Diffusion-optimized convection dryers and their applications in the coating industry

by

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ABSTRACT

This presentation starts out with a summary describing properties of convection dryers applied in the coating industry today. It is pointed out that the drying rates of these dryers are insufficient to meet the requirements needed in current coating lines. Typical dryer configurations and their performances are summarized and it is shown that the "convection dryers", applied in the coating industry today, have drying rates below 1 g/(m^2 s). This is insufficient for the present-day drying technology applied in the coating industry. Furthermore, high air flow rates are employed to carry out the drying and high energy requirements exist for dryer operations. All this requires new efforts to advance the drying technology applied these days in industrial coating lines.

The presentation describes the development of diffusion-optimized convection drying and demonstrates that it now achieves drying rates that are four times higher than conventional drying rates, for water-based films. This is verified quantitatively based on experimental investigations.

The presentation also deals with drying rates that can be achieved when ultrasound is applied and demonstrates that high sound rates are necessary to achieve a maximum increase in the drying rate of 1.8. Frequencies should be above the hearing range of the human ear to keep the sound bearable.

The theoretical basis of diffusion-optimized convection drying and of ultrasound drying is explained and a diagram is derived that illustrates the drying rates of solvents such as ethanol, methanol and acetone. This offers a good opportunity to demonstrate the applicability of diffusion-optimized convection drying.

In its second part, this presentation looks at the basic equations of fluid mechanics and the energy and mass transport equation. It points out that the continuity equation contains no term form the diffusive mass transport. Short-

comings due to this missing transport term are outlined for the drying of thin liquid films. It is shown that the introduction of the missing diffusive mass transport term into the continuity equation allows new dryers to be thought of and appropriate drying elements to be designed.

In its third part, the presentation describes the development of diffusion-optimized convection dryers for thin liquid films. It is demonstrated that such dryers achieve drying rates that are four times higher than the drying rates of conventional dryers for water-based films. Theoretical considerations along this line are presented and it is verified experimentally that the predicted increased drying rates can also be achieved in practice.

A test-section is described, based on a micro-balance to measure the drying rates of elements that use the diffusion optimized drying concept. This test-section is shown in following Fig. 1.

Fig. 1: Micro-balance based test sections and achieved drying rates

The experimental results are presented to indicate that several orders of magnitude of increased drying rates were achieved with diffusion optimized convection drying elements. These elements are indicated in Fig. 2 and it is also shown that 10 of these elements can be combined to make up a one-meter dryer, operating as a diffusion optimized convection dryer. With such a dryer, drying rates can be achieved as shown in Fig. 3. There are several orders of magnitudes higher than the drying rates achievable with convection dryers of today.

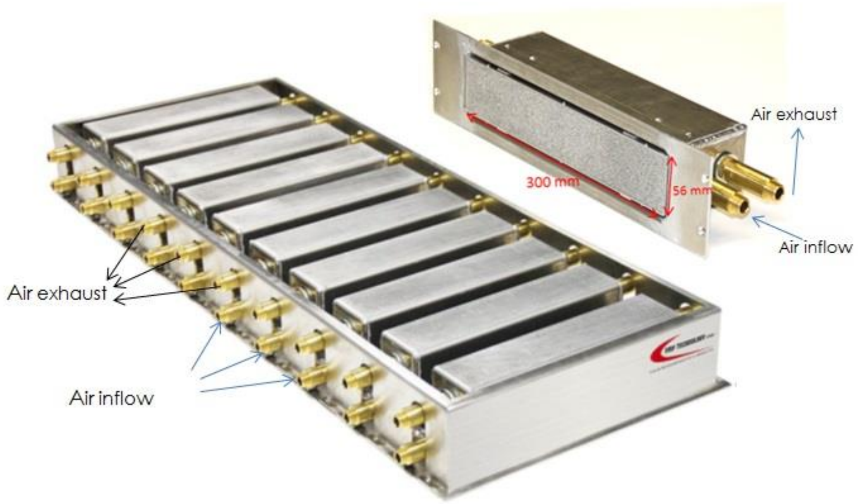

Fig.2 Drying element and 1 dryer consisting of 10 elements

With the test section in Fig. 1, laboratory experiments can be carried out to obtain the drying rates for a combination of two elements of diffusion optimized convection dryers. In the presentation results are described that were obtained for different temperatures and different distances of the porous medium plate of the film to be dried.

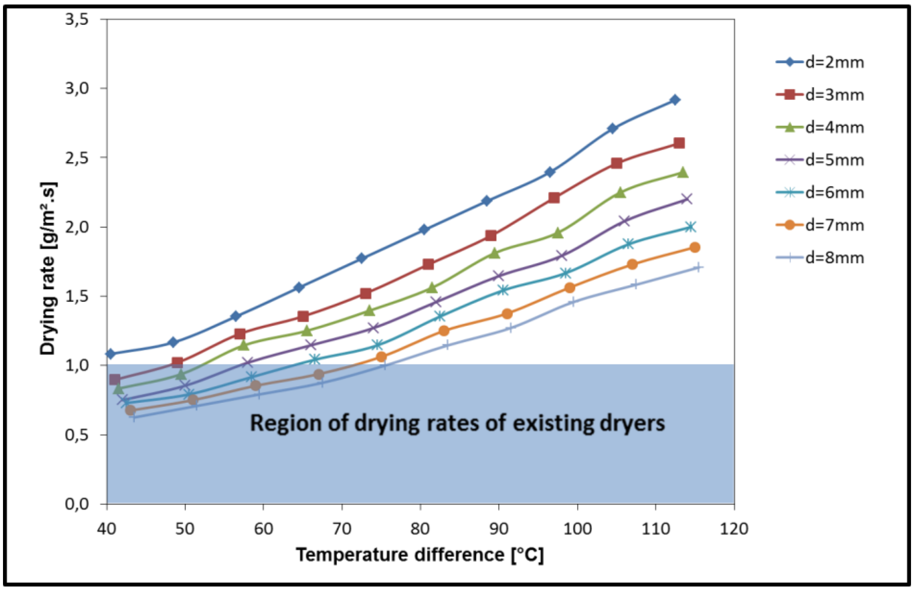

Fig. 3: Experimental results of drying rates with diffusion optimized convection dryer

The results presented in the figure above will be discussed and theoretical considerations are presented to show why higher drying rates come about as diffusion optimized convection dryers.