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电机与电器

中频真空电弧的等离子体特性

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摘要：

目前应用于未来多电和全电飞机(电流频率360~800 Hz)的中频真空开关正成为研究热点，中频真空电弧理论的研究正不断深入。分析了电弧等离子体连续光谱的辐射理论，在假定中频真空电弧处于部分局部热力学平衡态(partial local thermodynamic equilibrium，PLTE)的基础上，结合实际光学通路的简化模型，得到通过双波段窄带连续光谱测量电子温度和电子密度的方法，然后设计了中频真空电弧的参数测量系统实现上述过程。该系统由添加了双波段窄带滤光片的彩色数字电荷耦合器(change-coupled device，CCD)摄像机和电弧图像数据分析程序组成，能够同时拍摄电弧图像并获取所需数据。在对光学通路模型进行标定后，利用该系统观测了中频(400、650和800 Hz)电弧形态的演变，并测量了真空电弧的电子温度和电子密度，结果表明理论分析和实验过程有效。中频情况下，电弧主要呈现过渡态电弧和扩散态电弧2种形态。过渡态电弧演变迅速，并在电流峰值时刻转变为扩散态电弧。有效值约为8 kA的中频电流在峰值时刻电子温度处于0.5~3 eV之间，而电子密度量级为1020~1021 m-3, 这些与其他学者得到的电弧等离子体参数相符。

关键词： 连续光谱辐射 电子温度 电子密度 中频真空电弧

Plasma Characteristics of Intermediate-frequency Vacuum Arc

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Abstract:

The vacuum switch used in intermediate frequency (360~800 Hz) power system of more/all electric aircraft is being developed, and the theoretical understanding of the arcing process at intermediate frequency is increasing. The continuum emission theory of arc plasma was analyzed, electron temperature and electron density of intermediate frequency (400~800 Hz) vacuum arc were obtained by application of a simplified optical-channel model and detection on the intensities of dual-narrowband continuum emission spectra. Then, a plasma-parameter diagnostic system was designed to implement the above measurement. This system consists of a color CCD camera with a dual-narrowband filter and arc-motion picture analysis software, and it can record the arc appearance and the data for measurement simultaneously. After calibrated by using standard source of radiance temperature, the system was applied to observe the arc mode evolution and measure the plasma parameters. The results confirmed the validity of analysis and measurement in this work. At intermediate frequency, the transition arc mode and the diffuse arc mode exist during arc evolution. The transition arc evolves rapidly, and converts into the diffuse arc at the peak current. At the current peak of 8 kA with different frequencies, the electron temperature varies from 0.5~3 eV, and the electron density ranges from 1020~1021 m-3, which are in agreement with those achieved by other researchers.

Keywords: continuum emission electron temperature electron density intermediate-frequency vacuum arc

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