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Measurement and correlation of hydraulic resistance of flow through woven metal screens

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Abstract

In this study, an experimental setup was established to measure the pressure drop of flow through woven metal screens. Four woven metal screens with different porosities of the plain-square type were tested in this study. The Reynolds number based on the equivalent spherical diameter of the metal screen ranged from low *Re* ($Re = 85$) to high *Re* ($Re = 12000$). The range of porosity was 0.834–0.919. Based on the measured pressure drops of the four woven metal screens, this study developed an empirical equation of friction characteristic of plain-square-type woven metal screens. All experimental data for the plain-square-type screens lie within ±30% of the empirical equation. Based on the fact that the measured pressure drops of single-layer and multiple-layer woven metal screens can all be fit into a single equation, it is noted that the velocity developing region is very short for woven metal screens. In order to obtain good agreement between the fitted empirical equation and measured data, this study noted that an empirical equation should be developed for each type of the woven metal screen. This study developed five empirical equations respectively for the five types of metal screens, (plain square, plain dutch, fourdrinier, full twill, and twilled dutch types) of which experimental data were available in open literature and the present study.

Keywords: Porous media; Woven metal screens; Pressure drops; Transport properties

1. Introduction

The augmented heat- and mass-transfer characteristics of porous media have led to numerous applications. Kays and London [1] pointed out that an effective way to increase the performance of a heat exchanger is to increase its surface area to volume ratio. Open cell porous matrix such as an unconsolidated bed of small particles, woven metal screens, or foam matrixes provides excellent heat-transfer characteristics due to its large surface area to volume ratio. Therefore, woven metal screens have been used in solar-receiving devices [2], high-efficiency heat exchangers [1], energy-storage units [1], regenerators in Stirling cryocoolers [3], electronic coolers [4,5], catalytic reactors [6], and others. In filtering industry, woven metal screens are also widely used in the filtering of fluids due to their good resistance to chemical, thermal, and mechanical influences in comparison with textile and paper made filters. Other advantages of woven metal screens include easy arrangement,

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Nomenclature

D_P	equivalent spherical diameter of porous media
f_k	friction factor, defined in Eq. (1)
L	length of the test section
P	pressure
Re	Reynolds number based on the equivalent spherical diameter of porous media
S_v	surface area per unit volume of solid phase
U	velocity of the fluid

Greek symbols

ρ	density
μ	viscosity
ε	porosity

high permeability and relatively small deviation of the pore size from the mean value.

Although woven metal screens offer the aforementioned merits, information on hydraulic resistance of woven metal screens is required when using these types of materials in any systems. Woven metal screens are usually classified by weaving types; there are four common types: the plain weaves, twill weaves, fourdrinier weaves, and dutch weaves. Plain weaves: This is the most popular wire cloths weave. Each weft wire passes alternately over and under each warp wire and each warp wire passes alternately over and under each weft wire. Warp and weft wire diameters are generally the same. Twill weaves: Each weft wire alternately passes over two, then under two successive warp wires and each warp wire passes alternately over two and under two successive weft wires, in a staggered arrangement. Fourdrinier weaves: This kind of weave is a mixture of plain and twill weaves and is also called semi-twill weaves. Dutch weaves: The warp wires remain straight; the weft wires are woven to lie as close as possible against each other in a linen weave forming a dense strong material with small, irregular and twisting passageways that appear triangular when diagonally viewing the weave. The schematic diagram of these four types of woven metal screens is shown in Fig. 1.

In 1964, Kays and London [1] presented the measured friction factor of four woven metal screens (plain square type). Armour and Cannon [7] investigated the hydraulic resistance of five types (plain square, fourdrinier, full twill, plain dutch, and twilled dutch types) of woven metal screens through experiments made in a round channel with only a single layer of metal screen. They provided an equation for the calculation of pressure drop based on the flow velocity, the porosity, and the geometry of the screen. Sodré and Parise [8] designed an experimental procedure to investigate the friction factor of the plain-square woven metal screen adopted in the Stirling engine regenerator. They developed an equation to evaluate the pressure drop in the annular bed of screens.

Though many studies were devoted to analyzing the pressure drop through woven screen matrices, there is still a need to find out if there is a general empirical equation suitable for various types of woven metal screens. In this study, a series of experimental tests was conducted to determine the flow friction characteristic of woven metal screens. Four woven metal screens (plain square type) with different porosities were tested. A general empirical equation was developed to correlate the dimensionless pressure drop (f_k) and flow velocity (Re) for the four woven metal screens and the empirical equation is extended to high Re region. Comparison of the empirical correlation with experimental data in open literature validated the empirical correlation. Following the form of the correlation developed in this study, an empirical correlation is also developed for each one of the other four types of metal screens (plain dutch, fourdrinier, full twill, and twilled dutch types).

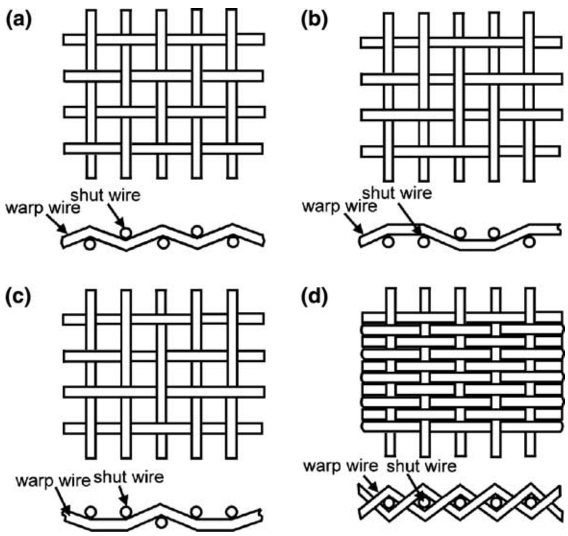

Fig. 1. Schematic diagram of four common types of woven metal screens: (a) plain weaves, (b) twill weaves, (c) fourdrinier weaves, and (d) dutch weaves.