九州大学学術情報リポジトリ
Kyushu University Institutional Repository

Numerical analysis and modeling of non-spherical particle’s motion

張, 煒

https://doi.org/10.15017/1866292

出版情報：Kyushu University, 2017, 博士（工学）, 課程博士
バージョン：
権利関係：

（様式２）

氏　　名　：張 煒

論 文 名　：Numerical analysis and modeling of non-spherical particle's motion
（非球形粒子運動の数値解析及びモデリング）

区　　分　：甲

論 文 内 容 の 要 旨

Around the world, coal is an indispensable primary energy and responded for 36% of the electricity production. However, since coal has a high CO_2 emission intensity, it makes a greater contribution to the global warming. Hence there is an urgent need to realize a clean coal technology to reduce the CO_2 emission. Many technologies have been developed, such as, coal washing, low-NOx burner, and IGCC. Among them, the IGCC (Integrated Gasification Combined Cycle) system is the leading candidate for the electricity production with CO_2 capture at present. The IGCC system has many benefits than the conventional pulverized coal power plant. In a whole IGCC system, a coal gasifier and a purification system of the syngas determine whether the IGCC system can be commercialized or not. Therefore, the coal gasifier designing meets a lot of requirements. All of these requirements indicate that the designer of the coal gasifier must have a deep understanding inside the gasifier. Since the phenomenon of the solid-gas multiphase flow inside the gasifier is complex, Computational Fluid Dynamics is often applied. However, usually in the solid-gas two-phase simulations, in order to reduce computational cost and simply the numerical problem, the particle's real shape is neglected and assumed to be spherical. Some works have been done and begin to unravel the motion characteristics of a spheroidal particle by experiments and simulations, but most of them only focused on the behavior of a single spheroidal particle. A numerical study to model the effects of a non-spherical particle's shape on the particle's motion and apply the model to industrial problems has not been published yet.

This dissertation mainly investigates the particle shape effects. As the first stage, this dissertation focuses on the behavior of the spheroidal particle. A new spheroidal particle motion model is developed and applied to isotropic turbulent flow and real scale jet burner flow. And single spheroidal particle's ignition behavior is also discussed. The results suggest that the particle's shape effect may have significant influences on the particle's dispersion, ignitability, flammability, and the concentration of combustible gases released by the particle, which

require further study.

This dissertation consists of six chapters shown as follows.

In chapter one, the background of this study is introduced. The meaning of coal utilizing in the world is explained and the IGCC technology is introduced. The problems need to be solved are listed.

In chapter two, a new spheroidal particle motion model is proposed. A simulation of a single spheroidal particle moving in a uniform flow is performed. The motion is discussed and its drag coefficient curve is examined by extracting the PDF (Probability Density Function). The PDF is similar to the sine curve's PDF. Thus the spheroidal particle motion model is proposed based on a random number, the maximum and minimum drag coefficient, and sine curve's PDF. Here the random number represents the spheroidal particle's rotation.

In chapter three, the new model is introduced into a two-way solid-gas simulation code. It simulates the particles' dispersion in an isotropic turbulent flow. The results of the particles' dispersion are analyzed by D (Distribution) number method and RDF (Radial Distribution Function) method. The differences between the new spheroidal model and empirical spherical model are discussed. The results are organized in terms of the Stokes number and demonstrate that the particle's shapes do affect the particles' dispersion behavior.

In chapter four, an experiment and correspondingly a simulation of particles' dispersion of a real scale jet burner are presented. The newly proposed spheroidal and empirical spherical model are used. Simultaneously, the particle's diameter distribution effect is also considered and discussed. Compared with the particle's shape effect, the particle diameter distribution has a much stronger impact on the particles' dispersion behavior in both simulation and experiment. Thus in the simulations considered the particle's diameter distribution, the results may still be able to keep a certain accuracy while using the empirical spherical particle motion model. However, in the simulations with mono-diameter particles, the particle's shape effect is obvious and shall be considered carefully.

In chapter five, a simulation to investigate the single spheroidal particle's ignition behavior is performed. The particle releases volatile gas and its velocity is calculated using a newly developed devolatilization model called Extended-CPD (Extended Chemical Percolation Devolatilization) model. The volatile gas is assumed to be methane and the gas reaction is calculated by two-stage global reactions. The results are in quite well agreement with the published experimental results. The diffusion and premixed regions or flames around the particle are distinguished by employing the Flame Index.

In chapter six, the conclusions are presented and the future works are suggested.