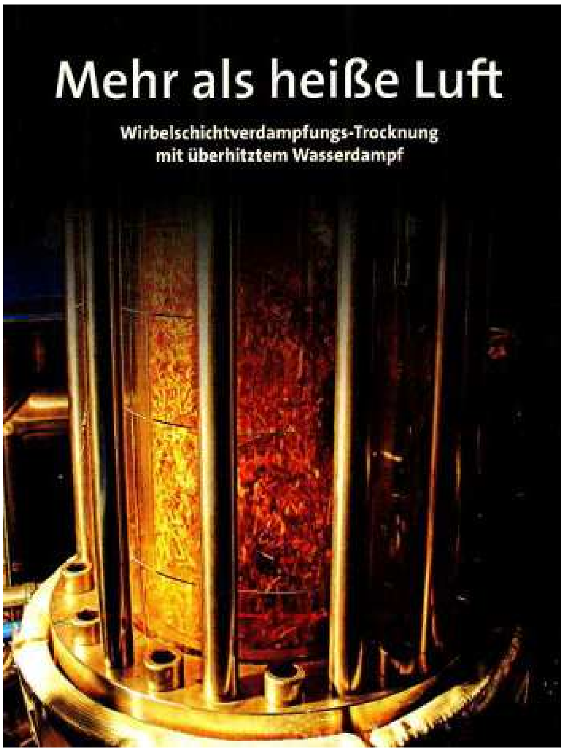
Translation of an article in “Verfahrentechnik 06/2013”



Much more than just hot air

Fluidised-bed steam drying with superheated water vapour

Mirko Löhn, Hartmut Hafemann

Drying methods that use steam for removing moisture from the material to be dried are employed in various sectors of industry and have been the state of the art for some time. The advantage of fluidised-bed steam drying is that the energy of the superheated water vapour that is released during the drying process can be made available again through vapour condensation.

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Fluidised-bed steam drying systems use superheated steam instead of hot air as the fluidisation and drying medium. The product in the drying process gives off its moisture to the circulated process steam in the form of water vapour at saturation temperature, which depends on the process pressure.

If steam drying with superheated water vapour takes place at a pressure level above atmospheric pressure, the water that has to be removed in the drying process is released in the form of superheated water vapour with a high energy content. Vapour condensation allows this energy to be made available again as part of a highly efficient multiple utilisation system, which automatically implies that the primary energy is put to multiple uses and that CO_2 emissions are reduced.

Closed dryer system

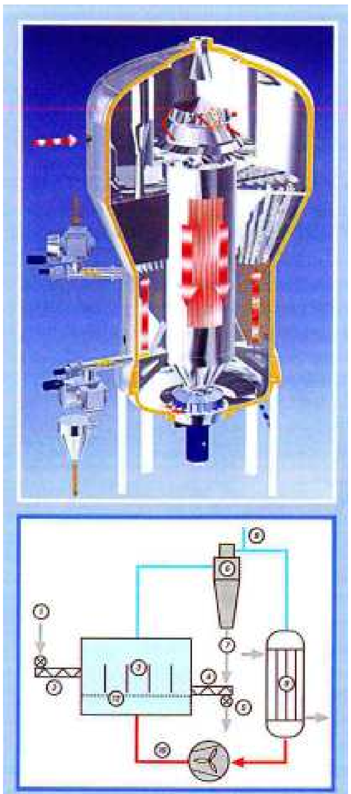
Drying with superheated steam rather conventional hot-air drying provides for shorter drying times, while the particle streams are still dried very uniformly and homogeneously. Closed-system dryers offer another essential advantage: odour emissions can be almost entirely eliminated, and the oxygen-free steam atmosphere prevents undesired oxidation reactions during the drying process.

There are also other process steps that can take place in parallel with drying. Heat treatment, for instance, can easily be combined with drying. Another possibility is to condition the product in the drying plant, independently of the drying process proper. Volatile substances can be removed from the product in a closed cycle and be recovered by condensation in downstream plant elements. Together with the water vapour atmosphere, the elevated system pressure also provides optimum conditions for sterilisation of the material to be dried.

The drying process

The technologically required components are integrated as compact elements in the dryer (operating principle of fluidised-bed steam drying): the fluidised bed (3) forms in the annular space around the central superheater (9). The circulated steam that is required for fluidisation is extracted by a fan (10) below the superheater, from where it flows upwards through the distributor plate (12) and into the fluidised bed. The feed material continuously enters the system through the inlet elements (1 and 2), from where it travels through the fluidised bed to the discharge elements (4 and 5). The dust that is carried along by the circulated steam is separated from the steam in the field of centrifugal forces generated by the rotary separator (6), and is then fed back into the main product stream in the dryer's discharge section (7). The steam flows into the superheater, from where it is extracted by the fan and returned into the fluidised bed.

As water evaporates, excess steam is produced in the fluidised bed. This steam is discharged from the dryer (8) above the rotary separator and can then be put to further use as an energy source.



Funktionsprinzip der Wirbelschicht-Verdampfungstrocknung: *Eintragssystem (1 und 2), Wirbelschicht (3), Austragssystem (4 und 5), Rotationsabscheider (6), Austragsbereich (7), Dampfaustrag (8), Überhitzer (9), Ventilator (10), Anströmboden (12)*

Operating principle of fluidised-bed steam drying: Inlet elements (1 and 2), fluidised bed (3), discharge elements (4 and 5), rotary separator (6), discharge section (7), steam outlet (8), superheater (9), fan (10), distributor plate (12)

Dried materials of different structures and compositions after drying (reference particle d=5 mm); Wood chips (left): steam temperature 200°C, v=4 m/s , p=2 bar; corn stillage (centre): steam temperature 200°C, v=3.0 m/s, p=4 bar; spent grain (right): steam temperature 200°C, v=2.5 m/s, p=3 bar

Integration of the dryer

To make full use of the energetic advantages that the process offers, certain conditions should either be present so the dryer can be efficiently integrated into a factory's energy concept, or they have to be created.

Operation of a fluidised-bed steam dryer (WVT) requires heating steam at pressures of approx. 20 bar plus. This steam can be the waste steam from a co-generation plant (electrification), if the boiler house is able to generate steam at the necessary high pressure level. The vapour that is produced in the drying process, is, for instance, used in a sugar factory's evaporator station for thin-juice concentration, and finally leaves the process in a condensed state as waste water.

A pilot plant that can be operated at the pressures and temperatures typically encountered in industrial systems offers the necessary basis on which this drying technology can also be made available for other products.

The pilot plant

The fluidised bed that is generated in the pilot plant has a diameter of 200 mm. The plant is operated discontinuously with fluid velocities of up to 8 m/s, an operating gauge pressure of up to 4.5 bar, and process temperatures of up to 210 °C. The plant is started with hot air, until the intended saturated-steam temperature has been reached. Water vapour is then fed into the system to expel the air from the plant.

The moist feedstock enters the pressurised drying section from above, through a product inlet lock. When the lock is opened, the moist material drops into the process section, which is delimited at its bottom end by a screen plate. Fluidisation already starts as the feed material falls freely through the upward flowing superheated water vapour. The dried material leaves the drying section through a second product lock below the screen plate.

The excess steam that is produced during the drying process is discharged in a controlled manner so the system pressure will remain constant throughout the entire drying period. The relevant measured quantities are recorded and visualised with a process control system that provides for semi-automatic operation of the plant.

To improve the flow properties of the products that are to be dried in the fluidised bed, some materials have to be pre-conditioned before they undergo treatment in the drying system, and the screen plate has to be adapted to the special characteristics of the product.

With this pilot plant it is possible for the first time to simulate industrial process conditions for examining the specific drying kinetics of different kinds of materials in a pressurised fluidised bed that works with superheated water vapour, and to assess and analyse the properties of a product after drying. The installation of the pilot plant was co-financed by Deutsche Bundesstiftung Umwelt DBU as part of a research project (DBU Ref. No.: 26568-24/2).