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Structured catalytic reactors for ozone abatement in more electrical aircrafts

Alexandre Guérin, Yousef Swesi, Amaury Gillet, Marie-Line Zanota, Régis Philippe, Valérie Meille*

CP2M (formerly LGPC) - CNRS/CPE Lyon/UCBL, University of Lyon, Villeurbanne, France

**Corresponding author E-Mail: valerie.meille@ircelyon.univ-lyon1.fr - present address: IRCELYON, University of Lyon, Villeurbanne, France.*

1. Introduction

In aircrafts, outside air is not directly fed to passengers, because it contains high ozone concentration at elevated altitudes. Catalytic converters are thus necessary to lower ozone concentration to authorized values. Such equipments already exist but have to evolve to take into account the energetic constraints of more electrical aircrafts. Concretely, ozone reduction has to be performed efficiently at temperatures lower than 100°C, so that the ozone concentration of fresh air entering the aircraft cabin does not exceed 100 ppb (for 3 hours) and 250 ppb instantly.

To improve the ozone converter efficiency, different solutions car arise from catalyst and/or reactor optimisation, keeping in mind that the pressure drop must be kept very low.

In this study, a focus was made on the reactor configuration, using a single commercial catalyst coated on different structures in order to find the best trade off between pressure drop and mass transfer efficiency.

2. Methods

The chosen catalyst is a commercial Pd/alumina that was coated on 8 different structures: 3 metallic monoliths (300, 400 and 600CPSI), 3 ceramic monoliths (300, 400 and 600CPSI) and 2 metallic foams (3.8mm and 2mm mean cell size) which were characterized by X-ray tomography and corresponding image treatment in order to obtain a full statistical description of the objects, see Table 1.

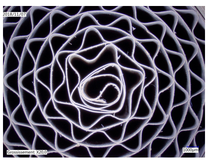
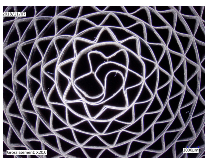
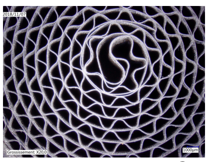
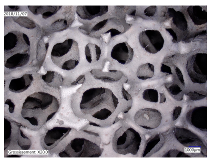
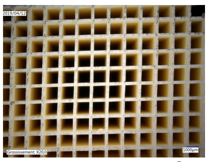
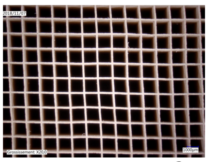
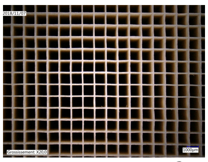
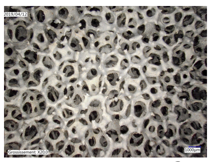
 MM300 – 3250 m^2/m^3	 MM400 – 3720 m^2/m^3	 MM600 – 4400 m^2/m^3	 FM3.8mm – 433 m^2/m^3
 MC300 – 2250 m^2/m^3	 MC400 – 2750 m^2/m^3	 MC600 – 3380 m^2/m^3	 FM2mm – 895 m^2/m^3

Table 1. Different structures used in the ozone converter.

The reactor was filled with cylindrical structured segments of 2.5cm (i.d.) x 2.5cm (L). The same O_3 concentration, residence time and gas velocity than in an actual aircraft equipment were used. The pressure drop was measured experimentally using a differential pressure sensor and were modelled using the Darcy-Forchheimer correlation. The ozone conversion were measured thanks to an ozone analyser (BMT).

3. Results and discussion

Whereas ceramic and metallic monoliths show a pure viscous flow behaviour in the gas velocity range of experimental conditions explored, it was necessary to consider an inertial term in the case of foams.

The reaction was found to be drastically limited by external mass transfer. Using the classical approach consisting in considering a full external mass transfer control, volumetric mass transfer coefficient were estimated from the ozone conversion (X) through the equation: $k_D S_v = \frac{-u_v ln(1-X)}{L}$, where S_v is the specific surface area of the structure (m^2/m^3) determined from image analysis, L the length of the 2 segments and u_v the superficial gas velocity [1]. Figure 1 both shows the pressure drop ranking of the structures and the corresponding volumetric mass transfer coefficient at a given flow rate.

Foam structures showed low performances with regard to the corresponding pressure drop which is traduced by a tradeoff index I (see [1] for definition) lower than 0.1. Metallic monoliths with 400CPSI presented the best compromise at the moment, with I close to 0.4. The missing value concerning MM600 should reach even better performances with an acceptable pressure drop.

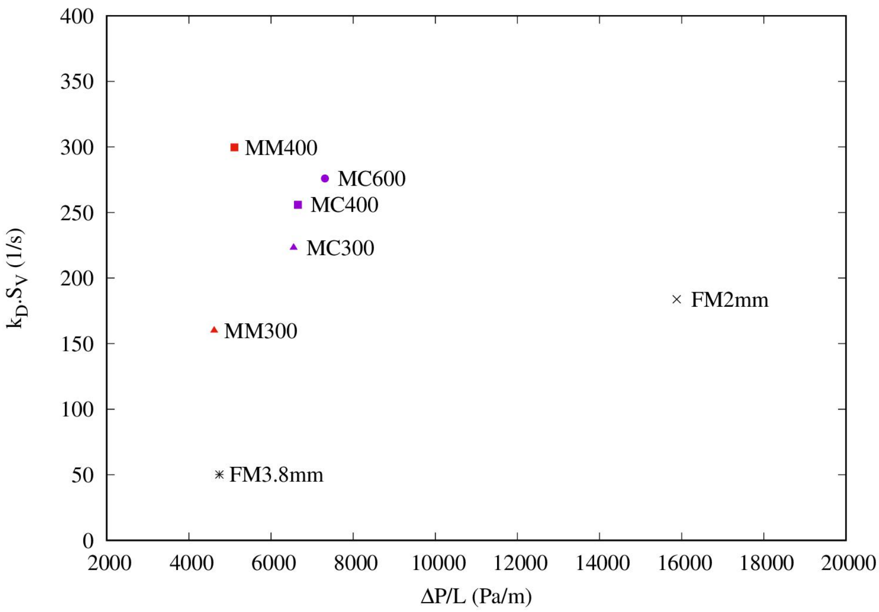


Figure 1. Volumetric mass transfer coefficients vs. pressure drop for the different structures at 120°C, $8Nm^3/h$, u_v=6.6m/s

4. Conclusions

After an appropriate selection of the internal structure (compromise between pressure drop and mass transfer efficiency), attention is now paid to the robustness and lifetime evaluation of the catalyst layer to several contaminants (H_2O, SO_2, COV) mimicking the true life of such an ozone catalytic converter.

References

[1] L. Giani, G. Groppi, E. Tronconi, Ind. Eng. Chem. Res. 44 (2005) 4993-5002