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EXPERIMENTAL RESEARCH ON MAGNETOHYDRODYNAMIC (MHD) FLOWS IN LIQUID METAL COOLING SYSTEMS FOR FUSION REACTORS

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ABSTRACT

Several projects for thermonuclear installations and hybrid facilities (thermonuclear neutron sources) consider liquid lithium or lead-lithium eutectic usage as a coolant and a tritium production source.

Liquid metals and salt melts are significantly electrically conductive media. In the case of thermonuclear devices with magnetic and magnetically inertial plasma confinement the operation of these media will occur in the presence of strong magnetic fields, which requires the study of thermal hydraulics in configurations as close in geometry as possible to realistic devices.

EXPERIMENTAL APPROACH

- The research team has at its disposal magnets capable of creating stationary magnetic fields of up to 2.7 T. Usage of mercury gives the highest value of Grashof number (one or two orders of magnitude higher than with other metals). Mercury, therefore, allows us to perform heat transfer experiments at the lowest heat fluxes and liquid metal volumes.
- The experiments are conducted in a fully automated mode, which minimizes errors and allows for the acquisition of extensive experimental data.
- Due to the poor wetting of stainless steel by mercury and the small thickness of the channel walls, wall conductivity can be neglected. For investigating systems with realistic wall conductivity, a method for forming intermediate copper coatings has been developed.
- Mercury experiments are conducted with strict adherence to necessary personnel and environmental protection protocols, with waste disposed of by licensed specialized organizations.

METHODS

Scanning probes

- Studies of the flow structure are carried out by scanning submersible probes, which make it possible to reconstruct three-dimensional fields of average and fluctuating temperature and fields of average longitudinal velocity.

Temperature measurements

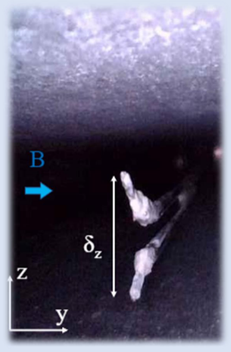
- Temperature is measured by miniature thermocouple sensors with sizes of up to 50 µm. In practice, sensors with a size of 300 µm possess the necessary durability for long-term experiments

Velocity measurements

- Velocity measurements can be performed using temperature-correlation-based mean velocity sensors, electro-potential velocity sensors, and pressure measurements.

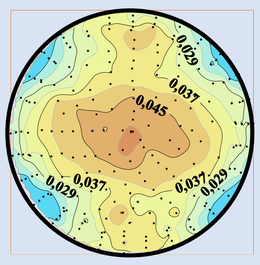
Parameters	Values
Heating rate	0-100 kW/m2
Magnetic field	2.7 T (30 mm gap) 1.8 T (60 mm gap) 1.65 T (110 mm gap)
Channel size	Pipes - diameter 19 mm, 40 mm Ducts – 16 x 56, 56 x 56, mm x mm
Liquid metal	Mercury (as a model liquid)
Temperatures	20-180,˚C

Experimental facility HELMEF



Invasive measurements of temperature and velocity are available .

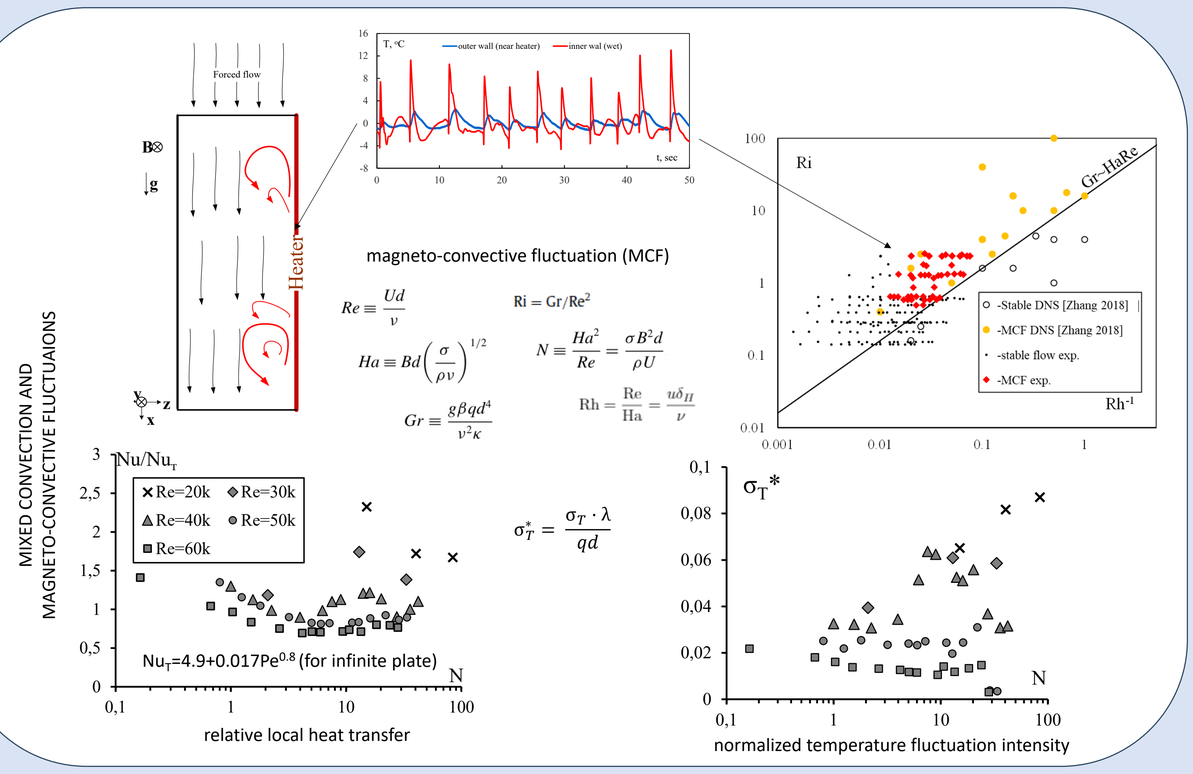
$$Ux = \frac{E}{cB\delta_z}$$

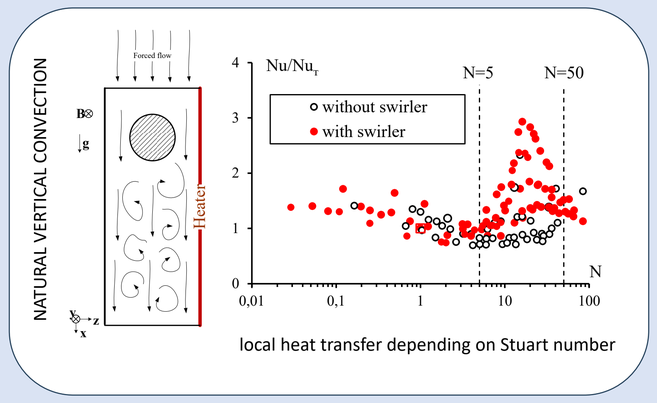


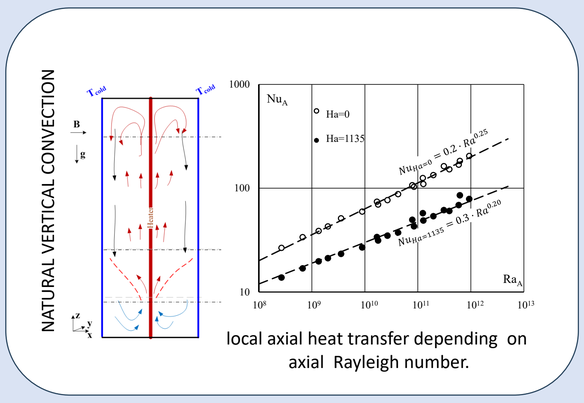
Example of experimentally reconstructed fields of temperature fluctuation intensity in 19 mm pipe.

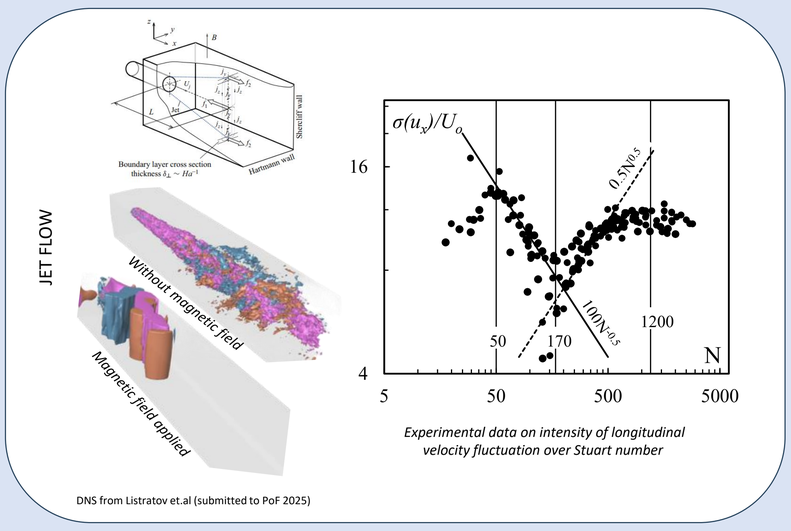
OUTCOME

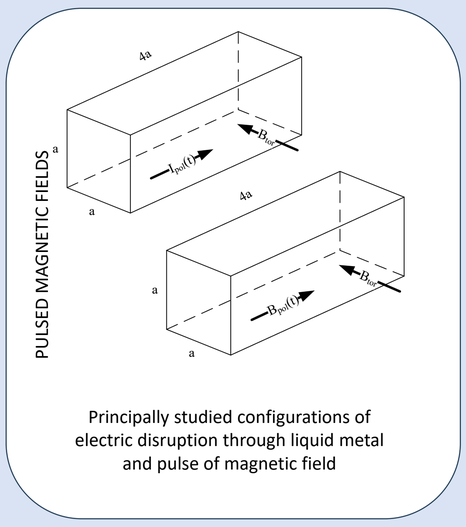
- We invite to collaborate in design of liquid metal systems, whose specific components or simplified versions could be tested in laboratory experiments.
- We are interested in establishing direct communication with developers to perform experiments aimed at verifying numerical codes.











CONCLUSION

The developed experimental approach enables the acquisition of data on the phenomenology of liquid metal systems under strong magnetic fields in a controlled laboratory experiment. Approaches have been established to describe previously unreported and unforeseen hydrodynamic phenomena, such as magneto-convective fluctuations and jet disintegration in a magnetic field. Confirmation and quantitative assessment of the effectiveness of vortex promoters on forced flow have been provided. Experimental methods are being developed to study the effects of electric current breakdowns and pulsed magnetic fields on liquid metal systems.

ACKNOWLEDGEMENTS / REFERENCES

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