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Thermal performance augmentation by rib-arrays for helium-gas cooled First Wall applications

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Highlights

- **The applicability of attached and detached rib-arrays in helium-gas cooling channel of the First Wall for enhancing the heat transfer and increasing the cooling performance were analyzed and evaluated.**
- **For the attached V-shape rib-array the best thermal performance was obtained and structural temperatures maintain below the upper limit of 550 °C for a thermal load of 0.75 MW/m² and a mass flow rate of 0.049 kg/s.**

1. Computational Model

- Flow and conjugated heat transfer were computed for an unscaled section of the First Wall with the Detached Eddy Simulation approach.
- The computations were conducted for pressurized helium-gas with a mass flow rate of $\dot{m}$ = 0.049 kg/s, an inlet pressure of p_{in} = 8 MPa(abs) and an inlet temperature of T_{in} = 340 °C.
- Heat flux densities of 0.75 MW/m² and 0.08 MW/m² are applied.

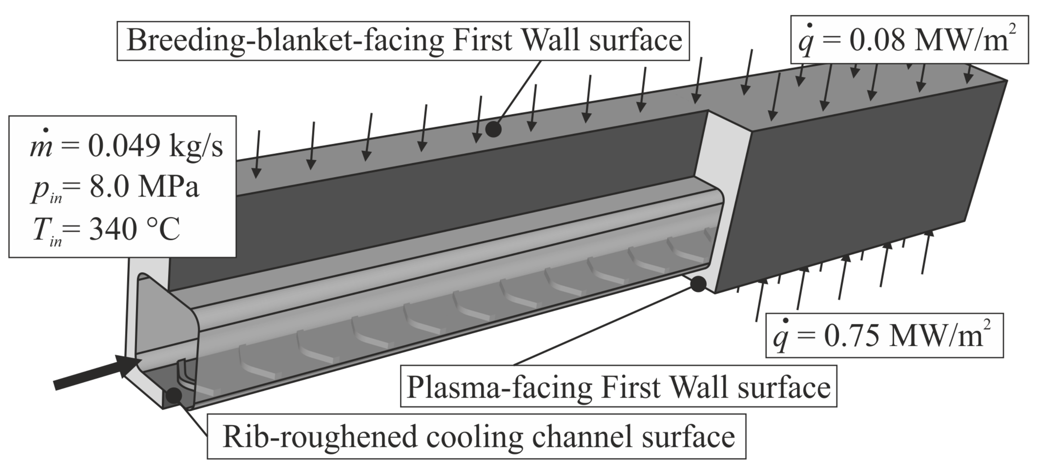

Fig. 1 Computational domain.

- The plasma-facing cooling channel surface was structured by attached or detached rib-arrays of centrally positioned, transversally oriented or 60 deg. V-shape rib-elements with different rib-element cross-sections (square, 2 mm radius round-edged front- and rear-rib-surface, trapezoid).

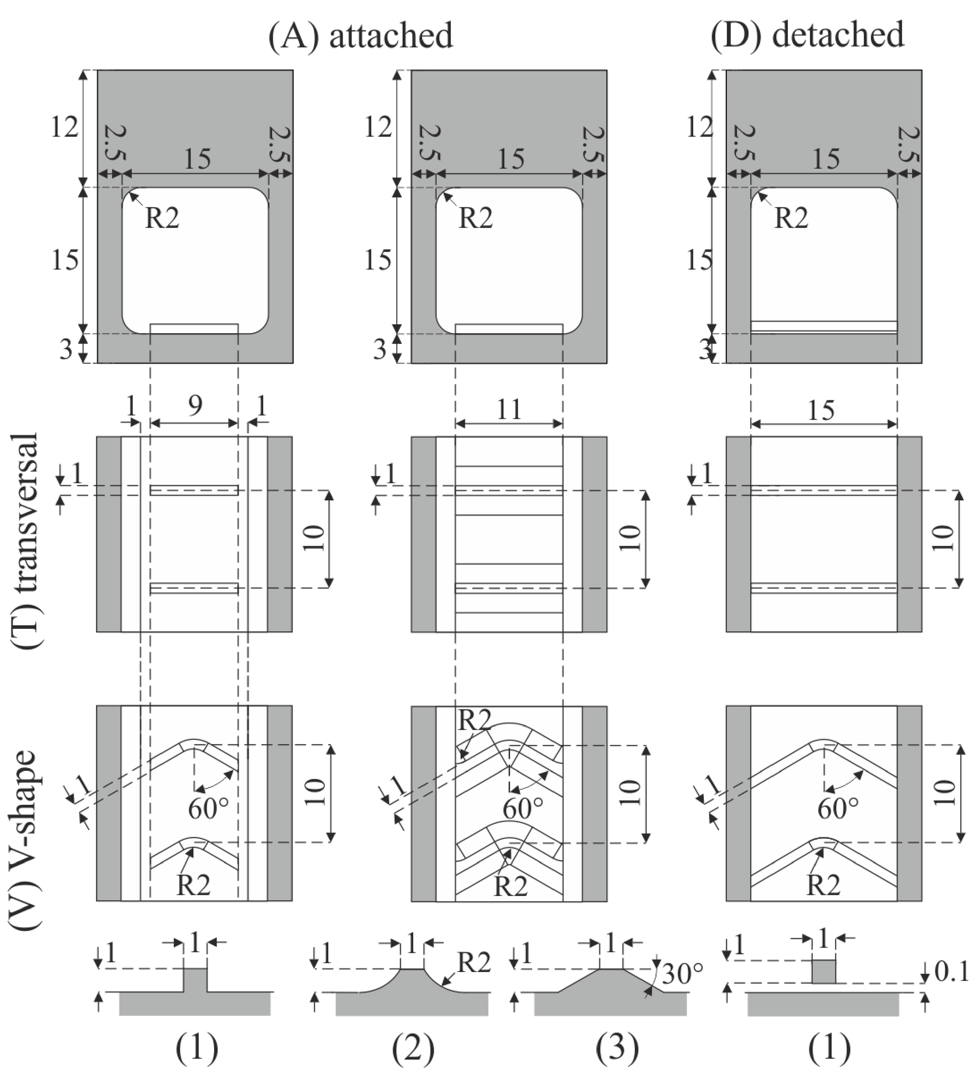

Fig. 2 Rib-array configurations. All dimensions in mm.

2. Manufacturing Concept

- To manufacture the presented rib-arrays, ladder-like tapes of rib-elements can be inserted into support notches located at the cooling channel side walls or bottom.

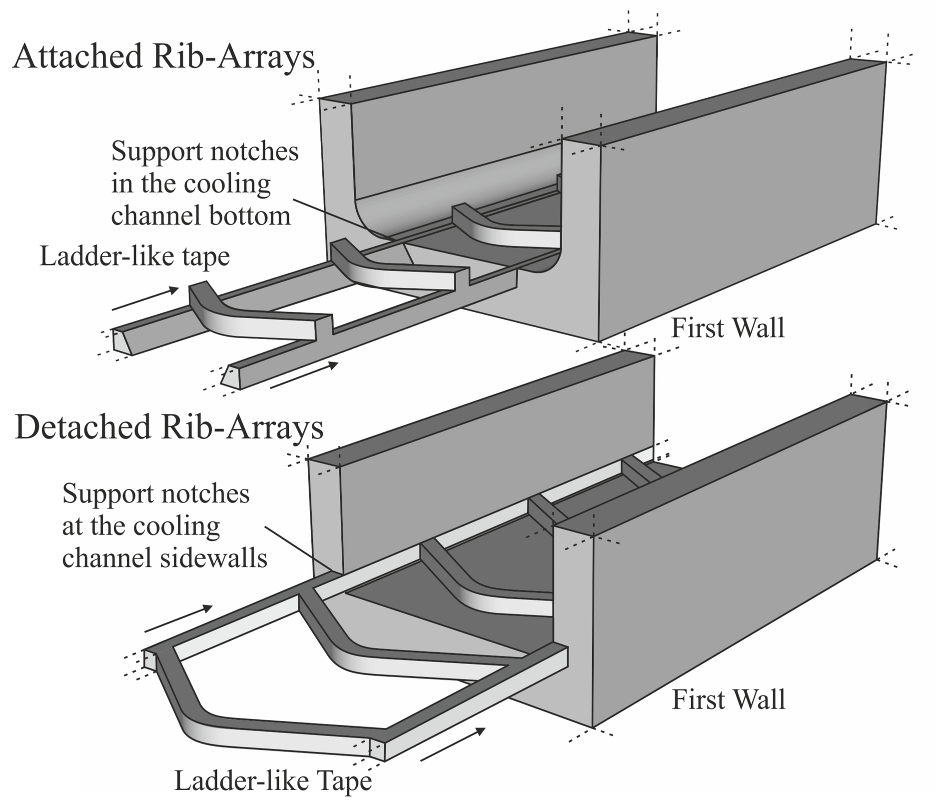

Fig. 3 Manufacturing concepts.

3. Temperature Distributions

- The V-shape rib-elements provide the best cooling performance.
- Maximum temperatures increase with 16.1 °C/m (AV1) or 19.8 °C/m (DV1) and maintain below 550 °C for extrapolated channel length of 1.31 m (AV1) and 1.79 m (DV1).

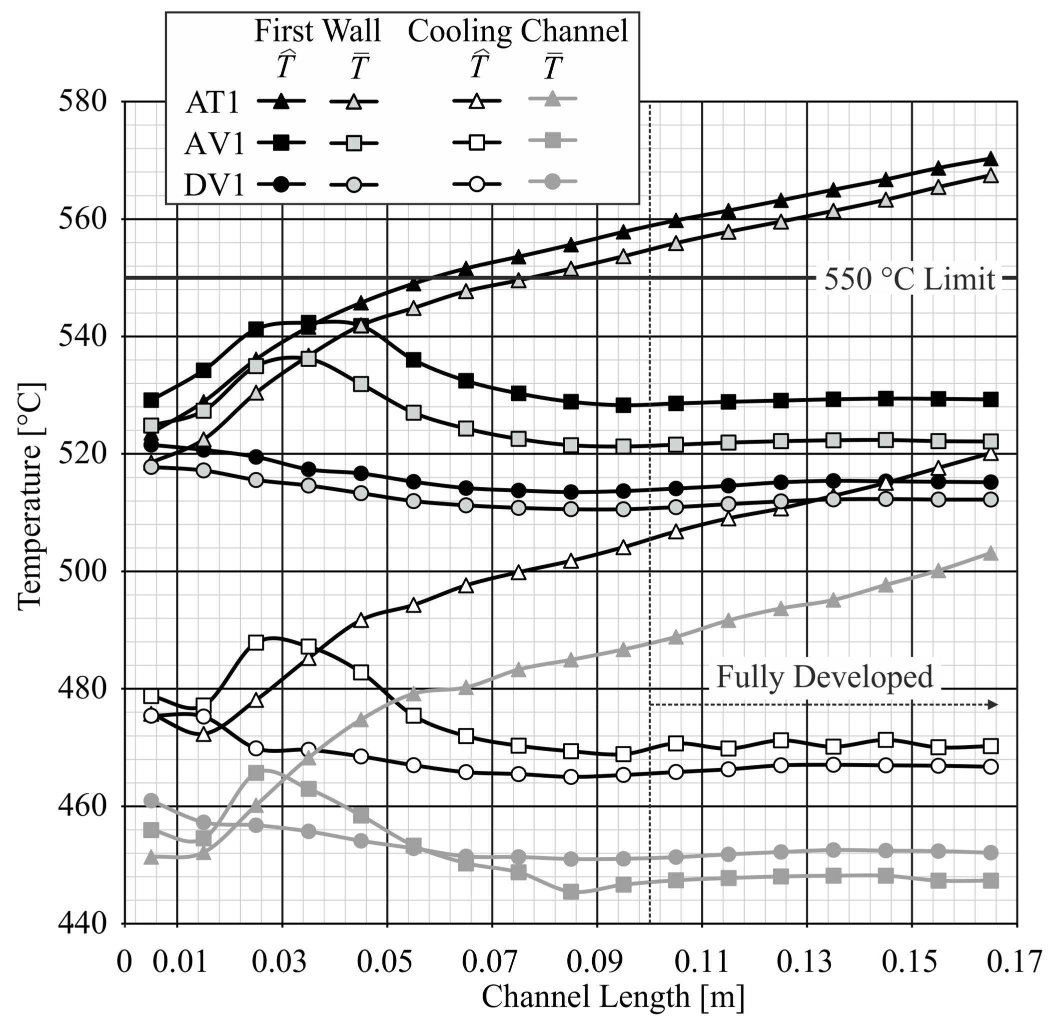

Fig. 4 Mean temperatures $\overline{T}$ and maximum temperatures $\hat{T}$.

4. Heat Transfer Coefficients and Pressure Drop

- The V-shape rib-arrays cause the strongest secondary flow structures in crosswise direction, and, thus, the mixing between the 'hot' wall boundary layer flows and the 'cold' core flow is intensified and heat transfer is significantly enhanced.
- The correspondiong heat transfer coefficient gradients along the cooling channel of the V-shape rib-arrays are 4900 W/m2·K / m (AV1) and 6900 W/m2·K / m (DV1).
- The increased pressure drop of the detached rib-arrays is attributed to the increased form drag due to the enlarged transversal cross-sectional area and to the development of flow stagnation regions at the conjunction of the rib-elements and the sidewalls.

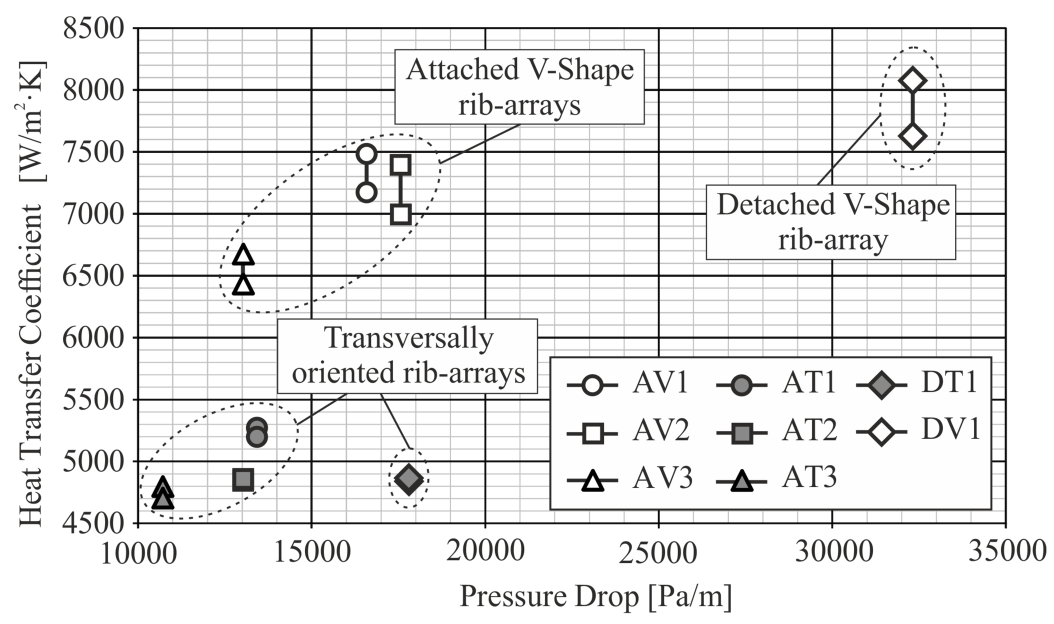

Fig. 3 Heat transfer coefficient and pressure drop.

5. Thermal Performance

- Compared to smooth cooling channels, the pumping power can be significantly reduced to obtain equal heat transfer performance (cooling) by the use of the presented V-shape rib-arrays or, from another point of view, the heat transfer coefficient can be increased for equal pumping power.
- Best thermal performance were obtained for the attached V-shape rib-array with square rib-element cross-section (AV1).

EUROfusion

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