FINITE ELEMENT MODEL FOR MICROWAVE HEATING USED IN CHEMICAL RECYCLING OF PLASTIC WASTE MATERIAL

A. Frisa-Rubio[1], C. González-Niño[1], N.R. García-Polanco[1], T. García-Armingol[1]

[1]Fundacion CIRCE, Zaragoza, Spain

Abstract

Introduction
Over the last years, there has been an increasing interest in plastic recycling as an alternative to reduce fossil fuel dependency. In this light, chemical recycling has been presented as a promising strategy to maximise the recycling rate, although this technology presents drawbacks such as its high energy consumption. In addition, the use of conventional heating technologies reduces the potential environmental benefit of recycling. As a potential solution to solve this issue, the substitution of conventional heating technologies by microwave (MW) heating can bring important benefits. The purpose of the current work is to design and optimize a MW reactor for polymer recycling using up to 8 ports emitting electromagnetic waves, simulating the physical process of material heating inside the vessel. Several works are available in the literature concerning single-frequency simulation (S-F) for different geometries and applications, however, few research articles delve into multi-frequency (M-F) simulation.

Use of COMSOL Multiphysics®
In this model, the finite elements simulation of the microwave heating of the reacting mixture is achieved coupling the "Electromagnetic Waves, Frequency Domain" physics from the RF Module with the "Heat Transfer in Fluids" physics from the Heat Transfer Module through the "Electromagnetic Heating" Multiphysics. This complex problem also included temperature-dependent permittivity values that were obtained experimentally.

Results
A prediction of the electric field and temperature distribution in the reactor over time was obtained using the proposed framework under different geometrical configurations. Special care was taken to avoid the induction of temperature hotspots in the domain of the chamber, ensuring uniformity of processing conditions. The main expected results consist in the design of an appropriate MW reactor for depolymerization, capable of producing an homogeneous electric field and reducing the heating time to reach the target temperature (170-200 °C).

Conclusions
The model generated was proven a useful tool for reactor design and optimisation, being able to capture temperature changes in the reacting mixture due to the electromagnetic heating induced by the microwaves. Additionally, the framework developed for this model can be easily modified to predict the performance of other microwave-assisted reactions.

Keywords: Electromagnetic Heating, Design Optimization, Microwaves, Plastic Recycling, Multi-Frequency Microwaves.

Figures used in the abstract

Figure 1 : 3D geometry of the proposed MF microwave reactor, where the waveguides are easily identifiable. Right: cut plane showing the norm of the electric field generated in the reaction chamber. Colorbar values in V/m.