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Plasma Facing Components with Capillary Porous System and Liquid Metal Coolant Flow

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Liquid metal (LM) can create renewable protective surfaces on plasma facing components, with an additional advantage of deuterium pumping and tritium extraction if liquid lithium (LL) is used. LM can also be utilized as an efficient coolant, flow driven by the Lorentz force created with the help of the magnetic field in fusion devices. Capillary porous systems can serve as a conduit of liquid metal and simultaneously provide stabilization of the liquid metal flow, protecting against spills into the plasma. Recently within the framework of the U.S. DoE domestic LM divertor PFC design project, we proposed [1] a combination of a fast-flowing LM cooling system with a porous plasma facing wall (figure 1). The system takes advantage of a magnetohydrodynamics (MHD) velocity profile, as well as attractive LM properties to promote efficient heat transfer from plasma to lithium at low pumping energy cost, relative to the incident heat flux on the PFC. An example of non-uniform energy flux from the plasma is applied on the porous surface is shown in figure 2. In case of disruption leading to excessive heat flux from plasma, liquid lithium evaporation can stabilize the temperature due to high evaporation heat and apparent vapor shielding [2].

The proposed capillary porous system with fast flowing liquid metal (CPSF) was optimized analytically for conditions of a Fusion Nuclear Science Facility [3]: 10T toroidal field and 10 MW/m^2 peak heat flux. Computational fluid dynamics analysis confirmed that a CPSF system with 2.5 mm square channels can pump enough LL so that no additional coolant is needed, to maintain LL PFC surface temperature below 450 °C, at speeds > 7 m/s. Higher PFC surface temperatures are observed with lower coolant speeds, at which LL evaporation could on the one hand contaminate the plasma [4], while on the other hand leading to a lithium vapor box type of dissipative solution [5]. Scaling of the flow parameters allows initial proof of concept experiments using Galinstan as a surrogate liquid metal for LL [6]. Recent advances in 3D printing technologies provide new opportunities in manufacturing CPSF system components using tungsten [7]; additionally SiC nano particle composites with wide variety of properties can be used. *Supported by the U.S. DoE under Contract Number DE-AC02-09CH11466.

References

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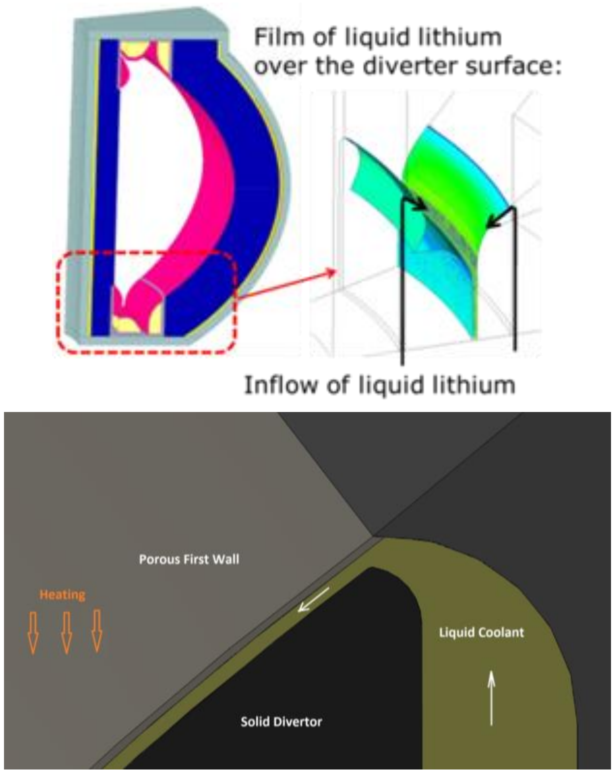

Figure 1 Flowing liquid lithium wall concept with porous wall

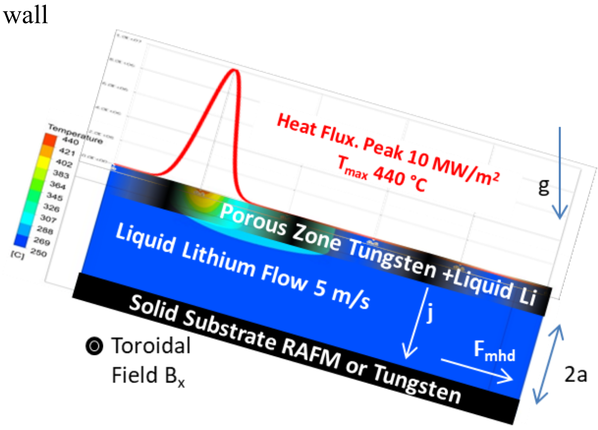

Figure 2 Schematic of the liquid lithium divertor with porous plasma facing