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Studies of the Non-Equilibrium MHD Power Generation in the Shock Tunnel

Masahiko MIYATA (宮田昌彦)

The properties of plasmas in the non-equilibrium MHD power generator have been studied theoretically and experimentally. Using a three-fluid plasma model, relaxation processes in a Raval nozzle and in a MHD generator were analysed numerically. Main assumptions of the calculations are 1) slightly ionized argon is used as the working gas, 2) one dimensional motion of the fluid, 3) steady state and 4) three body recombination of ions. Results of this calculation show the values of the electron density and electron temperature in the nozzle is 5 times higher than that of the predicted by the equilibrium theory and the relaxation length in the power generator depends on the inlet electron temperature. Experimental verifications of the theory were made in the argon shock tunnel. But electron density in the nozzle varies following equilibrium chemical reactions and current density may be affected by the Lorents forces in the generator. Preliminary experiments of the non-equilibrium ionization were made in the He-K blow-down facility. In an applied electric field electrical conductivity of the plasma agreed well to the two-temperature theory if the loss parameter was taken to be 10, but in the power generation experiments the plasma was in thermal equilibrium. Following these preliminary works, MHD power generation experiments in the argon shock tunnel were made using the plasmas with gas temperature of 3000° K, gas pressure of 0.3 atm., Mach number of 3.0 and using the magnetic fields of 0.61 Wb/m². Measured electrical conductivity agreed very well to the non-equilibrium theory, and output power of the generator reached to 400 kW. This work shows that the type of the most effective non-equilibrium MHD power generator is the supersonic blow-down wind tunnel with pre-ionization at the inlet of the generator.