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RECENT DEVELOPMENTS OF COMBINED MICROWAVE-ASSISTED HOT-AIR VIBROFLUIDISED BED DRYER WITH HOMOGENEOUS DISTRIBUTION OF ELECTROMAGNETIC FIELD

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1. DESCRIPTION OF FLUIDISATION TECHNOLOGIES

The wide-spread application of fluidisation technologies is due to their well-known advantages, however, certain material characteristics such as large particle sizes, tendency to adhere, etc. inhibit the formation of the fluidised state, or because of anomalousness of such features (formation of bubbles, channelling, nodulizing, etc.) occurs in the bulk and they damage the regularity of the processes taking place in the operation.

The fluidisation anomalies can be eliminated or at least reduced by improving the vibratory features of the dryer or by means of mechanical energy transfer (Szabó et al., 2002, Toledo 1994).

One possible way of mechanical energy input is the vibratory driving of the porous material, i.e., preparation of the so-called vibro-fluidised bed. In practice this procedure is used to complement gas-fluidisation procedures, in which the mechanical energy transferred to the fluidised material is affected by the vibration of the gas-distribution grid that conveys the material, thus the air-vibro-fluidised bed is formed.

The procedures carried out in the air-vibro-fluidised bed, e.g., drying, agglomeration, instantisation, etc., have the following considerable advantages in food engineering:

- The pulse-transmitted vibration energy propagates in the granulous product equally, which causes controlled movement of granules.
- The homogeneous bed and intense movement of granules developing in the air-vibro-fluidised bed produce favourable conditions for heat and particle transmission.
- Operation times are reduced considerably due to the homogeneous bed and intense movement of granules.
- With the formation of the air-vibro-fluidised bed the velocity of the fluidisation gas can be reduced, thus the flue-dust loss as well as the extent of air pollution can also be reduced.

2. MICROWAVE-ASSISTED INTENSIFICATION OF HEAT AND PARTICLE TRANSFER PROCESSES

For the intensification of the heat and particle transfer processes in the hot-air vibro-fluidised bed, convective dissipation heat transfer is combined with microwave heat transfer. The new procedure does not only reduce the operation times, but the controlled process of granule-formation can also improve the characteristics of the end-product considerably, thus a product with required quality can be prepared(Neményi et al., 2000, Rajkó et al., 1997)

The microwave-assisted energy transfer is of low heat, it provides gentle treatment and a new means for modern and environment-friendly procedures. In one of such procedures the rehydrated agglomeration of the heterodisperse granules as well as the following drying, assisted by concentrated microwave energy input, reduces the overall number of germs in the treated material under certain conditions.

However, homogeneous, single-mode electromagnetic field is needed for the continuous maintenance of the suitable heat and mass transfer coefficientsso that the level of the microwave energy input could be changed, at the same time, to ensure the realisation of selected technological strategies matching the characteristics of the material (Szabó et al., 2000, Tulasidas et al., 1995).

3. DEVELOPMENT OF THE EQUIPMENT, DATA PROCESSING ALGORITHM

In our work we developed a microwave drying and measuring equipment, a hot-air vibro-fluidised cavity resonator with homogeneous distribution of electromagnetic field (Fig. 1).

Figure 1. Combined microwave-assisted hot-air vibrofluidised bed experimental drying equipment with homogeneous distribution of electromagnetic field.

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Description of the equipment:

- 2.45 GHz operating frequency.
- fitted coupling with tuning probes.
- magnetron output changeable continuously and intermittently from 100W to 700W.
- homogeneous electromagnetic field in the cavity resonator, i.e., drying chamber (one-mode resonator).
- circulation of the drying air as well as fluidisation are assisted in combination with the convective drying channel without changing the electromagnetic field pattern.
- the dissipated (P_d) power in the drying material and the fluctuating movement of the fluid bed are determined by measuring the input (P_i) and reflected (P_r) powers with a direction coupler designed specially for the resonator chamber.
- determination of the reflecting factor Γ and the absorption factor ε”, characteristic of the drying material, from the measured values.
- online processing of the measured data, measurement and control of parameters based on fuzzy logics.

The block scheme of the equipment can be seen in Fig. 2.

The data measured with the above system can be analysed by means of the following relationships (Ludányi, 2001):

– damping of the direction coupler (**L_{dB}**)

$$L_{dB} = 10\lg\frac{P_M}{P_d} \qquad \textbf{(1)}$$

where P_M stands for magnetron power, P_d is the power dissipated in the drying material

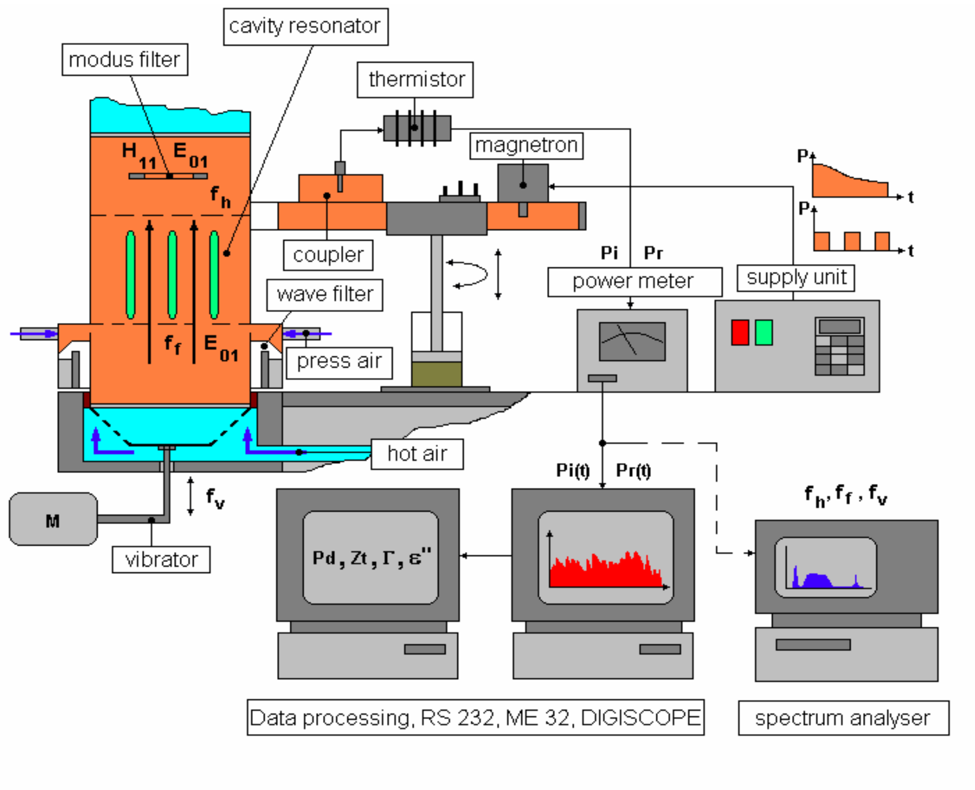

Figure 2. Block scheme of microwave drying and measuring system.

– coupling coefficient (**C_{dB}**)

$$C_{dB} = 10\lg\frac{P_d}{P_i} \qquad \textbf{(2)}$$

where P_i is the input power directing towards the drying material

– directional coefficient (**D_{dB}**)

$$D_{dB} = 10\lg\frac{P_i}{P_r} \qquad \textbf{(3)}$$

where P_r is the power reflected from the drying material

– power dissipated in the drying material (**P_d**)

$$P_d = P_i - P_r \qquad \textbf{(4)}$$

– reflection coefficient, which gives the value of reflection from the drying material (**Γ_t**)

$$\Gamma_t = \sqrt{\frac{P_r}{P_i}} \qquad \textbf{(5)}$$

– detected input and reflected powers (**$P_{i\,det.}$, $P_{r\,det}$**)

$$P_{i\det} = P_i \pm \Gamma_t^2 P_{cl}$$
$$P_{r\det} = P_{cl} \pm \Gamma_t^2 P_i \qquad \textbf{(6)}$$

where P_{cl} stands for the coupled power of the direction coupler in closed position, and $P_r=\Gamma_t^2 P_i$

– characteristic impedance of the drying material (**Z_t**)

$$Z_t = \frac{1+\Gamma_t}{1-\Gamma_t} Z_{0W} \qquad \textbf{(7)}$$

where Z_{0W} stands for the characteristic impedance of the waveguide, at present $Z_{0W} = 489\ \Omega$

– the drying material as the absorption factor (ε”), characteristic of the energy consumption of the dielectric material

$$\varepsilon'' = \frac{P_d}{55{,}6 \cdot 10^{-14} \cdot E^2 \cdot f} \qquad \textbf{(8)}$$

where E stands for the electric field strength and f is the operating frequency

In the above-mentioned relations parameters $\mathbf{L_{dB}}$, $\mathbf{C_{dB}}$ and $\mathbf{D_{dB}}$ characterize the direction coupler, while the values of $\mathbf{P_i}$, $\mathbf{P_r}$, $\mathbf{P_d}$, $\mathbf{\Gamma_t}$, $\mathbf{Z_t}$ and **ε”** characterize the drying material.

The data-processing algorithm can be seen in Figure 3.

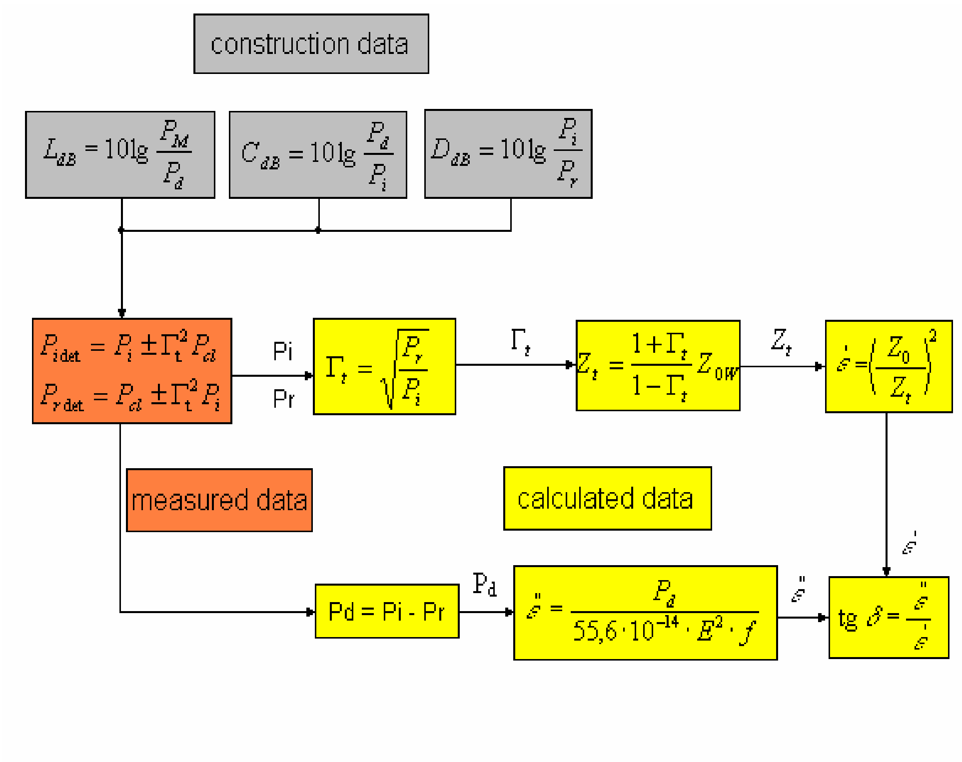

Figure 3. Computational algorithm for the determination of parameters characterizing the direction coupler and the drying material.

3. CONCLUSIONS

The results obtained with high-power irradiation for a short period of time, as well as those with low-power irradiation for a long period of time can be interesting. For example at high power irradiation, the non-thermic (specific) effect of microwave energy can be investigated because the fluidisation can be theoretically made by air with decreasing temperature.

The vibrational frequency of the gas-distributing grid as well as the fluctuating motion of the fluidised bulk practically modulate the time series of the reflected power, Pr(t), which is derived from the slow vibrational time series characterising the rewetted material. As the head of the thermistor can filter out the frequency of the gas-distributing grid, thus the detected Pr(t) time series contains only the two series of signals which are characteristic of the rewetted material and the fluctuating motion of the fluid bulk. Study of these frequencies with a spectrum analyser can give useful information about the operational interrelationships of the microwave-assisted hot-air vibro-fluidised bed dryer.

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