

USAGE OF MICROWAVES FOR DECONTAMINATION OF SENSIBLE MATERIALS AND CEREAL SEEDS

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ABSTRACT: Nowadays, microwaves are used in more and more applications such as medicine, treatment of materials, thawing, defrosting, transmission of information and many more. New usages for microwaves consist of decontamination and sterilisation of seeds and sensible materials, such as very old books, fabrics, paintings, statues etc. In order to achieve best results without damaging the treated materials and objects, microwaves are to be used very carefully, and the treatment must observe certain parameters, such as heating time, final temperature, rate of heating, uniformity, pulse and pause ratio etc. This paper describes some of the research that has been carried out during the preparation of Mr.Ursu's doctoral thesis, concerning these special applications of microwave treatments.
KEY WORDS: microwave, sensible materials, heating, cereal seeds, old books

1. INTRODUCTION

The old objects, such as books, paintings, statues etc are often affected by fungi, microorganisms, insects and other biological hazards, and their damaging effect is emphasized by humidity and low levels of pH (acidity). Also, the cereal seeds tend to be affected by the same agents. In order to decontaminate and/or sterilise such sensible objects and materials, several methods have been used with more or less success, such as fumigation, chemical treatment, exposure to high and/or low temperatures etc. Of course, the scale of the decontamination process is very different between these two special cases, but the principle remains the same: the pests have to be neutralised in order to prevent them to do more damage. The microwave treatment begins to prove itself as a good answer for this problem.

Briefly, the heating of objects exposed to microwave occurs because of the dielectric and conduction losses phenomena, under the effect of the electric component of the microwave radiation. The specific volume power of conversion $\boldsymbol{P_v}$ expresses the heat developed in the time unit in the volume unit of the dielectric placed between the plates of a capacitor:

$$P_v = \omega \cdot \varepsilon_0 \cdot \varepsilon_r \cdot E^2 \cdot \mathrm{tg}\delta \qquad (1)$$

which is a very important quantity that determines the capacitive heating speed. According to the above relation, in identical thermal conditions, for a given dielectric with approximately constant relative permittivity ε_r and total losses angle δ, the increasing of the heating speed is possible by increasing of the angular frequency $\omega = 2\pi\nu$ and the intensity of the applied electric field $\boldsymbol{E}$. The maximum value of electric field is limited by the breakdown occurrence in the material (breakdown field strength), so the efficient dielectric heating can be attained by increasing of the frequency, thus the use of microwaves becomes justified in electro-thermal processes. The microwave electromagnetic field features large penetration depth in dielectric, so the heat is produced in all its volume and a rapid and uniform heating is attained [1].

2. OLD BOOKS AND SENSIBLE MATERIALS

The treatment of old books and sensible materials is usually carried out by means of special chemical substances, which rebalance pH, eliminate pests, block the damaging chemical reactions etc. These substances are specific to every particular case and must be used with utmost care, as their benefits are often accompanied by disadvantages, such as toxicity for environment and/or human operators, difficult operations, long-term secondary effects on the treated object etc. Research proved that microwaves are able to emphasize the beneficial effects of the chemical treatment, as they produce volume heating of the treated object. Of course, every treatment formula must be carefully tested, in order to strictly avoid any further damage. [2]

Here is the case of a very old book, affected by high acidity, which leads to flexibility loss, hardening and crumbling of paper (fig.1). For pH measurements, a NORONIX PHT1140 device was used, fitted with a pH probe and a temperature probe (fig.2) [3].

Before starting the experiment, the high acidity affected zones were circled and their pH was measured. The initial result was 4.65, so the paper was very acid. After treatment with 1% solution of magnesium oxide (magnesia) along with 30 seconds exposure to microwave in the 350W experimental microwave research installation from University of Oradea (fig.3) set on power level 3, the pH value became 7.40. After exposure at level 6, pH reached 7.79, and after exposure at level 10 (maximum power), pH reached 8.01, so the treatment made the paper to become basic.

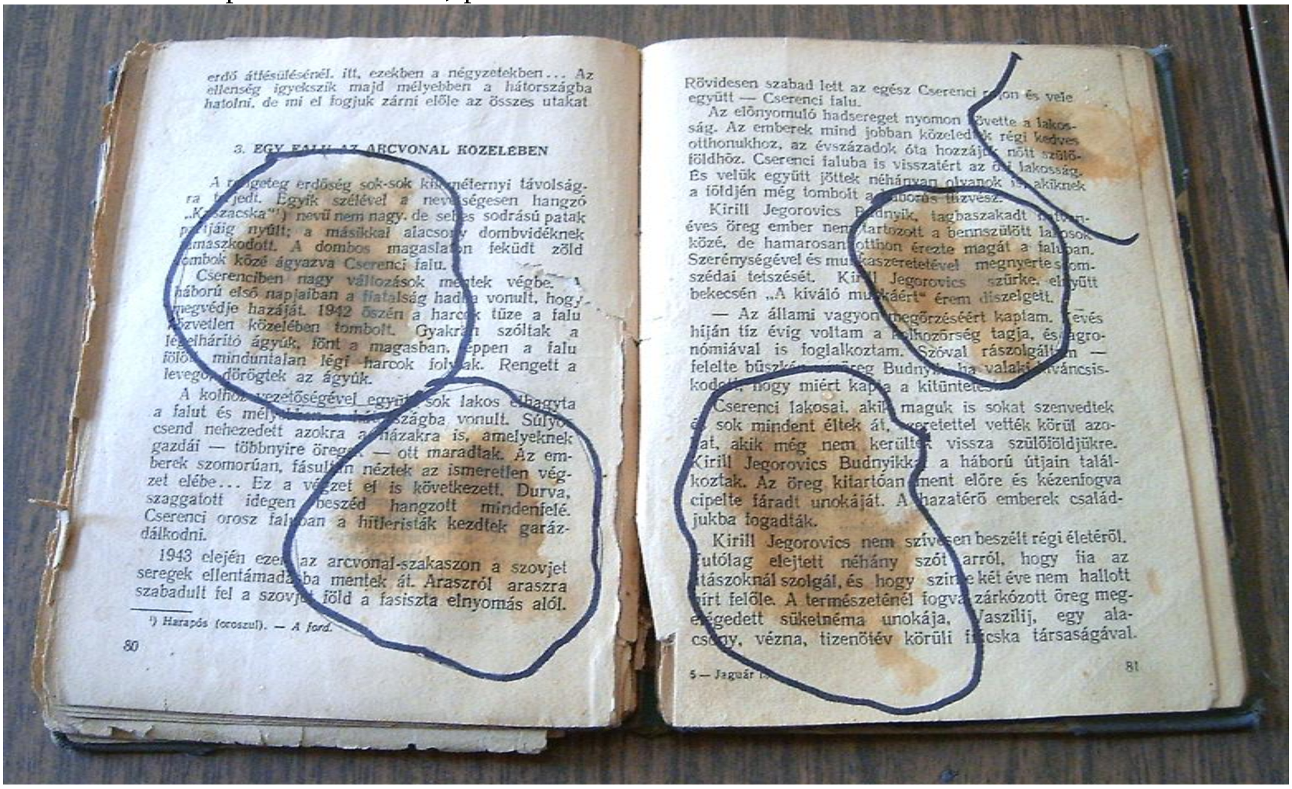

Figure 1. Old book, affected by high acidity. [3]

Figure 2. pH measurement for the treated old book. [3]

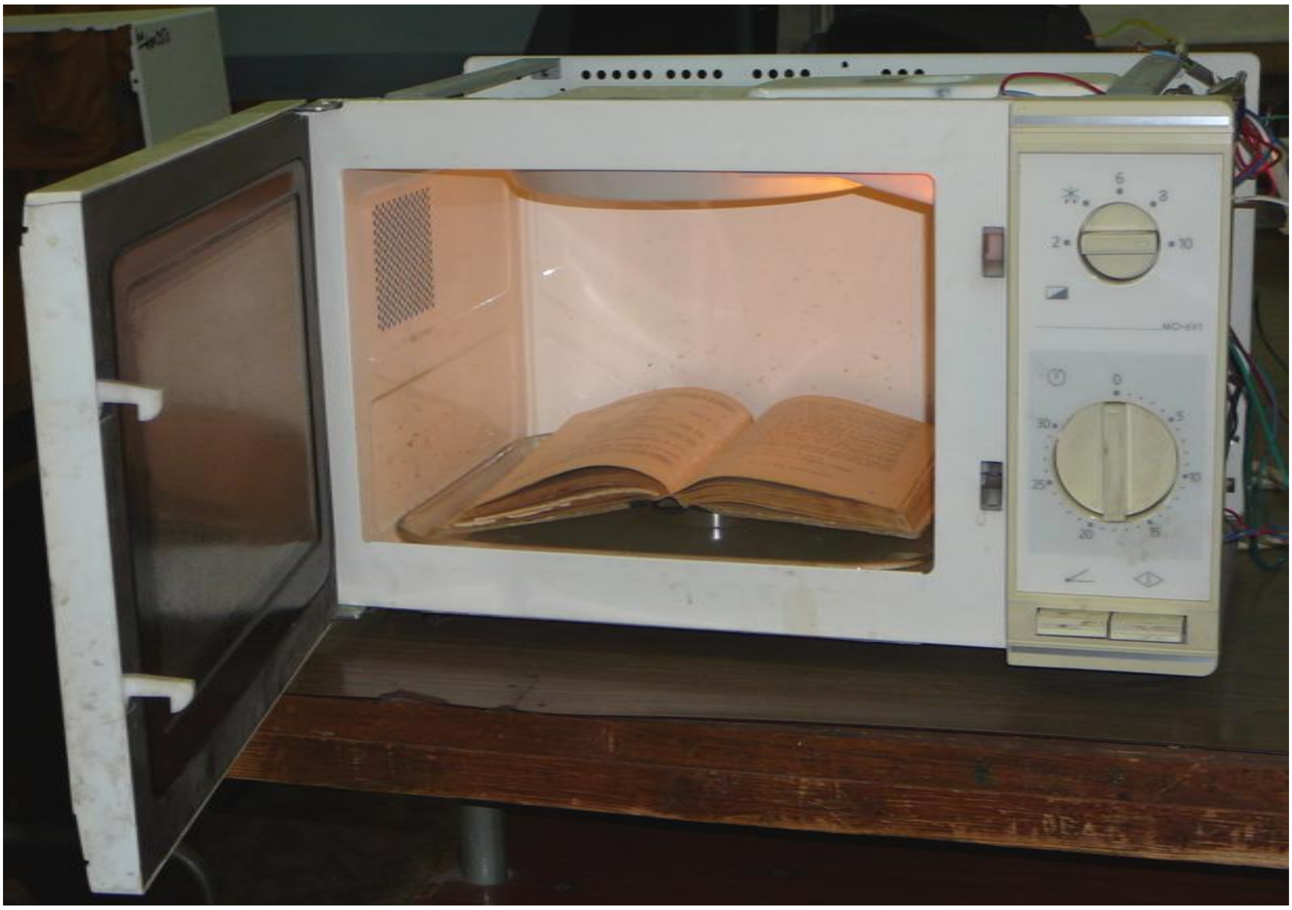

Figure 3. Old document, ready for treatment with magnesia and microwaves in the experimental microwave research installation at the University of Oradea. [3]

In order to evaluate the influence of microwaves on the chemical treatment, the experiments and measurements were repeated as follows: document untreated and unexposed, document untreated and exposed for 60s to maximum microwave power, document treated and unexposed, document treated and exposed to maximum microwave power for 60s, 120s and 180s, The results are shown in tab.1.

Table 1. Temperatures and pH values for an old document. [3]

Document	Ti (ºC)	Tf (ºC)	ΔT (ºC)	pH
untreated, unexposed	28.2	28.2	-	5.5
untreated, exposed 60s at maximum power	29.5	40.1	10.6	5.7
treated 1% magnesia solution, unexposed	29.3	29.3	-	7.4
treated 1% magnesia solution, exposed 60s at maximum power	29.4	45.1	15.7	7.8
treated 1% magnesia solution, exposed 120s at maximum power	29.7	58.2	28.5	7.9
treated 1% magnesia solution, exposed 180s at maximum power	31.2	61.5	30.3	8.0

These experiments are part of a preliminary phase of a larger research project, which will include the study of the microwaves influence on the destruction of pathogen agents in old documents and patrimony objects. This research is important because the patrimony objects have inestimable value, and their respectable age requires firm actions in order to preserve them in time.

3. CEREAL SEEDS

The microwave heating of cereal seeds offers the possibility to totally destroy any pathogenic fungi located on their surfaces or inside, without affecting their germination capacity or their properties for further use. Usually, cereal seeds were treated by fumigation, chemical substances, hot water vapours, high and/or low temperatures etc, but nowadays organic farms forbid the use of chemical reactants and allow only the physical treatment, in order to avoid soil and air pollution or other harmful effects upon the environment. Unlike the conventional thermal systems, the microwave / high frequency energy treatment feature short processing times, so this looks like an interesting solution.

The microwaves belong to the 300 MHz ÷ 300 GHz frequency interval. They penetrate the treated object, and the electric field intensity decreases with the penetration depth. During the microwave exposure, the treated product receives supplementary motion into the electromagnetic field in order to attain uniform temperature distribution.

The mildew in the seeds leads to the loss of the healthy appearance and the occurrence of bad smells, which causes economical losses as the quality of the seeds decreases. Also, some species of Aspergillus, Fusarium and Penicillum are able to produce micotoxins which can impede the use of the affected seeds in human and/or animal feeding.

Insects that breed into the seeds storerooms can also depreciate the seeds and cause serious problems with their alimentary use. They can be eliminated by means of chemical agents, fumigation, ventilation etc, but these operations may lead to environmental pollution and contamination of the seeds.

Fortunately, both fungi and insects are sensible to temperature variations, and this is very useful for the alimentary industry. Three temperature zones have been defined: optimal, sub-optimal and lethal. In the optimal temperature zone, these organisms are able to reproduce and develop fast. The sub-optimal zone is close to the optimal zone, where the organisms develop slower, but they are still able to survive and reproduce. The lethal temperature zone is above/below the sub-optimal zone, where the organisms are killed. Even if the sub-optimal zone does not destroy the insects, it is still useful for the decrease of the insect populations' development.

Temperatures in the sub-optimal and lethal zones are attained by various means. A temperature rise of just some degrees Celsius above the optimal zone slows down or even stops the insects' activities, and sometimes it even kills them. Exposure to 40-50ºC for short time periods may lead to 90% insect mortality, depending on the surviving capabilities of the insects and on other factors, such as humidity, exposure time and the species.

As in the case of old books and sensible materials, the cereal seeds must be treated with utmost care, under strictly observed conditions. As mentioned before, the treatment must not affect the germination capacity and the properties of the seeds.

The exposure time and the power level are to be strictly observed. These parameters, along with the useful microwave wavelength, are to be determined by further experiments and tests. [4]

4. EXPERIMENTAL DEVICE

As mentioned before, the parameters of the microwave treatment are very important in order to attain best results. The exposure time, the power level and the pause versus pulse ratio are to be determined by tests and must be programmed precisely in order to attain reproducible outcomes.

For this purpose, the experimental device, designed and realized within the doctoral thesis research of Mr.Ursu was used. It features accurate minute and second setting of the treatment time, power level setting in 10 steps of 10% each, as well as setting of clock frequency which drives the time division of the emitted microwave power. The block-diagram of the electronic digital settable timer is shown in fig.4.

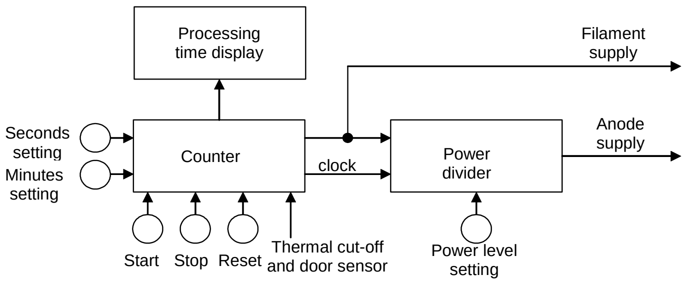

Figure 4. Block-diagram of the electronic digital timer, designed and realized. [3]

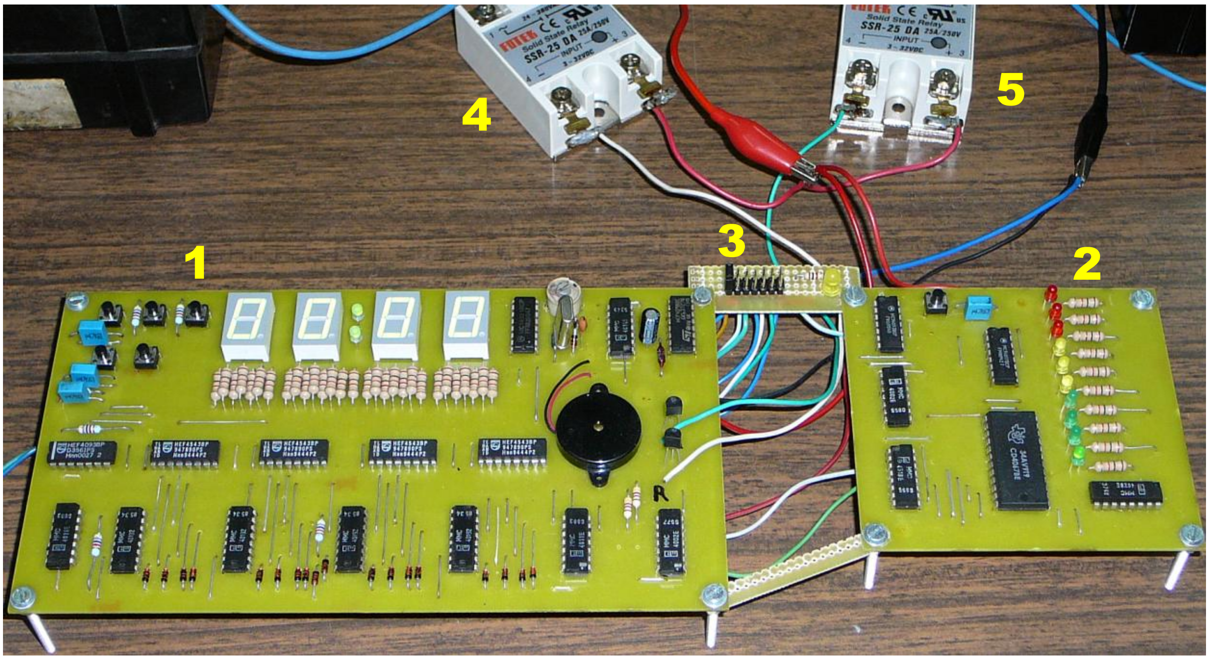

Figure 5. Electronic digital timer, designed and realized; 1 – timer and time display, 2 – time divider, 3 – clock frequency selector, 4 – static relay for filament command, 5 – static relay for anode command. [3]

The parameters are numerically shown on a LED display (time – minutes and seconds) and analogically on a LED row (power level – 10-40% green, 50-70% yellow, 80-100% red). The choice of the clock frequency for time division is made by means of a jumper, of values 16Hz, 8Hz, 4Hz, 2Hz, 1Hz, 0.5Hz şi 0.25Hz, given by the quartz time base of the digital timer. Fig.5 shows the assembled electronic command device.

By means of the designed and realized device, the microwave installation can be driven according to the parameters of the required operation. The electronic device sets the treatment time between 1 second minimum and 99 minutes and 59 seconds maximum. If needed, the treatment time can be extended by cascading more decimal counters and displays on supplementary PCB's. The power level can be set between 10% minimum and 100% maximum, in steps of 10% each, by means of time division. The novelty of this device consists in the choice of the clock frequency for time division.

Of course, the functions of this device with discrete elements can be reproduced by means of a single programmable microcontroller. This version of the driving device may offer other facilities, as real time display in *stand-by* state or on demand during operation, distinct visualization of the conditions that prevent the normal operation (no load, open door, overheating, time not set or set at wrong values, power supply problems etc), as well as the possibility of computer connection. This facility would make much easier the automation of the microwave treatment processes, because the computer might be fitted with a fuzzy-logic program which, based on the data input by the operator, concerning the required results (final temperature, speed of temperature rise, efficiency, productivity etc), may yield the most adequate combination of process parameters (voltage supplies, exposure time, division factor, clock frequency), to automatically set the installation and execute the treatment process.

The efficiency of a microwave installation depends greatly on the magnetron efficiency, as well as on the matching between the microwave elements: magnetron, waveguide, applicator and load. Practically, the microwave power *absorbed* by the load may vary between the nominal power of the magnetron at perfect matching, and zero at total mismatching; in the last case, all the microwave power reverses towards the magnetron itself, causing the overheating of the magnetron and waveguides, spark discharges etc. In usual cases, some degrees of mismatch are admitted, so the magnetron and the other elements are built in such manner that they can withstand the reflected microwave power; furthermore, the installation is fitted with thermal cutoff sensors in contact with its elements, which stop the entire installation of overheating becomes too intense and dangerous.

The applicator must also be designed and built with great care, so that it would provide optimum match with the load, in order to deliver as much as possible of the microwave emitted power to the load, thus minimizing the microwave reflected power. [3]

5. CONCLUSIONS

The decontamination and sterilization is utmost important for old books, fabrics, paintings and other sensible objects, as well as for large quantities of stored cereal seeds. The difference between these two cases resides in the scale of the implied devices, but the principle remains the same: the pests, fungi, microorganisms and other biological and chemical harmful agents must be destroyed or at least stopped from doing more damage, while preserving the properties of the treated objects and materials.

6. ACKNOWLEDGEMENTS

The research described here was part of the doctoral thesis of Mr.Ursu and part of the contract PN II Nr.51-082/19.09.2007 "Microwave technologies used for the stored agricultural seeds quality improvement".

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