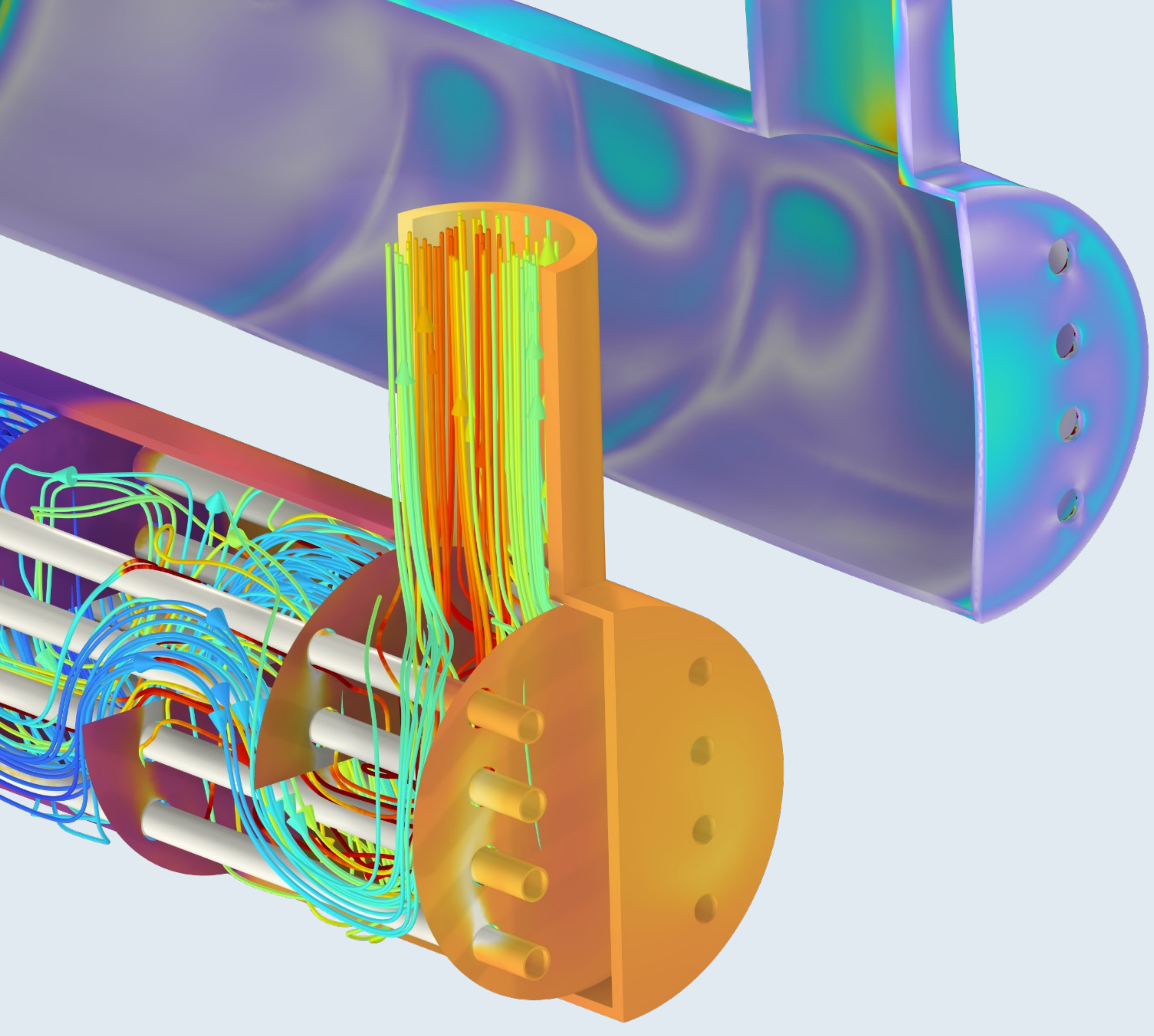

Thermal, Fluid Dynamic and Structural Enhancement of a Heat Exchanger

Design and performance enhancement of a compact heat exchanger for improved thermal efficiency and structural integrity.

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Abstract

The activity focuses on **improving the overall performance** and design of a **small-sized heat exchanger**. This heat exchanger is designed to raise the temperature of a fluid using tubular electric heaters.

The device consists of a **steel shell** with **two hydraulic connections** for fluid inlet and outlet. The case is sealed with a **flange** where the **tubular heaters are brazed**.

Critical issues were identified in the **thermal performance and structural robustness** of the system. In response to these findings, a **new design** was developed and simulated, with the **goal of enhancing** both **thermal efficiency** and **mechanical durability**.

The **new design** demonstrates **significant improvements**, ensuring **higher outlet temperatures** and **reducing stress levels** to meet structural integrity requirements.

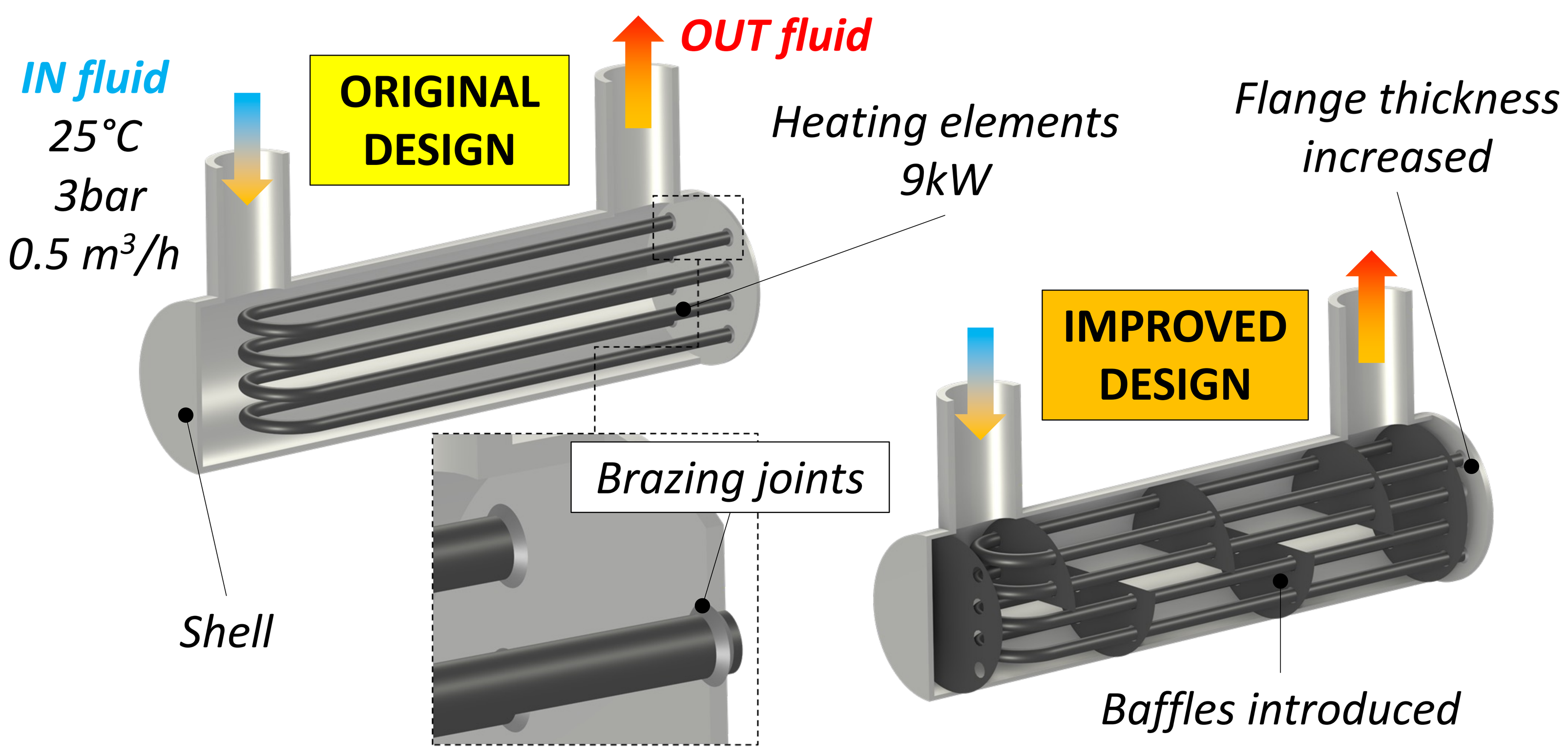

FIGURE 1. Left: Original heat exchanger design with main elements description and operating conditions. Right: Improved heat exchanger design with main changes.

Methods

The simulations are conducted using COMSOL Multiphysics®, employing the **Turbulent Flow k-epsilon** interface for fluid dynamics, the **Heat Transfer in Solids** interface for thermal analysis, and the **Solid Mechanics** interface for structural evaluation. Internal thermal strains due to temperature changes are accounted for using the **Thermal Expansion Multiphysics** coupling.

The brazing between the flange and the heating elements is modeled using **identity boundary pairs**.

The improved design incorporates **baffles** to optimize fluid dynamics and thermal performance, while also **increasing the flange thickness** to enhance structural robustness.

Results

The fluid inside the **original design** does not adequately flow around the heating elements, **potentially resulting in inefficient thermal performance.** From a structural perspective, a critical issue is highlighted near the **brazing joints**, where **stress values exceed the yield limit** leading to **failure risk** during the operating conditions.

On the **improved design** the baffles force the fluid to flow around the heating elements multiple times, leading to an **outlet fluid temperature 5°C higher** respect to the original design. From a structural perspective, the overall stress on the flange is lower due to the thickness increasing and the **stress on the brazing joints** stands **below the yield limit**, **improving the structural robustness** of the device.

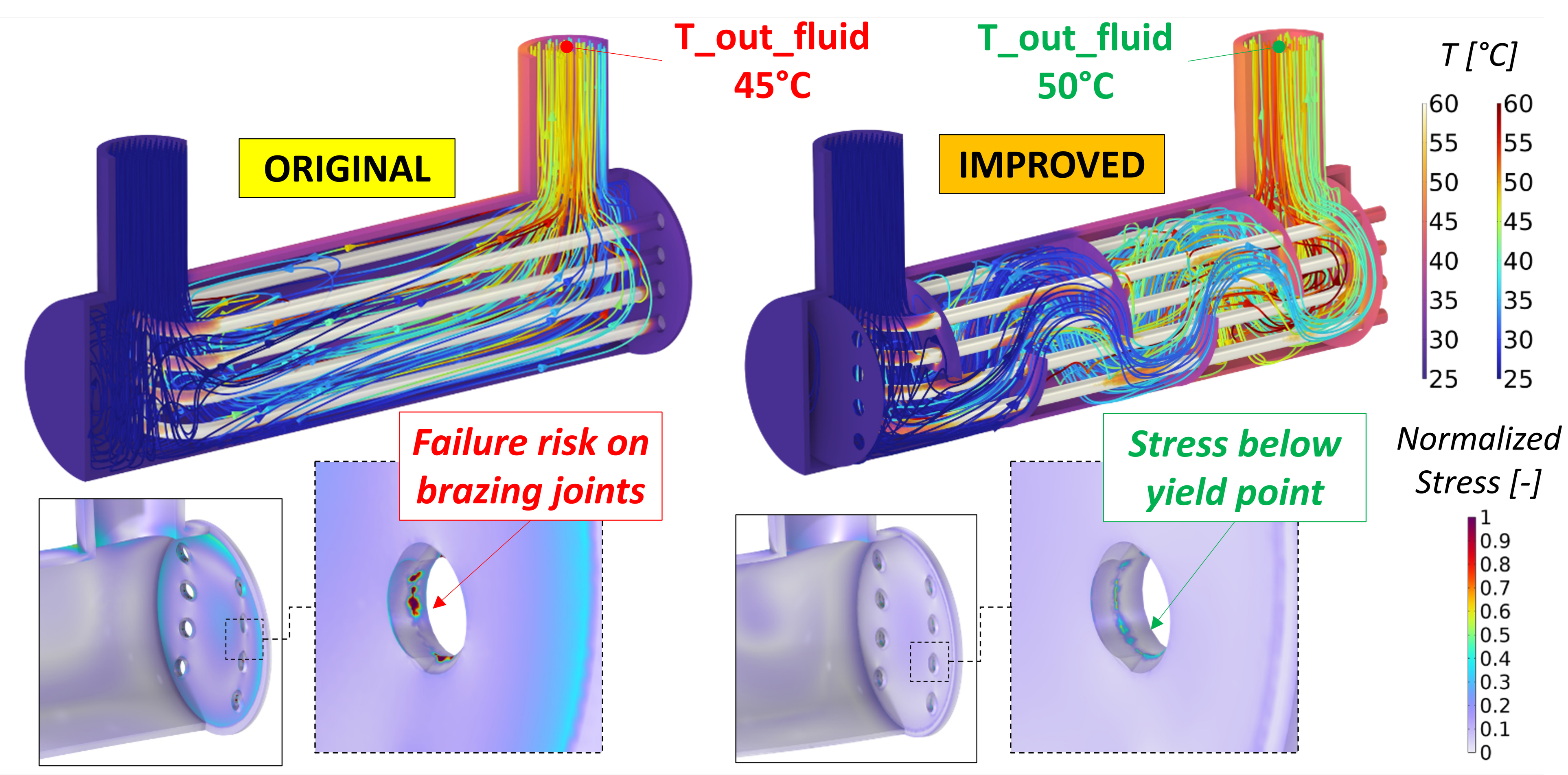

FIGURE 2. Temperature field, streamlines of flow (with fluid temperature color expression) and normalized Von Mises stress for original and improved design.

REFERENCES

1. COMSOL, Heat transfer Module User's Guide.
2. COMSOL, Structural Mechanics Module User's Guide.

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