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Grain velocity distribution in a mixed flow dryer

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ABSTRACT

For corn drying one of the most popular possibilities in Europe is to use a mixed flow dryer. Large differences in the vertical grain particle velocity in this type of dryers are causing differences in the residence time. Hence, uneven drying occurs causing under-drying or over-drying of grain portions. To investigate the influences of the dryer walls and the air ducts on the particle velocity distribution experiments have been carried out in industrial and laboratory sized dryers and the measurements were compared with discrete element models. The particle flow velocity distribution between the air ducts is modelled analytically based on arching hypothesis. Using discrete element models the effects of different possible constructional modifications causing more even vertical grain particle velocity distribution were analyzed.

1. Introduction

For the safe storage of harvested cereals the drying of agricultural products is one of the most important technologies in the whole processing line. From several drying methods the mixed-flow corn dryer is the most popular in Europe. Although such dryers have several different types, are produced by many manufacturers and are widely used, it is still necessary to optimize many of their segment processes. In these dryers the air and the grain are guided through the dryer shaft in co-current, counter-current, and cross flow modes at the same time [22]. The grain is transported step-by-step downwards the dryer shaft. At each discharge it is assumed that the grain bed moves in plug flow pattern. The bed material is assumed to be a connection of single grain layers' series the drying behaviour of which is described by means of a single grain model [8]. The aim of our investigations was to study how the mass-flow develops during the drying while the corn moves through the mixed-flow dryer. The influence of different forms of air ducts on the grain and air flows through a mixed-flow dryer has already been studied by Klinger [16]. The dryer was modelled as a series of co-current and counter-current elements. The same modelling concept was successfully employed to predict the general behaviour of the dryer and the influence of operating variables on drying performance [3]. In a dynamic form it has also been used in the development of an automatic dryer controller [20]. Cenkowski et al. [4] experimentally investigated the air-flow patterns in a mixed-flow dryer. They revealed that about 30% of the dryer shaft volume operates in a cross-flow configuration. Giner et al. [9,10] developed a two-dimensional model of the mixed-flow dryer including cross-flow elements. To calculate the grain drying process in each co-current, counter-current, and cross-flow element first of all it is necessary to know the proceeding of mass- and air-flow processes. Recent publications on the modelling of hot-air grain dryers are concerned with cross-flow, deep-bed and single kernel drying, for example [24,14,25,28]. Mellmann et al. [18] derived basic equations on particle flow in mixed-flow dryers which were operated in the interrupted flow regime and equipped with discharge gates. They described function of the discharge gate, the discharge characteristic and the solids mass flow rate by varying the discharge and standstill times, respectively and evaluated and measured the effect of residence time distribution inequalities on drying efficiency [19]. Our goal is to solve the residence time problem by modifying the drying equipment to get more even velocity distribution. In this article, the effect of particle–wall friction, ait duct's apex angle and wall angle to the vertical direction is modelled using 3D discrete element method.

2. Mass flow measurements

The mass flow experiments which were carried out by the pilot mixed-flow dryer at Leibniz-Institute for Agricultural Engineering Potsdam-Bornim e.V. (ATB) in Potsdam have illustrated how the bed material moves through the pilot dryer and the mixed-flow dryer. Dried wheat samples with a moisture content of 12–14% w.b. were used as bed material. The pilot dryer had two identical shafts. The left shaft covered with transparent Plexiglas® wall

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