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BRIEF ORIGINALS · KURZORIGINALIA

Microwave drying of wet processed wood fibre insulating boards

Michael Bartholme · Georg Avramidis · Wolfgang Viöl · Alireza Kharazipour

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Subject A continuous microwave dryer was used for drying wet processed wood fibre based insulating boards. Drying characteristics and energy consumption were compared with convective drying methods. Microwave drying turned out to be faster and facilitates even economical drying of thick boards.

Introduction

The reduction of drying times and energy consumption are incessant goals in industrial drying processes. In recent years the microwave technique has been established in different sectors of industry as an efficient drying method (Metaxas and Meredith 1983, Meredith 1998). Several investigations on microwave drying of wood and wood based materials have recently been carried out (Hansson and Antti 2003, Seyfarth et al. 2003, Hunt et al. 2005). In microwave heating, the electromagnetic energy is directly transferred into the material, absorbed by molecules and converted into heat energy; as a consequence the temperature rises much faster compared to conventional drying (Zielonka and Gierlik 1999). These properties have also been investigated for the drying of wet-formed biological materials, e.g. drying of bran-based packing material (Ansorge 1997). For the production of wood fibre-based insulating boards without binders only the wet process is used. The bonding forces of wood and the interlocking of fibres result in effective stabilisation of insulating boards so that it is possible to leave out adhesive agents (Lampert 1967). The drying of these wood fibre mats is conducted in gas heated drying kilns (convective drying). Convective drying of insulating boards, 20 mm thick, requires approximately 2 hours at between 160 and 220 °C. Convective drying of insulating boards over 20 mm thickness requires additional time and is therefore not cost-efficient and usually not used industrially. Accordingly, boards over 20 mm thickness are produced by gluing together several layers of thin boards. In this study microwave drying of wood fibre-based insulating boards is investigated with regard to drying time, core temperature and energy consumption. To compare microwave drying with industrial convective techniques, drying has also been conducted in a laboratory drying cabinet at a temperature of 170 °C. Tests with insulating boards of 20 mm thickness revealed that drying times in the laboratory drying cabinet are comparable with drying times of industrially scaled drying kilns. Furthermore the total energy consumption per kilogram of evaporated water for microwave drying was assessed and compared with literature values for convective dryers.

M. Bartholme · G. Avramidis · W. Viöl (✉)
Department of Sciences and Technology,
University of Applied Sciences and Arts,
Von-Ossietzky-Strasse 99,
37085 Göttingen, Germany
e-mail: vioel@hawk-hhg.de

G. Avramidis · A. Kharazipour
Büsgeninstitut, University of Göttingen,
Büsgenweg 2,
37077 Göttingen, Germany

Experimental

Insulating boards of beech fibres with dimensions $300 \times 500 \times 20\,\text{mm}^3$ were produced. For this purpose a suspen-

sion with a solid content of 2.5% was made of 500 g wood fibres and tap water and stirred for 1 h. Subsequently the suspension was put into a casting mould and the suspension was drained. The fibre mat thus obtained was put into a cold press for 2 min until the water content reached 120%, which corresponds to 1100 g of the fibre mat. These boards were dried in a microwave dryer with an oscillating conveyor belt (MWDA 6.6 kW, Fricke und Mallah Microwave Technology GmbH, Peine, Germany, airflow = 200 m^3/h) and in a conventional drying cabinet (UFE 800, Memmert GmbH & Co. KG, Schwabach, Germany, air flow = 19 m^3/h) at 170 °C to give a water content of approximately 5%. The water content was measured every minute during microwave drying and every 10 min during convective drying by weighing the samples. The difference between the measured weight and the weight of solid gave the water content; the difference between the measured weight and start weight of the fibre mat yielded the mass m_W of evaporated water. The core temperatures of the insulating boards during the drying process were measured with a fibre-optical thermometer (FTI 10, FISO Technologies, Canada) and its corresponding software (FISOCommander, FISO Technologies, Canada). The energy consumption per kilogram of evaporated water was calculated from the total electric input power P_t of the continuous microwave dryer (magnetrons, conveyer belt, ventilators) ,measured using an electric power meter, the mass of the evaporated water m_W and the drying time t_d:

$$E/m = P_t/m_W t_d \,. \tag{1}$$

Results and discussion

Figures 1 and 2 show the drying characteristics of insulating boards ($t = 20$ mm) dried in the drying cabinet and in the continuous microwave dryer. For each test parameter 3–5 samples were assayed. The drying curve (water content) for convective drying at 170 °C (Fig. 1) follows an exponential decay and the drying rate decreases with elapsed time. The drying process for 20 mm thick insulating boards was completed in 110 min. The core temperature for convective drying reaches the first maximum of 87 °C after approximately 20 min. As the drying process continues the temperature drops to 77 °C, due to the increasing insulating effect of the dried wood fibres and the cooling effect of evaporation. After 80 min and at a water content of 20%, the core temperature rises to approximately 140 °C at which temperature the drying process is complete. Figure 2 shows the drying curve (water content) of microwave dried insulating boards. The curve remains almost linear and the drying process is significantly accelerated compared to the convectively dried insulating boards. For microwave drying the drying process of 20 mm thick insulating boards is complete after 9 min. The core temperature increases to approx. 100 °C within 2 min and remains unchanged until the total water content falls below 30%. After 7 min drying and at a water content of less than 30% the microwaves heat the wooden material so that a significant temperature rise occurs due to the lack of evaporative cooling at the dry core. The total energy consumption for the microwave drying of 20 mm thick insulating boards was determined from Eq. 1

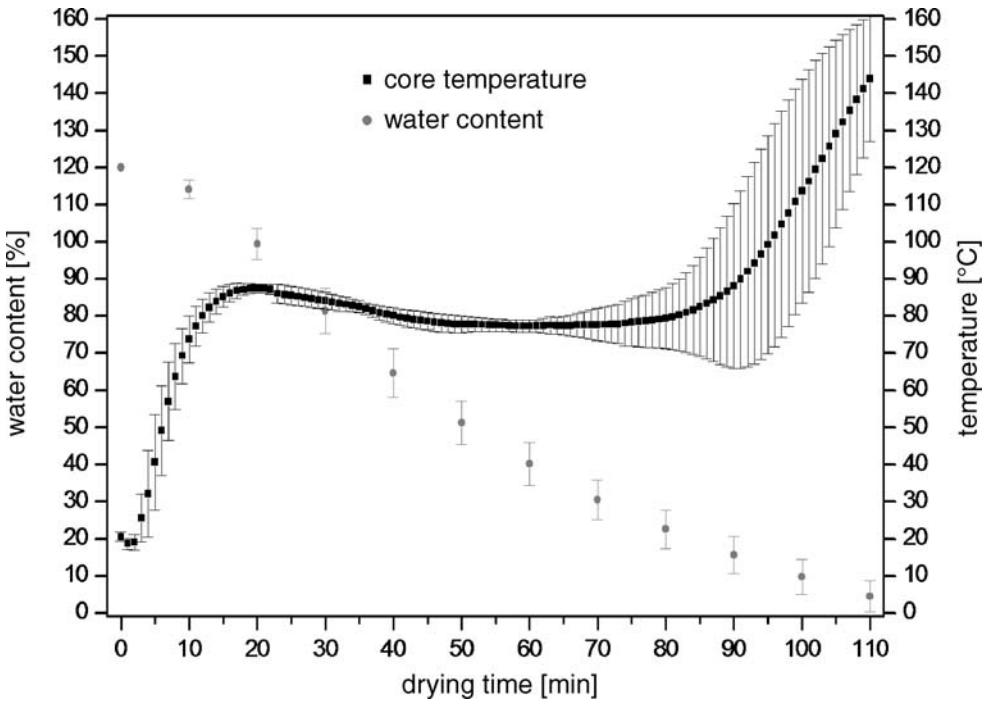

Fig. 1 Water content and core temperature versus drying time for convective drying
Abb. 1 Feuchtigkeitsverlauf und Kerntemperatur bei konvektiver Trocknung

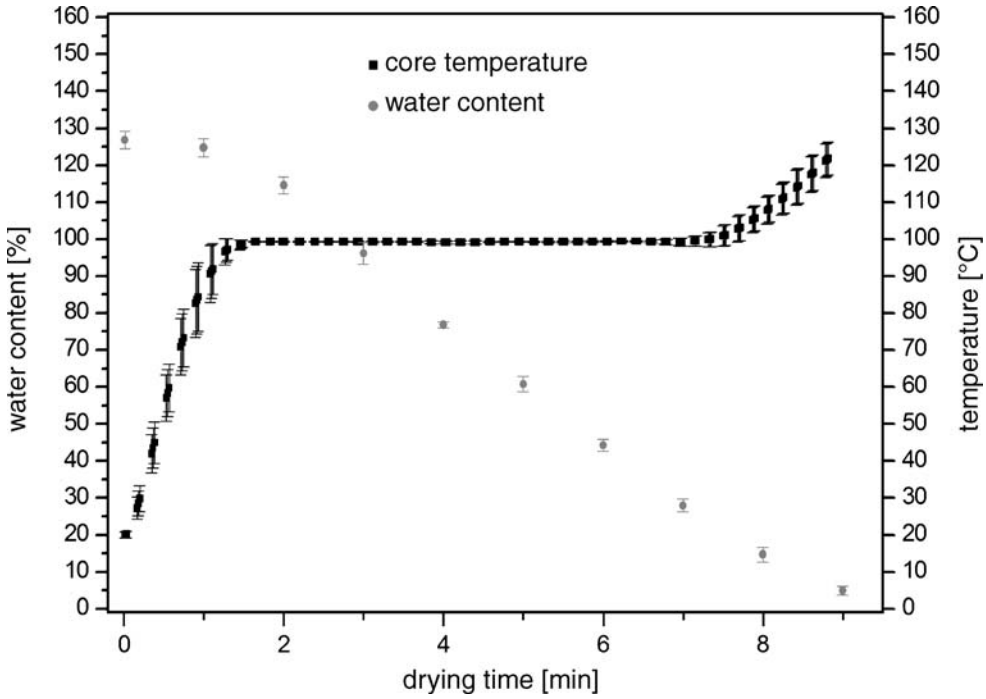

Fig. 2 Water content and core temperature versus drying time for microwave drying
Abb. 2 Feuchtigkeitsverlauf und Kerntemperatur bei Mikrowellentrocknung

using values for the total electric input power P_t 5.25 kW, a drying time t_d of approximately 540 s and a mass of evaporated water m_W 600 g. For these values the energy consumption per kilogram of evaporated water was determined to be approximately 4700 kJ/kg, which is in the range of energy consumption reported in the literature for typical convective band dryers (Mujumdar 1995).

To prove whether microwave drying of boards of more than 20 mm thickness is achievable within an economic time, additional drying tests with boards of 30, 40 and 50 mm thickness were conducted without a detailed investigation of moisture content progression and core temperature. Table 1 summarizes the results of these experiments. In all cases it is possible to dry the insulating boards in a fraction of the time required for convectively dried boards, so by microwave technology it is possible to omit gluing processes for the production of insulating boards thicker than 20 mm. For 30 mm boards the drying times can be reduced by a factor 15, for 40 mm boards by a factor 17 and for 50 mm boards by a factor 18. This means that with increasing board thickness the drying process for microwave drying becomes significant more efficient compared to convective dryings.

Microwave dried boards were equal to convectively dried boards regarding appearance and stability. Tests of the tensile strength according to DIN EN 1607 revealed no differences in internal bond strength between microwave dried and convectively dried insulating boards

Table 1 Drying times for 20, 30, 40 and 50 mm thick boards
Tabelle 1 Trocknungszeiten für 20, 30, 40 und 50 mm Plattendicke

Board thickness	Drying time microwave dryer	Drying time drying cabinet
20 mm	9 min	110 min
30 mm	11 min	170 min
40 mm	14 min	240 min
50 mm	18 min	330 min

Conclusion

It has been shown that microwave drying of wet processed fibre mats of 20 mm thickness can reduce the drying process by a factor 12, whereas the energy consumption per kilogram of evaporated water is comparable to convective dryers. Furthermore it was shown that insulating boards of thickness greater than 20 mm can be produced in an economic time by microwave technology. The stability properties of the boards were not negatively affected by microwave drying compared to convective drying. For the microwave dried boards, an abrupt temperature rise at a water content of approximately 20–30% demands process control to prevent material ignition.

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