Study Of A WCLL Breeding Blanket Concept For A Compact Nuclear Fusion Reactor

Raphaël DAVID-MENENDEZ[1], Krishshanth PIRAPAKARAN[1]

[1]French Alternative Energies and Atomic Energy Commission (CEA)

Abstract

Nuclear fusion represents a promising solution for providing clean and sustainable energy. However, to support fusion reactions, tritium, a rare isotope, must be continuously produced within the reactor. Breeding blankets, which surround the plasma, produce this tritium. These components also extract heat from the plasma.
Among the existing concepts, Water-Cooled Lithium Lead (WCLL) relies on the use of a pressurized water circuit to extract heat and liquid lithium-lead to generate tritium.
In the context of compact fusion reactors, which aim to optimize space requirements and increase performance, the WCLL concept could be considered. These reactors, emitting higher heat fluxes, would lead to higher temperatures as well as more severe thermal and mechanical stresses, requiring adjustments to the blanket design.
This work proposes to study the adaptation of the WCLL concept for compact reactors, with the objective of developing an optimized model validated by thermal and mechanical simulations.
The main objectives that the breeding blanket must fulfil are: to ensure sufficient production of tritium from lithium-lead, to ensure heat extraction via a fluid that cools down the structure while limiting the pressure drops of the cooling system and to ensure the integrity of the structures with respect to the various thermo-mechanical stresses.
The breeding blanket is submitted to heat flux coming from the fusion plasma, heat source due to nuclear reaction inside materials, heat transfer with the coolant and pressure from fluids.
In this purpose, COMSOL Multiphysics has been used to run 2D and 3D thermal, hydraulic and mechanical simulations. The geometry is implemented in the software in order to run 2D parametric optimizations. Temperature, stresses and pressure drops are extracted in order to find the best solution. These optimizations led to a design that meet the thermal, mechanical and hydraulic criteria. This design has been validated by detailed 3D simulations.
In conclusion, a new design of the WCLL breeding blanket is proposed. This design has the advantage of being simpler than existing WCLL concepts. However, other aspects should be investigated such as manufacturability or integration in the fusion chamber.

Figures used in the abstract

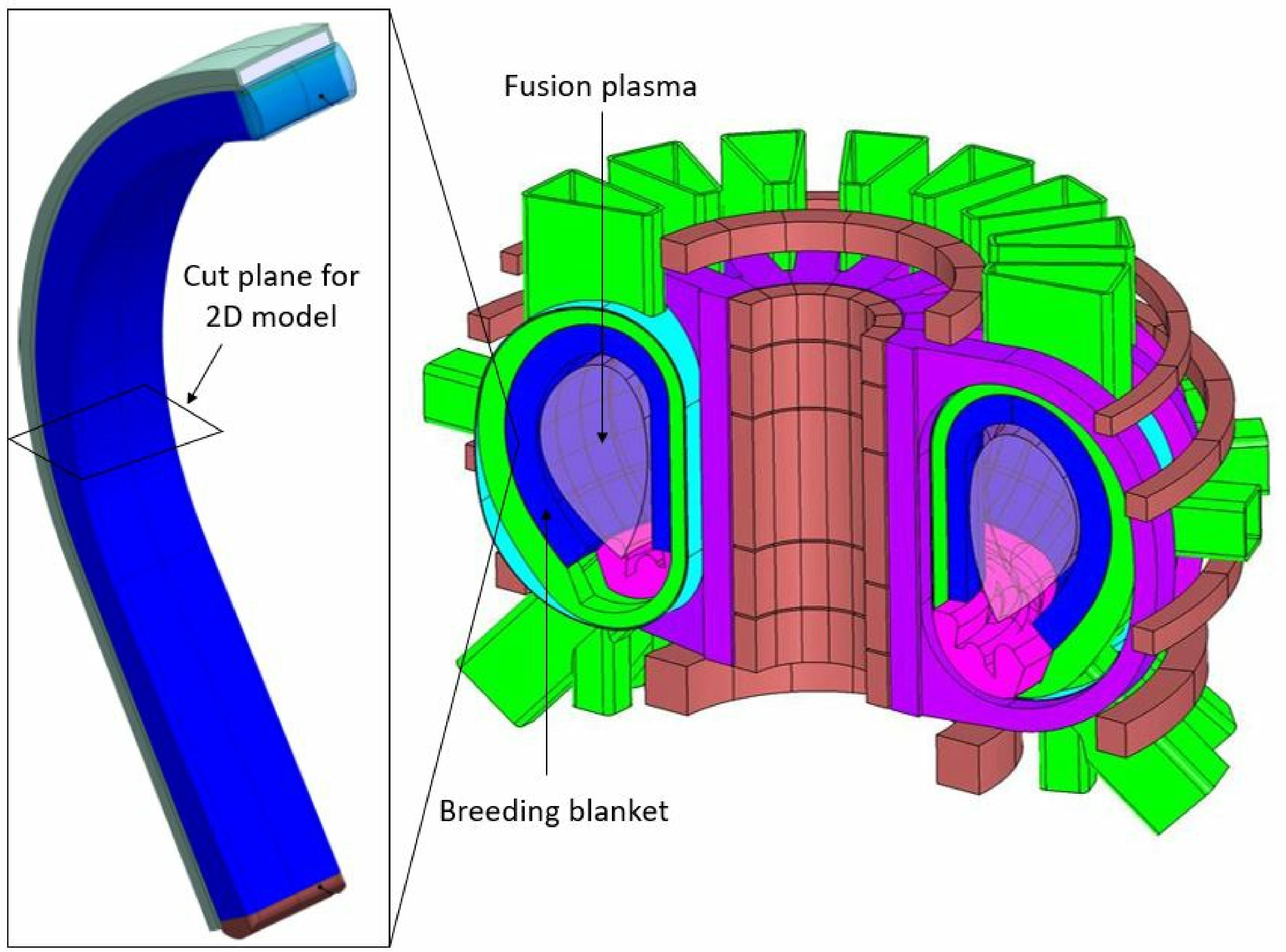

Figure 1 : Breeding blanket in a tokamak fusion reactor

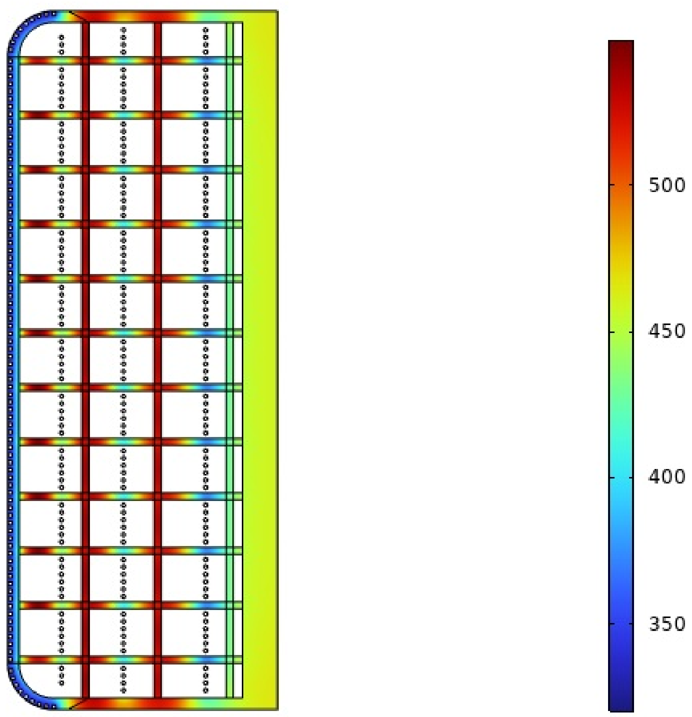

Figure 2 : Temperature field of the structure (°C)

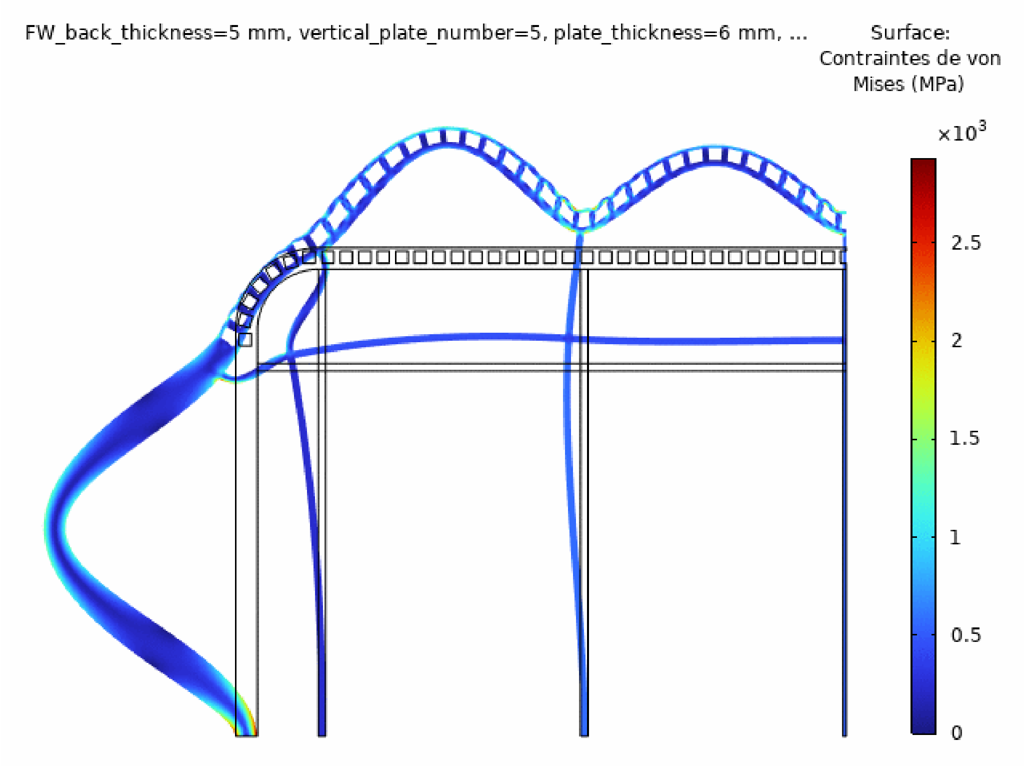

Figure 3 : Mechanical parametric optimization of the design