

Sludge pipe flow pressure drop prediction using composite power-law friction factor–Reynolds number correlations based on different non-Newtonian Reynolds numbers

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Abstract

When predicting pressure gradients for the flow of sludges in pipes, the rheology of the fluid plays an important role, especially with increasing concentration of the suspended matter in the sludge. The $f-Re$ relationship is often applied when designing pipelines, but it depends on the rheological parameters of the fluid and what definition of non-Newtonian Reynolds number is used. In this work, a database of 586 $\Delta P - Q$ points from tests with 10 different sludges of concentration 3.4 to 7.2% by mass, in 3 test pipe diameters, was established and used to rheologically characterise the sludges as Bingham plastic fluids. Five published definitions of the non-Newtonian Reynolds number were used to create composite power law correlations for the $f-Re$ relationship covering all flow regimes. Pressure gradient predictions based on each correlation were compared and ranked, based on 2 different statistical estimates of error. The correlations using the Metzner-Reed Reynolds number (Re_{MR}) and a Reynolds number proposed by Slatter and Lazarus in 1993 (Re_s) yielded the lowest errors in comparison with the experimental values. It is shown that these correlations can be used to predict pressure drop to within $\pm 20\%$ for a given sludge concentration and operating condition.

Keywords: composite power law, friction factor, non-Newtonian Reynolds number, pressure gradient, sludge rheology