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研究快报

FRACTAL CHARACTERIZATION OF LIQUID DISPERSION IN TRICKLE BED REACTOR

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INTRODUCTION

Dispersion is very important to the design of trickle bed reactor for both chemical and biochemical processes. The degree of dispersion often influences reactor performance and scale-up. The traditional method for modeling dispersion processes in trickle bed reactors is based on the convective-diffusion equation (CDE). The most commonly used is the longitudinal-dispersion model[1, 2]. The magnitude of liquid dispersion is usually considered independent of position along the longitudinal direction of the reactor. The main assumption of the longitudinal-dispersion model is that the mixing in the axial direction follows a Fickian type of diffusion regardless of the mechanism and process involved. A constant longitudinal dispersion coefficient D_L is used to quantitatively describe all the factors making different residence time distributions RTD[3]. Recently, the above method has been questioned due to its weak theoretical background. As Westerterp *et al*. stated [4, 5], the longitudinal-dispersion model has not been justified and it can lead to erroneous results. So the clarification on the dispersion model and theoretical treatment is greatly desired without doubt.

It has been well accepted that porous formations (natural or artificial) may exhibit fractal structures[9, 10]. The research on the dispersion process in consolidated porous media such as soil and rocks underground, and even solid catalysts has demonstrated that dynamic processes taking place in these structures have long-range correlation [6—8,11]. It is evident that the dispersion inside consolidated porous media is not Gaussian and can not be simply described by the CDE[6—8]. However, the trickle bed reactor used in chemical and biochemical processes belongs to unconsolidated porous media. Is there any similarity between consolidated and unconsolidated porous media with respect to liquid dispersion? The answer to this question can definitely play a vital role in clarifying the existent controversy on the longitudinal-dispersion model. Therefore, this paper is to experimentally investigate if the dispersivity is scale-dependent in trickle bed reactor at first, and then to interpret the experimental results by applying fractal analysis.

1 EXPERIMENTAL

The experiment was conducted with randomly packed 6 mm cylindrical particles. The packing was housed in a reactor 3.5 m in height and 70 mm in diameter. Air was blown into the reactor through a distributor at the bottom. The liquid phase,

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water, was rained in the cross section of the reactor from the top. The RTD of liquid phase was measured by a tracer injection system. The least-square method was used to fit the RTD data in order to get the model parameter. The tracer pulse was injected at one of the input ports numbered 1 to 5, along the longitudinal direction. The interval between any two neighbouring input ports is 50 cm. The nearest input port of tracer from the top is 100 cm to allow for the distribution of liquid. The injection and detection of tracer were carried out by a computer-aided system.

2 RESULTS AND DISCUSSION

At various liquid superficial velocities, the Peclet number Pe_L of liquid dispersion along the longitudinal direction of the reactor is presented in Fig. 1, which demonstrates an obvious non-linear dependency of Pe_L upon the superficial distance L_S between the injection point and the detecting point of tracer solution. This dependency could be expressed by a power law expression as follows

$$Pe_L = \frac{uL}{D_L} \sim L_S^{\beta} \tag{1}$$

Traditionally, Pe_L is only considered linearly dependent of the length scale L_S. As we know, the liquid flows down along the passages formed by random-heaped packing of catalyst pellets. The actual flow distance L is much longer than the superficial distance L_S because of the tortuousity of the flow passage. This is quite similar to the gas diffusion in porous media, so the actual length of liquid trajectory L depends on the yardstick size used for length measurement[11]. In this case, the trajectory of liquid flow can be abstracted into fractal curves, characterized by a scaling relation as shown in Eq. (1). The power in the scaling relation is the fractal dimension showing the tortuous extent of the liquid flow trajectory. The L in Pe_L should be of fractal.

By fitting the experimental results, the exponent β is acquired, the value of which changes from 1.57 to 1.72 with the superficial velocity

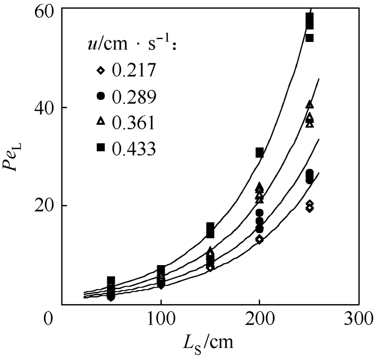

Fig. 1 Dependency of Peclet number Pe_L on superficial length scale L_S

from 0.22 m · s^{-1} to 0.43 m · s^{-1}. The variation of exponent β with superficial velocity u is due to the variation of liquid pulsing because the operation of the reactor is transforming from trickling flow to pulsing flow by increasing u at a fixed gas velocity. The enhancement of liquid pulsing leads to a longer distance of liquid flow along the passages, giving rise to higher fractal dimension. The interpretation of the experimental result by computer simulations based on fluid flow in porous media and fractal geometry is well under way and will be reported in a separate article.

3 CONCLUSIONS

Experimental investigation and theoretical analysis show that the trajectory of liquid flow inside trickle bed reactors is of fractal, demonstrating that the Pelect number Pe_L of liquid dispersion in trickle bed reactors is non-linearly scale-dependant similar to what was already shown in consolidated porous media. Pe_L itself is not adequate to fully characterize the extent of liquid dispersion inside the reactor. The fractal dimension of liquid flow trajectory is a parameter showing the regularity of liquid flow inside the reactor, the value of which may be influenced by operation conditions, packing type and liquid properties.

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信息与交流

林纸一体化工程将带动化工发展

2 月 16 日下午，由国家发改委组织有关部门、科研单位编制的《全国林纸一体化工程建设“十五”及 2010 年专项规划》，正式向全国发布.

林纸一体化是一项系统工程，对化工、包装、印刷、机械等行业具有明显的带动作用. 在关闭落后草浆造纸线后，将大力发展化学木浆、化学机械木浆，并规划在东南沿海地区建设 4 个年产化学木浆 50 万吨以上的大型项目.

据介绍，造纸业与化工有着非常密切的联系，需要大量化工原料如烧碱、二氧化氯等. 化学木浆是通过大量的化学及生化反应加工出溶解级木浆，除需增白以外，加工时还需化学提纯、脱树脂、解聚等；而化学机械木浆是通过机械和化学联合制浆法生产出来的木浆. 这两种木浆主要采用烧碱法、硫酸盐法和亚硫酸盐法制造. 这次全国林纸一体化工程建设可使化工和林业有机地结合起来，形成一条生产链.

目前世界造纸工业的总资产和销售额分别达到 4000 亿美元和 3000 亿美元，是仅次于电讯制造业和汽车工业之后的一个重要产业. 2002 年，我国纸及纸板消费量为 4332 万吨，国内产量仅为 3780 万吨，造纸总进口 1875 万吨，成为世界造纸工业中消费、生产和进口大国. 到 2005 年我国纸及纸板消费量约 5000 万吨，2010 年将达到 7000 万吨，市场潜力十分巨大.

（摘自“中国化工信息网”）