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Corresponding Author: Dr Dejan Brkic, PhD

Corresponding Author's Institution:

First Author: Dejan Brkic, PhD

Order of Authors: Dejan Brkic, PhD

Commentary

Comments on "Experimental study of the pressure drop in the cathode side of air-forced Open-cathode proton exchange membrane fuel cells" by Barreras et al., Int. J. Hydrogen Energy, 36 (13) 2011, 7612-20

Dejan Brkić, PhD, Strumička 88, 11050 Belgrade, Serbia, cell: +381642543668, e-mail: dejanrgf@tesla.rcub.bg.ac.rs, dejanbrkic0611@gmail.com

In their recent paper [1], Barreras et al. developed the equation for the friction factor in the transitional turbulent regime for the air flow in the cathode side of air-forced open-cathode proton exchange membrane fuel cells [Eq. (18) of the commented paper]. As the authors clearly noted, their equation can be compared with the widely known Colebrook equation [Eq. (5) of the commented paper]. The friction factor obtained by authors' equation differs from Colebrook's results up to 60%. Both equations are empirical and developed for the different conditions of flow, for different fluids, different geometry and materials of conveying channels and therefore, the different results are acceptable and expected. On the other hand, the Colebrook equation is well established and therefore it is already implemented in the numerous computing codes [2]. This is the main reason to express this new equation from the commented paper using Colebrook's expression (1). In the next equation, Colebrook's expression is actually noted as 'x'.

$$\frac{1}{\sqrt{\lambda}} = -14.17 + 5 \cdot \left(-2 \cdot \log\left(\frac{2.51}{\mathrm{Re} \cdot \sqrt{\lambda}} + \frac{\varepsilon}{3.71 \cdot D} \right) \right) = -14.17 + 5 \cdot x \qquad (1)$$

Where:

λ-Darcy friction factor (dimensionless)

Re-Reynolds number (dimensionless)

ε/D-relative roughness of inner surface of conveying channel (dimensionless)

'x'-Colebrook's expression for friction conductivity $1/\sqrt{\lambda}$ (dimensionless)

Eq. (18) of the commented paper is developed for the specific value of relative roughness of inner surface of conveying channels. Therefore, in Eq. (1), the relative roughness should be set as ε/D=0.03086 to preserve complete equality between here presented Eq. (1) and Eq. (18) of the commented paper. This value of relative roughness can be changed in a presence of certain liquid fluids [3,4].

Of course, the Colebrook and the equation from the commented paper are implicitly given for the unknown friction factor. Therefore they have to be solved using iterative procedure [5]. The Colebrook equation, 'x', is not supposed to be solved separately in iterative procedure if the goal is in solving of Eq. (1). In that way the convergence properties of Eq. (1) will be disturbed. So it is not allowed to calculate $1/\sqrt{\lambda}$ in iterative procedure using only the Colebrook expression 'x' and then to calculate new value of $1/\sqrt{\lambda}$ using $1/\sqrt{\lambda} = -14.17 + 5 \cdot x$. To conclude, Eq. (1) has to be solved as the single equation in an iterative procedure. There are numerous explicit approximations of the Colebrook equation [6], but equally, they cannot be used for the calculation of the friction factor of Eq. (1). New explicit approximations should be developed based on Eq. (1).

Using Eq. (16) and Eq. (18) [or Eq. (1) of this commentary], the diagram similar to the Moody's can be plotted [7]. Of course, the boundary, between the laminar regime [presented by Eq. (16)] and the turbulent regime [presented by Eq. (18) of the commented paper or Eq.

(1) of this commentary] has to be corrected compared with the Moody diagram as already described by in the commented paper.

Finally, it has to be noted that the authors of the commented paper misquote the source of the Colebrook equation. The Colebrook equation was developed by the Colebrook solely [8], but also, he used data from his joint experiment with White [9].

In this commentary, the Darcy friction factor is used (noted as λ). The authors of commented paper use f or f_D for the Darcy friction.

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