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Presentation of a test rig with its experimental procedure and uncertainty analysis of measurements for batch type fluidized bed drying of corn and unshelled pistachio nut

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ABSTRACT

This paper gives the hardware and software of a test rig with its experimental procedure, methodology and uncertainty analyses of measurements for batch type fluidized bed drying of corn and unshelled pistachio nut. The test rig is designed, constructed and operated for the analyses of drying performance of corn and unshelled pistachio nut in a batch type fluidized bed drying. The details of the test rig, the experimental procedure, the uncertainty analyses and the investigation of the effects of drying parameters on drying performance are the major scope of the paper. The accuracy of the experimental study herein is based on velocity, pressure, temperature and moisture measurements. Therefore it is vital and sensitive phenomenon for the determination of the uncertainties of the measurements before the current study as is the case with all other studies. The test rig is designed and constructed in accordance with literature review which is mentioned briefly in this paper. The basic terminology which is used in this study is also introduced herein. The overall uncertainties of velocity, pressure, temperature and moisture measurements are performed and found as 1.7%, 1.3%, 0.3% and 1.6%, respectively. Some pioneering studies related on conventional batch type fluidized bed dryers operated under atmospheric pressure are also tabulated as an original contribution to literature. Moreover, the effects of the particle mass, drying air temperature and drying air velocity on drying performance of the batch type fluidized bed dryer which is assisted with a conventional electrical heater unit are outlined without going into details in thermo- and fluid-dynamics of drying process.

1. Introduction

Fluidized bed dryer is widely used one for drying of wet and granular products such as chemicals, foodstuff, pharmaceuticals, polymer and resins. Due to rapid drying characteristics, it has been considered as an economical drying technique when compared with others [1].

The main advantages of fluidized bed drying among others are high rate of moisture removal, easy material transport inside dryer, easy control and low maintenance cost. However there are also some disadvantages of fluidized bed dryer such as high pressure drop, high electrical power consumption, poor fluidization quality of some particulate products (adhesive products, attrition or pulverization of particles, agglomeration of fine particles) and erosion of containing surfaces [2]. Fluidized bed dryers can mainly be classified as is seen in Fig. 1.

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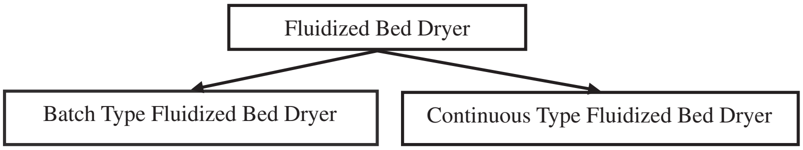

Fig. 1. Types of fluidized bed dryer.

A batch type fluidized bed dryer is generally preferred for small-scale production in the range of 50–1000 kg/h and for heat sensitive materials. In batch type, drying air temperature and air flow rate are generally fixed at a constant value. On the other hand, energy saving can be satisfied by controlling air flow rate and its temperature. Fig. 2 shows a typical batch type fluidized bed dryer and forces acting on a particle to be dried. Single particle motion in a fluidized bed dryer column can be simply analyzed by introducing forces acting on a particle. Particle in a fluidized bed is acted with three types of forces as weight of particle, W, drag force, F_D and buoyancy force, F_B .

For drying process, one of the main important parameters is Reynolds number based on minimum fluidization velocity which can be defined as follows:

$$\mathrm{Re}_{mf} = \frac{d_p u_{mf} \rho_f}{\mu} \tag{1}$$

where d_p is particle diameter, u_{mf} is minimum fluidization velocity, ρ_f is fluid density and μ is dynamic viscosity.

Other important terminology used in fluidized bed drying researches is moisture content which is defined as a measure of amount of water or its vapor included within a substance. Generally moisture content, MC is described as dry basis (kg water/kg dry solid) and it can be calculated by dividing weight of water, W_w by weight of dry material, W_d:

$$MC = \frac{W_w}{W_d} \tag{2}$$

Eq. (2) can be written as:

$$MC = \frac{W_b - W_d}{W_d} \tag{3}$$

where W_b is weight of material before drying.

Moisture ratio, MR is another parameter used in drying process and expressed by the following equation:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \tag{4}$$

where M_t is moisture content at time t, M_0 and M_e are initial and equilibrium moisture contents on dry basis, respectively. M_e is relatively small when compared to M_t and M_0 [3,4]. Thus, MR can be simplified as:

$$MR = \frac{M_t}{M_0} \tag{5}$$

Herein it is important to give a sight for the conducted researches on fluidized bed drying in order to design and construct a proper test rig. The related studies are tabulated in Table 1 in which the effects of drying air temperature and drying air velocity on drying performance are basically given. The results are generally summarized in terms of the effects of the drying air temperature and velocity on the drying rates by means of the predefined coded arrows.

The study of Kaensup et al. [5] is considered as an illustrative example in order to explain the coded arrows such that drying rate is increased (DR↑) when drying air temperature is increased (T↑) during the drying process of white pepper seeds in the fluidized bed drying assisted with electrical heating unit. As the study of Syahrul et al. [6] is considered, neither increasing nor decreasing in drying air velocity (V↑↓) and temperature (T↑↓) change the drying rate (DR→). The proposed table provides a great convenience in order to realize, compare and discuss the conducted previous studies in terms of the effects of drying parameters on drying performance. As a general consequence, it is observed that drying air velocity has a favorable effect on drying rates. However, there are some conflicting results about the effect of drying air velocity. Syahrul et al. [6], Kaymak-Ertekin [9], Çalban and Erşahan

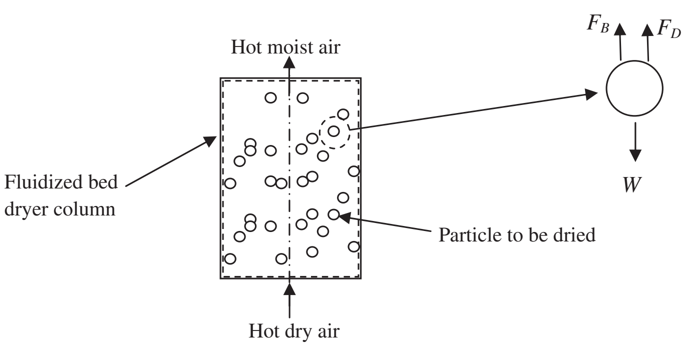

Fig. 2. Typical batch fluidized bed dryer and forces acting on a particle to be dried.