FRICTIONAL PRESSURE DROP OF AN ADDITIVE-BASED NON-NEWTONIAN FLOW IN A PACKED BED

*Suresh Kumar Patel & Subrata Kumar Majumder**

Department of Chemical Engineering, Indian Institute of Technology Guwahati, Guwahati, PIN-781039, Assam, India

*Address all correspondence to Subrata Kumar Majumder E-mail: skmaju@iitg.ernet.in

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The influences of non-Newtonian liquid with and without additive on the pressure drop and friction factor in a packed bed have been studied. It is shown that the effect of the additive-based non-Newtonian liquid properties on pressure drop is significant. The additive reduces the pressure drop depending on the concentration of the additive and non-Newtonian liquid. Generally, the Ergun equation is a sufficient approximation of typical bed porosities values encountered in packed bed reactors. However, it is demonstrated that the original Ergun equation is only able to accurately predict the pressure drop of single-phase flow over spherical particles, whereas from the present study it is seen that it underpredicts the pressure drop of single-phase flow of non-Newtonian liquid. The variation of pressure drop in additive-based non-Newtonian liquid has been analyzed by empirical modeling and modifying the Ergun equation based on the physical properties of the additive-based non-Newtonian liquid. The proposed modified Ergun equation is able to predict single-phase pressure drop in a packed bed with and without additive-based non-Newtonian liquid within ±10% error on average.

KEY WORDS: *packed bed column, pressure drop, non-Newtonian fluid, friction factor, additive*

1. INTRODUCTION

Packed bed reactors are extensively utilized in chemical, petrochemical, biochemical, and waste water treatment processes. Packed bed reactors belong to the most widely applied reactors because of their effectiveness in terms of performance as well as low capital and operating costs. In numerous applications both liquid and gases are used as reactants flowing through a packed bed. However, a study of non-Newtonian flow with and without additive is of particular interest to this work since it is not only essential for single-phase applications, but also constitutes the basis for studying two-phase flow through packed beds (Nemec and Levec, 2005). Dullien (1975) studied the single-phase flow behavior of liquid through porous media and the impact by the pore structure. The pore structure affects the diffusion mechanism when reaction rates are controlled by the size of the particles in specific practical applications. Sie and Krishna (1998) reported that for diffusivities in pores of catalysts, diffusion limitation generally will occur with particles having a diameter of a few millimeters. In catalytic processes where liquid is present, the catalyst pores are likely to be filled with the liquid and low diffusivity in the liquid phase may even increase the likelihood of diffusion limitation (Nemec and Levec, 2005). Limitation of the diffusion may be influenced by wall interfacial stress and other hydrodynamic aspects like pressure drop, heat transfer phenomena, size of the particles, and the flow behavior of the type of liquid. However, differently shaped particles also pack with different degrees of bed porosity, which results in different pressure drops as well as different overall bed activities. Cooper et al. (1986) reported the characteristics of optimum catalyst shape size and packing procedure for a specific system, considering two possible hydro-processing conditions. The considerations regarding the optimum structure of packed bed reactors are complex; therefore,

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