Oscillatory vapor shielding of liquid metal walls

Member of the EUROfusion consortium, DIFFER discovered that a protective vapor shield above the liquid metal self-regulates the surface temperature to 800-900°C. Self-repairing and self-protecting liquid walls are an attractive concept for future fusion power plants, where the reactor walls need to withstand extreme temperatures and particle impacts. This layer can repair itself by flowing in new liquid after being damaged and evaporated liquid forms a vapor shield in front of the divertor which can diffuse power to other parts of the reactor before it reaches the divertor. Outside fusion, oscillatory vapor shielding of liquid metal walls finds a lot of promising applications where temperature-regulation and self-healing of the surface are met. Either directions where the energy efficiency of the process can be increased (induction furnaces, electric conversions,) or energy should be recovered (cogeneration, pressure recovery turbines, H2 recovery…)

Description of the technology

Heat shields in fusion reactors (divertors) are exposed to extremely concentrated heat loads around 10 MW/m2, and intense particle impacts. These components must survive for two years under perhaps the harshest conditions that any made object must live through: comparable to conditions at the surface of the sun or a rocket exhaust. A thin vapour cloud in form of a liquid metal may be the solution to protecting the reactor walls of future fusion power plants to the extreme heat fluxes encountered. This liquid - for instance tin or lithium - flows through a mesh of tungsten and continuously repairs itself from plasma damage. Especially interesting is the growing and shrinking cloud of vapour that will form above the liquid, as it can absorb heat and incoming particles from the plasma before they hit the surface and radiate energy away over a much larger surface than the original strike zone.

The shielding concept has been tested as a 3D-printed prototype holder for liquid metal in DIFFER's research facility Magnum-PSI (a linear plasma generator that allows to study plasma-wall interactions in a fusion reactor) and discovered that a protective vapor shield above the liquid metal self-regulates the surface temperature to 800-900°C. Self-repairing and self-protecting liquid walls are an attractive concept for future fusion power plants, where the reactor walls need to withstand extreme temperatures and particle impacts for months to years between repairs.

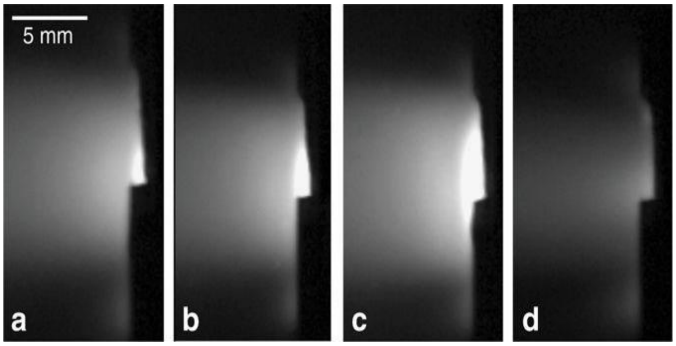

Figure 1: Vapour shielding in front of liquid tin exposed to dense plasma

Figure 2: Prototype holder for a liquid metal layer to protect the inner walls of future fusion power plants

FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

Oscillatory vapor shielding of liquid metal walls

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Innovation and advantages of the offer

The main benefits of this technology are: the shielding and self healing properties, the ability to automatically stabilize the surface temperature, and the self regulation of the surfaces temperature to 800-900°C.

Non-fusion Applications

Oscillatory vapor shielding of liquid metal walls finds a lot of promising applications where temperature-regulation and self-healing of the surface are met: Either directions where the energy efficiency of the process can be increased (induction furnaces, electric conversions,) or energy should be recovered (cogeneration, pressure recovery turbines, H2 recovery…). Promising applications are : fusion research, Big Science, Energy (combustion chambers, electric power conversion, power plants, pressure etc.).

EUROfusion Heritage

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. DIFFER is a member of the EUROfusion consortium, which comprises 30 fusion research organisations and universities from 26 European member states plus Switzerland and Ukraine. The solution is developed with the ambition to protect the divertor with a thin layer of liquid metal which can repair itself by flowing in new liquid after being damaged. Moreover, evaporated liquid forms a vapor shield in front of the divertor which can diffuse power to other parts of the reactor before it reaches the divertor.

The Vidi grant of the Dutch Research Council NWO gives mid-career scientists the opportunity to start their own research group on an innovative topic. The 800,000 Euro grant has a runtime of five years. Thomas Morgan will use the grant to appoint two PhD students and one post-doc researcher. DIFFER will support his research project with an additional investment of 200,000 Euro, funded partly of EUROfusion's support.

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