Thermographic detection of defects in wood and wood-based materials

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Introduction

Modern production techniques in the wood and wood-based industry reached a high quality standard at high output rates. While the speed of the production machines increases, it is necessary to introduce modern and faster working online inspection methods to supervise constantly the material for defects.
Thermographic cameras are able to detect not only invisible defects within wood-based materials [4 - 6] like laminated particle- and fiberboards, but can be used also to detect defects in lumber and engineered wood [3].

Principles of thermographic techniques

Infrared thermography is a fast and non-destructive testing and evaluation method that can rapidly measure and interrogate large surfaces for internal (invisible) defects and structural faults [1, 2].
If material under inspection is heated with radiators **(active thermography)**, the temperature of the surface will rise suddenly. The speed at which the heat front dissipates into the material depends on the thermal properties like density, heat capacity, thermal conductivity and the bonding quality between top surface layer and the base material. A defect in the sub-surface creates a barrier for the heat diffusion process and, therefore, the surface temperature above the defect will decrease more slowly than the temperature in other regions. The surface above such a defect will show a hot spot for a longer time as its vicinity covering good bonded material. The principle of this effect is shown schematically in Fig. 1.
In contrast to the fast dissipation of heat in metallic materials, the dissipation of heat in wood-based-materials is comparable slow. The detection of defects can take a few seconds or even some minutes after the heat impact depending on the material and depth of the defect.

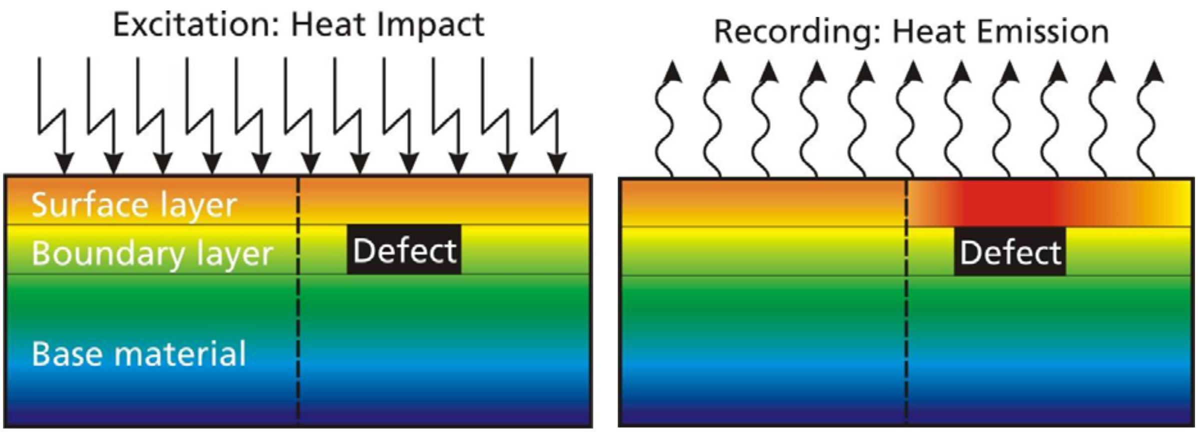

Fig. 1: Schematic drawing of the principle of infrared thermography, showing the uniformly distributed heat impact on the surface (left), the recorded heat emission (right) and the warmer region (dark) on the surface above the defect.

If the inspected material is heated during the production process **(passive thermography)**, the surface temperature will decrease after leaving the production line. Invisible defects within the material will appear as cold spots on the surface, because of the good insulation between the hot core material and the colder surface.

In both cases, active or passive thermography, the defects can be either detected as hot (active) or cold spots (passive) on the surface.

Active and passive on-line thermography

For active on-line thermography the material under inspection is placed on a conveyor belt that transports the samples with a velocity of more than 50 m/min along a heating source (three infrared radiators, Fig. 2). The surface is heated homogeneously by a few degrees centigrade. During the further transport the heat penetrates into the material and the infrared camera, which is placed above the conveyor belt, records the temperature on the surface.
The very high temperature resolution of 0.02 K allows the detection of defects and structural faults even deep within the material with high accuracy.
For all thermographic investigations a highly sensitive focal plane array (FPA) camera was used (Thermosensorik, 384 x 288 pixel) which works in the short wavelength band from 3.5 to 5 µm.

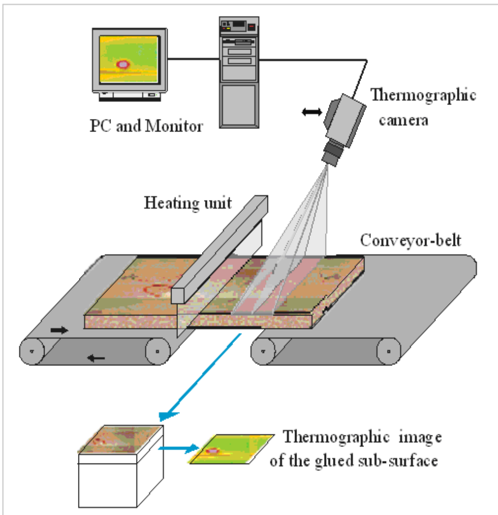

Fig. 2: Schematic drawing of the thermographic set-up for the detection of debondings and structural faults within the laminated material

For measurements in industrial production lines -using the heat of the production process- the thermographic camera can be positioned on a steel frame above the conveyor belt (Fig. 3). Depending on the used camera lens, the distance has to be adjusted to observe the full width of the produced material.
The measurements can be carried out immediately behind the laminating press to use the production heat. Locally different temperatures like cold and hot spots observed on the surface, indicate defects either within the glued joint or in the carrier material.
The surface temperatures of the wood respectively wood-based panels can vary between 40 °C for some décor paper adhesive bondings to the production of OSB and particleboards with temperatures of more than 100°C.

Fig. 3: Thermographic set-up just behind a paper laminating press. By moving the material along the infrared camera possible defects can be detected.

Results of some active and passive thermographic measurements

For first tests with active on-line thermography, different panels (HDF) of **laminating flooring** were placed on a conveyor belt and heated by a few degrees centigrade while moving along three infrared heaters.

The result can be seen in Fig. 4, where a blister shows up in the thermographic image as circular hot (red) spot. But moreover some extended areas show also a warmer behavior as its vicinity. Destructive tests showed that these areas have a decreased adhesion bonding in comparison to the rest of the material.

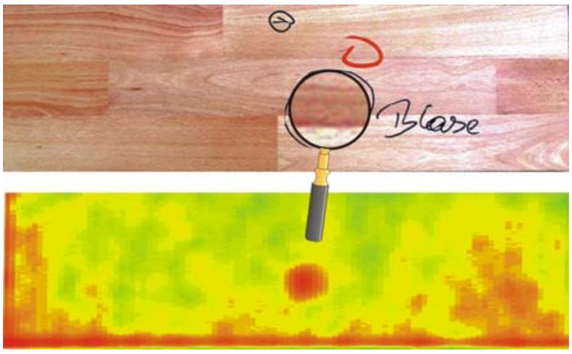

Fig. 4: Photo of a laminated flooring with no visible defect on the surface (top) and thermographic image (bottom) with a blister shown as red (hot) spot and poor adhesive bonding shown as irregular red areas.

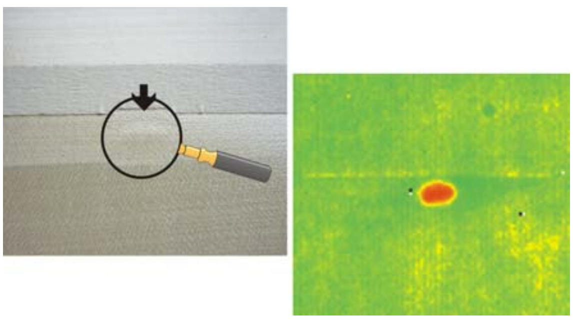

Fig. 5: Photo of a table top surface with a hardly visible defect (left) and the thermographic image (right) with a clearly visible hot spot (missing knot in the third layer of the plywood).

For the production of **high quality tables**, the surface veneer was glued on a panel of plywood and the surface covered with an UV-hardening lacquer system. In the beginning the surface of the coating showed a good quality but after a while some hardly visible irregularities showed up.
The active thermographic on-line measurement with a speed of about 20 m/min showed clearly defects in the depth of the veneer (Fig. 5). The destructive tests demonstrated that in the second or third layer of the plywood some knots were fallen out which showed such an unfortunately behavior while heating the surface coating.

Different measurements were executed in a variety of companies to find possible defects during the décor paper lamination of particleboards and plywood for **furniture boards.**
The measurements were carried out behind continuous and discontinuous presses on particleboards of thickness between 3 and 38 mm at a speed of 20 to 30 m/min. Here, besides damages caused by fork lifts occurring at the edges of the boards, also local dents of <1/10 mm in the surface, double-layer bonding of paper and splittings (Fig. 6) in the particle board could be detected.

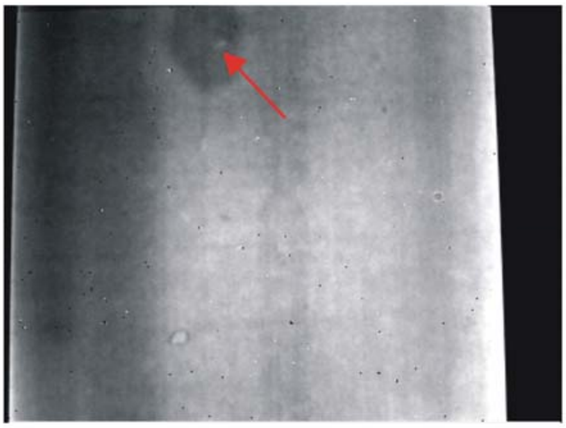
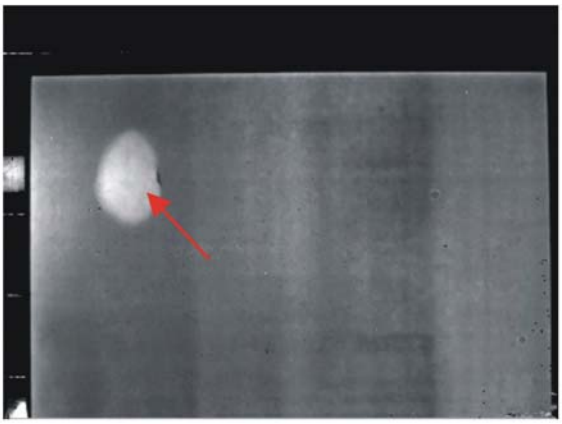

Fig. 6: Two thermographic images with splitting in the particleboards. One splitting in the lower surface layer of the 22 mm thick particleboard shows as a dark (cold) spot (left image) and another splitting in the upper layer of the board shows up as a white (hot) spot (right image).

The detection of defects in **laminating plywood (used for caravans)** is usually much more complicated as for particleboards, because of the different inhomogeneities of the plywood.
But anyway different defects during the laminating of plywood boards could be visualized, like the fallen off branches in the center layer (Fig. 7, left) and the faulty gluing at the veneer joints (Fig. 7, right) became especially obvious.

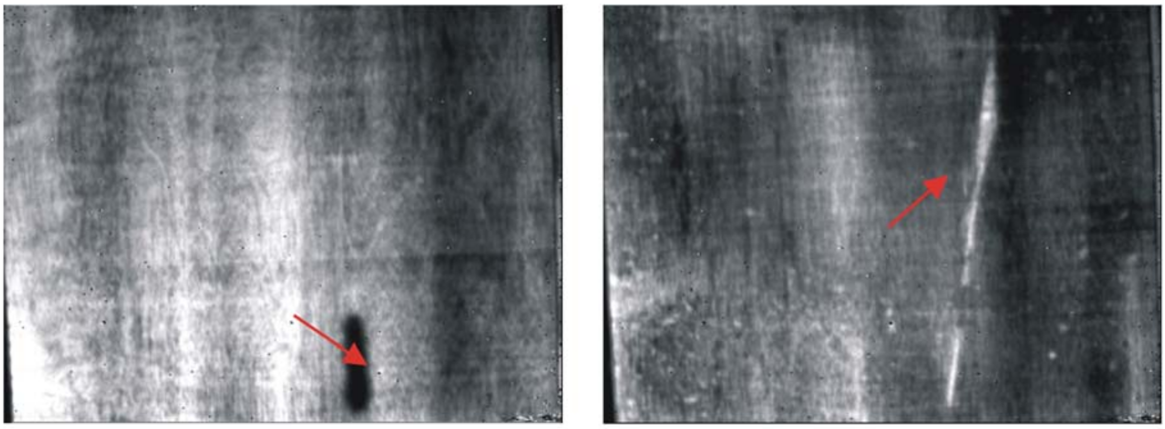

Fig. 7: Two thermographic images during the process of décor paper laminating of plywood. The left image shows a fallen off branch in the center layer of a 5 mm thick plywood and the right image shows a faulty gluing at the veneer joints of the last layer of the plywood.

Using the passive on-line thermography directly behind the pressing machine, the following defects could be found in numerous measurements:

- *Differences in thickness layers of glue*
- *Splittings in a particleboard on the upper or lower side*
- *Blister between décor paper and carrier material*
- *Delaminations of paper*
- *Faulty gluing of veneer layers in plywood*
- *Defects as well in plywood as in particleboards in the core or in the cover layers.*

One other interesting application of thermography in wood materials is the detection of compressed wood. Usually during the on-line thermographic inspection of small wood panels or wood boards the density differences within the material are so high, that every annual ring shows a clear thermographic signal. This is different for wood coming from tropical regions almost without any seasonal climatic changes and therefore without annual rings. But even in this material, fast changes of density can be found e.g. compressed wood that can not be industrial used in some cases e.g. for the pencil production.
Thermographic inspection with active on-line heating shows clearly the density differences within the wood (Fig. 8). The panels with compressed wood can be detected and marked or sorted out as poor quality.

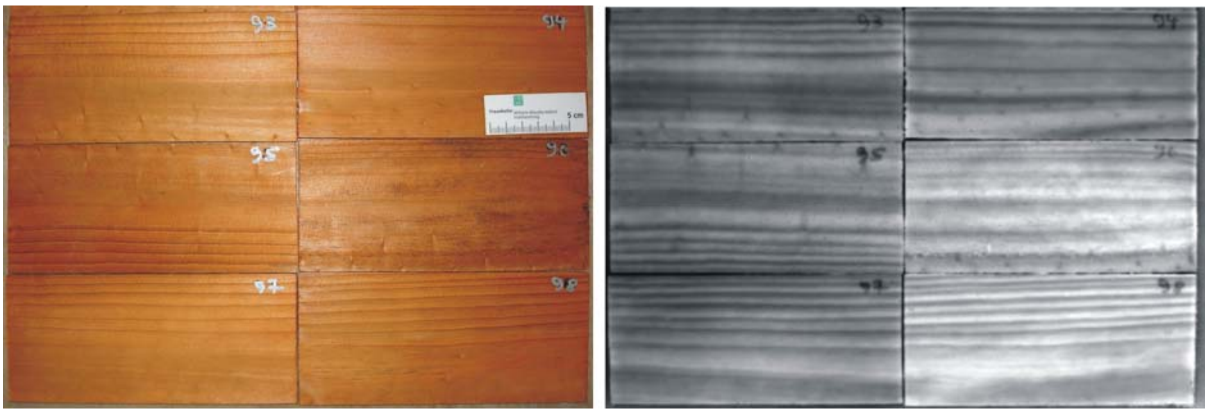

Fig. 8: The photo (left) shows a small wood panel and the thermographic image (right) the compressed wood as white (hot) area within the material.

Another interesting thermographic application is the detection of black knots in wood panels. Usually the detection of these black knots is even for the eye of an expert very difficult. It would be also difficult to use the above-described heating (IR-heating) techniques to find these faults. But applying high power ultrasound to the panel lets the complete material vibrate. In the case of cracks and loose knots the material will produce heat due to friction that can be clearly detected with an infrared camera (Fig. 9) and separated from tight bonded material or good knots

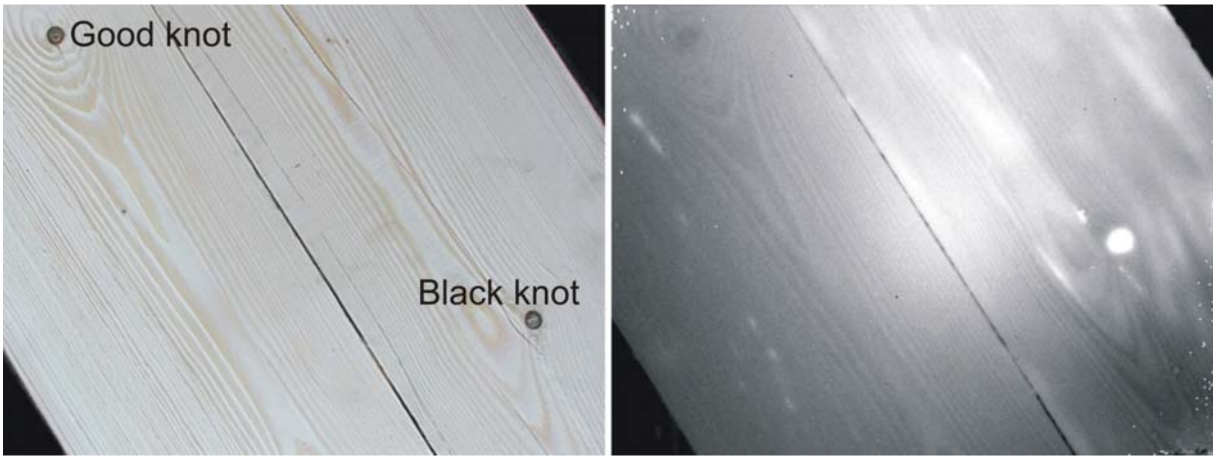

Fig 9: Photo of a wood panel with good and black knots (left) and a thermographic image (right) showing the black knots clearly as white (hot) spots on the surface.

Conclusion

After successfully finishing the first tests in the industry, it will soon be possible to introduce thermographic inspection systems to the wood-based panel industry for the detection of defects within the production process. The results of the thermographic testing can be used to mark the debonded areas or to remove the material completely from the assembly line. Depending on the price of infrared-cameras and its robustness to work in the rough environment without too much maintenance, the acceptance of companies will increase to use thermography as a possible tool of quality control.
The introduction of thermographic techniques for detection of defects in wood and lumber will take much more time and will probably work only in special applications. But the first positive results presented above show the possible outlook to introduce this technique also in the field of defect recognition in massive wood.

Acknowledgment

This research work was in parts funded, financed and supported by the “Stiftung Industrieforschung”.

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