Calorimetric determination of microwave energy absorption in - resonant or multimod applicators in a continuous-flow reactor

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Microwaves (MWs) cover a broad spectrum of applications, all having in common the MWs capacity of deploying energy "in situ", throughout the interactions matter-electromagnetic field, overcoming the losses implied when the same amount of energy should be transferred through one or several interfaces. When it comes to process intensification, the key is the efficiency of the deployed energy usage by the process.

In this work, we present the performances of a new applicator based upon two concepts: resonance and focus of the electromagnetic field (EM) on the target. At resonance frequency, the cavity stores the MWs energy – therefore, no MWs will be reflected back into the wave guide. The Q factor, proportional to the ratio of energy stored in the resonator and the energy dissipated per cycle, is a measure of the frequency selectivity of the resonator. When the applicator is at resonant frequency, the Q factor is very high. When the dimensions of the applicator are not in resonance with the MWs frequency, the Q factor drops drastically, since the reflected power starts having high values. The reflection coefficient, S11, witnesses how much of the delivered power is reflected back to the wave guide – the lower the value is, the smaller the fraction of power reflected back. The focusing capacity of the applicator is measured with the liquid absorbed power yield, η_{PL}, defined as the ration between the total power dissipated in the liquid phase and the total power introduced in the applicator. Closer to one the values of the yield, higher the applicator capacity to focus the MWs energy on the target.

In the case of MWs with a frequency of 2.45 GHz and TE_{10} mode, the smallest resonant cavity is a cube with the side equal to 86.525 mm. Unfortunately, when placing a load in the resonant cavity and attached a wave guide to it, the interactions matter-electromagnetic field will change the latter, increasing the energy reflected back. Starting from the aforementioned side, the dimensions of the new applicator were searched such that the liquid absorbed power yield to be maximum – the corresponding new side is 145.26 mm.

This new applicator was tested, both in laboratory and in COMSOL Multiphysics® modeling software, for several liquids with very different loss tangent magnitudes and temperature behavior, namely water, ethylene glycol, cyclohexane, acetic acid and 2-propanol, flowing through a special type of reactor, vertically coiled. The MWs generator is a solid-state Miniflow, with a maximum power of 200 W and a special integrated circuit to measure the direct and reflected power. A conventional multi-mode applicator with a special adaptor ensuring the transition from the coaxial guide to WR340 guide, thus permitting the usage of the same solid-state generator, was employed as reference against the new applicator, doing the same experimental and simulation work.

The parameters used to compare the performances of both applicators are:

- the specific power absorbed by the liquid phase (SAR);
- the liquid absorbed power yield;
- the Q factors;
- the reflection coefficient.

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