Heat and Mass Transfer Enforcement of Vibrating Fluidized Bed

Chu Zhide   Yang Junhong   Li Xuhui   Song Yang
Department of Thermal Energy Engineering, Tianjin University, Tianjing 300072, China

This paper briefly introduces the development of vibrating fluidized bed at home and abroad, elaborates the vibration properties of vibrating fluidized bed, the fluidizing velocity and pressure drop of the bed layer. It also deduces the non-steady state drying dynamic equations of vibrating fluidized bed, analyzes main factors which influence the drying rate and inquires into drying rules of fixed bed and vibrating fluidized bed.

Keywords: radiation drying, vibrating fluidized drying, optimized drying.

INTRODUCTION

Traditionally, dry ovens and dry rooms are used for drying, whose thermal efficiencies are not more than 10%. Although some improvements have been made on sifter type, tumble board hot air dryer, including ordinary radiation dryer, their thermal efficiencies are only about 30%. The thermal efficiency of the BG134 air spray rolling cylinder type single plank dryer, which is newly imported from C.KELLER Corporation Germany is 38%. The TDRN-1 roller press type single plank infrared dryer invented by Tianjin University has many high and new technologies such as high-temperature and fixed-direction, and its thermal efficiency has already reached 60%[1].

With energy of mechanic vibration stressed on, material will be fluidized and may reach much evener and stabler fluidizing state than by air fluidizing. Good drying results may be obtained with the influences of heat convection, heat conduction and heat radiation. It is shown by documents[2] that vibrating fluidized bed has five advantages.

Technology of vibrating fluidization has been widely used in industry in several developed countries, and it has gained more and more attention. According to statistics by chairman of the International Drying Institute A.S. Mujudar, at present, the ratio that mechanic vibration used in drying in developed countries is the highest[3] (as shown in Fig.1).

Fig.1 Application of Vibrated Processing Equipment

Fig.1 shows that 30% of vibrating fluidized beds are used in drying. But in our country now, they are mainly used in conveyance of materials. Design and analogical experiments have been carried out in China, and this has greatly improved the heat and mass transfer enforcement of vibrating fluidization[4-6], but deepgoing research on its basic rules is still expected.
THE ESSENTIAL PROPERTIES OF VIBRATING FLUIDIZED BED

1. Vibrating Property of the Bed Layer

According to the vibrating intensity of the bed layer (the ratio between the bed layer acceleration \(Aw^2\) and the gravitational acceleration \(g\), where \(A\) is the amplitude and \(w\) is the rotation frequency), the essential properties of the vibrating fluidized bed material layer are divided into three types: while \(Aw^2/g < 1\), it is called vibrating bed: materials stick stably and evenly to the surface of the bed layer; while \(Aw^2/g \approx 1\), it is called sub-vibrating bed: materials are in the tendency of jumping, but haven't jumped up yet; while \(Aw^2/g > 1\), it is called vibrating fluidized bed: materials are thrown up and the fluidizing layer is formed, materials are incessantly jumping up and down, rolling with the power of vibration, then the steady fluidizing layer appears. The collision opportunity increases and heat and mass transfer is enforced.

2. Minimum Fluidizing Velocity

Bratu and Jinesou, Gupta, Mujumdar and Mushstaev separately give the related formulas for calculating the minimum fluidizing velocity\(^{[7-9]}\). Though the formulas are different in forms, they all show that the increase of vibrating intensity can effectively decrease the minimum fluidizing air velocity. While vibrating intensity \(Aw^2/g = 1.3 \sim 9.85\), the ratio of many granular materials between the minimum fluidizing velocity of vibrating fluidized bed and the minimum fluidizing velocity of air fluidized bed reaches 1:6.

3. Pressure Drop of the Bed Layer

Compared with ordinary air fluidized bed, the influence of vibration can decrease the pressure drop of fluidized bed. The fluidizing curve of vibrating fluidized bed is different from ordinary air fluidized bed, it has two constant stages. Fig.2 is the relationship curve of the pressure drop \(\Delta P\) and the air velocity \(V\). In various vibrating conditions, forms of this type of curves have some differences. Compared with ordinary air fluidized bed, the bed layer's uniform fluidization can be reached at a rather small air velocity, and the value of the pressure drop in the first fluidizing stage is evidently lower than that of the minimum fluidizing pressure drop in air fluidized bed.

Researches by Hou Caiyun and Cao Chongwen et al. demonstrate that the bed layer pressure drop not only relates to vibrating parameters, but also changes with the material moisture content. It decreases with the decrease of material moisture content, and it is in fine linear relation with dry based material moisture content\(^{[8]}\).

![Fig.2 Fluidized pressure drop and fluidized velocity](image)

EXPERIMENTAL RESEARCH ON VIBRATING FLUIDIZED BED

That vibrating fluidized bed can get high heat transfer coefficient has been proved by many researchers. Mujumdar did many investigations on heat conduction coefficient of vibrating fluidized bed, and the results show that the heat conduction coefficient of vibrating bed is three times more than that of fixed bed in non-ventilating bed; With the increase of air velocity, vibration effect on heat conduction decreases little by little and this rule is identical with air fluidized bed. The effects that air velocity exerts on the heat given coefficient of the bed layer and wall surface are shown in Fig.3. In Fig.3 we see that while air velocity is lower than the critical fluidizing velocity, it belongs to fixed bed stage. At this stage, the heat given coefficient increases very slowly with the increase of air velocity, this is shown as curve AB, While the flowing velocity is greater than the critical velocity, the heat given coefficient rises quickly to its maximum point C as curveBC shows. Then the bed layer material is fluidized. But if the air velocity continues to increase, the heat given coefficient drops instead of increasing. Then we can draw a conclusion from Fig.3: Heat transfer in air fluidized bed is much better than that in fixed bed.

Vibrating fluidized bed can improve the bed layer mixing, improve the heat and mass transfer property, and raise the drying rate. It is reported by Laitsev et al. that the drying rate of vibrating fluidized bed is 1.5~2.5 times more than that of air fluidized bed. Osiuiki et al. found that the drying rate in constant rate stage is 6 times more than that of fixed bed\(^{[8]}\). The experiment result of milk powder drying which is given by Valohzr is: The drying rate of vibrating fluidization is 2~8 times more than that of air fluidization, and the multiple increases with the in-