等离子体雾化用等离子体发生器动静态特性研究 *

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摘　要：等离子体雾化法是当前球形金属粉末制备最具前景的方法之一，但由于其使用的关键等离子体发生器产生的射流不稳的问题，制约着金属粉末制备批次的稳定性。等离子体射流的不稳定性主要来源于电弧的大尺度分流，本文采用实验与信号分析的方法对电压信号进行时域、频域和时频分析来判断弧根的运动，揭示其动静态特性，以实现对等离子体发生器工作状态的实时监测。研究结果表明：反转电极等离子体发生器呈现上升型伏安特性，电压随电流的增大而增大，随着气流量的增大而升高；等离子体发生器在大电流情况下因产生了大尺度分流导致电压波动剧烈，大尺度分流造成的锯齿波状的信号为低频信号，频率在 0.2 到 3Hz 之间；采用短时傅里叶变换对电弧电压信号进行实时分析，可以准确地监测大尺度分流的产生，从而指导等离子体发生器工作参数的调整。

关 键 词：等离子体雾化；等离子体发生器；伏安特性；大尺度分流

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Research on the Static and Dynamic Behavior on the Plasma Torch Used for Plasma Atomization

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Abstract: Plasma atomization is considered as one of the most promising method for manufacturing spherical metal powders. However, because of the instability of the plasma jet generated by the key plasma torch, the uniform quality and fixed yield of spherical powders are not guaranteed. The instability of plasma jet mainly results from the large-scale shunting of the arc. In this paper, the experimental investigation of the plasma torch applied for plasma atomization was carried out and corresponding voltage signal was analyzed in time, frequency and time-frequency domains to judge the movement of arc root and reveal its static and dynamic volt-ampere characteristics, so as to realize the real-time monitoring of the working state of the plasma torch. The results show that the reverse polarity plasma torch has the rising volt-amperecharacteristics, with its arc voltage increasing with the increase of the arc currentand gas flow rate. The sawtooth wave of the arc voltage, caused by large-scale shunt, is a low frequency signal with the frequency in the range of 0.2~3Hz. The short time Fourier transformwas used to analyze the arc voltage signal in real-time, which can be used to accurately monitor the generation of large scale shunting and guide the adjustment of the working parameters of the plasma torch.

Key words: plasma atomization; plasma torch; voltage-ampere characteristics; large-scale shunting

目前，国内高性能球形金属粉末[1]（球形度高、流动性好、松装密度高、氧含量低、粒度细）严重依赖进口，价格高昂，而国内高性能球形金属粉末制备技术发展较为缓慢，主要体现在产量小、成本高、粉末批次稳定性差等问题上[2,3]。现有制粉技术包含：真空气雾化法（VIGA）[4,5]、电极感应气雾化法（EIGA）[6,7]、等离子体旋转电极法（REP）[8,9]和等离子体雾化法（PA）[10-12]。其中等离子体雾化（如图 1 所示）是将送入的丝状或棒状材料进行预加热熔化成金属液柱，金属液柱在与等离子体射流的交互作用下一次雾化成为金属液袋，金属液袋再在下落过程中二次雾化成为更

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