Design Constraints for Liquid-Protected Divertors

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Work on plasma surface interactions for liquid-surface-protected plasma facing components has been performed by the Advanced Limiter-Divertor Plasma-facing Systems (ALPS) Program. Fusion reactor designs with liquid first walls and divertors have also been investigated as a part of the APEX program. Operating temperature windows were established based on the fluid properties and power conversion efficiency requirements. Constraints were also imposed on the maximum allowable fluid surface temperature in order to limit the primary source of plasma impurities, *viz*. vaporization.

In this study, an additional constraint for the maximum allowable wall and coolant surface temperature gradients (*i.e.*, spatial heat flux gradients) has been quantified. A mechanistic transient three-dimensional model using the level contour reconstruction method has been used to follow the evolution of the liquid film free surface above a non-isothermal solid surface. Spatial variations in the wall and liquid surface temperatures are expected due to variations in the wall loading; thermocapillary forces created by such temperature gradients can lead to film rupture and dry spot formation in regions of elevated local temperatures. Parametric studies are performed for various coolant properties, liquid film thicknesses, mean coolant temperatures, and spatial temperature gradients. The results are used to develop generalized charts for the maximum allowable spatial temperature gradients for different coolants over a wide range of operating conditions. These charts will allow reactor designers to identify design windows for successful operation of liquid-protected plasma-facing components.