Liquid Vortex Shielding for Fusion Energy Applications

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Annular vortex flows can protect critical components in heavy-ion fusion (HIF) chambers, as well as fusion chambers for other inertial and magnetic fusion chamber applications. Such liquid vortexes have been developed for protecting heavy-ion beam tubes in the HYLIFE chamber, by forming a layer of liquid that coats the inside of the tube near the beam port. This annular liquid jet, formed in the vortex tube, provides additional neutron shielding for the final focus magnet and condenses vaporized molten salt that may enter the beam tubes. To maximize their effectiveness the vortex tube flow must have a smooth surface while being turbulent to promote high condensation rates. Particle Image Velocimetry (PIV) measurements that permit surface topology and turbulence structure characterization are being conducted to study the characteristics of turbulence in these vortex tubes.

Experiments to understand larger scale vortex flows, which may eventually serve as blankets to protect first walls in advanced inertial and magnetic fusion chambers, are also being conducted.

For optical measurement like PIV it is important to match the index of refraction of the fluid with the tube material. Here the novel use a low viscosity mineral oil, with an index of refraction matched to acrylic, is reported. The oil thermophysical properties are ideal for simulating molten-salt fluid mechanics, since they permit the Reynolds, Froude and Weber numbers to be matched simultaneously in experiments of around 25% of full scale size.