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Temperature and gas pressure in MDF-mats during industrial continuous hot pressing

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Background Temperature and gas pressure affect the hot pressing process and the properties of wood-based panels essentially. Elevated temperature of the furnish is needed to plasticise wood fibers and flakes, respectively, as well as to cure the adhesive. Plasticisation, mat compaction, and the development of adhesive bonds between the wood particles determine the density profile of the panels. Due to the compaction of air in the mat as well as due to the vaporization of water and volatile compounds from the wood particles and from the adhesive, an internal gas pressure develops in the mat during hot pressing. The level of gas pressure inside the mat affects heat convection into the mat. High gas pressure may lead to disintegration of the mat (blow, blister) upon release of external hydraulic pressure at the exit of the press.

Measurements of temperature inside wood-based panels during hot pressing are commonly done with thermocouples in all kinds of hot presses in laboratory and industrial application. Laboratory measurements of gas pressure in single daylight batch presses using a steel tube and a pressure transducer have been firstly described by Denisov and Sosnin (1967) and afterwards been frequently done in laboratory and industrial batch presses, e.g. by Kamke and Casey (1988). Gas pressure measurements inside mats during continuous hot pressing have not been published yet.

In order to gain a full understanding of the behavior of wood-based panel mats during hot pressing in batch and continuous systems, the authors develop an analytical simulation model of the hot pressing process based upon mathematical functions of the rheological and the thermodynamic behavior of MDF-fibers. The principles of an existing computer model as well as the needs for its improvement and completion are described by Bolton and Humphrey (1988), Humphrey and Bolton (1989), Bolton, Humphrey, and Kavvouras (1989), Humphrey (1991) as well as Steffen (1996). To complete the simulation model, the conditions of continuous hot pressing have to be defined exactly with regard to pressing pressure, gas pressure, and heat transfer into the mat.

Objectives The objectives of this project were to develop an apparatus for measuring internal mat temperature and gas pressure in MDF-mats and to test this apparatus in an industrial continuous hot press.

Das Projekt wird im Auftrag der Deutschen Gesellschaft für Holzforschung (DGfH) mit Mitteln der Arbeitsgemeinschaft Industrieller Forschungsvereinigungen (AIF) durchgeführt.

Material Measurements were carried out in a German plant equipped with a 28 m Siempelkamp ContiRoll press on 19 mm MDF-panels.

Method A miniature pressure transducer covering a range from 0 to 7 bar differential gas pressure was embedded in a plastic case for thermal insulation (Fig. 1). The sensor was prepared for sealed connection with air-filled stainless steel tubes of varying lengths. Tubes of about 0.5 to 1 m length and an outer diameter of about 2 mm were used. The temperature compensation of the transducer covered a range from 20 to 80 °C. Tube and sensor were not filled with oil because their dead volume was extremely small in relation to the volume of gas formed in the mat during hot pressing.

Thermocouples were mounted on the tip of the steel tube and inside the insulation case. The steel tube was pushed into the fiber mat between the pre-press and the hot press. The transducer case and a cable were placed beside the edge of the mat. A third thermocouple was placed on top of fiber mat prior to hot press entry. The entire measuring equipment including the cable traveled through the hot press and was disconnected behind the press. Platen temperatures varied between about 230 and 180 °C, the belt speed was 130 mm/sec.

Results The pressing program is shown in Fig. 2. The specific pressure immediately after press entry is as high as 4.5 N/mm^2 which leads to highly compressed surface layers and a relatively soft core layer at the beginning of the process. After about 2/3 of the pressing process, the panels are compressed by about 5 mm to achieve a relatively homogeneous density distribution through the core layer.

An exemplary display of temperature and gas pressure measurements at 95 cm tube length is given in Fig. 3. These measurements are explained as follows:

1. The mat surface temperature (★) at 95 cm from the mat edge reached about 190 °C, the surface temperature at about 50 cm from the mat edge was 170 °C.
2. The internal mat temperature (▲) hardly exceeds 110 °C at the end of the pressing process. The facts that no interrupt in temperature increase in the mat is visible at about 100 °C and the temperature increase stops at about 110 °C indicates that the boiling temperature of the mixture of liquids in the center of the mat is reached shortly before the mat leaves the press. 50 cm from the mat edge, a maximum temperature of 105 °C was reached.
3. The temperature of the pressure transducer (■) does not exceed the compensated range of 80 °C.
4. In the core layer of the mat, the curing temperature for the glue of approx. 100 °C is reached approximately 5 m or 40 sec. before the end of the pressing process.
5. The first peak in the bold gas pressure curve (about 1 bar above atmospheric pressure) results from the compression of air trapped in the mat. 50 cm from the mat edge, the air pressure peak reaches 0.8 bar. The air pressure decreases over a distance of 17 m to a residual pressure of about 0.6 bar before a new gas pressure peak starts developing.
6. The second peak in the gas pressure curve increases to nearly 1.5 bar. 50 cm from the panel edge, it would be about 1 bar. The second increase in gas pressure must be primarily attributed to the formation of vapor in the mat.

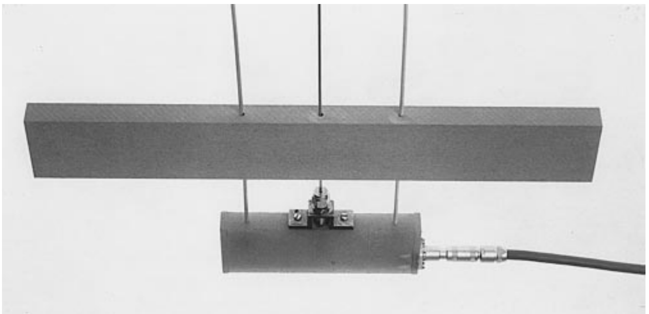

Fig. 1. Gas pressure transducer with insulation case, steel tube, and cable
Bild 1. Gasdruckübertragungs-Einheit mit Isolation, Stahl Kapillare und Kabel

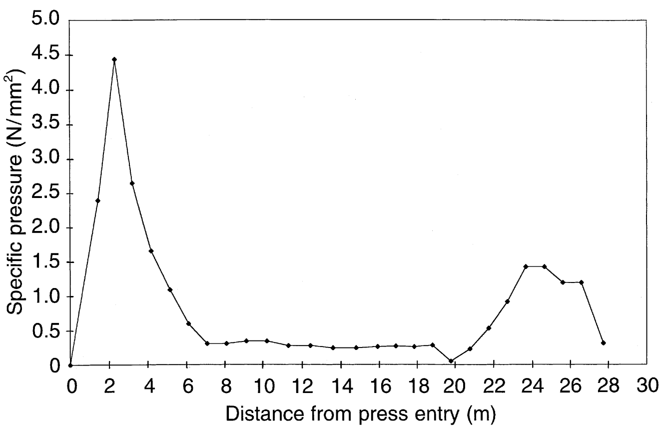

Fig. 2. Specific pressing pressure in the continuous MDF-press
Bild 2. Spezifischer Preßdruck in der kontinuierlichen MDF-Presse

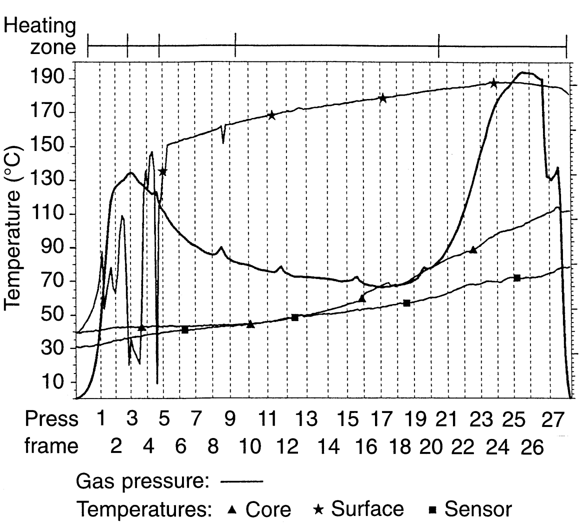

Fig. 3. Temperature and gas pressure within a 19 mm MDF mat in the continuous hot press; bold line = gas pressure, ★ = mat surface temperature, ▲ = internal mat temperature, ■ = temperature of the pressure transducer
Bild 3. Temperatur und Gasdruck innerhalb der 19 mm dicken MDF-Matte in der kontinuierlichen Presse: fette Linie = Gasdruck, ★ = Oberflächentemperatur der Matte; ▲ = Temperatur in der Matte; ■ = Temperatur der Druckübertragungs-Einheit

7. The finding that the second increase of gas pressure starts before the boiling point of the liquid in the mat is reached can most likely be explained with the second mat compression to final mat thickness which implies gas compression in the mat.
8. Gas pressure drops instantaneously when the panel leaves the press.

Conclusions

- The measuring system proved to produce reliable results and could be easily manipulated.
- Temperature and gas pressure values can be explained with specific features of the pressing program. The pressing conditions in an industrial continuous hot press could be deducted.
- The pressurization of air resulting from the initial mat compaction may influence the thermodynamic behavior of the gas mix in the mat considerably, which is subject to further investigation.
- The thermodynamic properties of the pressurized gas mix have to be characterized with regard to their effect on heat transfer in the mat.

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