AIR FLOW THROUGH MACRO POROUS CERAMIC STRUCTURES

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Abstract
Macro porous ceramic bodies which are specifically designed for filtration purposes, cooling systems and porous medium burning were fabricated in order to study the three dimensional network of porous structures using Darcy Forcheinhimer equation. Fitting parameters obtained from Darcy Forcheinhimer equation could be used to fabricate macro porous ceramic bodies with required porosity.

1. Introduction

Solid materials that are permeated by an interconnected network of pores are known as porous materials. Natural and manufactured porous ceramic materials have broad applications in engineering processes, including filters, heat sinks, mechanical energy absorbers, heat exchangers, pneumatic silencers, high breaking capacity fuses, cores of nuclear reactors and gas burners.

Property evaluation, when fabricating porous ceramic structures, is important in order to assess the performances of the sintered products. Currently there are several methods to investigate the properties of porous bodies, such as, permeability measurements, porosity measurements, stiffness measurements and bulk density measurements. In this study, the dependence of the air permeability on porosity of the sintered samples was investigated. Macro porous ceramic bodies were fabricated according to a fabrication method introduced previously for gas burners (*R.R. Dharmasena, P. Ekanayake and B.S.B. Karunaratne).* Controlled porosity and pore connectivity were achieved inside the ceramic structure using this fabrication method. The internal structure (the interconnectivity of the pores) was studied in three dimension by applying an air flow through a sample. For this, Darcy Forchheimer's equation (*S.M.H.Olhero et al)* and a modified Darcy Forchheimer's equation (*W. Zhiyong et al)* were used in correlating the pressure drop and air flow velocity.

Pressure gradient along the Y direction $\Delta P/\Delta Y$ is given by the Darcy Forchheimer equation (*S.M.H.Olhero et al)*;

$$\frac{\Delta P}{\Delta Y} = K_1 \mu U_o + K_2 \rho U_o^2$$

where, K_1 is the coefficient at low air flow, K_2 is the coefficient at high air flow , ρ is the density of air, μ is the viscosity of air and U_o is the velocity of air flow. In general K_1 and K_2 give the resistance to the air flow through porous body.

A mean value of pore sizes can be obtained from a modified Darcy Forchheimer equation (*W. Zhiyong et al)*. Using the modified Darcy Forchheimer equation it was attempted to correlate the expected pore sizes and observed pore sizes.

Pressure gradient along the Y direction $\Delta P/\Delta Y$, and mean pore size *d* is given by the modified Darcy Forchheimer equation;

$$\frac{\Delta P}{\Delta Y} = \frac{(1039 - 1002\varepsilon)}{d^2}\mu u + \frac{0.5138\varepsilon^{-5.739}}{d}\rho u^2$$

2. Experimental method

Polystyrene beads were used as the pore former. Nine cubic shaped green samples were fabricated under different compressing forces (10 N,20 N, 30 N) for three different pore former sizes (6 mm,7 mm, 8 mm) and sintered at 1250 °C for two hours to obtain porous samples. An air flow was applied through the sample in one direction at a time and the velocity of air and pressure drop across the sample were obtained (fig.1.0).
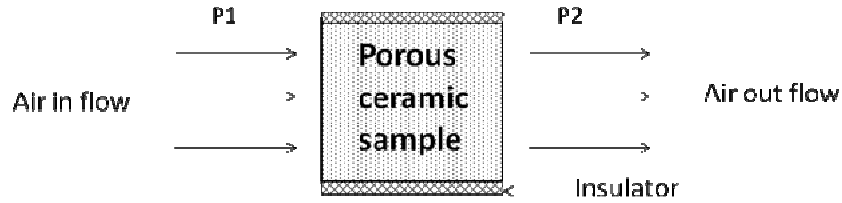
Figure 1.0

Observed readings were correlated with Darcy Forchheimer's equation and a modified Darcy Forchheimer equation.

3. Results and Discussions

Porosity values were determined for different pore sizes of porous ceramic cubes and it was observed that porosity has increased with the pore former size (table.1). The pressure gradient *vs* velocity of air through porous ceramic samples was plotted and the curve fitting was done according to the Darcy Forchheimer's equation and the modified Darcy equation separately. From the curve fittings, the constants (K_1, K_2) and mean pore sizes were obtained along each direction. In the fabricated porous ceramic body, the pore size is generally determined by the size of the pore formers. The mean pore sizes obtained by the fittings are in good agreement with pore former size (table.1.0).
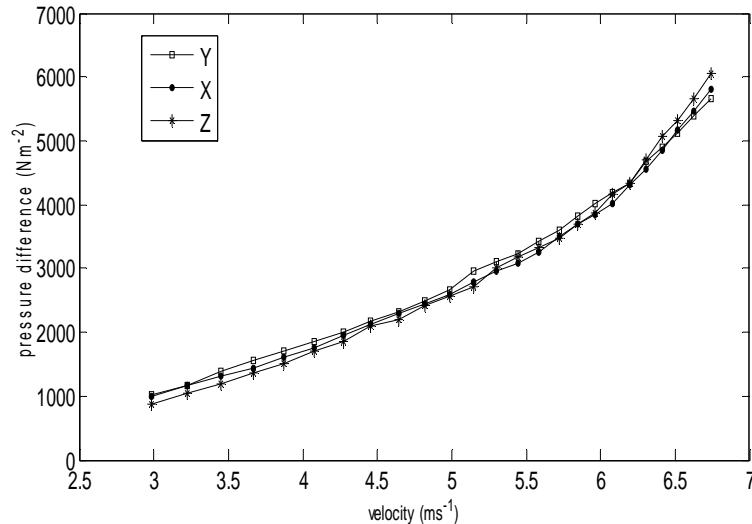

Fig.1.1 Pressure difference vs velosity of air through 6 mm-10 N porous ceramic body in X, Y and Z direction (compresing force when fabricating the samples was in Y direction)
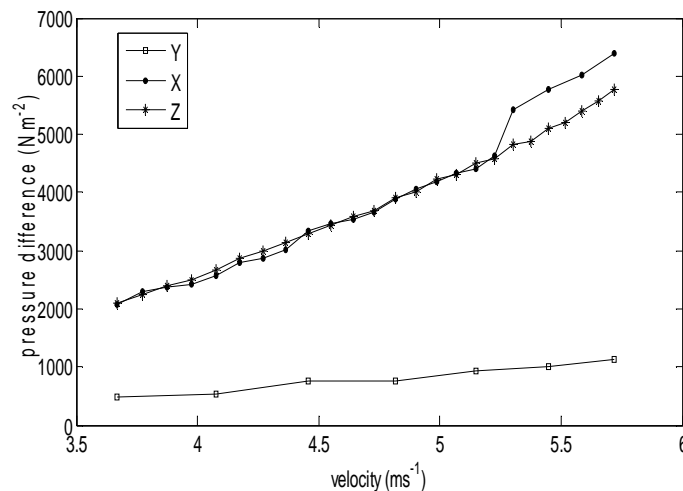

Fig.1.2 Pressure difference vs velosity of air through 7 mm-10 N porous ceramic body in X, Y and Z direction (compresing force when fabricating the samples was in Y direction)

Y direction is the compressing direction when samples were fabricated and X and Z directions are the perpendicular directions to Y direction

It was observed that the pressure difference along X, Y and Z directions are the same for 6 mm-10 N sample (fig. 1.1). Therefore, it can be concluded that 10 N force is not capable of making any difference in the connectivity of pores along all three directions in 6 mm pore sized sample. Moreover, for 7 mm-10 N sample, pressure difference along Y direction is the lowest and X, Z directions behave similarly in the velocity range of 3.5 - 5.5 ms^{-1} (fig1.2).
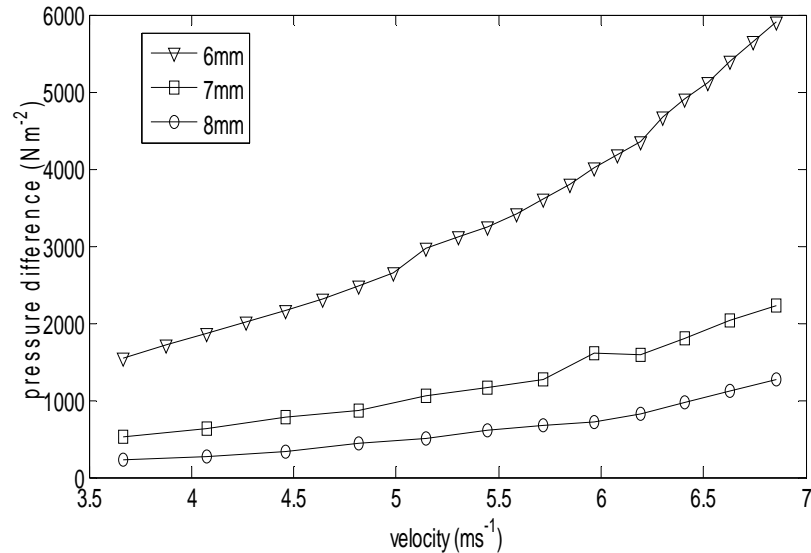
Fig.1.3 Pressure gradient vs velosity of air through 10 N porous ceramic bodies of 6 mm, 7 mm, 8 mm pore forner sizes (compresing force when fabricating the samples was along Y direction)
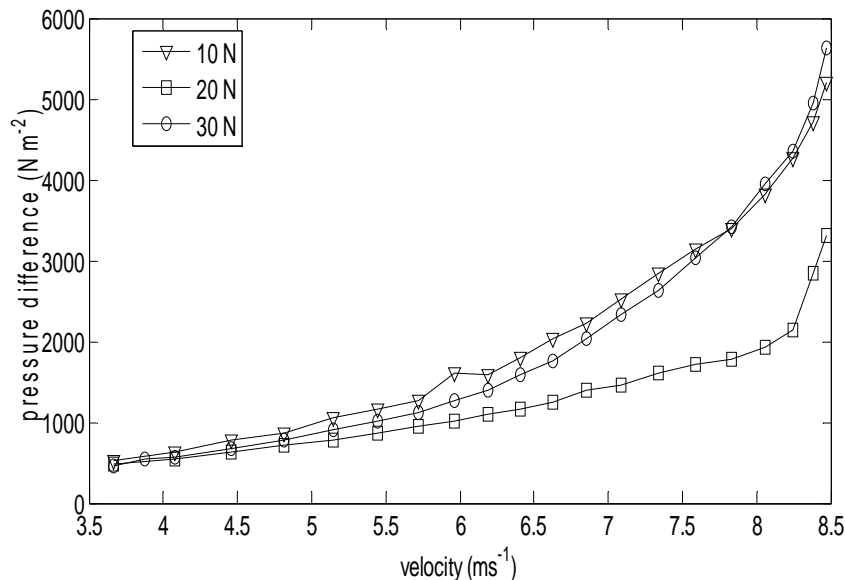
Fig.1.4 pressure gradient vs velosity of air through 7 mm (pore former size) porous ceramic bodies of 10 N, 20 N, 30 N applied pressures (compresing force when fabricating the samples was along Y direction)

It was also observed that the pressure gradient increases with decreasing pore former size (from 8 mm to 6 mm) in Y direction (fig 1.3). The porous ceramic body prepared with pore former size of 7 mm showed the expected behavior of pressure gradient at each applied compression .In this sample, the pressure gradient decreases with the compressing force (fig.1.4)

Table 1: porosity of different porous ceramic materials made under different compressing forces

Sample	Ceramic volume (ml)	Y direction			Porosity
		K_1 (mm^2)	K_2 (mm)	Mean cell size (mm)	
6 mm-10 N	24.0	3.91	2.22	5.2	0.65
7 mm-10 N	15.5	20.83	0.71	7.1	0.76
8 mm-10 N	12.5	10.10	0.31	-	0.81
6 mm-20 N	19.5	200.00	1.23	3.2	0.68
7 mm-20 N	11.0	20.83	0.60	9.1	0.79
6 mm-30 N	24.5	50.00	12.35	-	0.63
7 mm-30 N	15.0	9.62	0.68	-	0.76

4. Summary and Conclusions

It was attempted to obtain an idea about the 3D connectivity of pores in a porous ceramic sample which was fabricated according to a previously determined fabrication method (*R.R. Dharmasena, P. Ekanayake and B.S.B. Karunaratne).* The dependence of pressure gradient with the pore former size and compressing forces along the three directions were observed. The pressure gradient *vs* velocity along each direction was plotted and curve fitting was done with the Darcy Forchheimer's equation and the modified Darcy Forchheimer's equation for each sample. The permeability constants and mean cell sizes were obtained for each sample. 10 N compressing force is not capable of making any differences in the pore connectivity along the three directions in the case of pore former size 6 mm. A clear difference of the pressure gradients along the compressing direction was shown by the sample 7 mm-10 N. Pressure gradient decreases with increasing the compression and with increasing pore former size.

5. References

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