Politecnico di Torino

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ENERGETICS

DM 117/ENI - Design and optimization of Triply Periodic Minimal Surfaces as heat sinks for the cooling of high heat-flux components in fusion reactors

Funded By	ENI S.P.A. [P.iva/CF:00905811006] MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Politecnico di TORINO [P.iva/CF:00518460019]

Supervisor	SAVOLDI LAURA - laura.savoldi@polito.it

Contact	Luca Marocco, Politecnico di Milano

Context of the research activity	The research will address the development of new high-efficiency cooling solutions as heat sinks or heat exchangers in fusion reactors. More in detail, the innovative cooling solutions will check and exploit the potentialities of Triply Periodic Minimal Surfaces, which are 3D structures easy to print out by Additive Manufacturing techniques which enhance the fluid-to-fluid or fluid-to-solid heat transfer surface in a given volume. Progetto finanziato nell'ambito del PNRR – DM 117/2023 - CUP E14D23001950004

Objectives	Several components in fusion machines such as the MW-class gyrotrons, needed to inject radio-frequency heating in the magnetic confinement devices, or the divertor tiles in fusion applications, or the cooling of mirrors in the ECRH transmission line or launcher, are at a crossroads. They should allow the coolant to remove heat fluxes up to tens of ¿¿¿¿¿¿¿¿/¿¿¿¿2, possibly keeping it in single-phase, therefore intensive heat transfer is required. The adoption of Stochastic Cellular Materials for cooling enhancement is already a good practice in some applications: for example, the European gyrotrons employ compact matrices of Raschig rings (hollow cylinders of millimetric size) for the cooling of the resonant cavity, but the capability of design/simulating such structures is limited in view of the stochastic nature of the structure. The very-high-heat-flux components might benefit from the introduction of new cooling concepts for advanced heat transfer such as Periodic Cellular Material among which Triply Minimal Periodic Surfaces (TPMS), generated by sinusoidal and cosinusoidal functions in 3D. The latter are periodic structures able to achieve extremely large heat exchange area while simultaneously maintaining low pressure

	drops, and they may be built in different ways, playing with the periodic functions (some known types are the “gyroid” and the “diamond” ones). These complex structures and cooling systems, that can be easily realized by different techniques in Additive Manufacturing, need to be analyzed and modelled, to choose the more promising and performant for the specific applications. The objective of the activity is the development of new high-efficiency cooling solutions, employing TPMS, to be used as heat sinks in high-heat flux components (gyrotrons, divertor) or as heat exchangers in fusion reactors. This is a contribution to the development of the CO_2-free nuclear fusion reactors, that would help in preserving the achievements of the energy transition in the second half of the century, in a context of increasing electricity demand.

Skills and competencies for the development of the activity	Good knowledge of nuclear fusion engineering, Expertise in simulation and analysis of Heat Transfer problems