Engineering and Technology Journal e-ISSN: 2456-3358
Volume 07 Issue 09 September-2022, Page No.-1467-1470
DOI: 10.47191/etj/v7i9.05, I.F. – 6.484

Estimate Friction Factor for Polypropylene Pipes

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ABSTRACT: The major losses of fluid flow in plastic pipes due to friction are usually few or negligible in some cases, and this is due to the assumption that the value of the friction factor is small (small roughness). This work aimed to estimate the friction factor vs Reynolds number and to compared against previous data, the friction factor was estimated using an experimental model consisting of a polypropylene pipe with a nominal outside diameter 16mm and length of 8.5 meter and eighteen elbows connect to it, the results showed that the practical coefficient of friction factor is less than the value using the Basilius equation for smooth pipes which indicates that polypropylene pipes are smoother and that the numerical formula similar to the Basilius equation was $1.9231Re^{-0.509}$. Finally, the amount of energy lost due to the friction factor in PPR pipes is small compared to other types of pipes and this is due to the extrusion process that makes the inner wall smooth, but it cannot be neglected in fluid flow.

KEYWORDS: friction factor, Polypropylene Pipes, major losses, experimental model

I. INTRODUCTION

When fluid flows inside a pipe there is a loss of pressure, no matter how smooth the surface is and assuming a non-slip boundary where the fluid is bound to whatever solid surface it flows over. There is always some microscopic surface roughness that produces non-slip behavior (hence f ≠ 0)

The pressure change is due to the change in altitude and partly due to the head loss with the effects of friction, which is given in terms of the friction factor f which depends on Reynolds

Number and relative roughness f = φ (Re, ε / D) It is not easy to determine the functional dependence of the friction factor on Reynolds number and relative roughness (ε / D).[1]

Types of plastic pipes made from several plastic materials such as polyvinyl chloride (PVC), polyethylene (PE) or polypropylene (PP) today have replaced galvanized pipes in various applications such as drinking water, irrigation and ventilation systems.[2].Polypropylene pipes are chemical resistant, low pressure drop and long life.

Head losses occur in pipelines when connected to joints such as elbows, sudden expansion and contraction, etc., and large head losses occur due to pipe roughness.[3] the value friction factor of plastic pipes usually takes as zero, given that their inner surface is smooth. There are empirical equations that calculate the coefficient of friction for smooth pipes with the Reynolds number like the equation Blasius (1911).

The energy equation for fluids is Bernoulli's equation, which describes the difference between the sum of pressure energy($pressur\ head = \frac{\Delta P}{\rho g}$), kinetic energy($velocity\ head = \frac{\Delta V^2}{2g}$), and potential energy ($elevation\ head\ or$ difference. $= \Delta Z$) between two points, which is the total fluid losses H_T.described that in Bernoulli equation(1)

$$\frac{\Delta P}{\rho g} + \Delta Z + \frac{\Delta V^2}{2g} = H_T ------------1$$

Total fluid losses are the major losses caused by friction along the length of the pipe and the sum of the minor losses caused by adding fittings, etc.

The equation of fluid minor losses is:

$$h_{min} = (\sum_{i=1}^{n} k)\frac{V^2}{2g} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

The Darcy- equation for fluid major losses is:

$$h_{maj} = f(\frac{L}{d})\ \frac{V^2}{2g}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

The fluid total losses equation is:

$$H_T = h_{minor} + h_{major} = \left(\sum_{i=1}^{n} k + f\frac{L}{d}\right)\frac{V^2}{2g} ------4$$

Bernoulli equation at constant diameter ($\Delta V^2 = 0$)with horizontal level ($\Delta z = 0$) becomes: [4]

$$\frac{\Delta P}{\rho g} = H_T = \left(\sum_{i=1}^{n} k + f\frac{L}{d}\right)\frac{V^2}{2g} ------5$$

$$H_T = k_T\frac{V^2}{2g} ------6$$

$$k_T = \frac{H_T}{\frac{V^2}{2g}} = \sum_{i=1}^{n} k + f\frac{L}{d} -------7$$

$$f = \frac{(k_T - \sum_{i=1}^{n} k) \times d}{L} -------8$$

$$f = \frac{(k_T - \sum_{i=1}^{18} k_{elbow}) \times d}{L} -------9$$

Where the value of $k_{elbow} = 1.77$ This value was calculated in a previous work using the same method and used with a model of 18 elbows connected to each other without a length of pipe[5].

Reynolds number (Re) formula

$$R_e = \frac{\mathrm{dV\rho}}{\mu} -------10$$

For smooth turbulent flows in circular pipe the friction factor is approximated by Blasius (1911) formula[6, 7].

$$f = (0.3164\ \mathrm{Re}^{-0.25}) -------11$$

Where: $h_m(m)$=head minor losses, $h_m(m)$=head major losses, d= internal diameter of the pipe,n=number of fitting , k=fitting constant, k_T =total constants (pipe length and elbows) V(m/s) =average fluid velocity, g=gravity acceleration=9.81m, L(m)=pipe length, $H_T(m)$=tatal losses, $\mu(pa.s)$ = fluid viscosity ,*f*=friction factor, $\Delta P(pa)$=pressure drop, $\rho(\frac{kg}{m^3})$=fluid density, ΔZ = elevation difference.

II. METHODOLOGY

The PPR model was used to estimate the coefficient of friction factor, it was consisting of a pipe of 8.5 m in length and 16mm in nominal diameter (inside diameter = 12.7mm, area 0.000127 m^2), 18 elbows with a nominal diameter 16 mm also, a flow control valve, and two pressure gauges.

The model was constructed horizontally as shown in Figure (1). The experiment was carried out at different flow rates using the valve, and the time to fill a three-liter container and the pressure value at both ends were recorded. The values for volumetric flow rate, velocity, Reynolds number, velocity head, pressure drop, pressure head, overall model coefficient, empirical friction factor and friction factor using Blasius formula were calculated. Water was used in the experiments in an isothermal condition and took

$\rho = 1000\frac{kg}{m^3}$, $g = 9.81\frac{m^2}{s}$,$\mu = 1.002 \times 10^{-3} Pa.s$

III. MODELING AND ANALYSIS

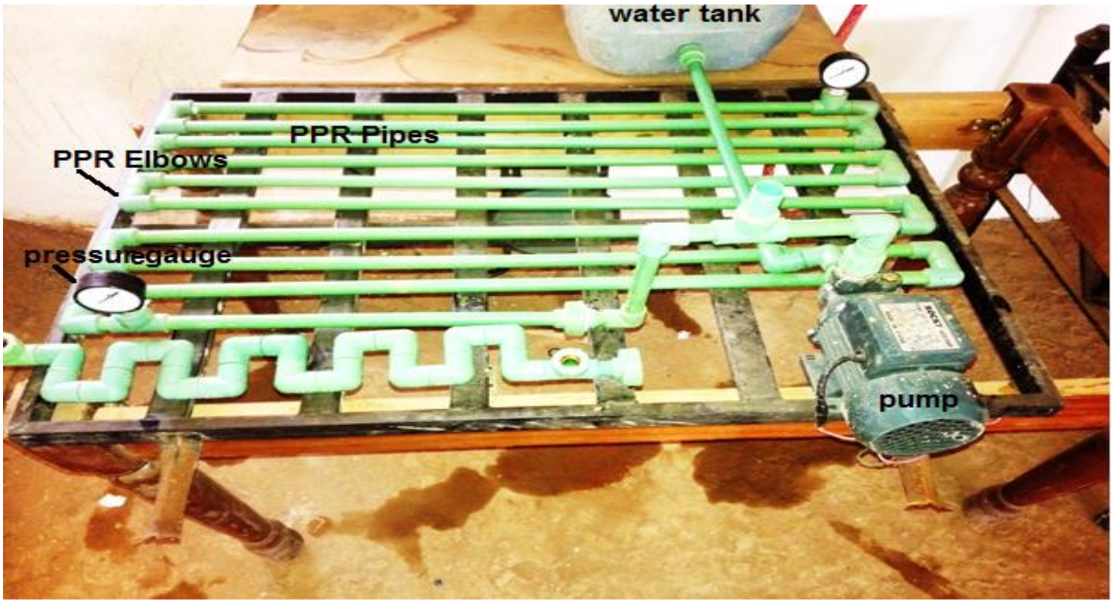

Figure (1): The experimental model

IV. RESULTS AND DISCUSSION

The table below shows the results of the experiment of the PPR model for seven randomized run tests. The time required to fill a three-liter container and the pressure values were recorded. Then the flow volume, velocity and Reynolds number were calculated. All values of Reynolds number were within the limits of turbulent flow, pressure head, head velocity, and the factor of the total constants was calculated, which consisted of a pipe length of 8.5 m and 18 elbows with a constant k equal to 1.77 for each one. When calculating the practical values of the friction factor, the value of the elbows constants was subtracted from the total model constants, and the result was value in the major losses resulting from the pipe, and we obtained the value of the friction coefficient. Finally, the coefficient of friction was calculated using the Basilius equation.

Figure (2) shows that the practical coefficient of friction factor is less than the value using the Basilius equation which indicates that polypropylene pipes are smooth and that the numerical formula similar to the Basilius equation was1.9231$Re^{-0.509}$

.

Table (1): elbows model experimental and calculations

No	**Time (s)**	$Q(m3/s) = \frac{volume}{time}$	**V(m/s)** $= \frac{Q}{area}$	**Calculated Reynolds number Eq (10)**	**Velocity head** $\frac{V^2}{2g}(m)$	**P$_1$ (pa)**	**P$_2$ (pa)**	**Pressure drops ΔP (pa)**	**Total losses Eq (5)** $H_T = \frac{\Delta P}{\rho g}$	**Total model constants Eq (7)** $K_T = \frac{H_{Total}}{velocity\ head}$	**Friction factor Eq (9)** $f = \frac{(K_T - 31.86) \times d}{L}$	**Friction factor Blasius Eq(11)**
1	84	3.57E-05	0.2821	3.57E+03	0.00406	142680.4	140571.8	2108.577	0.214942	53.002	0.031588635	0.0409
2	35.6	8.43E-05	0.6656	8.42E+03	0.02258	115268.9	105428.9	9840.027	1.003061	44.426	0.018775082	0.0330
3	29.3	1.02E-04	0.8087	1.02E+04	0.03333	105428.9	91371.68	14057.18	1.432944	42.991	0.016631024	0.0315
4	24.9	1.21E-04	0.9516	1.20E+04	0.04615	94885.98	77314.5	17571.48	1.79118	38.81	0.010384118	0.0302
5	24.5	1.22E-04	0.9671	1.22E+04	0.04767	91371.68	70285.91	21085.77	2.149416	45.088	0.019764188	0.0301
6	22	1.36E-04	1.077	1.36E+04	0.05912	82234.51	56228.73	26005.79	2.650947	44.839	0.019392153	0.0293
7	19.7	1.52E-04	1.2028	1.52E+04	0.07373	75908.78	45685.84	30222.94	3.08083	41.784	0.014827624	0.0285

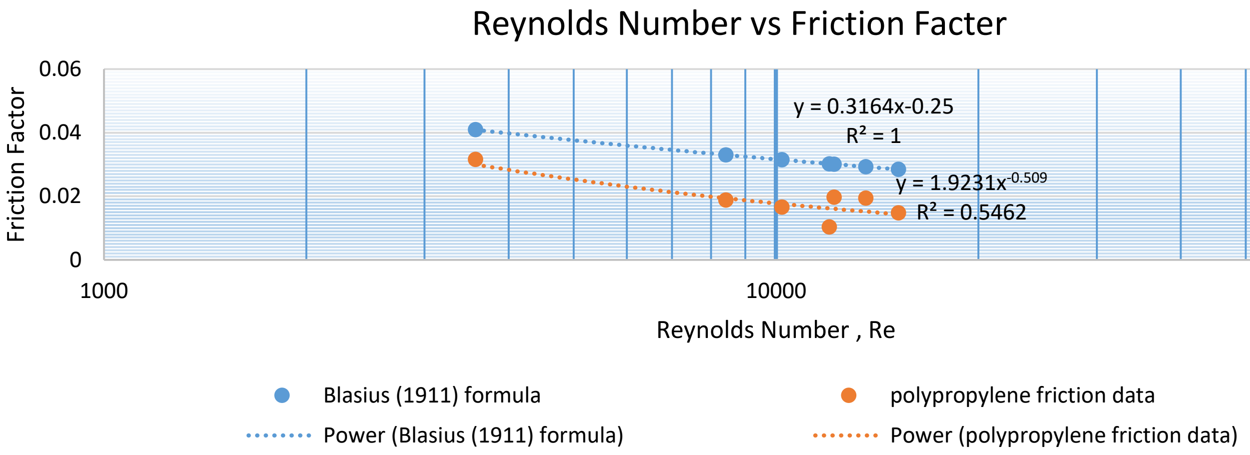

Figure (2): Experimental and calculated friction factor with Reynolds number

V. CONCLUSIONS

The friction factor was estimated by using this model in practice, and the result was that its value is less when compared between other type of pipes, and this is due to the method of manufacturing plastic extrusion, which makes the inner surface of the pipe smooth, the amount of energy lost due to the friction factor in PPR plastic pipes is small, but it cannot be neglected.

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