Introduction

Mobile Tiles for Inertial Fusion First Wall/Blanket Systems

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A critical issue facing inertial fusion power devices is the high heat and particle flux impinging on FW.

For solid wall designs the IFE environment produces extremely high pulsed temperatures and erosion/violation of FW.

These conditions limit material choice and lifetime of FW materials.

In contrast to MFE machines, IFE allows greater design flexibility for FW and blanked to address the issue of FW survival.

This poster describes a concept of a solid FW (mobile tiles)

By removing the graphite-based FW tiles on a predetermined schedule and post-processing these tiles the common problems associated with graphite-based solid walls can be mitigated:

- Erosion is managed by continual replacement
- Tiles are inspected and can be processed once removed
- Irradiation degraded thermo-physical properties such as thermal conductivity can be restored through the same annealing step used to remove tritium

Such a concept is decidedly low-tech, and similar to that employed in the Pebble Bed Modular Fusion Reactors

Full Chamber Representation

Laser Port Tiles

For sections of chamber walls without laser beam penetration, larger tiles will be used

These tiles will traverse vertically through the chamber without the need to twist to open for lasers

Chamber Wall Tiles

Top and Bottom Geometry

To avoid using two coolants we considered the option of cooling the FW tiles with the same liquid breeder used in blanket

Blanket consists of 90% liq. breeder and 10% structure

Choice of structural material depends on compatibility with Li. While V and SiC yield better TBR and can operate at higher temperatures than FS, they are more expensive, require more R&D and compatibility with Li could limit their operating temperature

Conclusions

Using mobile FW tiles that are periodically removed, annealed, and reinstalled tritium retention, surface erosion may be mitigated

Conceptual configuration developed with consideration for laser beam port accommodation and simple tile insertion and removal scheme

Tritium self-sufficiency can be achieved with a variety of options employing FW mobile tiles

Using ceramic breeders or Flibe is not recommended due to requiring at least 30% Be2C added in FW tiles

While liquid Na has the best heat removal capability for FW tiles, it adds the complexity of having two coolants. Either Li or LiPb can be used also to cool the FW tiles

A neutron protection is required, and while Li is the preferred breeder/coupler due to better heat removal capability, lighter weight, and no need for enrichment

Which is a material that depends primarily on compatibility with Li.

Neutronics Assessment and Assumptions

- Neutronics calculations performed to assess breeding potential for different design options
- Breeder options: Ceramic breeder (Li2SiO3), Fibre, Li, LiPb
- Coolant options: Li, Na, Liq. breeder
- Structure options: FS, V-4Cr-4Ti, SiC/SiC
- Considered Neutrons used in the graphite tiles to improve TBR
- Choice of structural material depends on compatibility with Li

Nuclear Heating in FW Tiles and Blanket

- Nuclear heating and surface heat flux calculated for use in thermal analysis
- Nuclear heating results scale with the neutron wall loading

- Peak surface heat flux at midplane ~0.37 MW/m²
- Drops to 0.03 MW/m² at top/bottom with an average value of 0.26 MW/m²
- Peak neutron wall loading at midplane ~0.09 MW/m²
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TBR Results for Liquid Breeder Options

- Three liquid breeder options considered with three structural materials
- Natural Li used except for LiPb where 90% Li-6 enrichment was also considered
- FW tiles consist of 75% C, 10% structure, 15% Na
- Blanket consists of 90% liq. breeder and 10% structure
- V provides best neutron economy with FS giving the least

TBR Results for Liquid Breeder Options (breeder in blanket)

- Breeding increased by ~2-5% when liquid breeder is used instead of Na to cool FW tiles

Preferred Design Option

- To avoid the complexity of having two coolants in the power cycle, it is preferred to cool the FW tiles with the same liquid breeder used in the blanket
- While both Li and LiPb can provide adequate TBR, Li is the preferred option due to its better heat removal capability, light weight leading to less pumping power, and no need for enrichment. The main issue is safety concern that can be mitigated by using He cooling in shield/VV
- Choice of structural material depends on compatibility with Li. While V and SiC yield better TBR and can operate at higher temperatures than FS, they are more expensive, require more R&D and compatibility with Li could limit their operating temperature

Carbon Composite Average Tile Temperature

- Material: High Conductivity 3-D Carbon Fiber Composite
- Fiber Coolant Channel, Lithium Contact

Carbon Composite hottest tile temperature

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Peak neutron wall loading at midplane ~0.09 MW/m²
- Drops to 0.03 MW/m² at top/bottom with an average value of 0.077 MW/m²

These tiles traverse the chamber along a coolant rod (shown in blue)

At the location of the laser ports, the tiles will rotate around the coolant rod by following a guiding rail on the coolant rod

Post-irradiation annealing of tile compact will recover thermal and mechanical properties of tile as well as recover

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