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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　Nepal Chandra Roy

学 位 論 文 題 名

Modeling and theoretical study of combustion of solid fuel over an inert porous medium
(多孔質体に付着した固体燃料の燃焼伝播に関する理論的研究)

Combustion of solid fuel in porous medium has attracted extensive attention of many researchers working in the field of combustion and the environment owing to its numerous industrial applications such as: in situ combustion for the recovery of oil, coal gasification, self-propagating high-temperature synthesis (SHS), incineration of solid waste, fire spread, diesel engine and pollution control and sintering process. Diesel particulate filter (DPF) regeneration process is such a typical example of technological application by which solid particulate matters trapped in the porous channel walls of a DPF are burnt out at a steady state. Due to unknown aspects of the combustion of solid matters in the DPF, uncontrolled and unsteady combustion occurs during the DPF regeneration process. Consequently, the DPF may encounter a loss of its mechanical integrity and sometimes it undergoes complete damage and so fails to trap particulate matters efficiently from the exhaust gas. Thus the regeneration process poses a major technological challenge even to the state-of-the-art DPF. To tackle this challenge and for better understanding of the process, the role of mathematical model is widely recognized. But the modeling approaches used to date for describing the regeneration process could not be able to serve the growing demand for engineering modeling tools to assist the diesel particulate filter and thereby for the development of system optimization because of the complexity of the models itself, lack of relevant mechanisms, many input data that are not usually available, computational cost, model consistency and reliability. For these reasons, this research has been motivated to develop a simpler model as well as to provide analytical expressions of the combustion characters of solid fuel deposited over an inert porous medium.

Chapter 1 contains a brief overview of research works on combustion of solid fuel occurring in various processes e.g., diesel particulate filter regeneration process, smoldering combustion, self-propagating high-temperature synthesis and sintering process. From the literature review, we will obtain an idea of developing a model and its theoretical solution. At the end of this chapter, the objective and the strategy of the thesis for achieving the target are presented through a flowchart.

In Chapter 2, a simple mathematical model has been proposed for the combustion of solid fuel deposited over an inert porous medium. With a view to simplifying the model, we introduce a simple parameter “ deposition of fuel ” instead of fuel mass fraction. We employ large activation energy asymptotic to obtain the analytical expressions of the temperature and species profiles as well as the moving speed of the reaction front. A numerical computation has also been performed to determine the sensitivity of the asymptotic analysis for variation of each of the physical parameters so that we can get a clear concept about the deviation of the asymptotic analysis from the numerical solution.

In Chapter 3, we develop a universal model to examine the behavior of combustion wave observed

in porous solid matters (e.g., smoldering, self-propagating high-temperature synthesis (SHS), diesel particulate filter (DPF) regeneration process). A detailed analysis of the opposed flow combustion of solid combustible (e.g., diesel particulate matters trapped in a DPF) deposited over an inert porous medium has been presented here. Analytical expressions of the combustion characters are obtained employing large activation energy asymptotic taking into account the sensible transport processes; namely, heat transfer between the porous medium and gas phases, radiation heat transfer from the porous medium, heat loss from the porous medium to the environment, mass transfer of oxygen from the gas stream to the surface of solid fuel and the effective diffusion in modeling the species diffusion. The applicability and adaptability of the model is then validated for predicting the characteristics of smoldering combustion and thus SHS process. We also solve the governing equations numerically and a comparison is made between the asymptotic analysis and the numerical solution.

It is well-known that one-dimensional propagation of a combustion wave is classified as forward and opposed. Both modes are jointly recognized not only in fire safety problems but also in technological applications. So a comparative study between the forward and opposed modes is the subject of Chapter 4. To accomplish this goal, firstly we find the analytical solutions of forward mode utilizing the model developed in Chapter 3 and then we use the solutions of opposed mode that are already obtained in Chapter 3. The lines of demarcation of unsteady behaviors of the reaction fronts of forward and opposed modes are identified for a variety of conditions aiming at the control of fire safety and the development of new technology.

In Chapter 5, we try to solve a practical application of forward and opposed modes considering the fact that a sample is ignited somewhere around the middle and after a short period of time, two reaction fronts separating from the ignition point propagate opposite to each other. The problem has been solved to some degree. The effects of various physical parameters have not been fully uncovered yet and so it is discussed as ongoing research.

Finally, the concluding remarks of the thesis have been summarized in Chapter 6. In addition to, the direction of future works is also mentioned in this chapter.