High-voltage photography: a new method for optical detection of moisture distribution in wood and wood-based panel products

J. Fromm, M. Süßfleisch, P. Schumacher

This study is based on experiments in which the distribution of moisture in freshly wood, oven-dried wood and various wood-based panel products was observed at different moisture contents. High-voltage photography was used to analyze cross sections of branches from *Picea abies* under different water conditions (60, 43, 19, 0%), determined gravimetrically by oven-drying at 103 °C after having taken the photographs. The voltage photographs show significant moisture differences between heartwood and sapwood which are usually not visible in trees with colourless heartwood. Moreover, moisture differences between compression wood and normal wood were clearly shown to exist. With regard to wood-based panel products moisture variations between different products as well as between the different components of one product were significantly observed by voltage photography and correlated to gravimetric measurements.

1 Introduction

The behaviour of wood is well-known to depend on its moisture content which affects strength, electrical resistance and also thermal properties. Thus, the moisture content of wood is important in many fields of wood technology, i.e. during impregnation or production of particleboards and other wood-based panel products (Kollmann and Côté 1968). According to Fengel and Wegener (1989) there are three important chemical methods for the determination of water in wood. The first one, oven drying at 103 °C until constant weight is reached is the simplest and most frequently applied method used as a comparative method in this study. The second method, titration with a selective reagent for water is the fastest and most reliable method (Fischer 1935). The third method consists in distillation with a water-immiscible solvent such as xylene, toluene or trichlorethene which has the disadvantage of requiring large quantities of wood. On the other hand, physical methods such as nuclear radiation techniques (Loos 1965), nuclear magnetic resonance (Karras and Rahkamaa 1971, Magnusson et al. 1972, Nanassy 1978), neutron moderation (Toepel 1969) and computer tomography (Wiebe 1992, Mathies 1996, Schaffner 1997) were also described as methods applicable for the determination of the moisture content of wood.

In the present study the attempt was made to determine the distribution of moisture in wood and wood-based materials by an optical method based on the fact that water in the various pores of the wood system influences the path of the electric current and subsequent light emission when high voltage is applied to the object. In the botanical field, this technique was already applied to analyse fresh and wounded leaves of beech and willow (Fromm 1992) as well as sun- and shadow-needles of spruce (Decker 1988). It represents a reliable, sensitive and useful index of the moisture characteristics of plant and animal tissue and is now being used for the first time to analyse wood and wood-based panel products.

2 Experimental

2.1 Material

2.1.1 Spruce Wood

Horizontally grown 15–20 year old branches from spruce trees (*Picea abies*) were cut in autumn 1997 and divided into 20 mm thick discs rapidly sealed in plastic bags in order to preserve their original moisture content. The fresh discs were photographed before being investigated by high-voltage photography. This was done in a dark room under stable conditions of air moisture, pressure and temperature. After taking the images the discs were dried out in steps from 60% to 43%, 15% and 0% average moisture content in order to achieve images at different...
Table 1. Description of investigated wood-based panel products
Tabelle 1. Beschreibung der untersuchten Holzwerkstoffe

<table>
<thead>
<tr>
<th>Type of wood-based panel</th>
<th>Wood species</th>
<th>Adhesives</th>
<th>Density (oven dry) (g/cm³)</th>
<th>Moisture content after moistening(%) vapour/immersed</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDF (Medium-density fiberboard) 16 mm thickness</td>
<td>Norway spruce/Pine</td>
<td>PMDI (Polymeric methane diphenyl diisocyanate) 3%</td>
<td>~0.67</td>
<td>25/42</td>
</tr>
<tr>
<td>Particleboard (3-layer) 19 mm thickness</td>
<td>Norway spruce/Pine</td>
<td>PMDI (Polymeric methane diphenyl diisocyanate) 5%</td>
<td>~0.67</td>
<td>20/42</td>
</tr>
<tr>
<td>OSB (Oriented strand board) 25 mm thickness</td>
<td>Norway spruce strands (200 × 20 × 1.3 mm)</td>
<td>PMDI (Polymeric methane diphenyl diisocyanate) 6%</td>
<td>~0.63</td>
<td>22/63</td>
</tr>
<tr>
<td>Plywood, (7-layer, 7 ply), 15 mm thickness</td>
<td>Beech (Fagus sylvatica)</td>
<td>PF Phenol-formaldehyde</td>
<td>~0.73</td>
<td>35/51</td>
</tr>
</tbody>
</table>

Before taking the high-voltage images, the specimens were weighed, photographed and moistened in two different ways. One set of specimens - covering all four products - was moistened in a desiccator at room temperature for 7 days in pure water vapour, while the other was submersed in water for 4 days after having been gently moistened in water vapour for 3 days. As shown in Table 1, the submersed specimens contained 1.5 to 2.9 times more water than the specimens which were only vapour-treated. Before taking the images from the transverse plane, excess water on the specimen surface was dabbed off with tissue paper and the specimens were weighed again. High-voltage photographs were made at a voltage of 40 kV and an exposure time of 2 sec.

2.2 The application of high-voltage photography
High-voltage photography does not require the use of a camera. Instead, the film is exposed directly through the agency of a high-voltage (1-40 kV), 100 Hz-frequency electric discharge which is caused to pass from the wood to be photographed, through the film, to a conducting plate on the other side. As shown in Fig. 1 a piece of wood or wood-based product 20 mm thick is connected to a grounded electrode and placed on a photographic film plate (acting as a kind of lensless camera) resting on an isolator above the second electrode, a flat metal plate. When an electrical tension in the order of 1-40 kV as a series of pulses, each with a duration of 100-200 μsec, is applied to the wood, electrical discharges occur in form of lightnings between the wood surface and the high-voltage plate electrode.

Such high voltage can, over a sufficiently short distance, result in a very intense electric field in the order of one million volts per centimetre, which will produce ionisation of gases in the area around the wood.

In contrast to conventional photography the object is placed in contact with the film itself, an unusual photographic condition. When moisture from the wood is excluded onto the film, it may penetrate the various layers and...