X-ray Diagnostics of Wood Invaded by Insect

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Abstract. *The problem of finding a suitable diagnostic procedure for the examination of structural elements has been closely analyzed in recent years. In this connection, the main material of interest is wood as a sort of heterogeneous matter, and the diagnostic procedure is directed towards enabling industrial application in the future. A new diagnostic method based on X-ray imaging has been proposed and tested; the technique utilizes the reduction of imaging information into 2D planar projection. It allows us to image clearly the rate of material damage through displaying the weighted damage rate.*

Keywords: X-ray, Diagnostic, 2D

1. Introduction

Currently, the protection of structural elements made of wood against decay fungi and wood-destroying insects is widely realized through the thermal treatment technique, which has been known and used in Germany since 1930. The principle of this method consists in heating the related wooden structures, by means of hot air whose temperature does not exceed 120 °C, for a period of 4 - 10 hours. Heat is accumulated inside wooden components of the structure under treatment, and the temperature of these components may reach as high as 60 °C within the cross-section, Fig. 1.

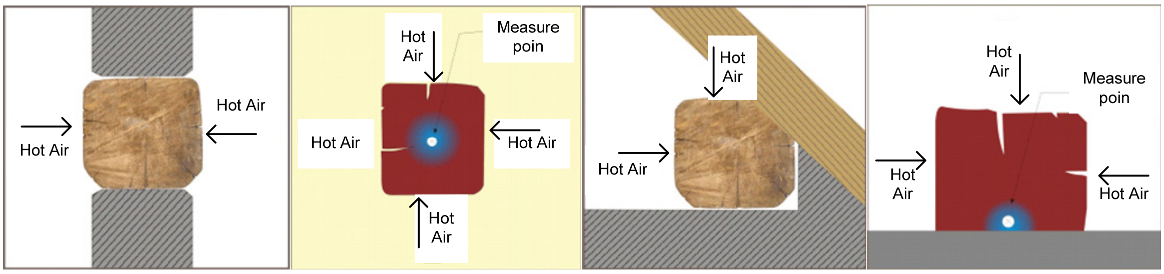

Fig. 1. Heat propagation and detection in a non-homogeneous material: wood.

At the temperature of 55 °C, all viable forms (including the ova, worm, nymph, and beetle) of wood-destroying insects perish; this temperature is the boundary value for the coagulation of proteins that nurture wood-destroying insects such as old-house borer (Hylotrupes bajulus), common house borer (Anobium punctatum), the death watch beetle (Xestobium rufovillosum), or the powder post beetle (Lyctus brunneus).

A necessary precondition for any sensible application of the method consists in diagnostics performed on damaged portions of structural elements. The diagnostics can be realized by means of non-destructive techniques or, alternatively, through destructive methods resulting in partial disruption of the examined element. This paper contains the proposal and analysis of a mobile non-destructive diagnostic method suitable for use with a damaged or disrupted structural element (Fig. 2). In connection with non-destructive diagnostics, the thermal treatment method constitutes a well-suited approach to be applied in artefacts and buildings of great historic value.

Fig. 2. Examples of wood invaded by decay-fungi and wood-destroying insects.

2. Treatment methods

The group of basic treatment methods includes the liquidation of insect foetus, fungus, or rot through the use of hot air or chemical preparations. In all application cases, these techniques are further modified or combined, and the extent of their use is usually determined from the diagnostic results.

Diagnostics

The diagnostics in buildings or in the applied structural elements containing wood are performed both visually and acoustically within the range of audible frequencies, or within the ultrasonic band. The application of acoustic methods frequently results in partial damage of the material. Suitable types of approach to the diagnostics of temperature distribution status include optical measurement methods or destructive methods utilizing probes introduced into a section through the material.

Destructive diagnostics

The rate of a material damage in 3D imaging can be determined by means of the acoustic diagnostic method whose application nevertheless poses certain risks; generally, there are two problems involved. In this respect, the first point of interest is related to erroneous interpretation of diagnostics by the employed software, whereby a mere 10 % damage may be rendered as a large-scale problem within the material volume; this fact follows from the characteristics of acoustic waves propagation through a heterogeneous material as well as from its reconstructions and interpretations of the damaged region. The other problem as mentioned above consists in destructive character of the applied diagnostics together with certain limitations to the use of sensors (namely its repeatability). Further, the situation is made somewhat more difficult by the fact that, owing to the rate of wood heterogeneity, every diagnosed component constitutes a unique entity having no identical counterpart.

Non-destructive diagnostics

The group of non-destructive methods classifying the rate and extent of damage or inhomogeneity in wood includes various techniques that utilize, as a source of the active system, an electromagnetic wave in X-ray range. Thus, wood treatment processes may involve the use of antenna systems applied in the diagnostics of breast carcinoma [2] or utilization of the X-ray diagnostic method known in the fields of human or veterinary medicine. With this technique, however, there occurs certain difficulty related to the evaluation of damage to the material volume. In spite of the fact, a cycle of tests using damaged material samples (Fig.3) has led to an alternative approach; this solution is based on the evaluation of the obtained shot image through a transparent X-ray method having a high rate of image resolution.

3. Solution proposal

The described method utilizes a high-quality X-ray shot of the diagnosed material as well as a very effective image processing technique. The image was segmented, with subsequent evaluation of the required mapping of damage rate realized through filtration. At this point, for example, the evaluation of shot no. 1 is represented in the resolution of damage probability shown is Fig. 3. For image processing, we applied the Otsu filter, the binary filter, and the mean filter. These filters were implemented by the help of convolution techniques [3]. While the Otsu filter automatically calculates the threshold value by the scatter maximization, the binary filter enables the user to define user value for sensitive separation of the structure from the image background [4].

The multiple Otsu filter is based on an algorithm [5], and it is capable of determining multiple threshold values in such a manner that the mutual scatter of intervals determined by these threshold values is the maximum. Threshold value of the i-th group, number of points on the i-th threshold, total number of points, total number of colour pigments, total number of threshold groups are computed.

The stages of processing (Fig. 3) represent individual steps of progressive filtration including the identification of main threshold values from the input x-ray image to the resulting interpretation composite together with the quantification of the individual image segments.

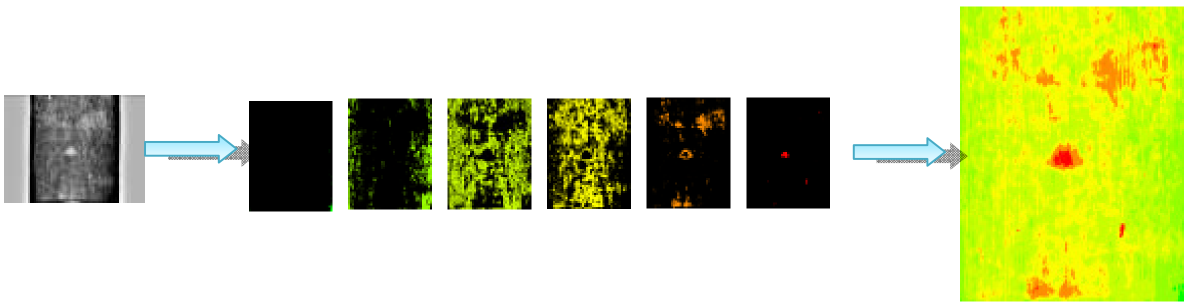

Fig. 3. Progress of filtration in X-ray images.

4. Experiments

Structural element infested wood-destroying insects such as old-house borer (Hylotrupes bajulus), common house borer (Anobium punctatum) was tested. The device used was following: X-ray source EcoRay HF1025, 40-100 kV, 0.32 – 50 mAs, focus 1.2 mm, digital radiography sensor Minolta, 87/125 mm/pixel, 500 x 400 mm, no filters was used. Scans were performed through the wall and in two orthogonal axis of wood girder for 3D evaluation. Fig. 4 shows maggot print inside wood sample acquired by X-ray shot – wood-destroying insects. Structural element infected wood-destroying insects in external location (old building) and experiment setup can be seen in Fig. 5.

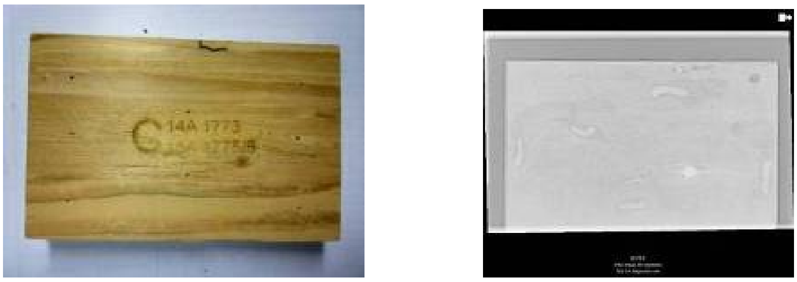

Fig. 4. The X-ray images of insects localisation.

Fig. 5. The X-ray diagnostic in external location – Na mlýně Štramberk.

5. Conclusions

We designed and tested an X-ray transparent diagnostic method for 2-D imaging and 3-D quality evaluation with respect to the assigned image parameters. The parameters were set in such a manner as to enable the imaging of shot sections showing the rate of damage to the heterogeneous structure building. Experiments were carried out with the application of microwave power to eliminate wood decaying fungi and wood-destroying insects.

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