論文審査の結果の要旨

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This dissertation presents a study on performance characteristics of gas-ejector applied for solar-powered ejector air-conditioning system. A theoretical model considering real physical processes inside an ejector is proposed and validated to evaluate the performance of ejector under overall operating conditions. The proposed model is able to accurately predict the performance of ejector, and the model is more feasible when applied to a variable geometry ejector with unstable heat sources.

Four main original achievements of the study are listed as follows:

1. It is confirmed by visualization and numerical methods that the driving flow Mach wave affects the driving flow and suction flow regions inside the ejector. The flow region further affects the ejector entrainment ratio.
2. The driving flow Mach wave characteristics from an adjustable nozzle inside a variable geometry ejector is studied by visualization and numerical methods. The characteristics of the occurrence and propagation of driving flow Mach wave is clarified.
3. The influence of driving flow Mach wave on the performance of ejector is validated by experimental method in a wide range of operating conditions.
4. A theoretical model is proposed considering the driving flow Mach wave, the model accurately predict the performance of ejector under overall operating conditions.

Moreover, this study achieves additional contributions:

1. A performance comparison between a convergent-divergent nozzle and a convergent nozzle applied to variable geometry ejectors is conducted. The performance characteristics of each nozzle is concluded.
2. The radial velocity distribution of the suction flow has significant influence on the ejector performance. The influence is discussed using numerical method.

The dissertation comprises eight chapters. Chapter 1 outlines the background and current status of the study, major problems, research objectives, research outline, and originalities of the study. The study is established for gas-ejectors applied for solar powered ejector air-conditioning systems. As the current acknowledged ejector theory is mainly established for fixed geometry ejectors using stable heat sources, the existing theoretical models are not able to evaluate the performance of ejector accurately when a variable geometry ejector is applied to use unstable heat sources. A major influence factor which is absent in the conventional ejector theoretical is the driving flow Mach wave. To propose a theoretical model considering the driving flow Mach wave, the main objectives of the current study is 1).Use visualization and numerical simulation methods to study the occurrence and propagation characteristics of the driving flow Mach wave inside a variable geometry ejector. 2). Establishing a theoretical model to accurately evaluate the variable geometry ejector under various operating conditions, and validate the theoretical model using experimental methods. Additional goals are 1). Suggestions to select the appropriate nozzle structure.

2). The consideration of the suction flow velocity distribution in the theoretical model.

Chapter 2 introduces a widely acknowledged theoretical model of ejectors, and an outline of theoretical model development. The important factors that should be considered in a theoretical model are introduced in this chapter, such as the driving flow Mach wave, the radial velocity distribution, and the development of a mixing shear-layer. The influence of the driving flow Mach wave is crucial, for it influences the driving and suction flow region inside the ejector. Clarifying the driving flow development by considering the influence of Mach wave will significantly enhance the accuracy and feasibility of a theoretical model.

Chapter 3 proposes a numerical investigation towards the driving flow Mach wave, as well as the flow inside variable geometry ejectors. Two variable geometry ejectors using a convergent-divergent nozzle and a convergent nozzle, respectively, are adopted in the simulation. The Mach wave characteristics from both nozzle are analyzed using the velocity contour inside the ejector. Meanwhile, a performance comparison is also conducted using the two ejectors. Lastly, the radial velocity distribution inside the ejector is discussed using the simulation result.

Chapter 4 proposes a visualization experiment on the driving flow Mach wave inside the ejector, and a simulation model on the driving flow development inside ejector considering the Mach wave. Firstly, Schlieren photography method is adopted to observe the Mach wave occurrence and propagation inside a transparent ejector. A fundamental driving flow Mach wave characteristics is obtained. In addition, variable geometry ejector is applied to the Schlieren system to study the influence of an adjustable nozzle on the Mach wave strength. Lastly, a simulation model is proposed to predict the driving flow development inside the ejector, the method of characteristics is used to consider the driving flow Mach wave. The simulation model is validated by the visualization results, it is proved that the driving flow development can be accurately predicted by the proposed simulation model.

Chapter 5 is an introduction of a theoretical model to evaluation the performance of ejector under overall operating conditions. The originalities of the proposed model is that firstly, the method of characteristics introduced in chapter 4 is adopted to predict the driving and suction flow region inside the ejector. And secondly, the radial velocity distribution of suction flow is considered to accurately calculate the suction flow rate. The proposed model is validated by both data from literature, and experimental data conducted in the current study. The results show that the proposed model can predict the performance of ejector with higher accuracy than the conventional theoretical model. In addition, the proposed model is more adaptive, it can accurately predict the ejector performance in a wide range of operating conditions.

Chapter 6 introduces the experimental study, the performance of ejector is tested under an wide range of operating conditions. The theory of the driving flow Mach wave is experimentally validated in this chapter. Firstly, the influence of the operating conditions, superheat temperature are discussed. Secondly, the performance of the convergent-divergent nozzle and the convergent nozzle applied to the variable geometry ejector are compared, it is validated that each nozzle has its advantage in a specific operating condition zone. Moreover, the performance characteristics of the variable geometry ejector under unstable heat source is discussed using experimental results.

Chapter 7 shows a theoretical study on a solar powered ejector air-conditioning system. A screening of refrigerant is conducted using the theoretical model proposed in chapter 5. In addition, a cycle simulation is conducted to discuss the electricity-saving potential of the solar-powered ejector air-condition system applied in Japan.

Chapter 8 is a conclusion of important achievements of the current study, as well as a statement of the future works. In the current study, the driving flow Mach wave is observed and discussed using visualization and numerical methods.

A simulation model using the method of characteristics is adopted to accurately predict the driving flow development considering the Mach wave. The simulation model is further adopted in a theoretical model which accurately predict the ejector performance under a variety of operating conditions. The theoretical models is validated by experimental test results. The theory illustrated in the current study brings a comprehensive understanding of the complex flowing and mixing process inside an ejector. In addition, the proposed theoretical model is proved to be practical to the application and optimization of the variable geometry ejector using unstable solar energy. The future work should be focused on operating an ejector air-conditioning system using solar energy in practical, as well as to further optimize the ejector structure to achieve higher performance.

本論文について、論文提出者が主体となって太陽熱エジェクタ空調に用いるガスエジェクタにおける可視化、数値計算、実験を行ったものであり、エジェクターの研究分野において、本研究の学術上の独創性と有用性は十分である。本論文は博士の学位論文として合格と認められる。したがって、論文提出者に博士（環境学）の学位を授与出来ると認める。

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