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INVESTIGATION OF ELECTRON BEAM HEATING CHARACTERISTICS IN AIR AT ATMOSPHERIC PRESSURE

Abstract

Atmospheric electron beam air plasma has attracted intense interests in past decade because of its unique merits, which promote its applications in field of surface hardening of metal, gas cleaning of toxic impurities, flow control, and plasma-assisted combustion in scramjet. In these applications, a small and light electron beam plasma generator (EBPG) is necessary. Two contrary problems are usually encountered with the EBPG designer in engineering application. One is reducing the structure size as small as possible; the other is enlarging it in order to avoid the structure ablation by the high energy electron beam. This is because the electron beam deposits large part of its energy in the local region while it collides with air molecules at atmospheric pressure, which leads to seriously heating of air. Thus, the heating characteristic induced by the electron beam is the key problem in the optimization of structure size for EBPG. In the present work, a two-dimensional unsteady heat transfer model combined with Monte Carlo model is established to simulate the electron beam induced heating effect in air at atmospheric pressure. The Monte Carlo model is adopted to deal with the complicated collisions between electron beam and air molecules and to calculate the energy deposition of electron beam in air. The heating characteristic of electron beam is coupled with the heat transfer model by the source term. In order to avoid the occurrence of numerical instability, a so-called finite volume method with SOR is employed to solve the heat transfer equation. Using the model, the time evolution of the temperature is calculated since the electron beam injects into the air. The results show that the temperature in the beam direct heated region is much easier to obtain steady value than the indirect heated region. The influence of beam energy, beam current and pressure on the temperature is examined. The spatial distribution of temperature indicates that the high temperature region varies widely with the different beam parameters. The effects of different size of EBPG on the distribution of temperature are also investigated. By analyzing the results, the structure of EBPG is optimized and a reasonable size of structure for specific EBPG is proposed.

KEY WORDS: electron beam, heating effect, atmospheric pressure, Monte Carlo