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Exploration of a fast pathway to nuclear fusion: first thermomechanical considerations for the ARC reactor

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Progress in technological fields such as High Temperature Superconductors, Additive manufacturing, new diagnostics, and innovative materials, has led to new scenarios and to a second generation of Fusion Reactor designs. A new Affordable Robust Compact (ARC) Fusion Reactor, which meets its goal in a cheaper, smaller but even more powerful, faster way to achieve Fusion Energy, has been designed at MIT.

An investigation of the load-following concept is necessary, in order to prove its feasibility on ARC reactor. We started from ARC's most close to plasma component, the vessel: finite element analysis models have been designed and thermo-mechanical analysis have been conducted. Thermal fatigue remains the main issue. The study demonstrated that the vessel is able to survive some years in particular conditions such as high temperature and variable thermal loads. This is quite enough, since ARC's vacuum vessel is thought to be replaced no later than two years, due to neutron embrittlement and neutron induced activation.

Supports, divertors and connections between the two walls should be designed and investigated, to improve vessel's resistance to disruptions without causing hotspots and stress concentrations during thermal expansion. Simulations on supports and channels disposition demonstrated that setting channel's inlet section in the upper side of the vessel, near supports is the best choice.

Indeed, Inconel 718 is not a good candidate from radioactive waste point of view, due to its neutron-induced activation properties. Therefore, few other materials were investigated, knowing the main material properties needed for vacuum vessel's structure. Reference materials used in fusion experiments and projects mostly come up to be less attractive than Inconel 718; for example stainless steels 304L and 316L, which show poor thermomechanical properties. However, the study found out that Vanadium alloys such as V-15Cr-5Ti could be a good substitute of Inconel for ARC's vacuum vessel.

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