Powder Technology 211 (2011) 127–134

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Interfacial stress in non-Newtonian flow through packed bed

Suresh Kumar Patel, Subrata Kumar Majumder *

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

ARTICLE INFO

Article history:
Received 7 February 2011
Received in revised form 2 April 2011
Accepted 13 April 2011
Available online 20 April 2011

Keywords:
Packed bed
Interfacial area
Non-Newtonian liquid
Wettability
Shear stress

ABSTRACT

This study investigates the pressure drop characteristics, shear stress in packed bed with shear thinning power law type non-Newtonian liquid. A mechanistic model has also been developed to analyze the pressure drop and interfacial stress in packed bed with non-Newtonian liquid by considering the loss of energy due to wettability. The Ergun's and Foscolo's equations were used for comparison with the experimental data. The Ergun equation was modified to account for the effect of flow behavior index of non-Newtonian fluid in the column. The intensity factor of shear stress and the friction factor were analyzed based on energy loss due to wettability effect of liquid on the solid surface.

1. Introduction

Packed bed reactors are most commonly employed in the chemical process industries among the several possible types of multiphase catalytic reactors. Their popularity halts from their effectiveness in terms of performance as well as low capital and operating costs. The non-Newtonian fluid flow through particulate bed system is important in a variety of chemical and biochemical processes [1]. Various examples of applications of the particulate system have been described by many authors [1–4]. Studies on the flow of fluids through porous media were restricted mostly to Newtonian fluids. Recently, the flow of non-Newtonian fluids through packed beds and porous media has received considerable attention because of its importance in various industrial applications. Considerable research efforts have been expended in exploring and further understanding of the basic phenomena of momentum, heat and mass transfer processes with and without chemical reactions in particulate system.

1.1. Previous work

Voluminous literature available on the flow of a variety of non-Newtonian materials through packed beds has been critically reviewed previously [5,6]. Wu and Pruess [6] described the non-Newtonian flow behavior in packed bed including beds of uniform size and of multi-size particles. Some other different studies related to Newtonian and non-Newtonian flow behavior in packed bed has been thoroughly reported in literature [7]. From the studies it is concluded that each study has its some uniqueness in its morphology which is contributing in some measure to the complexity of the problem. Similarly, often inadequate rheological characterization also adds to the complexity of such systems. While it is usual for most non-Newtonian materials to exhibit shear thinning behavior, many other features including time-dependency, viscoelasticity, yield stress, etc., are also present but not often measured. Certainly, the major research effort has been directed at developing simple and reliable methods of predicting the frictional pressure loss for the flow of non-Newtonian fluids through packed beds. Kozicki et al. [8] generalized the average velocity–pressure gradient relationship for arbitrary time-independent non-Newtonian fluids in porous media, based on the Blake–Kozeny capillary model. Mishra et al. [9] described average shear stress–shear rate relationship to predict the flow behavior of power law as well as non-power law fluids. The wall factor is also another phenomenon to affect the flow behavior in porous media which is a function of both diameter ratio and particle Reynolds number [10]. For Reynolds number below 1.0, this dependency is nearly same for settling in Newtonian and non-Newtonian liquids. In the range of $1 < Re_{\infty} < 200$, wall effect can be estimated for the non-Newtonian case from the relation applicable to settling in Newtonian liquids. Zhu and Satish [11] studied the drag phenomena which decrease with a decrease in flow behavior index and with an increase in the characteristic time. They found that both the normal stress difference and the bed voidage have a great influence on the resistance of visco-elastic flow through a packed bed. Rao et al. [12] studied the pressure loss-throughput behavior for the flow of inelastic power law fluids through randomly packed spherical particles and over wide ranges of operating and physical conditions. Sabiri et al. [13] investigation covers a large range of Reynolds number including creeping and inertial flow regimes. They

* Corresponding author. Tel.: +91 3612582265; fax: +91 3612582291.
E-mail addresses: skmaju@iitg.ernet.in, rsmaju@yahoo.com (S.K. Majumder).

0032-5910/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.powtec.2011.04.010