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直流アーク陰極点に形成される溶融金属池の動的挙動と表面温度評価

Dynamic Behavior of Molten Metal Pool Formed at the Cathode Spot of DC Arc and its Surface Temperature Measurements

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Study of the dynamic response of refractory metals, such as tungsten to the transient and extremely high plasma heat load in type-I ELM's and disruptions (>100 MW/m^2) requires experimental approaches different from those in steady state and low heat flux experiments(<10MW/m^2). In the present experiments, high current stabilized arc plasmas with ~GA/m^2 are used as a high heat flux pulse and steady state plasma source. The plasma heat flux onto the cathode surface is several hundred MW/m^2 in the steady state and is several GW/m^2 in the arc ignition and quench phase. These properties of high heat flux arc plasmas are very useful to study the transient behavior of the divertor materials during ELMs and disruptions in fusion reactor complementally with other ELM/disruption experiments.

On the other hand, arc plasmas are used in various devices, such as light sources, plasma arc cutting, electric circuit breakers and ignition plugs, etc. It is very important to understand the physical and chemical interactions of the high heat flux arc plasmas with the refractory metal cathode for improvement of these industrial devices. In the present experiments dynamic interactions of high current density arc plasmas with hot molten metal cathode are studied using a plasma arc cutting device, which can generate stable arc plasmas in a small fixed volume[1].

Images of the cathode hot spot obtained from a fast color camera clearly show that the rotation of local small hot cathode spot heats the Hf cathode surface gradually and forms the larger cathode spot on the center of Hf electrode after ignition. The cathode spot area spreads over gradually from the fixed local cathode spot to the whole cathode area with increasing the arc current. The temperature distribution estimated from the RGB and NIR signals of the hot cathode color images shows that the cathode surface temperature rises up between 3,700 K and 4,300 K. This temperature is higher than Hf melting temperature (T=2,503 K) and lower than or close to Hf boiling temperature (T=4,547 K). Thermionic electron emission current density is calculated from the estimated cathode surface temperature, supposing that whole cathode surface is solid H_f or solid HfO_2. Thermionic electron emission current I_{Hf} and I_{HfO2} are estimated to be ~160 A and 40 A, respectively when the preset arc current is I_{arc}=135 A. In Fig. 1 example of the cathode temperature profile is shown when RGB color CCD camera and RGB and NIR ccd camera are used to estimate the cathode surface temperature.

Unstable phenomena of the molten cathode pool, such as small droplet ejection accompanying wavy motion of the molten cathode pool and large droplet ejection from the cathode, are often observed when a new cathode with a flat cathode surface is used at the first time. Detail phenomena of the molten cathode pool will be shown at the meeting.

References

[1]Y. Yamaguchi, et al., Journal of the Japan Welding Society Vol. s29, No.1, pp. 010- 017(2011) in Japanese.

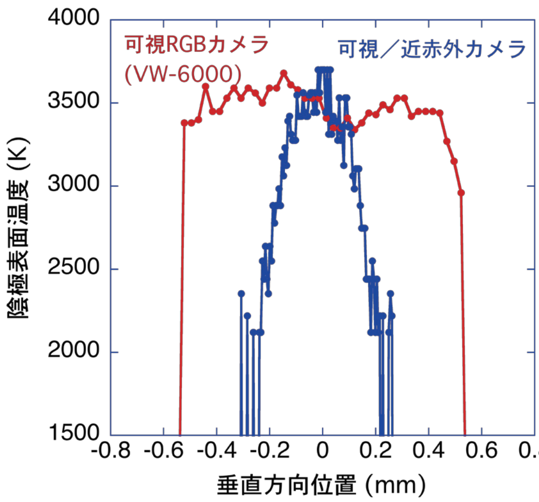

Fig. 1 Cathode surface temperature profiles at the arc quenching phase estimated by two different CCD cameras.