Thermal and Mechanical Analysis on Wendelstein 7-X Thermal Shield

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The stellarator fusion experiment Wendelstein 7-X is currently under construction consisting of a magnet system with 70 super conducting coils. This system is thermally insulated by multi layer insulation made of aluminized Kapton with a silk like fiberglass spacer and a thermal shield that is actively cooled by gaseous helium with a temperature between 50 and 70 K. The shield is mounted on the cryostat wall with special designed supports made of Torlon. The cryostat surfaces consist of inside walls of the outer vessel (OV), outer walls of the plasma vessel (PV) and supply and diagnostic ports allowing access to the plasma vessel for supply lines and diagnostic equipment.

The plasma vessel shield with a surface of about 200 m² is made of a glass fibre compound with embedded copper nets. The outer vessel and the port shields are made of brass having seizes of 500 m^2 and 700 m^2 respectively. The shield material is chosen in a way to reduce the eddy current forces on the shields and to maintain still sufficient heat conduction within the shield.
The basic thermal design requirement is to ensure a heat radiation below 1.5 W/m² from the shields to the cold structures that have a temperature of about 4 K (coil casings, support structures). This can be ensured with an average shield temperature of about 80 K. The shield cooling with forced flow gaseous helium is designed for a maximum heat load up to 6 W/m^2 for surfaces at room temperature (e.g. OV) and up to 9 W/m^2 for surfaces of about 330 K (PV and ports).
The paper presents a finite element analysis of the temperature distribution on the thermal shield of a 1/10 of the symmetric torus. The calculation takes into account the routing of the helium pipes and the thermal connections to the plasma and outer vessel shield. These connections are realized via copper tresses and copper stripes respectively. Because of very restricted space requirements the port shields have no cooling pipes. The heat falling on the port shields is conducted along the port shield axis either to the cryostat shield or to the plasma vessel shield, which doubles the heat load on both shields.

During an emergency shutdown of the magnet system the magnetic field will be ramped down from 3 to 0 T with a time constant of about 3 seconds. The fast change of the magnetic flux induces eddy currents in the thermal shield. The resulting eddy current forces are calculated with a finite element program using ANSYS. Based on these forces a mechanical analysis is carried out to check the shield displacements and stresses and to get forces on the shield supports.
The paper presents the calculation procedures and the results of the electro-mechanical and thermal analysis.