Prediction of Optimum Economic Pipe Diameter by Nomograph

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Appropriate sizing of process piping systems based on economic consideration is an essential requirement in almost every type of the fluid processing unit. In addition to the fluid transport properties the two cost factors viz, the cost of piping (fixed cost) and the cost of pumping (running cost) are to be taken into account for the prediction of optimum economic pipe diameter. Available correlations and nomographs in this context have used a constant cost factor which restricts their use for years to come. An attempt has, therefore, been made in this communication to predict the optimum economic pipe diameter for the viscous and the turbulent flow regimes with the help of nomograph prepared on the basis of modified equations, incorporating the cost factor. Values of economic pipe diameter obtained from the nomograph have been found to compare fairly well with the respective values calculated by the developed equations.

The investment for piping and pipe fittings amounts to 10 to 15% of the total investment in case of most of the chemical plants. It is, therefore, imperative to make a judicious choice as regards pipe sizes which gives close to a minimum total cost for pumping and fixed charges. Flow conditions being set, an increase in pipe diameter results in an increase of the fixed charges for the piping system and a decrease in the pumping or blowing charges, which implies that an optimum economic pipe diameter must exist.

Based on the principles of fluid dynamics and the economic data for the cost of power and pipe material the following equations have been developed for the prediction of optimum economic pipe diameter for flow in steel pipes. In case of viscous flow,

\[
\begin{align*}
(D_l)_{opt} & = 3.6 \cdot \left( \frac{q_f^{0.34}}{\mu_f^{0.18}} \right) & \text{For } D < 1'' \\
(D_l)_{opt} & = 3.0 \cdot \left( \frac{q_f^{0.36}}{\mu_f^{0.18}} \right) & \text{For } D \geq 1''
\end{align*}
\]

In case of turbulent flow,

\[
\begin{align*}
(D_l)_{opt} & = 4.7 \cdot \left( \frac{q_f^{0.45}}{\mu_f^{0.13}} \right) & \text{For } D < 1'' \\
(D_l)_{opt} & = 0.0257 \cdot q_f^{0.36} \cdot \left( \frac{K}{X} \right)^{0.18} & \text{For } D \geq 1''
\end{align*}
\]

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For turbulent flow condition

\[(D)_{opt} = 0.0144 \rho_f^{0.45} \mu_f^{0.13} \left( \frac{K}{X} \right)^{0.16}\]  

(6)

where,

\((D)_{opt} = \) optimum inside pipe diameter, m
\(q_f = \) fluid flow rate, m³/h
\(\mu_f = \) fluid viscosity, centipoise
\(\rho_f = \) fluid density, kg/m³
\(K = \) cost of electricity per kWh
\(X = \) purchase cost of new pipe per metre of pipe length if pipe diameter is 0.0254 m (= 1"")

[\(K\) and \(X\) values are to be in the same unit, eg, Rs, $, £, etc]

Figs 1 and 2 are the nomographs prepared on the basis of equations (5) and (6), respectively for a rapid estimation of economic pipe diameter for the complete flow regime of fluids.

**RANGE OF APPLICABILITY OF THE NOMOGRAPH**

The range of applicability of the nomographs is presented in Table 1.

The ranges of variables cover the normal operating ranges for industrial piping systems.

**ACCURACY OF NOMOGRAPHS**

The values of optimum economic pipe diameter obtained from the nomographs have been found to agree well with their respective values obtained from the equations (5) and (6).

**Example:**

\(q_f = 500\ \text{m}^3/\text{h}\)
\(\rho_f = 1000\ \text{kg/m}^3\)
\(\mu_f = 5\ \text{centipoise}\)
\(K = \text{Rs}\ 0.25/\text{kWh} (\approx 0.02/\text{kWh})\)
\(X = \text{Rs}\ 20/\text{metre} (\approx 1.6/\text{metre})\)

\$(1.0 \approx \text{Rs}\ 12.5)\)

The optimum economic pipe diameter for the above case for both the viscous and the turbulent flow conditions can be calculated and compared in the following manner.
Solution:

(a) Viscous flow condition:

From equation (5)

\[(D_l)_{opt} = 0.0257 \times (500)^{0.36} \times (5)^{0.18} \times \left(\frac{0.25}{20}\right)^{0.18}\]

\[= 0.146 \text{ m}\]

From nomograph (Fig 1),

\[(D_l)_{opt} = 0.150 \text{ m}\]

Percentage deviation of nomograph value from the calculated one,

\[\frac{0.150 - 0.146}{0.146} \times 100 = 2.74\]

(b) Turbulent flow condition:

From equation (6),

\[(D_l)_{opt} = 0.0144 \times (500)^{0.45} \times (1000)^{0.13} \times \left(\frac{0.25}{20}\right)^{0.16}\]

\[= 0.287 \text{ m}\]

From nomograph (Fig 2),

\[(D_l)_{opt} = 0.300 \text{ m}\]

Percentage deviation of nomograph value from the calculated one,

\[= \frac{0.300 - 0.287}{0.287} \times 100 = 4.53\]

REFERENCES


2. Ibid, Fig 13-2, p 435.