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Design of Microwave Cavity for Heating Applications

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ABSTRACT

Much attention has been given to microwave technology due to their ability of reducing carbon emissions during heating in manufacturing operations. In comparison to conventional heating techniques, microwaves provide a number of benefits, such as faster heating, less thermal damage, and environmentally friendly processes. Heating must be consistent and effective for the use of microwaves in manufacturing process. In this paper, microwave cavity applicator was designed and simulated for heating applications. The cavity designed at frequency of 900 MHz to be accomplished to contain large size of samples. Distribution of the fields inside the cavity and the heating efficiency were simulated using COMSOL Multiphysics software.

1 Introduction

Radiation, convection, and conduction are the three main types of heat transmission used in conventional heating methods. Since the heat is transferred from the heat source to the exterior of the target material before going inside, these techniques take many hours to achieve the desired temperature. This includes high energy consumption and continuous exposure to high temperatures, which causes surface damage and property degradation [1].

In contrast, heating in microwave technology is performed either directly by molecular vibration or through particle charging [2,3]. Microwave heating takes less time than conventional heating [4]. It is also environmentally good because it uses less energy and emits less carbon than traditional heating does.

The use of microwaves in industry becomes difficult for the following reasons. To begin, most studies have been carried out on a laboratory size. Furthermore, Only the heating of a small portion of the cavities is taken into consideration, as the target materials only fill between 0.1 and 0.001 of the cavity volume. Second, most studies focus on heating efficiency rather than homogeneity.[5] for example, investigated the heating effectiveness of plastic particles rather than heating uniformity by adjusting microwave power and chamber volume. Large-scale heating research, in particular, focuses on great efficiency. High heating efficiency is also a prominent concern in various studies on drying or biodiesel synthesis [6,7]. However, concentrating mostly on heating efficiency and neglecting uniform heating might have major consequences. For instance, overheated regions reduce the material's quality and the reactor's ability to function [8]. This paper describes in detail some of the general design features of the cylindrical microwave cavity to operate effectively for heating applications.

2 Design

Using the COMSOL Multiphysics program, as illustrated in Figure 1, a cylindrical cavity with a reduced centre frequency has already been designed. Since the cavity is designed to operate in its TM010 mode at 900 MHz, the inner radius of the cavity has to be 128 mm. To ensure that there is no interference between the TM010 mode and the TE111 mode, a mode chart is used to select a suitable height of cavity depending on the ratio (2ad); as a result, the cavity's height being selected to be 200 mm. It should be mentioned that 900 MHz is an ISM frequency with a number of low-cost power amplifiers capable of producing high microwave powers of up to 1 kW. The greater cavity volume allows for bigger sample volumes, in this case up to a few cm3, based on the sample loss factor. The cavity is made up of three parts: the cavity body, the bottom cap, and the side part that holds the coupling connector. However, the Q factor can only be sacrificed by around 25%, aluminium is chosen as the cavity's metal because it is easy to machine, inexpensive, and has a less bulk contrast with copper.

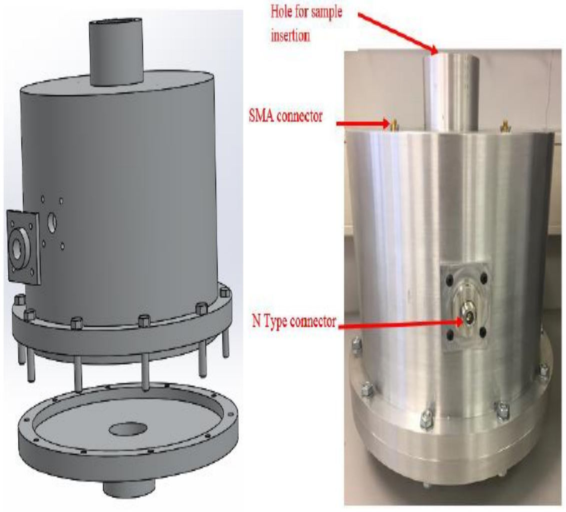

Figure 1 large aluminum cylindrical cavity resonator. [9]

There are two different types of coupling used: the side-wall N connector permits high power to be filled into the cavity, allowing samples to theoretically be heated and characterized at the same time. SMA connectors at the top of the cavity allow cavity perturbations in the usual way, to investigate a sample's dielectric properties. The connection loop, which is positioned in the centre of the cylindrical metal wall's side. In simulations, the coupling loop's radius is 5 mm, whereas in real-world applications, it is 25 mm. Simulation

For dielectric properties investigation using 900 MHz cavity, electromagnetic fields distribution should be precisely estimated. In addition, when using microwave heating for sample heating, it is important to figure out the temperature profile of the sample. In a real test, it is challenging to observe the temperature distribution and electromagnetic field distribution within a sealed metal chamber. Therefore, using computer-based finite element analysis, Both the distribution of the electromagnetic field and the temperature profile had been estimated. COMSOL Multiphysics, a commercial finite element analysis program, was used to carry out the numerical simulation. which is frequently used for microwave heating study. The numerical simulation employed this, which is extensively used for microwave heating analysis.

3 Geometry

To create the cavity model COMSOL requires a number of steps to be followed, firstly, the geometry is created which reflects the shape and size of the cavity. The method of creating the cavity is represented in Figure 2.

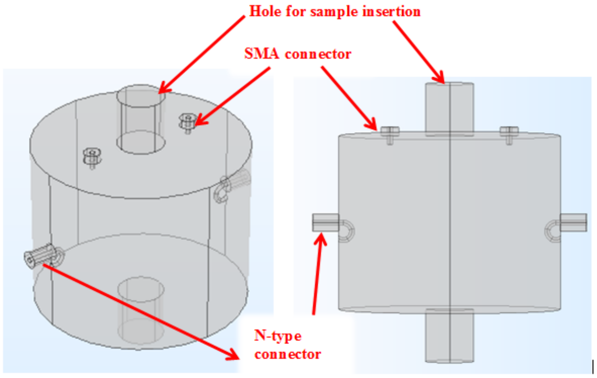

Figure 2 labelled diagram of the geometry of the cavity.

4 Mesh

The mesh size has an impact on the convergence and precision of the analysis, making it a crucial component of the simulation. For instance, the calculation time increase 16 times, and memory use increases eight times, when the mesh size reduces in half. Figure 3 shows the initially generated mesh. The level of accuracy of this mesh can be increased by changing the element size. Completing this step means that the model can now be solved.

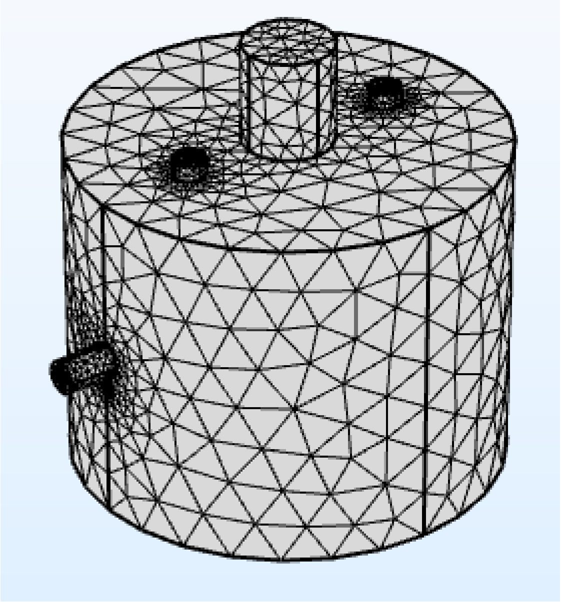

Figure 1 generated mesh.

5 Field distributions

خطأ! لم يتم العثور على مصدر المرجع. presents the electric field distribution for the TM010 mode inside this large cylindrical cavity, including the 2.5 cm diameter sample gap which behaves as a microwave neck. COMSOL software is used to compute and visualize them. From the centre of the cavity to the border walls, the electric field's strength drops until it reaches zero.

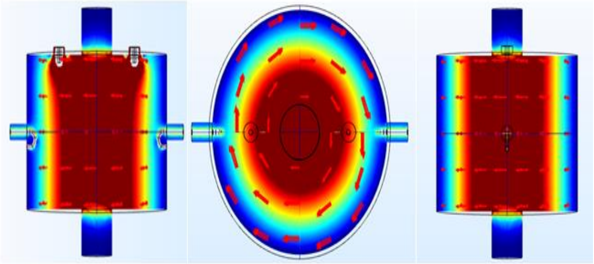

Figure 4 Distribution of the electric field in a 900MHz cavity using the TM010 mode.

6 Temperature distributions

For the first thirty seconds, the temperature in the centre of the sample (potato) is shown against time in Figure 5. The potato has a low thermal conductivity, which causes heat to spread slowly. After 30 seconds, the temperature profile displays a prominent peak in the middle.

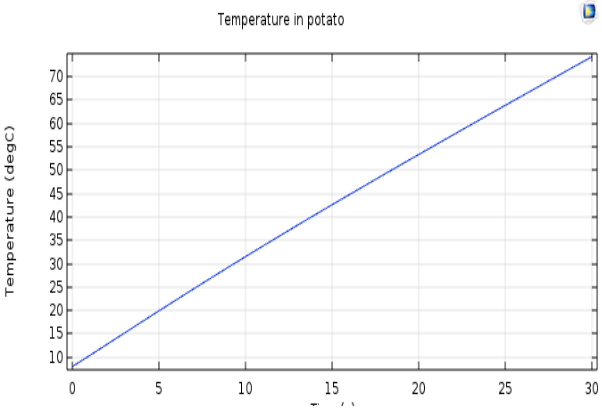

Figure 2 Temperature in the center of the sample during the first 30 seconds of heating

7 Conclusions

In this work, microwave cavity resonator was designed and simulated for heating applications at frequency of 900 MHz to be accomplished to contain large size of samples. Distribution of the fields inside the cavity and the heating efficiency were simulated using COMSOL Multiphysics software.

The power absorbed in the sample is determined to be roughly 60% of the input microwave power. The majority of the excess power is reflected back via the port.

The sample (potato) has a low thermal conductivity, which causes heat to spread slowly. After five seconds, the temperature profile displays a prominent peak in the middle.

When the potato is heated further, the temperature in the core finally rises to 70 °C, and the water contents begin to boil, dehydrate the center and transmitting heat to the outside regions via steam.

Conflict of interest: The authors declare that there are no conflicts of interest.

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