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Generalized method for determining the pipe friction loss of flowing pulp suspensions

Scope

The purpose of this Technical Information Paper (TIP) is to provide up-to-date correlations for basic pipe friction data obtained from laboratory flow loops and pulp mill piping systems and to propose a method estimating pipe friction over a wide range of flow rates. Because of the complex nature of the friction loss curve, it is not possible to recommend a single equation or a simple method for all pulps under various flow conditions. Hence, this TIP provides a means of determining the *minimum* value of pipe friction loss that can be expected based directly on all available published data. Consequently, it does not necessarily provide directly the actual design value of friction loss, and some judgement must be made by the designer. Each designer will have to determine and apply his own safety factor depending on company policy, projected expansions, possible flow system alternations, effects of other pipe fittings, and effects of other variables such as temperature, fiber aging, and past history. This TIP simply provides a strong basis from which to develop the design estimate.

This method has resulted from a view of published data, design correlations, and procedures for obtaining the pipe friction loss as explained in TAPPI TIP 0410-12 “Pipe Friction Pressure Loss of Pulp Suspensions - Literature Review and Evaluation of Data and Design Methods” (1). The approximate consistency range is 2% to 6% oven-dried.

The basis for the proposed method is a review and research work done by Duffy and coworkers, University of Auckland, New Zealand (2,3,4,5).

Safety precautions

No safety precautions have been specified for use with this technical information paper.

Introduction

As indicated by the friction loss curves for pulp suspensions in Figure 1, the frictional pressure drop or friction loss is not a simple function of velocity. At low bulk velocities, there is a flow regime in which the flow resistance increases as a power function of bulk velocity and stock consistency. Flow resistances in this regime have been correlated for a wide range of pulps (1). For most chemical pulps, the friction loss curves go through maxima as bulk velocity increases. Beyond the maxima there is a regime characterized by flow resistance which decreases as bulk velocity increases. Gross over-design can result if the correlations derived to predict flow resistances before the maxima in the friction loss curves are misapplied to predict flow resistances in the regime beyond the maxima. At higher bulk velocities the friction loss curves for most chemical pulps pass through local minima, and flow resistance again increases as bulk velocity increases.

For most mechanical pulps the friction loss curves have inflection points rather than maxima and minima, and at no velocity does flow resistance decrease as bulk velocity increases.

At very high bulk velocities in smooth pipes the flow resistances for both chemical and mechanical pulps are lower than those for water flowing alone at the same flow rate. The point at which a pulp curve crosses the water curve is termed the onset of drag reduction.

This TIP presents specific correlation equations in the “Equations and data” section for the region before the maximum in the friction loss curve and presents a method for calculating realistic but conservative values of the pipe friction component over other ranges of flow rate. Application of this method should avoid gross overdesign.

It must also be pointed out that all methods of determining pipe friction loss are based on steady-state flow where adequate upstream and downstream calming sections have been provided. In practice this is sometimes not the case. The friction loss per unit length of pipe immediately following a flow disturbance (bends, valves, contractions, etc.) can actually be higher than for calmed flow (see Reference 8).

Determination of pipe friction loss

The following pertinent design data are required: pulp type, oven-dried consistency, stock temperature, pipe material, pipe diameter, and bulk velocity based on design daily mass flow rate.

Step 1

Calculate the velocity, $V_{\max}$, at the upper limit of the linear region in the friction loss curve using equation (1) and the appropriate parameters from Table 1. If the design bulk velocity V is less than $V_{\max}$, go to Step 2. If the design bulk velocity V is greater than $V_{\max}$, go to Step 3.

Step 2

Calculate the value of flow resistance $\Delta H/L$ by substituting the appropriate values for stock parameters K , α , β , and γ from Table 2, design values for bulk velocity V , pipe diameter D , and oven-dried stock consistency C into equation (2). Use this value of flow resistance for design and proceed no further.

Step 3

Determine the bulk velocity at the onset of draft reduction V_w where the pulp pressure loss curve intersects the water pressure loss curve from equation 3. If the design bulk velocity V is greater than V_w , go to Step 4. If the design velocity is less than V_w (but greater than $V_{\max}$), go to Step 5.

Step 4

Calculate the friction loss for water flowing alone under the same conditions of bulk velocity, pipe diameter, and temperature using accepted correlations. For smooth pipes use equation (4). For rough pipes and pipe fittings, use accepted correlations for water (e.g. Ref. 6). Use this value of flow resistance for design and proceed no further.

Step 5

Calculate the flow resistance at the upper limit of the linear region in the friction loss curve $(\Delta H/L)_{\max}$ by substituting the value for $V_{\max}$ (Step 1) and the appropriate value of oven-dried consistency C , pipe diameter D , and stock parameters K , α , β , and γ from Table 2 into equation (2). Use this value of friction loss $(\Delta H/L)_{\max}$ calculated at $V_{\max}$ for all values of bulk velocity V between $V_{\max}$ and the point where this value intersects the water curve (near V_w).

The value of pipe friction $\Delta H/L$ calculated from Steps 1 to 5 forms the *basis* for design. If $\Delta H/L$ is calculated for the region before the maximum in the curve (Step 2), it will be an accurate estimate of the friction loss component. At velocities greater than $V_{\max}$ the friction loss estimate using Steps 3 to 5 will usually be a conservative approximation (see Fig. 1). The design engineer can then apply the safety factor F appropriate to the system in question.