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FTP/P1-28: Potential for Improvement in High Heat Flux HyperVapotron Element Performance Using Nanofluids

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HyperVapotron (HV) elements have been used extensively in high heat flux neutral beam stopping devices in nuclear fusion research facilities such as JET and MAST. These water-cooled heat exchangers use a cyclic boiling heat transfer mechanism to effectively handle power densities of the order of 10-20 MW/m2, but are inherently limited by their critical heat flux. The use of a nanofluid as the coolant, instead of water, promises to enhance the heat transfer performance of the HV and increase the critical heat flux by a factor of 2 or 3. Such enhancement would produce a step-change improvement in the power handling capability of future high heat flux devices such as the divertor and heating and current drive systems. This paper describes the potential to improve HV performance using nanofluids.
A molecular dynamics simulation (MDS) code has been used to determine the existence of heat transfer mechanisms that depart from classical thermodynamics and that might explain the augmented heat transfer performance of nanofluids. A basic nanofluid is synthesised and the path of the nanoparticle along a temperature gradient is tracked and compared with a simulation of the base fluid alone. The results indicate a new type of heat transfer mechanism in which the nanoparticle exhibits greater thermal diffusion, with an optimum particle size manifesting in the data.
Experiments have been conducted in which the flow field in a full-scale HV model is visualised and measured using particle image velocimetry (PIV). The experimental rig design is supported by computational fluid dynamics (CFD) analysis. Relevant past studies have yielded qualitative experimental results, but the PIV results reported here provide quantitative data to aid the understanding of the preliminary flow field inside the HV (i.e., before a heat flux is applied) and to assist CFD validation. Further, using both water and Al2O3 nanofluid as the flow medium, the PIV observed flow structures are compared to allow an assessment of the effect on heat transfer performance. Thus, these PIV measurements offer the first evidence for enhanced heat transfer in HV devices when nanofluids are used as the coolant. The improved understanding of the cooling advantage of nanofluids and their effect on the HV flow regime facilitates the design of advanced high heat flux systems of future fusion machines.

Country or International Organization of Primary Author

UK

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Author: Mr SERGIS, Antonis (UK)

Co-authors: Dr BARRETT, Thomas (EURATOM/CCFE); Prof. HARDALUPAS, Yannis (Imperial College London, Mechanical Engineering Department)

Presenter: Mr SERGIS, Antonis (UK)

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