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Numerical Simulation of High Frequency Electromagnetic Wave in Microwave Cavity for Soot Oxidation

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Abstract. Soot oxidation temperature by high frequency electromagnetic energy was proposed using numerical simulation by combining electromagnetic with transient thermal analyses. Equation of electric field distribution in a microwave cavity with perfect electric conductor surfaces and TE_{10} mode is formulated from Helmholtz equation. The dissipated heat distribution is calculated from the electric field distribution. Six study cases for electric field and dissipated heat distributions were implemented by using ANSYS software based on finite element method. The impact of dielectric sample properties, position, size and shape inside the microwave cavity were predicted. The results from the simulation of electric field and dissipated heat were compared with available data in literature and showed the validity of the analysis. It was found that the electric field forming hot spots at penetration depth and front corners of the soot sample and penetration depth is equal to 12mm but equal to 0 for samples with dimensions less than penetration depth. Dissipated heat pattern depend on electric field pattern and dielectric properties.

Introduction

Soot is produced as a result of diesel fuel burning in vehicles and power plants, which is contributes in air pollution. Soot particles are mostly spherical with less than 1 mm diameter that agglomerate after the end of combustion, to form chain-like structure [1]. Soot is a strong absorb of microwave energy. The high frequency electromagnetic energy or microwave energy is commonly used for material heating. Key advantages of microwave heating include volumetric, rapid, reversed and selective heating [2]. To understand the microwave heating phenomenon many numerical studies were conducted. Sekkak *et al*. [3] solved heat conduction equation in microwave cavity with three-dimensional finite element method edge based to determine temperature distribution of dielectric material post in microwave oven. Tada *et al*. [4] solved Maxwell equations employing two-dimensional finite deference time domain (FDTD) to investigate the electromagnetic field in a microwave applicator filled partially with a dielectric material, operating in the dominant TE_{10} mode at a frequency of 2.45 GHz. The electric field and power distributions were predicted for a lossy material. Huang *et al*. [5] solved the coupled electromagnetic field equations, reaction equation and heat transport equation by using FDTD method to predict temperature rising and transmitted power through the electromagnetic cell. Shayeganrad *et al.* [6] theoretically and experimentally investigated the sparking of metal objects within the microwave oven, based on the electrostatic field. The finding revealed that thick metal pieces tend to reflect the microwave, while thin metal objects produce electric current on the surface and this current with microwave frequency produces high electric field and spark at the tips. Shukla *et al.* [7] compared the temperature distribution within multi-sizes cylindrical sample heated in microwave furnace with conventional furnace, using a two-dimensional finite difference approach. Their finding was that the efficiency of microwave heating depends on the sample size and material thermal conductivity. Makul *et al.* [8] analyzed heat generation by microwave energy inside hardened cement paste. The finding was the compressive strength of the hardened cement paste increased and then slightly decreased from 14-18 days. Ciacci *et al*. [9] proposed two-dimensional mathematical model for the microwave-induced