Numerical Analysis of a Low Power Non-transferred Arc Plasma Reactor for Methane Conversion

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It was simulated that thermal flow characteristics and methane conversion reaction in the low power arc plasma reactor for efficient storage and transport of methane, the main component of shale gas. The temperature and velocity distributions were calculated by a self-developed magnetohydrodynamics (MHD) and a commercial ANSYS-FLUENT codes, and the chemical reactions of methane conversion was included in the numerical analysis using chemical reaction data from HSC chemistry code.

It was performed according to the kind of discharge gases as (1) Ar and H2, (2) He and H2, (3) N2 and H2. Total flow rate of discharge gas was 9 L/min, and the hydrogen gas flow rate was fixed as 1 L/min. In the actual experiments for the methane conversion reaction, the input power was 169, 295, and 410 W at 0.620, 1.430, and 0.424 A, respectively. The simulated results verified by the comparison of calculated arc voltage and measured arc voltage with permissible low error as 2 to 4 %. Although high temperature region over 1,600 K that is able to pyrolyze methane gas was generated in all operating condition, those volume is depends on the kind of discharge gases due to the different transport properties. At the He-H_2 discharge gas, despite the middle input power, the high temperature region over 1,600 K is smaller compared with those of Ar-H_2 and N_2-He discharge gases. At the Ar-H_2 and N_2-H_2 discharge gases, the temperature region is almost equal. Since the electrical resistance at the Ar-H_2 discharge gas was lower than N_2-H_2, relatively high temperature region was widen at the smaller input power.

The chemical reactions of methane conversion were applied to the numerical analysis. The conversion reactions of methane were to three C_2 hydrocarbons gases as ethane (C_2H_6), ethylene (C_2H_4), and acetylene (C2H2). It was calculated that the concentration of these C_2 hydrocarbons at the exit of reactor. Those values were correspond with measured values within 5 %.

It was developed the numerical analysis method which simulates chemical reactions by thermal flow, and verified by comparison of the calculated and measured values for the input power and concentration of chemical species. As a result, it was revealed that the effect of the discharge gas is important to correctly predict the methane conversion by thermal flow. In addition, the temperature range of the variables defining for methane conversion is also important.