EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

3D-printing for tungsten structures to hold liquid metal

Considering the evolution of high thermal stresses at the plasma facing surface (PFS) in fusion technology, a novel design for liquid metal divertor targets were developed of tungsten using 3D-printing. By introducing designed voids in the tungsten structure, they can serve simultaneously as both reservoir for the liquid metals (LM), and as wicking channel up to the PFS. The structure holds a liquid lithium alloy that protects the plasma-facing components through conduction of heat and vapor shielding.

Description of the technology

3D-printing of tungsten, when combined with liquid metals (LM) significantly reduces thermal stresses at the plasma facing surface (PFS), and consequently open up many new design possibilities.

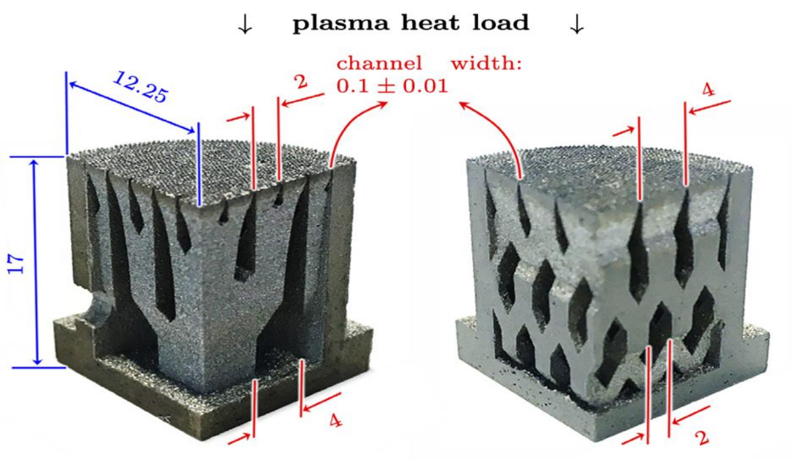
Liquid metal divertors aim to provide a more robust alternative to conventional tungsten divertors. However, they still require a solid substrate to confine the liquid metal. This approach proposes a novel design philosophy for liquid metal divertor targets, which allows for a two orders of magnitude reduction of thermal stresses compared to the state-of-the-art monoblock designs.

The main principle is based on a 3D-printed tungsten structure, which has low connectedness in the direction perpendicular to the thermal gradient, and as a result also short length scales. This allows for thermal expansion. Voids in the structure are filled with liquid lithium which can conduct heat and reduce the surface temperature via vapor shielding, further suppressing thermal stresses. The relaxation of the strength requirement allows for much larger failure margins and consequently for many new design possibilities.

The full publication can be found here: https://pure.tue.nl/ws/portalfiles/portal/125072892/Rindt_2019_Nucl._Fusion_59_054001.pdf

Demonstration of the novel void design only achievable by 3D-printing to create a porous structure capable of diverting liquid metals. In the figure, quarter sections of the two divertor designs are shown: (1) Left, tree-type. (2) Right: V-type. The voids in the structure work as both reservoirs for the LM, as well as wicking channesl up to the PFS.

(Rindt, P., et al. Nuclear Fusion 59.5 (2019): 054001)



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Innovation and advantages of the offer

3D-printing of tungsten is found to be a highly flexible manufacturing technique that allows for optimization of various design parameters due to a high degree of geometric control. It can be used to produce LM components for experimental purposes with great ease, while improving the robustness compared to traditional monoblock designs. This can be extrapolated to other liquid metal divertor designs. The main added value here is the novel design of voids in the structure (tree-type and V-type) which are only achievable using 3d-printing.

Non-fusion Applications

3D printing of such metals and alloys as substrates for liquid metal, does not have to be tungsten. The technique has many promising applications in other areas that have high heat flux components, that advance heat pipe technology, or that are applicable in the semiconductor industry. In general, 3D-printing of tungsten is a very flexible manufacturing technique which can optimize various design parameters by excellent geometric control. Therefore, it is optimal for producing LM components with high robustness either for experimental purposes as well industrial applications with high thermal stresses, as compared to traditional monoblock designs. This can be extrapolated to liquid metal divertor designs for DEMO and beyond.

EUROfusion Heritage

The robustness of the divertor remains a critical challenge on the way to practical fusion reactors. Additionally, neutron irradiation inevitably leads to material degradation, under which even the state-of-the-art tungsten monoblocks face harsh conditions such as melting, erosion, and cracking of both the surface and bulk material. Because of this, the monoblocks are heavily dependent on actively controlled heat-load mitigation strategies. This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014–2018 under grant agreement No. 633053.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission