A Comprehensive Update and Performance Evaluation of Friction Factor Formulae

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INTRODUCTION

Water and solutions are used in many technological and engineering processes (chemical, mechanical, water treatment and distribution, biomedical and pharmaceutical processes). Movement of these essential materials in the reservoir is channeled by the conservation of mass, momentum, and energy. Applications of these movements range from the low-temperature condition in gas liquefaction to high temperatures and pressures in rocket momentum systems. Actual design of all these processes requires an accurate knowledge and values of the fluid transport parameters in the pipeline and channel systems. In a specific situation, viscosity of the liquid, diameter of the pipes and tubes coupled with the friction factor are needed to calculate headloss and energy requirement in the channel and pipeline systems. A precise value of friction factor is necessary in the computation of headloss and the energy. In mechanical, chemical, water supply and biomedical processes, numerous factors are involved in the pipe network and liquefied transport systems. In medical sciences and biomedical engineering, conveyance of a physiological liquid takes place through the catheter tube into the body of a human being, which indicates that accurate computation of $\boldsymbol{F_f}$ in the catheter is an significant factor to discharge adequate liquid. Some of these significant design factors in the pipeline systems are the lengths, diameters and F_f of the pipes, water level in the reservoirs, head-discharge characteristics of the pump, water demands at different nodes and performance characteristics of different valves and minor elements in the pipe systems (Gupta and Bhave, 2007; Özger and Yıldırım, 2009a; 2009b).

Parts of these parameters in pipe network systems remain fixed at different periods of the pipe, while some parameters would fluctuate during the life span of the pipe systems. The fluctuating parameters can be considered to be imprecise parameters. Basic equation for computing the head loss in the pipe network and pipeline system is either Hazen-Williams or Darcy-Weisbach equation that requires calculation of F_f. Darcy – Weisbach equation is expressed as follows:

$$h_L = \frac{\lambda L V^2}{2gD} \quad (1a)$$

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$$h_L = \frac{8\lambda LQ^2}{g\pi^2 D^5} . \tag{1b}$$

where; h_L is the head loss; λ is the F_f; L is the length of the pipeline or pipe system; D is the diameter of the pipe; V is the mean velocity in the pipeline or pipe system; g is the acceleration due to gravity and Q is the flow (discharge) in the pipeline or pipe system.

Colebrook – White's formula presented an implict expression for calculating F_f. The expressions are (Colebrook and White 1937; Colebrook, 1939; Mahendra, 2008; Mehran and Ayub, 2011; Oke *et al.,* 2015a):

$$\frac{1}{\sqrt{\lambda}} = -2\log_{10}\left(\frac{k}{3.7D} + \frac{2.51}{R_e\sqrt{\lambda}}\right) \tag{2a}$$

$$\frac{1}{\sqrt{\lambda}} = 1.74 - 2\log_{10}\left(2\frac{k}{D} + \frac{18.7}{R_e\sqrt{\lambda}}\right) \tag{2b}$$

$$\frac{1}{\sqrt{\lambda}} = 1.14 - 2\log_{10}\left(1 + \frac{9.3}{R_e\frac{k}{D}\sqrt{\lambda}}\right) + 2\log\left(\frac{D}{k}\right) \tag{2c}$$

where; λ is the friction factor; k is effective roughness size of the pipe wall and R_e is the Reynolds number.

Estimations and computations of exact values of F_f in the pipe networks are bedrock in many engineering applications (transfer of liquid and solutions through chemical reactors as well as in industrial processes which involve single-phase, double-phase). In health and medical sciences, and biomedical engineering processes, solutions flow are attained at high flow rate in blood vessels. These solutions are transported through catheter tube into the body of patients, which requires accurate value of F_f. (Shaikh *et al.,* 2015). It has been shown that computation of accurate value of F_f requires an implicit equation known as Colebrook – White's formula. This implicit equation needs the use of numerical algorithms that are complex and not as fast as the explicit equations. In hydraulics of complex and supercritical pipe-flow systems it is difficult to use Colebrook – White's formula, which indicates that reliable F_{ff} are preferred. The needs for more robust and accurate F_{ff} have led researchers to propose and develop new F_{ff}. Today in mechanical, hydraulics, fluid and other engineering, there are various explicit formulae, which present a varying degree of accuracies depending on the complexity of their functional forms. It has been stated that the most complex F_{ff} usually provide higher efficiency and there is the need to establish accuracy of these F_{ff} (Özger and Yıldırım, 2009a; Shaikh *et al.,* 2015). These are F_{ff} found in literature. Moody (1944; 1947):

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