Use of the microwave method in controlling wood-destroying insects and dry rot *(Serpula lacrimans)*

Introduction

With the microwave technology a method is available that makes a targeted treatment for a wide range of infestations possible. It acts both against wood destroying insects, as well as against dry rot *(Serpula lacrimans)*. Since it leaves the building components intact it is particularly suited for heritage conservation. The application can be integrated to coincide with control and repair work and should be individually planned to each project.

Wood preservation measures that take advantage of the heat sensitivity of wood destroying organisms gain more and more importance. Due to the hot air treatment, heat treatments against wood destroying insects are a generally accepted standard in technology. The effectiveness of these methods is based on exceeding the respective lethal temperature of the target organism. It causes the coagulation of protein in wooddestroying insects -larvae, eggs , pupae and adult insects die off. Mainly building components infested by larvae of old-house borer *(Hylotrupes bajulus)*, common furniture beetle *(Anobium punctatum)*, deathwatch beetle *(Xestobium rufovillosum)*, beech furniture beetle/ fan bearing wood borer *(Ptilinus pectinicornis)*, house borer *(Hadrobregmus pertinax)* and powderpost Beetles *(Lyctus spp.)* are treated. Also the cell structure in dry rot *(Serpula lacrimans)* is damaged by heat, to the extent that the fungus dies.

The hot air treatment and the microwave treatment are both thermal techniques, but they differ in important respects. When using the microwave method

- the wood is heated from within and not via the surface
- a significantly smaller area is treated (the radiating surface of the horn antenna is 20cm x 33cm)
- the targeted material reaches a high temperature in a relatively short period of time
- the object being treated must not be enclosed
- the treated area can be immediately re-entered or used after the generators are switched off

Technical requirements and mode of operation

A microwave system consists of microwave generators (10-step power regulation), horn antennas (base 33cm x 50cm or 23cm x 29cm), a control unit with temperature sensor and thermal probes. A separate power supply (230V/16A) is required for each system. A microwave meter, an infrared camera, a wood moisture meter, a thermo-hygrometer, a digital camera, various tripods and other accessories also belong to the basic equipment. The knowledge needed for the operation of the microwave system is acquired through schooling .The operator should have a sound knowledge of wood and wood preservatives when using this method in the fight against wood destroying organisms.

Figure 1:
A microwave system during the treatment of a joist, control unit in the foreground, two generators with attached horn antennas in the background

The generators produce microwaves in a frequency of 2.45 GHz and generate a maximum of 1.1 kW. Using the horn antennas the electromagnetic waves are directed on the construction. This causes a constant orientation and reorientation of dipolar water molecules in the electromagnetic field within the treated material. As a result, the electromagnetic energy is converted into thermal energy.

The equipment is mobile and it is used directly at the construction site. Since the antennas are connected to the generators with a 2.50 m lang cable it is possible to treat a broad range of constructions. The output of the Generator is adjustable in 10 different levels.

As described it is possible to reach a high temperature in the interior of an object without heating the surface excessively. Therefore the method is also suitable in treating sensitive objects with painted surfaces or works of art. Dry wood can easily be heated, since the molecularly bound water in the wood is sufficient to cause the desired reaction. Another positive effect is attribute of wood to store heat very well.

Figure 2: Treatment of a gallery balustrade with a coloured surface, infested with the ordinary furniture beetle *(Anobium punctatum)*, an infrared recording taken shortly after the removal of the antenna.

Construktions less than 8 cm thick can be treated from one side. If it is stronger, it is preferable to use two antennas from opposite sides. A one-sided treatment of beam is also possible, but is time consuming and can require the use of doublers and insulation to reduce the loss of warmth over the surface. The size of the antenna is not the same size as the radiating surface. Therefore the antennas must be partially overlapped in some applications.

In contrast to wood, dry mineral based building materials do not contain sufficient moisture to achieve a sufficient thermal reaction. On the other hand the microwave method is well suited for rapid drying of wet masonry. This generates a temperature level which is also sufficient for controlling dry rot. In this respect the drying of wet masonry and treatment against dry rot can be combined. The technical effort depends on the extent of infestation and the thickness of the construction to be treated.

Lethal temperature of the target organisms

The killing effect of this method is dependent on the temperature and length of exposure. When treating with high temperatures there is rapid success, at lower temperatures more time is needed. The results from experiments held in the MPA Eberswalde (Materialprüfanstalt Brandenburg GmbH) and BAM Berlin (Bundesanstalt für Materialforschung und -prüfung) demonstrate this impressively.

organism	sourroundings	temperature	time	source
dry rot *(Serpula lacrimans)*	wood	53° C	2 min.	source 1
common furniture beetle *(Anobium punctatum)*	wood	70 °C	1 min. 40 sec.	source 1
old-house borer *(Hylotrupes bajulus)*	wood	60 °C	1 min. 40 sec.	source 1
	air	55 °C	20 min.	source 2
	air	60 °C	8 min.	source 2
	air	70 °C	4 min.	source 2
	air	80 °C	3 min.	source 2
	air	90 °C	2 min. 30 sec.	source 2

source 1: BAM Berlin, Untersuchungsbericht 4.1/8497 v. 04.07.2012
published in „Untersuchung zur Wirksamkeit von Mikrowellen“, journal Schützen und Erhalten, Sept. 2012, S. 29 – 31

Quelle zu 2: MPA Eberswalde, Untersuchungsbericht
published in „Bekämpfung des Hausbocks *Hylotrupes bajulus (L.)* durch Hitze – neue Randbedingungen“, journal Holztechnologie, Jan. 2013, S. 16 - 20

Practical Application

The first step of the treatment is to determine and optimise suitable locations for the antenna, the level of power needed and the exposure time. The operator prevents the exceeding of the definite temperature level. Switching off or scaling down the generators has a direct effect on the temperature development. If conditions allow, the treated cross-sections of wood will be heated up to 100 °C. This does not impair the technical properties of the wood since thermal decomposition does not occur until temperatures of ca. 130 °C are reached and held at for several hours or days.

Concerns about uncontrolled heat development in the areas around metal parts can not be confirmed in practical use. These so-called hotspots remain below critical temperature limits. Bolts and washers typically used in wooden constructions cause no problems whereas larger metal parts would reflect the microwaves and damage the system itself.

In the treatment of coniferous wood, liquefaction from resins are observed, which emerge on the wood's surface. Another effect is a reduction of wood moisture content after an extended exposure time.

The method is restricted by the unchangeable forms of the antennas. This results in limiting its application. For example it may be sometimes not possible to achieve the necessary temperature in a remote corner without overheating the areas nearby. Special care is also required at the treatment of thin objects, because the heat development may be uneven. Besides they have large surface area in correlation to their volume, so that they cool down faster.

Occupational health and safety

If the human body is exposed to an electromagnetic field with a proportionally strong power density, it causes an increase in body temperature. This can not be perceived by the receptors of the skin. In the worst case this would lead to internal burns. The body can dissipate low-level temperature elevation through normal thermoregulation. Particularly at risk are parts of the body with a low blood circulation such as the eyes.

The application of the microwave technology is to be exclusively used by skilled experts, that monitor the application with proper equipment continually. It is not allowed to leave an operating system unattended. Since the system works with open microwaves, more occupational health and safety measures are required. A limit value of 5 mW/cm² for working within electromagnetic fields was set by the Berufsgenossenschaft [BGV B11, 2001]. It is derived from the specific absorption rate (SAR), the measure of the energy absorption in body tissue. The users protect themselves primarily by keeping a sufficient distance from the unit and the direct radiation of the antenna. While working a radiation

monitor must be continuously worn on the body. The device warns optically at 12.5 % of the limit and acoustically if 50 % of the limit is reached. By this means it is also possible to determine which areas are must be closed and marked during the treatment. Animals, plants, medical and sensitive technical devices should be removed. An alternative is the use of a reflective foil to shield.

Monitoring and documentation

With the microwave method relatively small areas are treated. In relation to the size of the treated area there are more opportunities to control the effectiveness than at other methods.

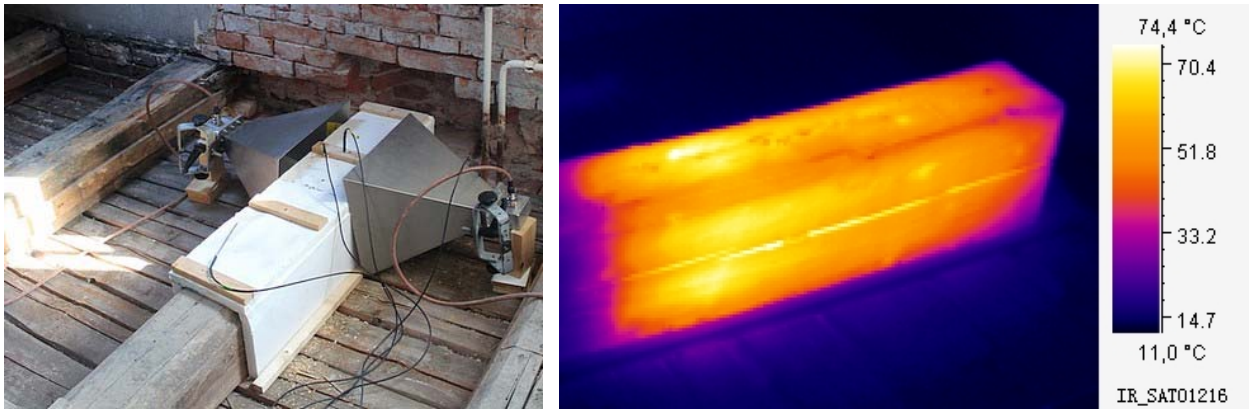

Figure 3: Treatment of a ceiling beam, contaminated by dry rot *(Serpula lacrimans)*, antennas on both sides, infrared recording were made shortly after completion of the treatment

The temperature profile can be recorded using 4mm thick thermal probes that are placed in relevant points in the wood. They should show the slowest and the fastest rise of temperature during the operation. These values can be read directly off a display on the control unit and are recorded at regular intervals. The positioning of the antennas and sensors will also be documented by photos or drawings. In addition the temperature of the objects surface is recorded by use of an infrared camera. A homogeneous temperature image confirms an even temperature distribution in the interior of the objekt. Based on the information of the monitoring an objekt-related documentation is created after the procedure.

Ensuring the success of microwave treatment

The success of the treatment - the killing of the target organism - can be proved through temperature records taken during the treatment. In addition the customer has the opportunity to put test specimens into the object. They are taken out after completion of the treatment and sent to specialized laboratories where they will be subjected to corresponding vitality tests.

Figure 4:
Control of success: The insertion of test specimens for subsequent viability test in the laboratory

There is no preventive wood protection achieved by using the microwave method. The reinfestation of treated wood is possible. Also larvae from non-treated areas may migrate into treated areas. If the risk for an infestation continues to exist, a chemical preservative treatment should be used additionally.

In February 2012, the completely revised DIN 68800 “Holzschutz” was published. In section 10 of the DIN 68800-4 „Bekämpfungs- und Sanierungsmaßnahmen gegen holzzerstörende Pilze und Insekten“ the microwave treatment is listed as an electro-physical process against a limited insect infestation. It is described as a special procedure, in contrast to generally used methods in renovation. Therefore the application should be specifically tailored to each individual case.

Cost calculation

The costs are determined by the dimension and geometry of the objects and their accessibility to the technology (antennas). The maximum temperature limit (e.g. treating objects with painted surfaces) also influences the calculation. In addition there is the equipment needed to prepare the worksite, expenses for travel and accommodation. The documentation of the treatment will be invoiced separately.

To establish a cost calculation without inspecting the object before, we need an investigation report of the area of infestation, the descriptions of the object to be treated as well as photos. Objects that should be treated must be determined and clearly marked by the Customer or an entrusted planner.

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