An Assessment of Alternative Divertors for the European DEMO


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Introduction and Motivation

The scale of DEMO, in terms of size, power and complexity, poses unique challenges to exhaust physics. The large energy reservoir requires care in designing exhaust systems, especially in the presence of the large uncertainties that still remain in the physics and in the controllability of the transitions. In this context, ITER solution will extrapolate to DEMO, hence building margin is essential.

Fig. 1. Summary of the different activities carried out in WP10TT1A/DC.

EUROfusion’s WP10TT1A/DC project was aimed at investigating the benefits and complexities associated with alternative divertor configurations, as a potential mitigation strategy. The project addressed both physics and engineering assessments in a synergic way (see figure on the left for an example of the activities). We investigated Snowflake (SFD) Super-X (SXD) and X-D (SXD) divertors and compared them with the baseline single null (SND).

Engineering

Structural calculations based on finite element calculations of stresses in the toroidal field coils were carried out. Both hoop and out of plane forces lead to excessive stresses, beyond the acceptable limits. New configurations closer to D-shape (morphing) and box intercool structures to increase rigidity improve the designs of both the SFD and SXD (see Fig. 4).

Fig. 4. Stress maps for the initial and final TF coil configurations.

Conclusions

An extensive comparison between the baseline SND configuration and a number of alternative divertor options has been performed, here showing some of the highlights. Simulations that extrapolate the behavior of the exhaust plasma suggest that an increased margin is possible in configurations with a longer connection length. In other words, SXD and XD can operate with less Ar or more power crossing the separatrix than the SND. Simplistic estimates based on the Langyel model seem to confirm this observation. Alternative designs lead to significant engineering complexity, especially when it comes to TF coil design and control. The latter is particularly problematic unless internal coils are introduced in the design.

Assuming that the SND will have a suitable engineering design, moderate modifications in the divertor could lead to additional physics margin and an incremental complexity. With this philosophy, a hybrid SND/SXD solution was developed with the major radius of the outer strike point halfway between the original SND and SXD. This led to better physics than the SND (see Fig 2) and less complex engineering than the SXD. Exploring the continuum of the solutions could therefore be beneficial.

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