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Structured Cooling Channels for Intensively Heated Blanket Components

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Highlights

- The thermal hydraulics of helium-gas cooled structured channels were analyzed and evaluated
- **Semi-detached ribs** ► highest heat transfer ► best cooling performance ► reduced local heat transfer deterioration
- **Dimples** ► heat transfer increase without significant pressure drop rise ► large regions of low heat transfer

1. Objective

- Investigation of turbulent flow and heat transfer in structured cooling channels
- Evaluation of truncated attached and semi-detached upward directed V-shaped ribs and spherical dimples for helium-gas cooled First Wall applications

2. Simulation Details

- Turbulent flow and heat transfer were determined in a FW cooling channel model of DEMO
- $Re = 1.05 \cdot 10^5$ (0.0490 kg/s and 0.0407 kg/s) ►inlet pressure of p_{in}= 8 MPa(abs) ► inlet temperature of T_{in} = 340 °C
- LES with dynamic Smagorinsky SGS-Model ► incompressible helium-gas
- Periodic boundary conditions in streamwise direction
- Constant heat flux ► $\dot{q}_{PF}$ = 0.75 MW/m² on the plasma-side-facing FW surface ► $\dot{q}_{BB}$ = 0.08 MW/m² on the breeding-blanket FW surface

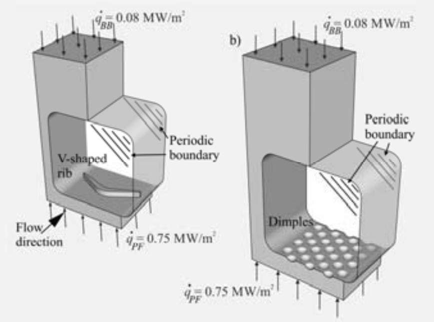

Fig. 1. Sketch of the computational domain for the ribbed channel and the dimpled channel.

3. Global thermal hydraulics

- **V-shaped ribs** ► HTC ratio is 2.6-2.8, PD ratio is 5.4-5.8
- **Semi-detached V-shaped ribs** ► additional heat transfer ► cooling performance increase
- **Dimples** ► heat transfer increase without significant PD (HTC ratio is 1.31-1.38, PD ratio is 1.0-1.11) ► the closer the dimples, the higher the heat transfer

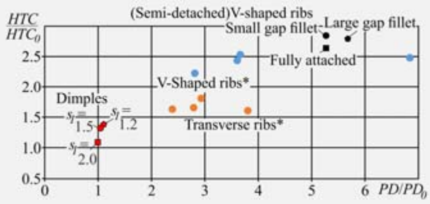

Fig. 3. Normalized global heat transfer coefficient (HTC) ratio vs normalized pressure drop (PD). *S. Ruck, F. Arbeiter, Detached eddy simulation of turbulent flow and heat transfer in cooling channels roughened by variously shaped ribs on one wall, International Journal of Heat and Mass Transfer 118 (2018) 388-401.

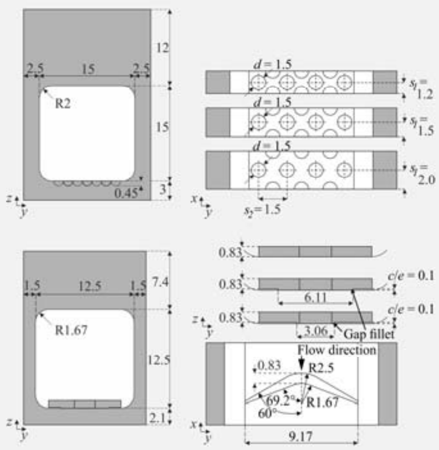

Fig. 2. Geometric details of the dimpled channels and the rib-roughened channels.

4. Local heat transfer

- **V-shaped ribs** ► local heat transfer deterioration at the rear surface and behind the rib reduced
- **Semi-detached V-shaped ribs** ► narrowed regions of low heat transfer
- **Dimples** ► low HTC ratio in the upstream dimple halves ► large regions of $HTC/HTC_0 < 1$ ► high wall temperatures expected

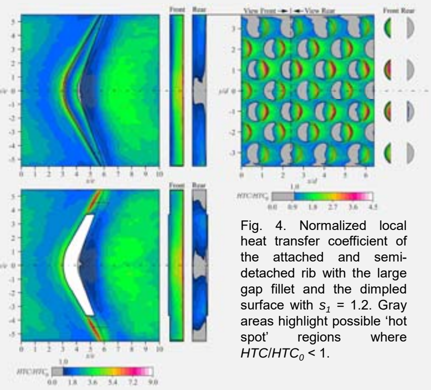

Fig. 4. Normalized local heat transfer coefficient of the attached and semi-detached rib with the large gap fillet and the dimpled surface with s_1 = 1.2. Gray areas highlight possible 'hot spot' regions where $HTC/HTC_0 < 1$.

5. Conclusion

- **V-shaped ribs** ► highest HTC ► local heat transfer deterioration and the pressure drop increase can be reduced by shape optimization
- **Semi-detached V-shaped ribs** ► additional heat transfer provided ► no additional PD compared to attached ones
- **Dimples** ► large regions of $HTC/HTC_0 < 1$ can lead to high wall temperatures

EUROfusion

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