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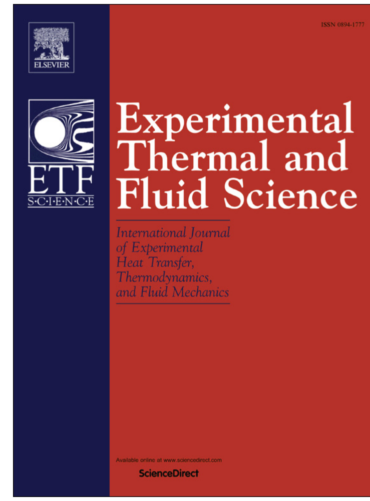

Experimental investigation on incipient mass flow rate of micro aluminum powder at high pressure

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Experimental investigation on incipient mass flow rate of micro aluminum powder at high pressure

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Abstract

Experiments on powder entrainment have been carried out to study the influence of different variable parameters on incipient mass flow rate. A semi-empirical model was established by taking into account many affecting parameters, including: initial total pressure, particle mean size, throttling orifice area and powder volume fraction. This model could be used to predict the incipient mass flow rate with particle mean sizes from 10μm to 100μm. By comparing the relative error between the semi-empirical model and previous model, the results show that the semi-empirical model has higher prediction accuracy than previous model.

In the progress of particle entrainment, there exists three stages: flow-out stage with gas (stage I), flow-out stage with large amounts of particles (stage II), and flow-out stage with small amount of particles (stage III). The result of stage I shows that there exists a pickup delay for particles, which is good for the ignition sequence matching research of powder engine.

Keywords: Semi-empirical model, Powder entrainment, incipient mass flow rate, Powder engine, High pressure

1. Introduction

Since using metal powder as fuel, and gas or solid particles as oxidant, powder engine has the functions of thrust regulation and multiple pulse ignition. In the early 1960s, American Bell Aerospace Company first launched the ignition validation work for aluminum powder (AL)/ammonium perchlorate (AP) powder rocket engine [1-3]. However, this project was rarely reported because it was put on hold due to limitation of powder fluidization and particle combustion technologies. As the fields of deep space detection and hypersonic flight vehicle springing up gradually, the powder engine concept has been put forward, such as Mg/CO2 powder rocket engine used for Mars exploration and the metal powder scramjet engine used for hypersonic flight vehicle [4-9]. Other work like experimental verification on them has also been widely carried out [10-13].

In the developing process of powder engine, the high efficiency technology for particle ignition is one of the key research points, and successful engine ignition is not only depends on the powder fuel's own physical and chemical properties, but also the state of powder fluidization and conveying.

At present, there are many public research reports on ignition properties of particle fuel (such as magnesium, aluminum, boron, etc.), and some ignition mechanisms of particles were revealed, which are beneficial to the design of engine ignition energy to a certain extent [14-15]. However, previous ignition mechanism researches were mainly based on static particles. It is not applicable to powder engine for its requirement of particle dynamic ignition. As a result, it is necessary to study the ignition characteristics of powder fuel in moving state.

As one of major influence factors for powder engine ignition, the value of incipient powder mass flow rate directly relates to the success of ignition. When working conditions remain the same for ignition energy, excessive incipient mass

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