

## **MATHEMATICAL MODELLING OF HEAT EXCHANGE IN TURBULENT SLURRY FLOW WITH ENHANCED DAMPING OF TURBULENCE**

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Solid-liquid flow, named as slurry flow, appears frequently in chemical engineering, power plants, food and mining industries and is often strongly influenced by heat exchange between the transported materials and the surrounding, (Rozenblit et al., 2000). Solid-liquid flow could be classified as stationary bed, moving bed, heterogeneous, and pseudo-homogeneous, or as settling or non-settling types, (Doron et al., 1987). Settling slurry is formed mainly by coarse particles. However, it can exist as well for fine and medium solid particles for sufficiently low bulk velocity. When predicting the frictional head loss of slurry flow with coarse or medium particles, it is reasonable to assume the Newtonian model, as now one can measure rheology in such slurries, (Shook and Roco, 1991). Non-settling slurries contain fine particles and can form stable homogeneous mixture exhibiting increased apparent viscosity. Such slurries usually exhibit yield stress and require proper rheological model. Additionally, they demonstrate thicker viscous sublayer, resulting in increased damping of turbulence which appears in near a wall region. In this case a mathematical model, which includes apparent viscosity concept, suitable rheological model, and properly defined wall damping function is required.

The paper deals with solid-liquid turbulent flow in horizontal pipeline. The slurry contains fine solid particles of averaged diameters below 50  $\mu\text{m}$  surrounded by water as a carrier liquid. It is commonly known that such slurries exhibit non-Newtonian behavior and turbulence damping in near a wall region, (Wilson and Sellgren, 2003). This causes that mathematical modelling requires proper rheological model in order to calculate apparent viscosity and additionally suitable turbulence damping function, called also the wall damping function. In order to develop the mathematical model for slurry flow with heat exchange it is assumed that the slurry flow is homogeneous with moderate and high solids concentration and the flow is fully developed and axially symmetrical. Starting point in developing mathematical model for such slurry flow are time-averaged momentum equations in which apparent viscosity is calculated by appropriate rheological model. Problem of closure is solved by two-equation turbulence model. However, results of prediction of frictional head loss and velocity distribution fails if standard turbulence damping function is used in chosen two-equation turbulence model. For this reason, the new turbulence damping function, especially developed for slurry flow which exhibits turbulence damping in near a wall region, was proposed, (Bartosik, 2009). The new turbulence damping function was successfully

examined in comprehensive range of rheological parameters and flow conditions, (Bartosik, 2010). Current mathematical model, presented in the paper, is extended by time-averaged energy equation in order to predict heat exchange in turbulent slurry flow which exhibits turbulence damping. Finally, the mathematical model comprises four partial differential equations, namely momentum and energy equations, and equations for kinetic energy of turbulence and its dissipation rate. The mathematical model assumes non slip velocity at the pipe wall and was solved by finite difference scheme using own computer code. The mathematical model is suitable to predict velocity distribution, frictional head loss, and temperature distribution of fine-dispersive slurry in horizontal pipeline.

**The main objective of the paper is to examine the influence of solids concentration on temperature distribution by taking into account the mathematical model with and without additional damping of turbulence.** The additional damping of turbulence is included by taking into account the new wall damping function, while the standard wall damping function is used for the other case.

Numerical predictions of fine dispersive slurry flow exhibit substantial influence of solids concentration on quantitative and qualitative temperature profile, especially at the pipe wall. Results of numerical prediction demonstrate importance of turbulence damping near a pipe wall and are presented as figures and conclusions. Possible cause of damping of turbulence in near a wall region is discussed too.

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