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On the pressure drop modeling of monofilament-woven fabrics

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Abstract

Pressure drop of monofilament-woven fabrics is often calculated via the so-called orifice model in which a discharge coefficient is assigned to the weave's unit cell. In all previous models of woven fabrics, the filaments were assumed to have circular cross-sections—an assumption which is not entirely accurate especially when there is a considerable tension in the warps and wefts. Following the methodology developed by Lu et al. [1996. Fluid flow through basic weaves of monofilament filter cloth. Textile Research Journal 66 (5), 311–323], a new set of expressions are derived for calculating the most constricted open area, and so the discharge coefficient, of plain-woven monofilament fabrics having filaments with elliptical cross-sections. Conducting numerical simulations for computing the pressure drop of such fabrics, we observed a logarithmic relationship between the discharge coefficient and the Reynolds number. It was also shown that the discharge coefficient decreases by increasing the aspect ratio of the filaments' cross-section.

Keywords: Air permeability; Monofilament fabrics; Filament with elliptical cross-section; CFD

1. Introduction

Permeability of monofilament woven fabrics is of great importance in many applications and has been vastly studied in the past. In 1971, Rushton and Griffiths reviewed various theories of fluid flow through woven monofilament fabrics developed by then and concluded that the so-called orifice analogy is the most appropriate modeling approach for calculating permeability of a monofilament fabric. In the orifice model, the open area between the filaments is treated as a submerged orifice and, depending on the geometry of the opening, a discharge coefficient is determined for the pore (Pedersen, 1969). Inspired by the work of Pedersen (1969), Lu et al. (1996) developed an orifice model for calculating the permeability of monofilament fabrics. In their model, the discharge coefficient is presented as follows:

$$C_d = \sqrt{\frac{\rho V^2(1-\alpha_c^2)}{2\Delta P \alpha_c^2}}, \tag{1}$$

where ρ, V, α_c and ΔP are flow density, superficial velocity, effective fractional open area (EFOA) and pressure drop, respectively. EFOA is given by $\alpha_c = A_c/l_f^2$, where A_c is the most constricted area and l_f is the filaments' center-to-center distance.

Since the infancy of the orifice model, discharge coefficient has been related to the flow Reynolds number in the following form (Pedersen, 1969; Gooijer et al., 2003; Wakeman and Tarleton, 2005):

$$C_d = k_c Re^{m_c}, \tag{2}$$

where k_c and m_c are constants for fabrics having filaments with circular cross-sections. Note that Reynolds number is defined differently in different studies. Following the work of Pedersen (1969), Lu et al. (1996) defined their Reynolds number based on the wetted perimeter of the orifice, W_c, where the flow is most constricted:

$$Re = \frac{4\rho V l_f^2}{W_c \mu}, \tag{3}$$

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