Controlling Microwave-Induced Temperature Distribution in a Wooden Load Through a Two-Source Excitation

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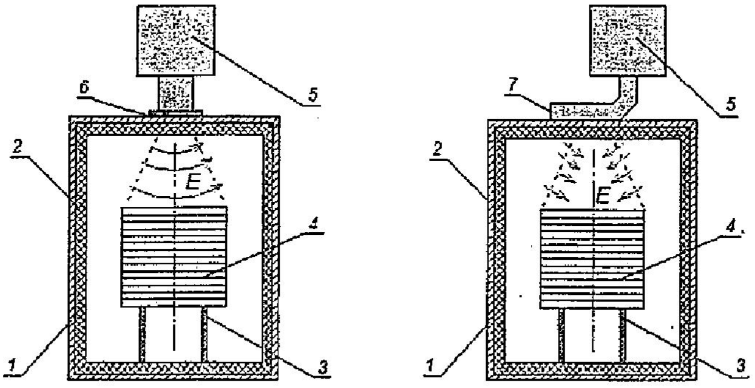
Obtaining even temperature distribution in the volumetric materials with dielectric losses exposed to the microwave radiation was addressed in this work. Two types of radiators, (1) with a rectangular aperture and (2) with a teardrop aperture, were used for heating a multi-layer wooden bar. The temperature distribution in the bar was measured in the direction of radiation. With a rectangular aperture, the maximum temperature reached inside the bar was at some distance from the surface of the bar facing the radiator. With a teardrop aperture, the maximum temperature was at the surface of the bar facing the radiator. It's expected that an even temperature distribution in a treated object can be obtained by simultaneous using both types of radiators

Keywords: electric field intensity, microwave heating, microwave power, volumetric material.

INTRODUCTION

Obtaining a uniform temperature distribution in volumetrically heated dielectric material is one of the most important tasks in creating industrially applicable microwave processes [1]. Often, microwave systems used for volumetric heating of dielectric materials, are fabricated in the form of a rectangular chamber with radiation sources connected to one or more generators. An open end of a rectangular waveguide working at the dominant, TE_{10}, mode is the most simple microwave radiator. Positioned at different places of the walls, the radiators create a complex filed distribution, which significantly changes after placing an object to be treated in the chamber. Despite the success in computer modeling of the heating processes, measurement of the temperature distribution in a real object, can be very useful. This was the objective of preliminary experiments, described in this paper.



(a) (b)

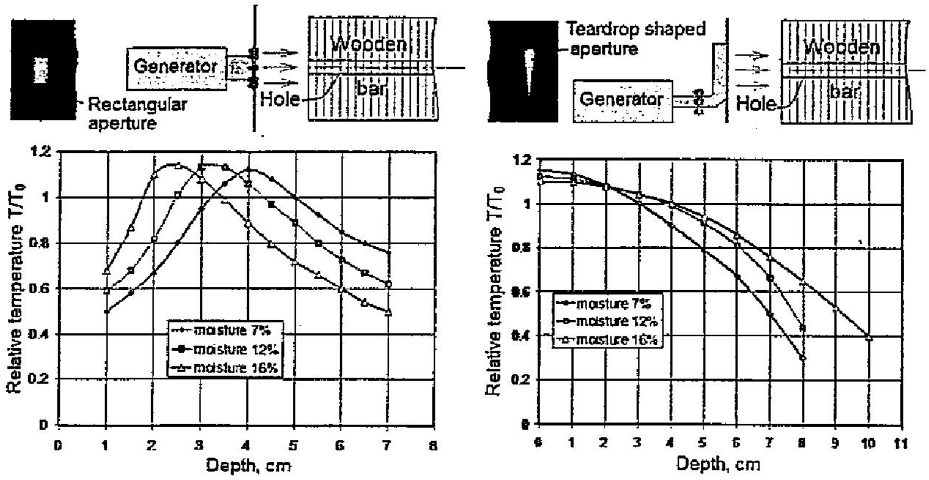
Figure 1. Microwave unit for heating a volumetric dielectric material. 1 - microwave chamber; 2 - absorbing material; 3 - support from a radio transparent material; 4 - wooden multi-layer sample; 5 - microwave generator; 6 - rectangular radiator; 7 - teardrop radiator.

TEMPERATURE DISTRIBUTION MEASUREMENT SCHEME

Experimental apparatus for volumetric heating of a homogeneous dielectric material by a single microwave power source with a frequency 2450 MHz, output power 600W, and two different radiators located on the upper wall of a 60x60x60 cm chamber is presented in Figure 1. The heated sample was a wood bar formed by 30 identical square boards of dry (9% humidity) pine wood with thickness 1 cm and length 20 cm. The temperature distribution was measured along the bar thickness. The bar was placed on a microwave-transparent stand at 24 cm below the radiator with its square side facing the upper wall of the chamber. The power reflected from the sample was not measured. Two types of radiators, with different apertures, were used for these measurements: (1) an open end of a rectangular waveguide (Figure 1a) and (2) a slot in the wide wall of a rectangular waveguide (Figure 1b).

The temperatures was measured without radiation by a thermo-couple moved in the direction of the wave radiation through a small hole previously drilled in the center of the bar. The estimated measurement accuracy (including errors caused by positioning of the thermo-couple) did not exceed 1°C. To exclude the effect of power reflected from metallic walls of the chamber, they were covered with the standard absorbing plates with thickness 2 cm. In the same time, results of measurements were practically the same in the presence and in the absence of the absorbing plates.

The first open waveguide radiator (1) operated with the TE_{10} mode and created radiation with electric field approximately parallel to the irradiated surface of the bar (Figure 1a). The second radiator was fabricated as an end section of a standard rectangular waveguide, shorted at one end, and with a teardrop slot through the middle of the wide side of the waveguide, operating with the dominant, TE_{10} mode [2].The slot has length 15 cm and the width 3.6 cm in its widest part.



(a) (b)

Figure 2. Relative temperature distribution inside the wooden sample at different values of moisture; (a) irradiation through the rectangular aperture, (b) irradiation through the teardrop shaped aperture; $T_0 = 80^0$C.

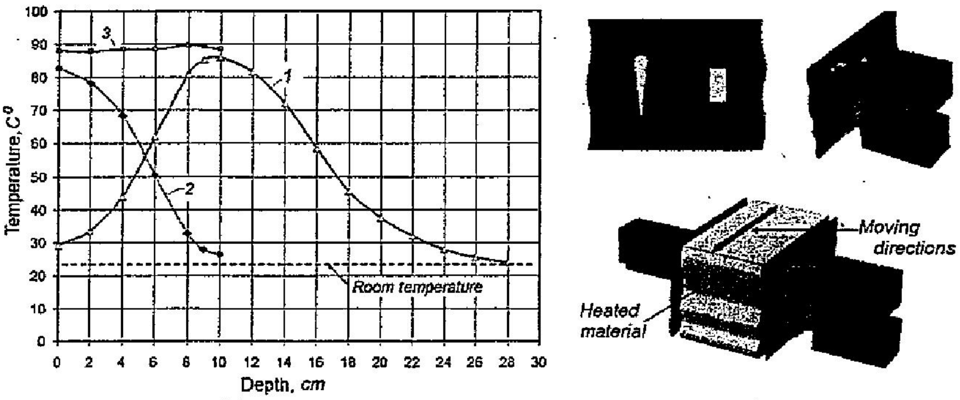
TEMPERATURE MEASUREMENTS

The measured temperature distributions in the direction perpendicular to the surfarce of the wooden bar facing the radiator is presented in Figure 2a for irradiation by the rectangular aperture and different values of moisture. It is seen that in this case the highest temperature occured in a layer inside the bar. This effect is known and was discribed previously [3]. Curves in Figure 2b present the temperature distribution obtained with teardrop aperture. It is seen that independently on the moisture content, the maximum temperature was at the surface of the bar.

It follows from comparing curves in figures 2a and 2b that the simultaneous use of both rectangular and teardrop aperture radiators can flatten the temperature distribution along a treated sampl. In practice, the effect of simultaneous heating by both radiators can be controled by the choice of a power or operating time for the MW source feeding one of the radiators.

RESULTS

The curves in Figure 3a were obtained for the same wooden bar subsequently exposed to the rectangular aperture radiator (curve 1) and teardrop aperture radiator (curve 2). The operating time for each exposure was chosen to achieve the maximum temperature of approximately 80^0C. Taking into account the temperature distribution superposition, one can expect that simultaneous heating by two microwave sources with the rectangular and teardrop apertures gives a uniform temperature distribution in the material



(a) (b)

Figure 3. (a)Temperature distribution inside the wooden sample, (b) possible realization of the irradiation by two radiators with the teardrop and rectangular apertures.

with dielectric losses. It is demonstrated by curve 3 in Figure 2, calculated by superposition of curves 1 and 2. It is seen from results of measurements obtained for each radiator, that at the simultaneous use of both radiators, the temperature deviation in the material heated to 80-90^0 may be limited by 3-5^{0}C. A possible positioning of the radiators is shown in Figure 3b.

CONCLUSION

A method for obtaining an even temperature distribution in the volume of dielectric objects was proposed and investigated. This method is based on the superposition of complementary temperature distributions in the material under the condition that the object is heated by two sources with different polarizations of the excited field. It is expected that in some cases, a practical realization of this method will improve the quality of MW heating.

ACKNOLEGEMENT

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