AN ANALYTICAL STUDY OF RADIATION EFFECT ON THE IGNITION OF MAGNESIUM PARTICLES USING PERTURBATION THEORY

M. BIDABADI, S. MONTAZERINEJAD and S.A. FANAEE

Iran University of Science and Technology
Department of Mechanical Engineering, Combustion Research Laboratory, Narmak, Tehran 16844, Iran
bidabadi@iust.ac.ir , sara_montazeri@mecheng.iust.ac.ir, sab.famech@gmail.com

***Abstract*-- An analytical method is proposed to solve the heat Energy equation of combustion of magnesium particles with allowance for the heterogeneous chemical reactions and the region of the thermal influence of the particle on the gas. In this model the solution of the problem in a steady formulation is found and the flame propagation mechanism is considered to be radiation and conduction. Radiative heat transfer plays a major role in single particle combustion. Flame equations of the single particle combustion are solved via the new nonlinear differential equation by using perturbation theorem. In this paper we can apportion the magnesium-particle ignition to regular regimes and also regime of particle extinction and the ignition. Under the steady approximation, the values of particle and gas phase temperatures are calculated and by adding radiation term in conservative equations, both of these parameters will be increased.**

***Keywords*— heterogeneous, Radiative heat transfer, nonlinear equation, perturbation theorem.**

I. INTRODUCTION

The problem of physicomathematical modeling of ignition and combustion of metal samples is of considerable interest for various branches of industry (Fedorov *et al.*, 2003).

The main objects described in Fedorov *et al.* (2003) are the pointwise and partly distributed models of ignition of small metal particles with low-temperature oxidation proceeding on the particle surface. The heat dissipated in to the gas phase was ignored. This means that the thickness of the so called surrounding film is negligibly small. It seems of interest to study the effect of this parameter on the thermal history of the reacting particle.

Particle diameter plays a significant role in determining the relevant combustion mechanisms by affecting the characteristic transport diffusion time relative to the chemical kinetics time. A large diameter particle at high pressure may burn under diffusion controlled conditions, whereas a small particle at low pressure may burn under kinetically controlled conditions (Yetter and Dryer, 2001; Huang *et al.*, 2006). The oxidizer type also has strong effects on magnesium particle combustion, since the flame and surface temperatures can be affected by transport in the surrounding gas. In the last two decades with the rapid development of nonlinear science, an ever increasing interest of scientists and engineers in the analytical techniques for nonlinear problems appeared. The widely applied techniques are perturbation methods. Perturbation method is one of the well-known methods to solve the nonlinear equations which was studied by a large number of researchers such as Bellman (1964), Cole (1968) and O'Malley (1974). A valuable model of ignition of single magnesium particle, proposed by Fedorov and Shul'gin (2006), is expanded in this study. In previous theoretical models (for example, Fedorov *et al.*, 2003; Fedorov and Shul'gin, 2006; Fedorov, 1994; Fedorov, 1996) it is assumed that radiative heat transfer was neglected. The radiation term is added to the previous model (Fedorov and Shul'gin, 2006), and its effect on the combustion of magnesium particle is investigated. The initial investigation of the combustion of bimodal aluminum and iron particles is also studied with help of the presented model.

II. MATHEMATICAL FORMULATION

Combustion of fine metal particles, which takes place in the gas phase (where evaporated sample particle reacts with oxidizer) is formulated here.

We consider a metal particle of radius r_p surrounded by a gas layer of thickness L-r_p. We assume an exothermic chemical reaction of oxidation to proceed on the sample surface.

The main focus of this research is made on the effect of radiation on the combustion of metal dust particles. This paper develops the previous model published by Fedorov and Shul'gin (2006).

Then the mathematical model that describes the temperature fields in general case T_i has the form

$$\rho_i c_i \frac{\partial T_i}{\partial t} = \lambda_i \frac{1}{r^{\upsilon}} \frac{\partial}{\partial r}\left[r^{\upsilon} \frac{\partial T_i}{\partial r} \right] + Q_{rad}. \tag{1}$$

The temperature of the ambient gas and sample particle are indicated by T_i.

In the previous relationship, υ is the factor of symmetry equal to 0, 1, and 2 for the planar, cylindrical, and spherical cases, respectively, ρ_i, λ_i and c_i are the density, thermal conductivity , and specific heat of the phase; the subscript i=1 and 2 refers to parameters of the gas and the particle respectively. Q_{rad} is the radiation heat transfer, which was not taken into account in previous models but is considered in the present article. In fact, it distinguishes the present study from the previous works in this field.

Radiation heat transfer is given by the Stefan-Boltzmann law,