INNOVATIVE MINICHANNEL COOLING SYSTEM FOR GYROTRON CAVITIES

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Technical needs: Increasing performances are constantly demanded to new gyrotrons. The heat load on the cavity wall is a major limiting factor. In Raschig Rings (RR) cavities, heat transfer is limited by the minimum Glidcop cavity thickness that ensures mechanical stability. Actual mini-channel (MC) designs on the TH1507U 1.5MW 140GHz CW gyrotron have shown unacceptable stresses (440MPa in nominal conditions). The proposed system increases the heat exchange while limiting thermo-mechanical stresses and anisotropic deformations.

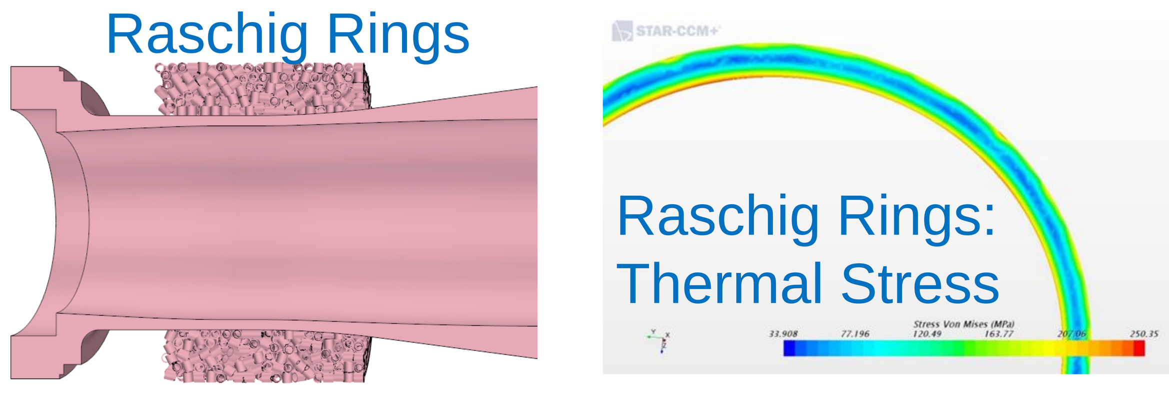

Figure 1. TH1507 RR structure and stress profile (nominal conditions).

Figure 2. First develop. of TH1507 MC structure and stress profile (nominal).

Solution and design: The structure relies on an adaptive profile of the outer element (jacket) that dilates and displaces during operation.

- To increase heat exchange: The fluid flow is placed as close as possible to the heated wall.
- To limit stress: A bypass gap closes the MC once the thermal steady state is reached
- To avoid friction: The axial displacement of the (flexible) water jacket equals the cavity thermal expansion to follow cavity motion.
- To ensure the radial correct position of the jacket: Multiple inlets injects a radial flow that counterbalances the MC inner pressure.

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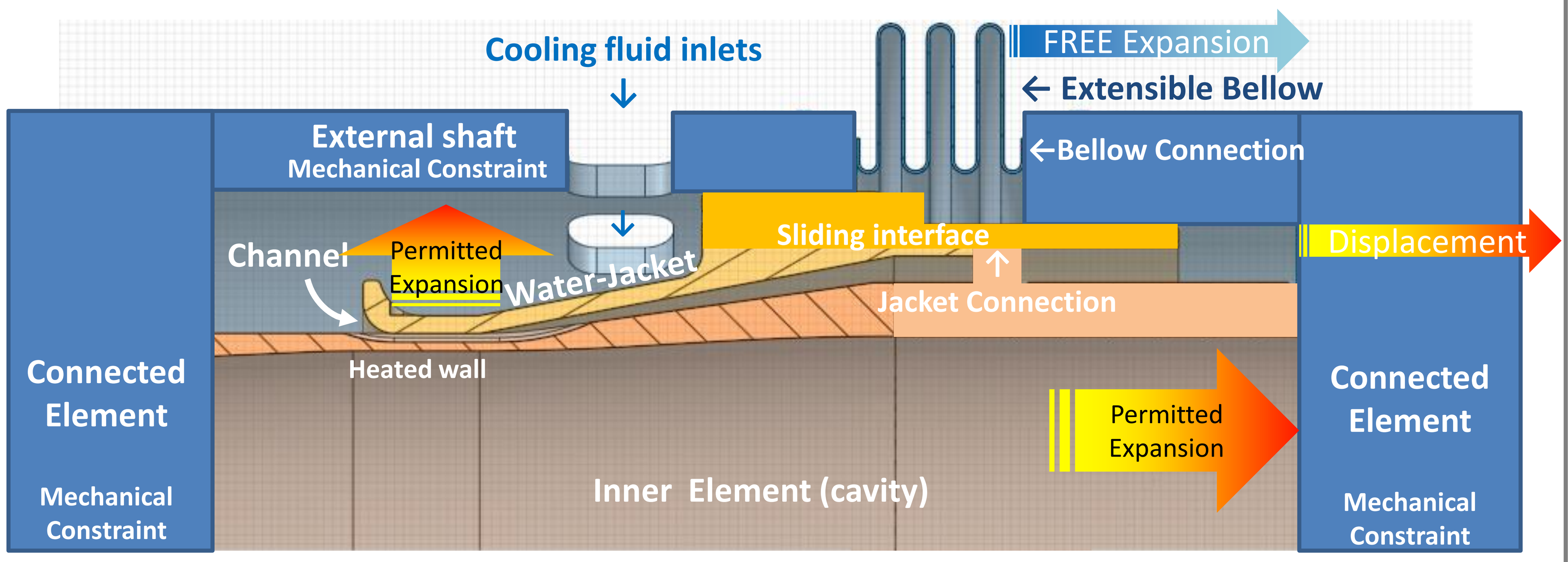

Figure 3. Functional diagram of the proposed cooling system.

Computed performance: Compared to Raschig rings cooling solution, for the same initial peak heat load of 1.85 kW/cm² and water flow of 50 l/min, a multiphysics simulation TH1507U cavity, shows a max temperature reduced from 279° C to 228° C with a stress level of 211 MPa, giving margin of 38 MPa before plasticization. The fatigue life is of 537000 ON/OFF cycles (reaching steady state regime).

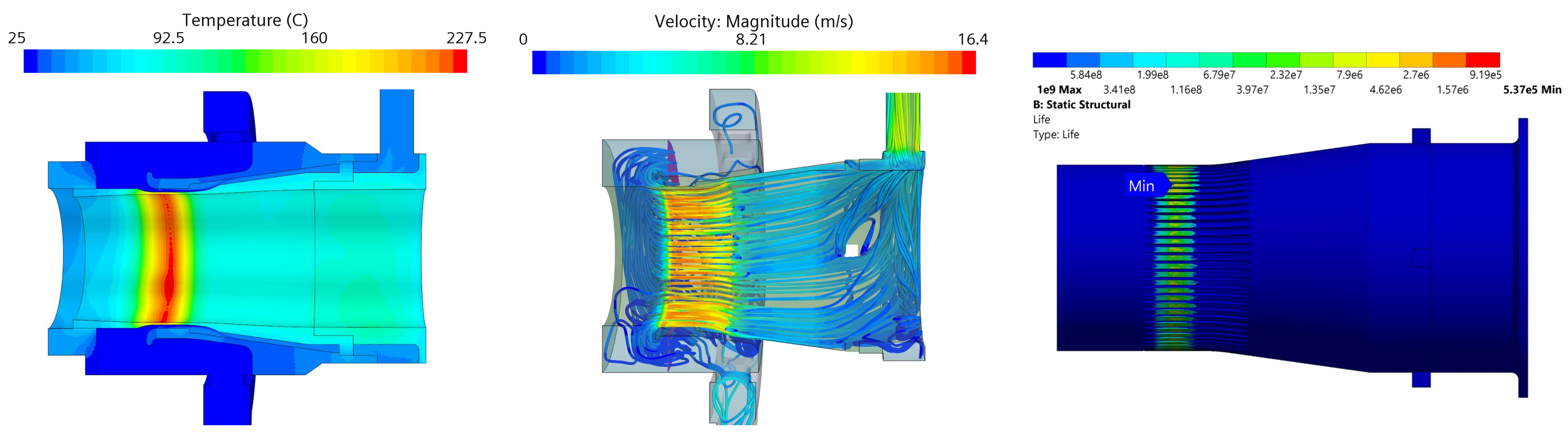

Figure 4. Temperature, velocity and fatigue life plots.

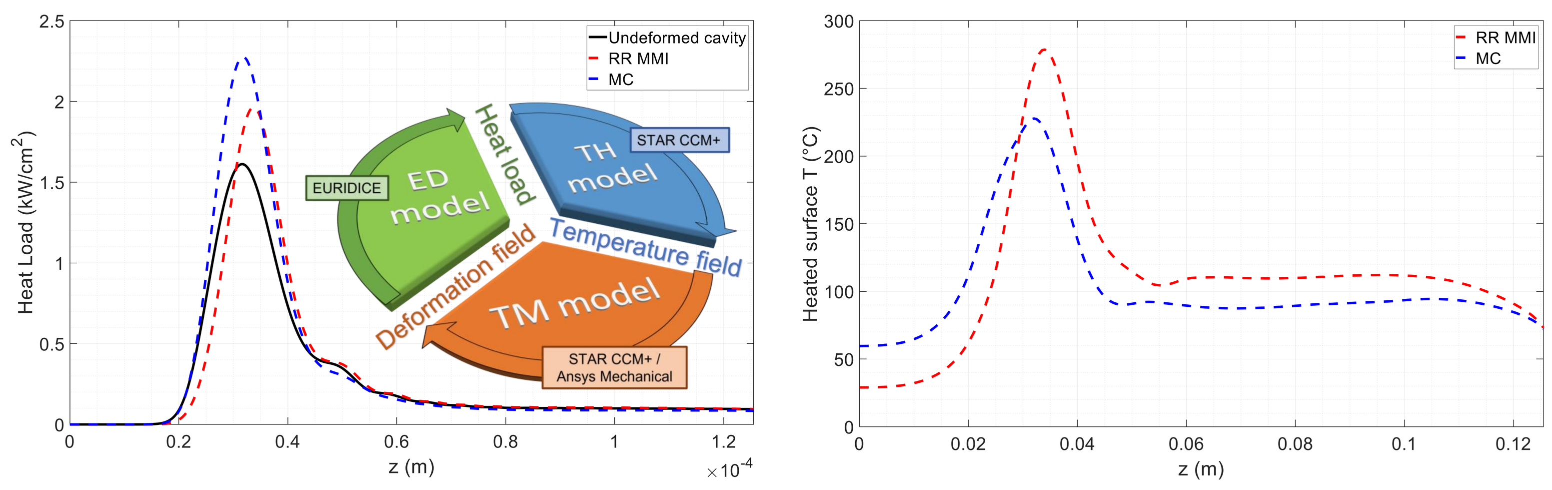

Figure 5. Profiles of heat load (left) and temperature distribution (right).

	Peak heat load (kW/cm²)	Peak cavity temperature (°C)	Max V.M. Stress (MPa)	Yield strength (MPa)	Stress margin before Plasticization margin (MPa)	Pressure drop @ 50 l/min (bar)
TH1507U RR	1.96	279	292	220	-72	0.9
TH1507U MC	2.27	228	211	248	38	1.9

Table 1. Maximum values and comparison with RR solution (@50 l/min).

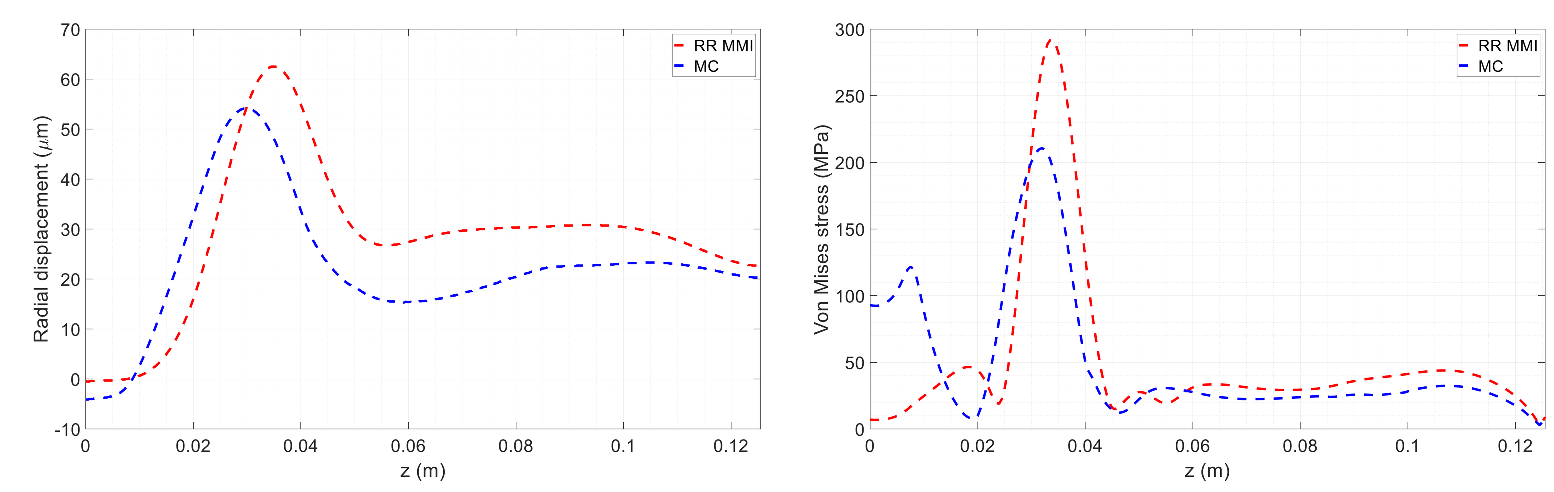

Figure 6. Profiles of radial displacement (left) and Von Mises Stress (right).

Mockup realization: The proposed device can be realized by traditional mechanical processes and proven brazing techniques. A mock-up has been manufactured for technological validation at KIT. Pressure drop have been measured and thermodynamic tests are ongoing at KIT.

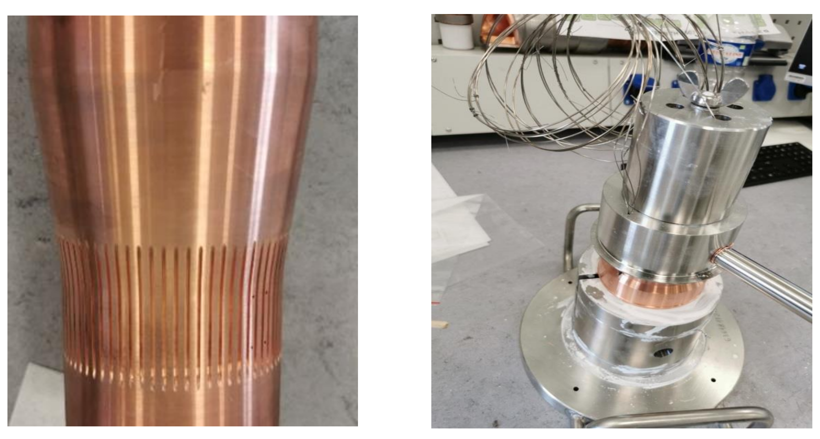

Figure 7. Glidcop cavity and Mockup.

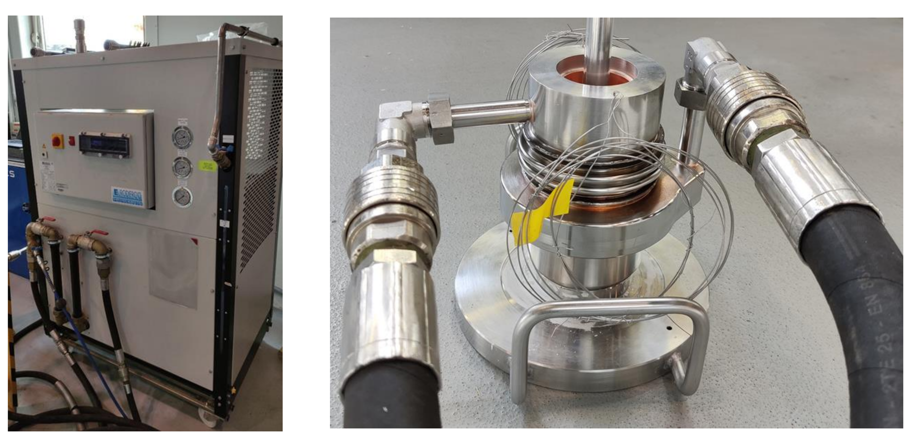

Figure 8. Thales Hydrodynamic test bench.

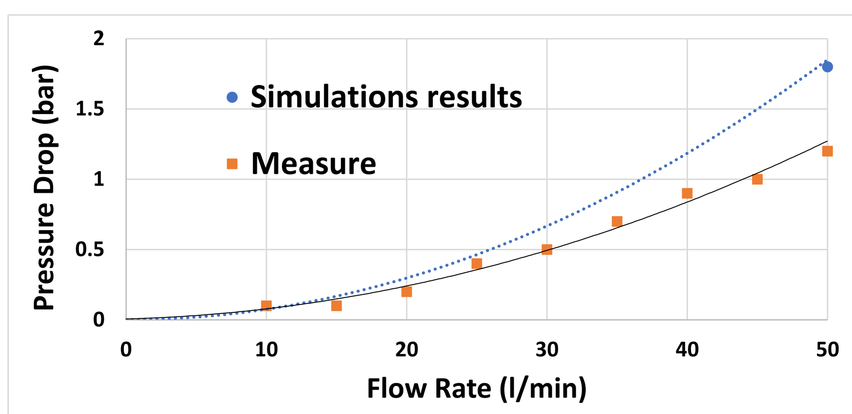

Figure 9. Pressure drop (meas vs sim).

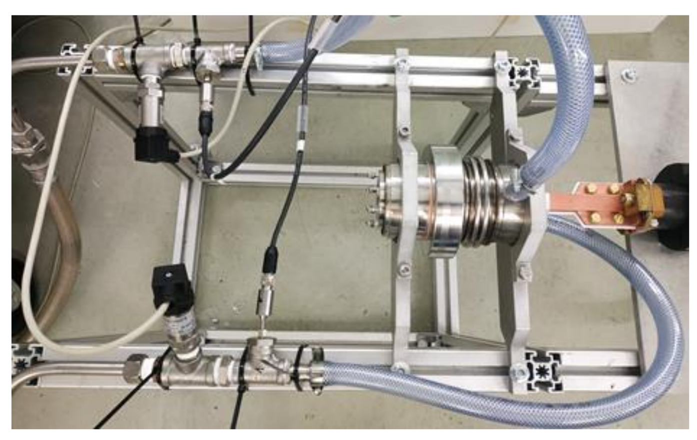

Figure 10. KIT Induction test stand.

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