Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Dry pressure drop in spiral wound wire mesh pads at low and elevated pressures

A. Eddie Setekleiv, Hallvard F. Svendsen*

Department of Chemical Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

ARTICLE INFO

Article history:
Received 18 May 2015
Received in revised form 23 December 2015
Accepted 19 January 2016
Available online 25 January 2016

Keywords:
Porous media
Wire mesh pad
Drag
High pressure
Ergun equation
Scrubber

ABSTRACT

The dry pressure drops for 8 wire mesh pads were measured experimentally. The pads were of a spiral wound configuration and made of stainless steel wire. They ranged in porosities from 97.64% to 98.9% and with specific surface areas from 283 m^2/m^3 to 593 m^2/m^3. The range of heights was 50–150 mm. A total of three fluid systems were used; One low pressure system using air at 1 bar and two high pressures systems, nitrogen and natural, gas at pressures of 20, 50 and 85 bars. The data were fitted to a modified Darcy–Hazen–Dupuit type equation, which included the specific surface area of the wire mesh pads, $\Delta P\epsilon^2/(\rho_g U_g^2) = f(SL) + \mu_g \epsilon S^2 L/(\rho_g U_g)$, with a mean standard deviation of ±5.3%. In addition a correlation encompassing literature data was developed with standard deviation of ±13.4%. A discussion is provided on the impact of specific surface area on dry wire mesh pad operation. Two other correlations for predicting dry pressure drop in wire mesh pads were also examined.

1. Introduction

Wire-mesh pads are used for gas/liquid separation in systems with small amounts of liquid droplets. For equipment such as pumps and compressors, unsatisfactory separation of suspended droplets in the gas stream may result in poorer performance and possible breakdown. In other cases there may be a desire to recover precious products from the gas stream. Mesh pads are ideal for removal of fine mists and sprays and an overview of mesh pad selection criteria is given by Fabian et al. (1993a,b), Anonymous (2005) and GPSA (2004).

The purpose of this investigation is to study dry pressure drop in wire mesh pads. Knowing the dry pressure drop of a wire mesh pads is an important basis for both design and operation of wire mesh pads.

2. Pressure drop in permeable media

A brief overview over the variables governing fluid flow through permeable media is given. A good short introduction is given by Helsør and Svendsen (2007) and a more extensive analysis by Lage (1998). One of the best known equations governing flow through permeable media was developed by Ergun (1952) for fluid flow through packed columns:

$$\frac{\Delta P}{L} = 150\frac{\mu_g U_g}{d_p^2}\frac{(1-\epsilon)^2}{\epsilon^3} + 1.75\frac{\rho_g U_g^2}{d_p}\frac{1-\epsilon}{\epsilon^3} \tag{1}$$

Here ΔP is the pressure drop through the packing, L is packing height,ϵ is porosity of the media, ρ_g is gas density, μ_g is gas viscosity, U_g the gas velocity and d_p the particle diameter.

Eq. (1) may be seen as a specific form of the Hazen–Dupuit–Darcy equation, Lage (1998):

$$\frac{\Delta P}{L} = \frac{\mu U}{K} + C\rho U^2 \tag{2}$$

Eq. (2) may be seen as the sum of contributions to the total pressure drop by skin drag, the viscous term, and form drag, the density term. C and K are constants which have to be determined experimentally. The linear term was suggested by

* *Corresponding author*. Tel.: +47 73 59 41 00; fax: +47 73 59 40 80.
E-mail address: hallvard.svendsen@chemeng.ntnu.no (H.F. Svendsen).
http://dx.doi.org/10.1016/j.cherd.2016.01.019
0263-8762/

Darcy (1856), while the full equation was proposed by Dupuit (1863). Viscosity was introduced by Hazen (1893). Eq. (1) was originally developed for spherical particles and can be written in terms of specific surface area per volume of packing. For a bed of spheres:

$$S_{Er} = \frac{6(1-\epsilon)}{d_p} \tag{3}$$

as given by Ergun (1952). Eq. (1) may be re-written as:

$$\frac{\Delta P}{L} = \frac{25}{6}\frac{\mu_g U_g S^2}{\epsilon^3} + \frac{7}{24}\frac{\rho_g U_g^2 S}{\epsilon^3} \tag{4}$$

Eq. (4) thus suggests that not only velocity and the physical properties of the fluids are important in describing pressure drop through permeable media. In addition to the height of the packed medium the specific surface area is an important parameter. For pressure drop in dry wire mesh pads York and Poppele (1963) proposed the following relation:

$$\Delta P = f_c S L \frac{\rho_g U_g^2}{\epsilon^3} \tag{5}$$

York and Poppele (1963) stated that the coefficient f_c was a function of Reynolds number. However, it is clear that the specific surface area of the packing is considered as a contribution to the overall pressure drop. Dave (1987) also proposed a correlation for wire mesh pads containing the specific surface area. This relation may be written as:

$$\frac{\Delta P \epsilon^2}{0.5 \rho_g U_g^2} = C_d k \frac{1}{\pi} S L \tag{6}$$

The factor k varied with type of wire mesh pad. For spiral wound pads $k = \frac{2}{\pi}$ while for layered pads $k = 0.83$. Which suggests:

$$\Delta P_{layered} = 1.3 \cdot \Delta P_{spiral} \tag{7}$$

C_d was a function of Reynolds number where wire diameter, d_w, was used as a characteristic length scale and given as:

$$Re_w = \frac{\rho_g U_g d_w}{\mu \epsilon} \tag{8}$$

The coefficient C_d was a function of Reynolds number:

$$C_d = \frac{a}{Re_w} + b + c \cdot Re_w + d \cdot Re_w^2 \tag{9}$$

However at low Re_w large discrepancies between the data and the correlation were seen which may imply that the geometrical effects were not modeled correctly as skin friction is more dependent on geometrical properties than the form drag.

3. Experimental apparatus

A total of 8 wire mesh pads were tested, see Table 1. The pads were all made of stainless steel and were of a spiral wound configuration. They ranged in porosities from 97.64% to 98.9% and the range of heights was from 50 mm to 150 mm. The purpose of using different mesh pads was to investigate how different geometrical characteristics affected pressure drop over the pads. Two of the pads with support grid are shown in Fig. 3. The LP mesh pads, Table 1, were tested in a low pressure rig using air as the gas medium, Section 3.1. The HP mesh pads, Table 1, were tested at high pressures in a different rig, see Section 3.2. In the high pressure rig nitrogen and natural gas were used. Properties of the fluid systems used are described in Section 3.3.

Prior to conducting the experiments the mesh pads were weighed and the parameters in Table 1 calculated. To calculate the properties of each pad the method described by Helsør and Svendsen (2007) was used. Mesh type A was said to have uniform characteristics from vendor. However, as seen in Table 1 the properties vary somewhat between actual properties and the properties stated from vendor. This is seen for mesh type B as well.

3.1. *Low pressure rig*

The low pressure rig, see Fig. 1, comprised seven parts connected by flanges and packings. The gas was fed through a horizontal pipe mounted 90° on the column. The flow rate was measured by a volume flow transmitter, Flowtech DMV 6331. The mesh pads were all mounted inside a section of transparent PMMA with a diameter of 100 mm. This allowed visual inspection of pad operation. Four rods around the PMMA section held the weight exerted by the top part of the column. For a full overview of the system see Fig. 1. The pressure drop over the wire mesh pads was measured using a differential pressure transmitter from Fuji, FCX-C with an accuracy of 0.1% of total span (±3.2 Pa).

3.2. *High pressure rig*

The experimental setup, see Fig. 2 comprised the 252 mm column, Fig. 2 number (5), connected to two internal circulation loops, one for gas and one for liquid. A fan, immersed in a glycol bath to ensure temperature control and steady operation, ensured a continuous circulation of the gas medium. To ensure that all liquid inside the circulation loop could be

Table 1 – Geometric properties of 8 wire mesh pads. L is the height of the wire mesh pads, D_{mesh} is the diameter, d_w is the wire diameter, ρ_{mesh} is the density of the pad, S is the specific surface area and ϵ is the porosity.

Mesh (–)	L (mm)	D_{mesh} (mm)	d_w (mm)	ρ_{mesh} (kg/m^3)	S (m^2/m^3)	ϵ (%)
LPA05	50	100	0.27	187	344	97.68
LPA07	70	100	0.27	163	301	97.97
LPA10	100	100	0.27	153	283	98.09
LPA15	150	100	0.27	154	284	98.08
LPB10	100	100	0.15	145	593	97.78
LPC10	100	100	0.15	80	290	98.91
HPA10	100	252	0.27	168	311	97.90
HPB10	100	252	0.15	160	532	98.00