Vacuum drying of slurries with filter press dryer

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学位論文要旨

Dewatering of slurry is one of the most important operations for the production of particles via liquid phase reactions in various industries as well as sludge treatment of wastewater. The production of dry fine particles from the slurry is commonly carried out by mechanical filtration followed by a drying process. However, this process requires the cake discharge from a filtration chamber into a dryer, which brings additional cost and sometimes material degradation especially for nanoparticles. The present work proposes a new technology utilizing one chamber which can accomplish both mechanical dewatering and drying without cake transportation. The new filter press dryer employs filtration and vacuum drying processes. By optimizing the operating parameters in filtration and drying stages, the energy consumption for producing dry fine particles can be reduced. In addition, this technology has not only an ability to dry the slurry up to almost 100% but also a possibility to control the particle packing structure in the dried cake. This work were aimed at investigating the effect of parameters and operating conditions on the drying rate and studying the drying mechanism in filter press dryer and studying the fundamental drying mechanisms of FPD by constructing a simple featured model dryer (FMD) that possess the essential structure of FPD.

1. Study of effects of operating conditions on drying characteristics

A new type of filter press which is capable of dewatering slurry by filtration, squeezing and drying in a single chamber is developed. The slurry particle is filtrated under the constant pressure of 95 kPa. squeezed by vacuuming the chamber (6kPa-abs) the

chamber in dewatering step. In the drying process, a filter cake is heated by steam via thin diaphragms (PTFE) while vacuuming the chamber. The basic performance of filter press is investigated using the slurry of magnesium carbonate which forms an incompressible filter cake. The studies parameters are slurry concentration, filtration pressure, steam temperature and diaphragm thickness. As a result, it is found that higher flow rate of filtrate flow is obtained at lower slurry concentration and filtration pressure. However, slurry concentration and filtration pressure do not affect the drying process. The evolution of cake temperature showed that drying process can be divided into 3 regions; (1) the region where the cake is heated from the initial temperature to the boiling point, (2) the region in which water in the cake evaporates at the boiling point, and (3) the region where the cake of almost 100% solid is heated up to the final temperature. Moreover, the results showed that by using a higher steam temperature and/or a thinner diaphragm is effective for significantly reducing the drying time, altering the temperature evolution of the cake as well as the time-change in the water content. Since new filter press utilizes a single chamber for filtration, squeezing and drying, there is no need for cake discharge into a dryer, which prevents the dust generation as well as the cake contamination.

2. Study on fundamental characteristics of filter press dryer (FPD) with a feature model dryer (FMD)

A simple featured model dryer (FMD), which heats filtered cake through a thin diaphragm, is developed in order to study the fundamental characteristics of filter press dryer (FPD). By employing the featured model dryer, we may open it at any time and

measure the temperature and local water content at any location of cake. The featured model dryer is found to express the basic performance of filter press dryer.. The results obtained with the featured model dryer showed that the local water content in the cake is only a function of the local cake temperature. The relationship between the water content and the cake temperature is unique characteristic for a given cake and a given drying condition, which can apply to both filter press dryer and featured model dryer. Furthermore, the average water content in cake decreases exponentially with time when the water content is higher than 5% of the initial water content and the drying rate constant is higher for a thinner diaphragm and higher vacuum pressure. In addition, the results showed that the temperature in Region 2 fluctuated more significantly at a higher vacuum pressure. At a lower absolute pressure, the evaporate water is highly localized to form densely packed particle near the drain outlet. Since the particle layer blocks the passage of evaporated water, another passage of evaporated water would newly form. The formation of disappearance of vapor passage in the cake cause the fluctuation of pressure at a given point in the cake, resulting in the fluctuation in the temperature.

学位論文審査結果の要旨

平成18年8月1日に口頭発表と質疑応答を行い、その後に開催した学位論文審査会において以下のように決定した。

本論文は、同一チャンバー内でろ過、脱水、乾燥を短時間で行うことができる、フィルタープレスと乾燥機を一体化した間接加熱型フィルタープレスドライヤーに関するものである。フィルタープレスドライヤーの基礎的な性能評価を行うとともに、小型モデルを製作してその乾燥機構について詳細に検討した。その結果、フィルタープレスドライヤーのろ過過程は定圧ろ過モデルで表現できること、また、乾燥過程については、ケーク加熱膜厚さが薄いほど乾燥時間を短縮できること、さらに、小型モデルを用いた実験より、ケーク局所含水率はケーク局所温度のみの関数となり、この関係はフィルタープレスドライヤーを用いた場合の平均ケーキ含水率とケーキ温度の関係にも適用できることを示した。そして、乾燥時のケーキ平均含水率は指数関数的に減少し、小型モデルで得られた乾燥速度からフィルタープレスドライヤーの乾燥速度を予測できることを示した。

以上のように、本論文は、フィルタープレスドライヤーの実用化に不可欠な、ろ過・脱水・乾燥機構の解明と、乾燥時間の予測法を提案しており、その工学的価値は高く、博士（工学）の学位に値すると判断する。