Seminar

Institute for Plasma Research

Title : Study of Thermal, Electrical and Fluid Dynamic Behaviour of Arc Plasma Devices

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Date : 8th December 2015 (Tuesday)

Time : 03.30 PM

Venue : Seminar Hall, IPR

Abstract:

Plasmas having nearly identical electron and heavy species temperatures but significantly different radiation temperatures are termed as thermal plasmas. Such plasmas are usually formed in atmospheric pressure gaseous electric discharges and characterised by their high energy density, high temperature, easier process control and flexibility in producing chemically inert as well as reactive environment for high temperature plasma chemistry and plasma processing. Atmospheric pressure arc plasma devices, subject of this study, belong to this thermal plasma category. The devices find wide applications in industries like cutting, welding, melting, surface treatment, waste treatment, gasification, metallurgy, thin film technology, nanomaterial synthesis, novel material production, fusion research etc. Steep gradients in plasma quantities, extremely high temperature at the core, high fluid dynamic flow fields, highly nonlinear variation in plasma properties and mutual interactions among thermal, chemical, electric, magnetic and fluid dynamic fields are some of the characteristic features of such systems. The nature of the plasma jet delivered by an arc determines the process design, the quality of the processing work done and its suitability for a particular application.

My Ph D work primarily focuses on nitrogen arcs together with argon over a range of power levels and operating parameters. Industrial nitrogen plasma torches have the advantages of operating with usual tungsten based refractory electrodes and radical rich non-oxidizing high temperature environment for enhanced plasma chemistry and efficient processing. Being a molecular gas, Nitrogen naturally offer higher voltage drop compared to argon for the same electrode configuration and easily associates higher power.

Major contributions from the study include (a) Design and development of a segmented electrode plasma torch suitable for operation with nitrogen as well as argon and capable of operating with electrical power beyond 50 kW. (b) Design and development of a double calorimetric setup for experimental measurement of delivered heat flux profiles under different operating conditions. (c) Development of a CFD model of the developed torch for understanding the physics behind characteristic features observed. (d) Computation of thermodynamic and transport properties of nitrogen plasma under thermal equilibrium and non-equilibrium conditions using Chapman-Enskog Approach. (e) CFD simulation of the nitrogen plasma torch using the computed thermodynamic and transport properties and analysis of the observed distribution of temperature, velocity, pressure and potential inside the torch under different operating conditions. (f) Experimental estimation of the heat flux profile delivered by the torch under different operating conditions using double calorimetric setup with argon and nitrogen as plasma gas. (g) Experimental determination of temperature of the emanating plasma jet using emission spectroscopy technique. (h) Study of the features of instabilities exhibited by the torch under different operating conditions and working gases.

While the spectrum of information extracted on thermal, electrical and fluid dynamic characteristics of nitrogen arc devices may be used for newer applications in the frontier areas of plasma processing, the same obtained for argon arc devices are used in the study to enhance credibility of the obtained results through comparison with existing data and generating data in the extended regime of operation where availability of data is scarce. The study offers a detail understanding of the nitrogen plasma devices from both physics point of view as well as technological applications. However, the study can be continued further to explore many important aspects of such devices such as exploring the physics behind the instabilities using time dependent numerical simulation. This will lead to a better understanding of the transient events occurring in the device in absence as well as presence of magnetic field. This is very much important as the instabilities in the DC plasma torch highly affect the performance of the plasma assisted process. In fusion research, high heat flux sources like DC plasma torch operated in hydrogen, is used for analysing plasma-material interaction. The study will also support in understanding the time-dependent events in such devices.