CHEMICAL ENGINEERING COMMUNICATIONS
2020, VOL. 207, NO. 2, 213–230
https://doi.org/10.1080/00986445.2019.1578757

Artificial intelligence (AI)-based friction factor models for large piping networks

Nusrat Parveen, Sadaf Zaidi, and Mohammad Danish

Department of Chemical Engineering, Z.H. College of Engineering and Technology, Aligarh Muslim University, Aligarh, India

ABSTRACT
In large piping networks, evaluation of friction factor is a time-consuming process and poses computational complexity. This is because the friction factor has to be evaluated for every pipe segment and that too by using implicit correlations. In the present study, this issue has been addressed by developing artificial intelligence (AI)-based friction factor models namely, support vector regression (SVR), artificial neural networks (ANN) and gene expression programing (GEP) to predict the friction factor for the turbulent flow regime. The developed models have been compared with the existing correlations based on the statistical parameters and have shown excellent prediction accuracy with the lowest average absolute relative error (AARE), root mean square error (RMSE) and highest correlation coefficient (R) as 1.43%, 0.0003, 0.9993 for SVR while for ANN they are 2.11%, 0.00095, 0.9978 and for GEP they are 7.14%, 0.0024, 0.9864, respectively. Leave-one-out cross-validation on the test set $\left(Q^2_{ext}\right)$ for SVR, ANN, and GEP are obtained as 0.9976, 0.9957, and 0.9726, respectively. Furthermore, the performance of these AI-based models, i.e. SVR, ANN, and GEP models and the various well-known correlations have been studied for estimating pipe friction factor in both smooth and rough pipes with different values of relative roughness. The SVR-based model significantly outperforms the existing correlations and the GEP-based model and marginally the ANN-based model. AI approach reduces the computational complexity and the time-consuming iterative solution of implicit correlations for large pipe networks without compromising the accuracy.

KEYWORDS
Friction factor; turbulent flow; artificial intelligence (AI); support vector regression (SVR); average absolute error (AARE); correlation coefficient (R)

Introduction

Friction factor evaluation in the laminar flow regime is quite simple as it depends solely on Reynolds number (Re). But, in the turbulent flow regime, friction factor is a complex function of relative roughness (ε/D) and Reynolds number (Re). In this regard, Colebrook and White (Colebrook, 1939) have proposed the following relation for calculating the friction factor, f for turbulent flow regime, i.e. when Re > 4000, as

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left\lfloor\frac{(\epsilon/D)}{3.7}+\frac{2.51}{Re\sqrt{f}}\right\rfloor \quad (1)$$

The implicit nature of Equation (1) requires an iterative solution for the calculation of friction factor and thus, becomes more time- consuming when it has to be evaluated multiple times for large pipe networks. Many explicit approximations of the Colebrook–White correlation have been used to evaluate the friction factor with varying error levels compared to the Colebrook–White correlation. In the past, various models were developed such as adaptive neuro-fuzzy inference system (ANFIS), evolutionary polynomial regression (EPR) and model tree (MT) for the prediction of friction factor (Davidson et al., 1999; Giustolisi and Savic, 2006; Özger and Yildirim, 2009; Salmasi et al., 2012; Yildirim, 2009). Salmasi et al. (2012) applied two AI techniques namely, ANN and gene expression programming (GEP) for predicting the friction factor. They found that the ANN model had low accuracy than the GP model. Moreover, the performance of the GP model was also poor in comparison to some of the Colebrook–White approximations. Similarly, Giustolisi and Savic

CONTACT Mohammad Danish mohddanish.chem@zhcet.ac.in Department of Chemical Engineering, Z.H. College of Engineering and Technology, Aligarh Muslim University, Aligarh, U.P. 202002, India.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gcec.