論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	A Study of MHD Electrical Power Generation Using Xenon-Seeded Noble Gas Plasma
著者(和文)	ORK KIMSOR
Author(English)	Kimsor Ork
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12760号, 授与年月日:2024年3月26日, 学位の種別:課程博士, 審査員:奥野 喜裕,岡村 哲至,平井 秀一郎,末包 哲也,笹部 崇
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12760号, Conferred date:2024/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 エネルギー 系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 工学 ）
学生氏名： Student's Name	ORK KIMSOR	審査員主査： Chief Examiner	奥野 喜裕

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Magnetohydrodynamic (MHD) electrical power generation directly converts the enthalpy of a high-temperature conductive working gas (e.g., plasma) into electrical energy in accordance with Faraday's law of induction without the use of mechanical moving parts, such as those in gas turbine systems. Consequently, it can operator with working gases that have high temperatures than can be used in gas turbine systems, which in turn allows power plants to achieve a high thermal efficiency. This would lead to reduced consumption of fossil fuels and remarkedly reduced thermal pollution. A working gas with high electrical conductivity is needed to achieve high performance of an MHD generator. Conventionally, alkali metal (Cs, K) is usually added to the noble gas (Ar, He) to enhance the electrical conductivity. Because of some complications in the material handling, few methods that do not use alkali metal have been suggested, one of them is the use of Xe that has a relatively low ionization potential among the noble gases as a seed material. The addition of Xe to other noble gases may reduce the pre-ionization power (net power for producing plasma) and Xe is not solidified in the power generation system; consequently, the system can be expected to be significantly simplified. Therefore, it is worth to study the feasibility and features of Xe-seeded noble gas plasma MHD power generation.

In the present thesis, the feasibility, power generator performance, challenges, and future prospects of a Xe-seeded noble gas plasma MHD generator that utilizes a noble gas Xe as a seed material instead of alkali metal were studied. The conclusions of the present study are as follows.

Similar to the conventional alkali metal seeded plasma, in Xe-seeded noble gas plasma, uniform plasma can be produced and maintained, and under the same total ionization degree the same power generator performance can be obtained. However, in alkali metal seeded plasma, stable and uniform plasma is achieved when the critical Hall parameter exceeds the Hall parameter generally based on the linear perturbation theory, whereas in Xe-seeded noble gas plasma, uniform plasma is maintained when the characteristic time of electron number density is longer than the residence time of the working gas even under the electron temperature condition at which the unstable plasma is suggested from the linear perturbation theory.

Adding small amounts of Xe (Xe seed fraction around 0.01–1.0%) to mother gas (noble gas) reduces the pre-ionization power ratio while maintaining high power generator performance. Particularly, among the mother gases Ar, Ne and He, Ne/Xe provides the highest generator performance, and at seed fractions around 0.05–1.0%, the pre-ionization power ratio decreases to about 60% of that for pure Ne. Adding excessively amounts of Xe, however, deteriorates the performance. These are attributed to a relatively small atomic weight of Ne, a small collision cross section of Ne atom with electron, a low ionization potential of Xe, and a large atomic weight of Xe and a large collision cross section of Xe atom with electron.

In the MHD power generation experiments with Ne/Xe plasma pre-ionized by a radio frequency (RF) electromagnetic field, the enthalpy extraction ratio (ratio of output power to thermal input) increased with increasing RF input power ratio. The enthalpy extraction ratio of about 5% was obtained for seed fractions of 1.0% and 5.0%. In the numerical simulations for this experimental generator, when an appropriate inlet electron temperature (inlet ionization degree) is assumed (for instance, at seed fraction of 1.0%, the inlet electron temperature is 6280 K (the corresponding inlet ionization degree is 1.70×10^{-4})), the plasma structure obtained in the simulations is almost identical to the nonuniform plasma structure observed in the experiments, as too does the enthalpy extraction ratio. Thus, the experimental results can be reproduced by the numerical simulation. Moreover, in the experimental generator, if an inlet ionization degree of over $5–6\times10^{-4}$ is achieved, an enthalpy extraction ratio above 20% can be obtained, which is expected to surpass that for pure Ar.

In alkali metal seeded plasma, the plasma with high electrical conductivity is relatively easy to be produced and maintained; nevertheless, there are concerns about the handling of seed material when operating power generation system. For Xe-seeded noble gas plasma, on the other hand, in addition to

reduction of pre-ionization power by adding Xe, the generator performance equivalent to that of alkali metal seeded plasma can be expected, and the issues when operating power generation system can be eliminated. Here, the key is to achieve the appropriate electron temperature (ionization degree) at generator inlet. In other words, if an appropriate inlet electron temperature (inlet ionization degree) can be achieved under a low pre-ionization power due to the addition of Xe, a promising power generation system that eliminates the concern issues in alkali metal seeded plasma can be constructed, that is suggested by the experiments and numerical simulations in the present study.