BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING institute of process engineering

19 AIChE Annual Meeting, Orlando, FL

Experimental Verification of Pressure Drop for Removal of VOC

David Jecha*, Vladimir Brummer

email: jecha@fme.vutbr.cz

Introduction

This research is focused on experimental acquisition of pressure drop data and obtaining mathematical dependencies of catalyst pressure drop for flue gas emission cleaning equipment. This paper presents the results of the experimental verification focused on the analysis of the selected types of catalysts for VOC removal (Volatile organic compounds) from a hydraulic characteristic point of view.

Experimental unit

The INTEQ II is a laboratory (pilot) unit for testing of industrial catalysts. In the experimental unit, it is possible to test solid catalysts (HoneyComb, Pall, Lessing or Raschig rings, various saddles such as Berl or Intalox, Interpack bodies, or spheres), filter sleeves and candles.

Measurements of some types of materials forming the regenerative or catalytic support were performed for different fluid flow rates (air) in the range of 7 - 50 m^3/h. The material which formed the support was placed on a sieve inside a 150x150 mm square tube. The height of the support was different for various diameters and was designed to cover as wide a measurement range of differential pressure sensor as possible.

Tested materials

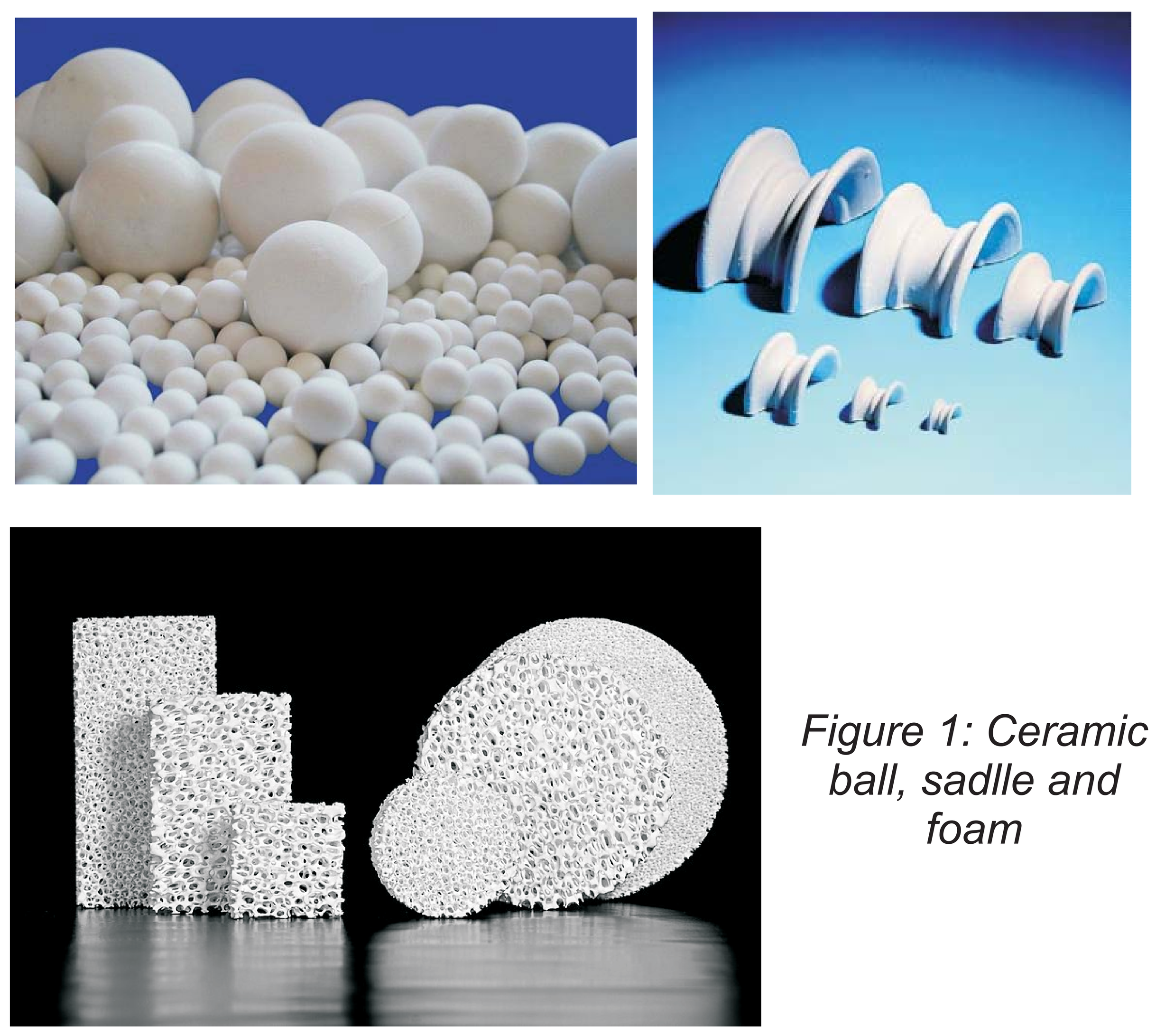


Figure 1: Ceramic ball, sadlle and foam

Medium		Air	
Temperature		22 °C	
Pressure		101 325 Pa	
Catalyst height		15 cm	
Catalytic cross section		15x15 cm	
Balls 1		**Saddle**	
Diameter	3-5 mm	Size	20 mm
Spacing	44%	Spacing	74%
Surface	620 m^2/m^3	Surface	390 m^2/m^3
Weight	1400 kg/m^3	Weight	660 kg/m^3
Real flow	5 - 50 m^3/h	Real flow	5 - 50 m^3/h
Speed of flow	0,07 - 0,62 m/s	Speed of flow	0,07 - 0,62 m/s
GHSV	1 481 - 13 034 h^{-1}	GHSV	1 484 - 13 051 h^{-1}
Catalyst height		9,6 cm	
Catalytic cross section		15x15 cm	
VUKOPOR 20PPI		**VUKOPOR 60PPI**	
Diameter pore	1,5 mm	Diameter pore	0,9 mm
Spacing	71%	Spacing	89%
Surface	350 m^2/m^3	Surface	350 m^2/m^3
Weight	440 kg/m^3	Weight	350 kg/m^3
Real flow	4,5 - 54 m^3/h	Real flow	4 - 53 m^3/h
Speed of flow	0,057 - 0,679 m/s	Speed of flow	0,052 - 0,662 m/s
GHSV	2 056 - 23 020 h^{-1}	GHSV	1 806 - 21 151 h^{-1}

Table 1: Properties of catalyst supports

Pressure loss equation

Leva equation

$$\frac{|\Delta p|}{L} = \frac{f_m \cdot 2 \cdot G^2 \cdot (1-\varepsilon)^{3-n}}{D_p \cdot \rho \cdot \theta_s^{3-n} \cdot \varepsilon^3}$$

Colbun-Chilton equation

$$\frac{|\Delta p|}{L} = 27 \cdot \frac{\rho^{0,85} \cdot V_0^{1,85} \cdot \mu^{0,15}}{D_p^{1,15}}$$

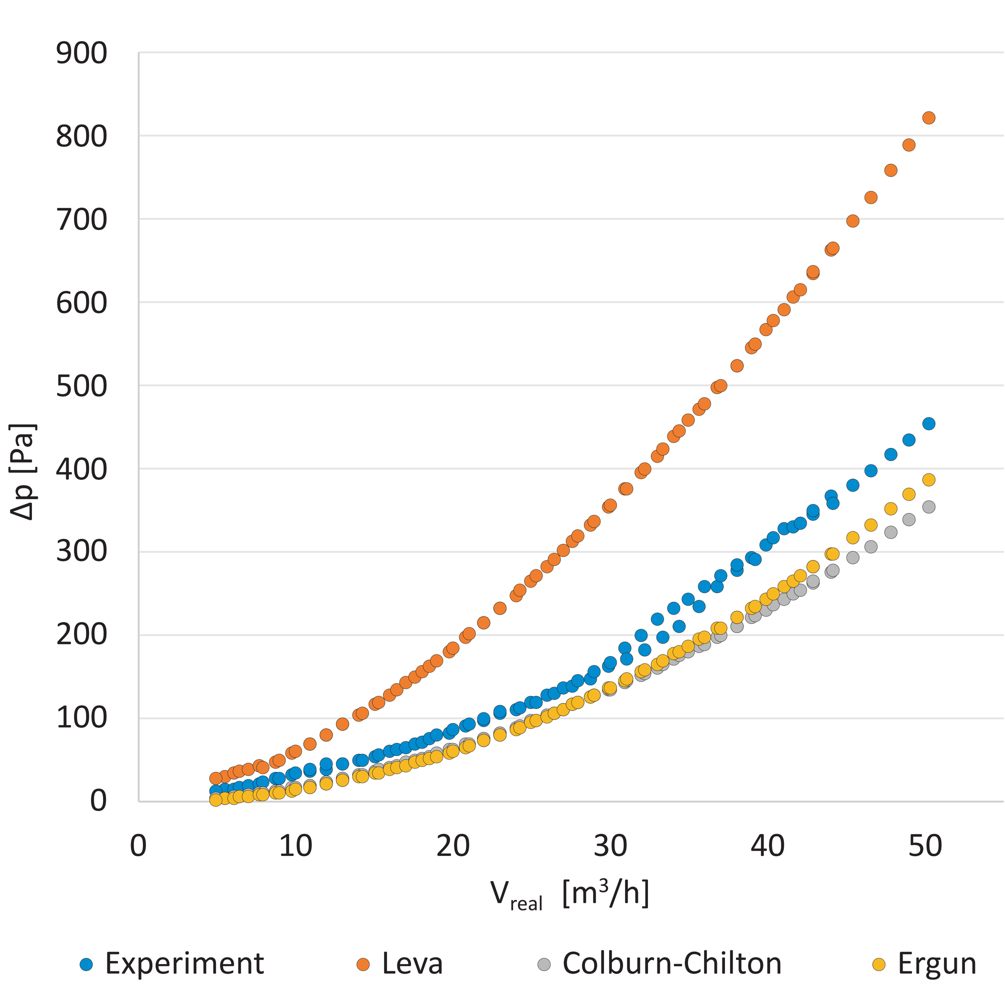
Ergun equation

$$\frac{|\Delta p|}{L} = 0,15 \cdot \frac{D}{D_p^2 \cdot \rho} \cdot \frac{(1-\varepsilon)^2}{\varepsilon^3} + 1,75 \frac{G^2}{D_p} \frac{1-\varepsilon}{\varepsilon^3}$$

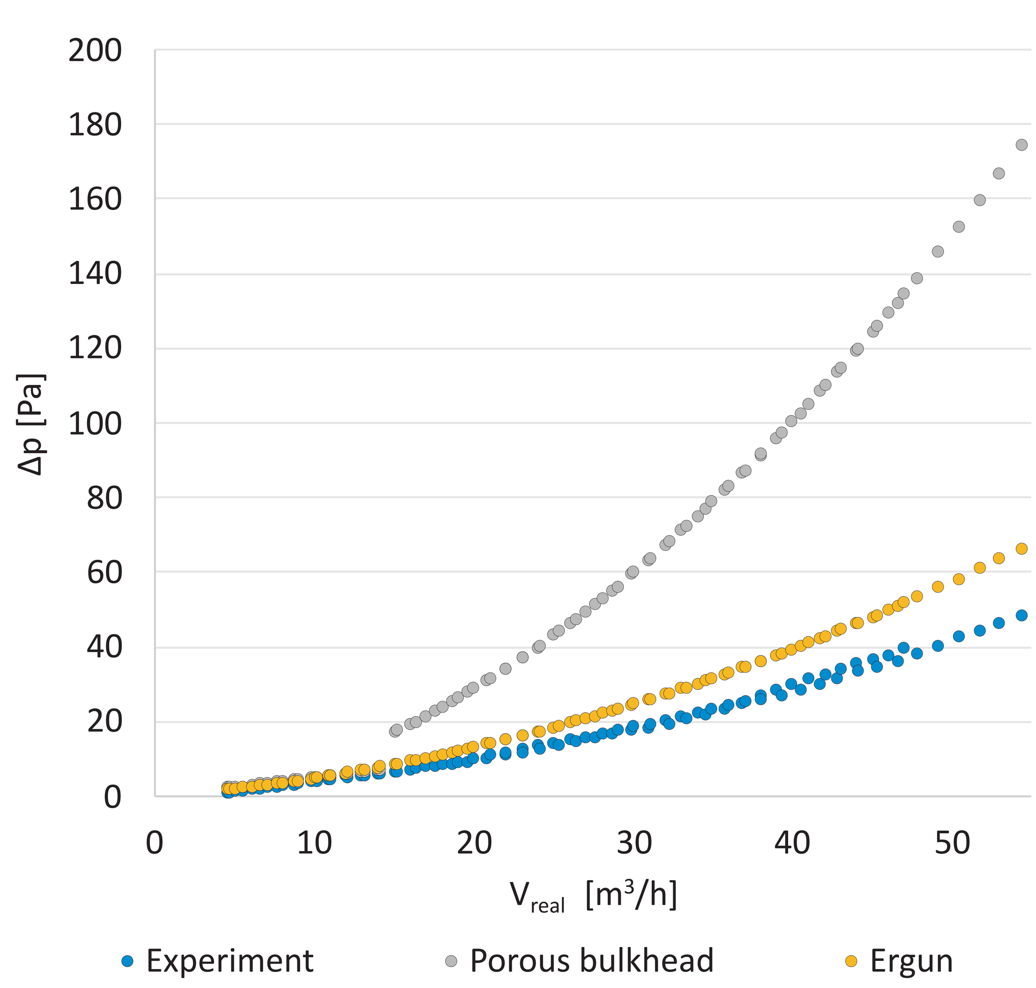
Equation for porous bulkhead

$$\Delta p = \frac{\lambda_{pp}}{8} \cdot \alpha \cdot h \cdot c^2 \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot a_r \cdot \rho \cdot r_h$$

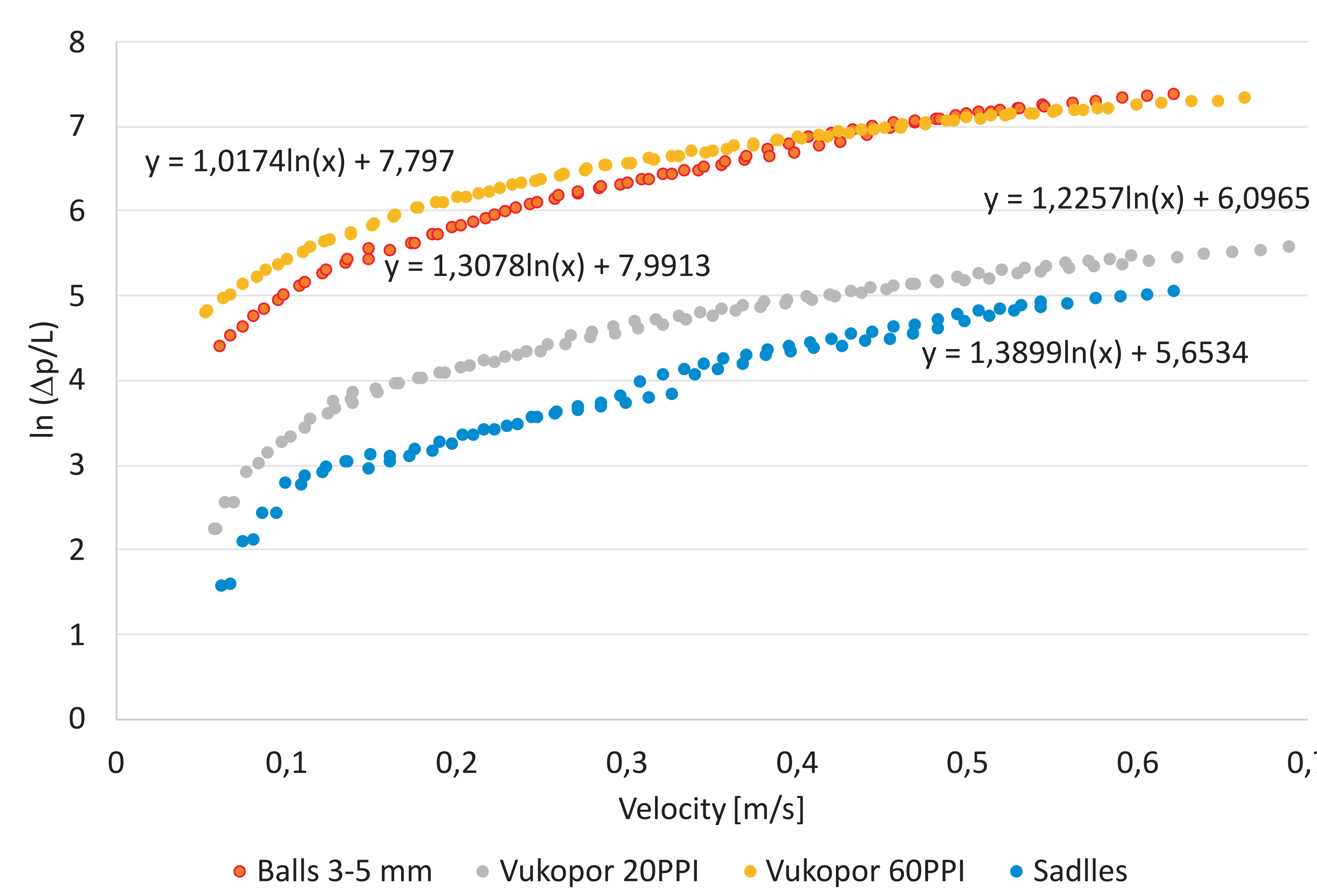
Experimental results



Grafe 1: Pressure loss comparison calculated and measured for 3-5 mm balls



Grafe 2: Pressure loss comparison calculated and measured for VUKOPOR 20PPI



Grafe 3: Dependence of pressure drop on velocity for different catalyst supports

Conclusion

A very good agreement was found for the measured pressure losses of the spherical catalyst with the pressure loss calculation according to the Colburn-Chilton formula. None of the equations used describes perfectly the pressure loss for ceramic saddles where it is necessary to use new equations for this type of bulk catalyst. For the studied porous foam, as a new type of support, the pressure drop was best described by the Ergun equation. However, even in this case, the calculated pressure losses were 10-15% higher than the measured ones.

When comparing the individual carriers, it is assumed that the loose support - saddles and foam Vukopor 20PPI create the lowest pressure losses. However, on closer comparison, it is evident that 3-5 mm balls have a 2 times higher surface area than other supports.

For the specific use of the catalyst, other operating conditions (e.g. fouling) must be taken into account. The choice of the proper catalyst depends on its properties (shape and surface area) and pressure drop. The results of the research are new approximations of ln (dP) and air velocity for individual investigated catalyst supports.

Acknowledgments

The results of this project Strategic Partnership for Environmental Technologies and Energy Production (CZ.02.1.01/0.0/0.0/16_026/0008413) were co-funded by the Ministry of Education, Youth and Sports.

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS