cut size particles
- Prevent nucleation
- Limit particle losses

There are three established methods to fulfill these requirements[2,3]:

- Evaporation tube
- Thermodenuder
- Catalytic Stripper

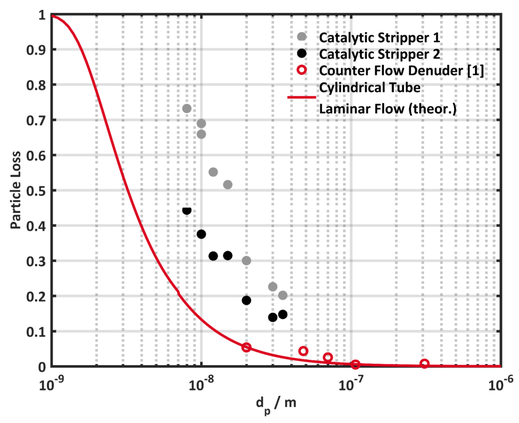

Figure 1: Diffusional particle loss comparison between two different catalytic strippers, the counter flow denuder [1] and the theoretical behavior of a cylindrical pipe

We present a counter flow denuder (CoFD) as an alternative approach to the existing methods. This device can tackle many downsides of the established devices. Figure 1 shows the relative particle loss as a function of particle diameter for different methods.

Working Principle

The counter flow denuder consists of a porous glass tube surrounded by a stainless steel tube. The sample gases inside the glass tube are exchanged with the gases in the outer purge gas channel by diffusion. Antiparallel flow directions of the inner sample flow and the outer purge gas flow ensure a high concentration gradient over the whole length of the device. Figure 2 schematically illustrates the working principle of the counter flow denuder.

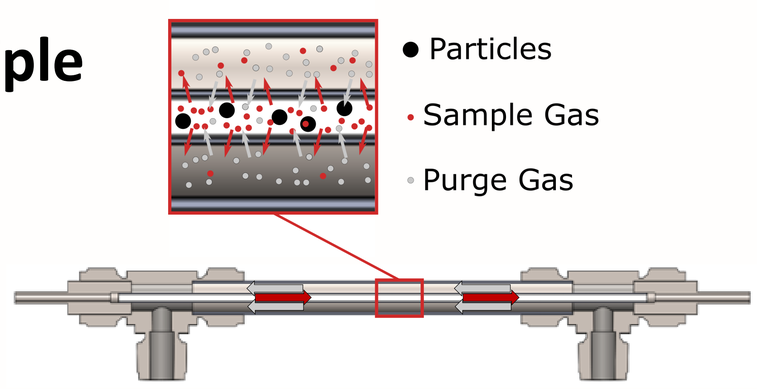

Figure 2: Drawing and schematic of the working principle of the counter flow denuder

Experiment and Results

Laboratory based experiments were performed to test the potential of the counter flow denuder for engine exhaust conditioning. The formation of a nucleation mode after conditioning an aerosol containing soot and gaseous sulphuric acid, was monitored. The CoFD was compared with an evaporation tube and a catalytic stripper. Figure 3 shows a schematic of the experimental setup.

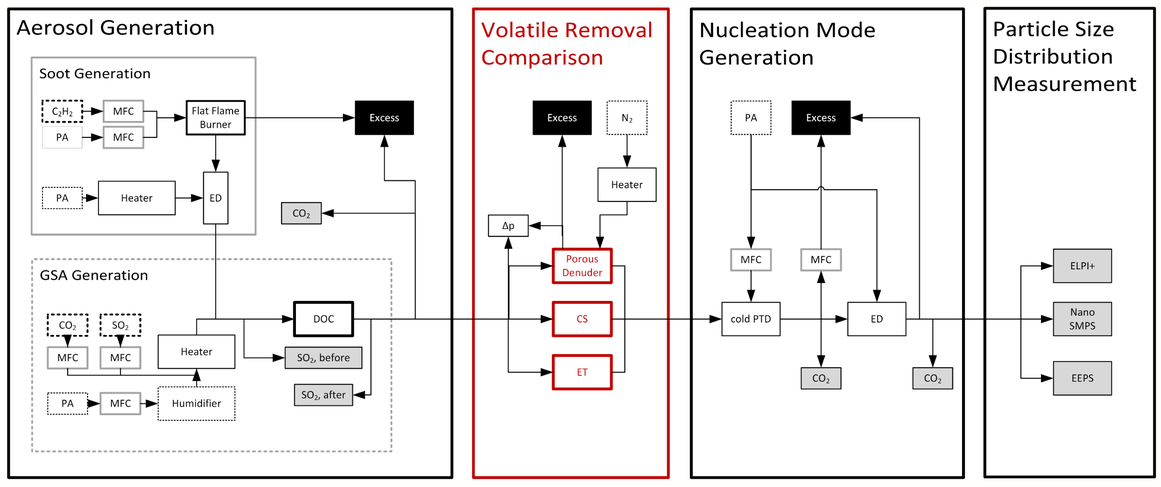

Figure 3: Schematic drawing of the experimental setup used to compare the counter flow denuder with an evaporation tube and a catalytic stripper.

The results in Figure 4 show that the CoFD prevents the formation of a nucleation mode at moderate SO_2 feeds and lowers the particle size and number concentration at high SO_2 feeds, taking the evaporation tube as a reference. The catalytic stripper prevents the formation of a nucleation mode entirely.

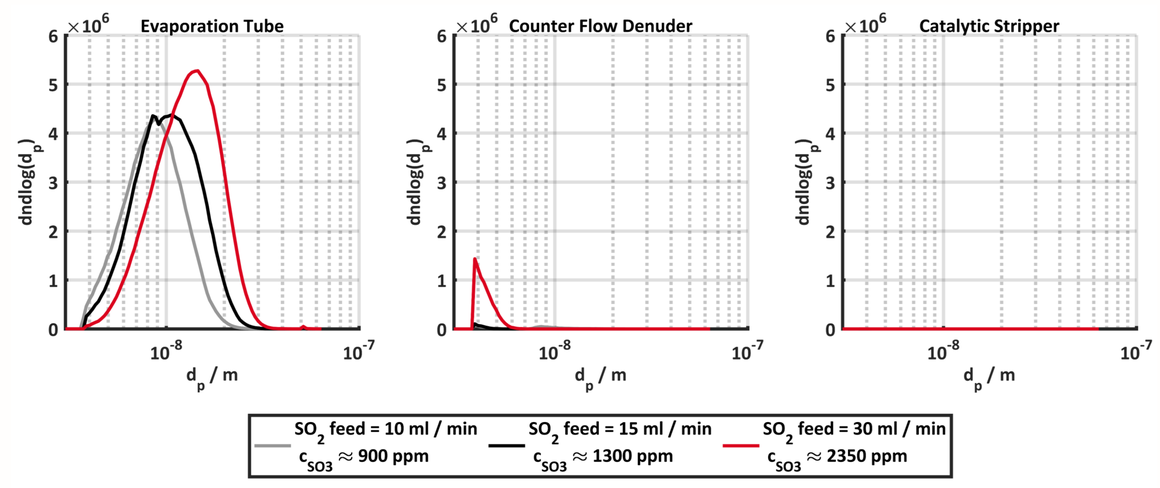

Figure 4: Nucleation particle size distribution for the evaporation tube, the CoFD and the catalytic stripper for different SO_2 feeds

Conclusion

We demonstrated that the use of a counter flow denuder can prevent the formation nucleation mode particles in a laboratory generated exhaust similar to engine exhaust. Further experiments will be conducted to test the removal of other substances and to determine the long-term stability of the device.

References

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