THERMAL STRESS ANALYSIS OF 1 MW GYROTRON COLLECTOR

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At the DIII-D tokamak, up to 6 gyrotrons supply ECH power to the plasma. Each gyrotron injects 800 kW for 5 s at the tokamak during normal operation and are designed to generate 1 MW for 10 s pulse lengths. A power of ~2000 kW is absorbed by the collector of each gyrotron from the electron beam.

The gyrotrons are manufactured by Communications and Power Industries (CPI). The collectors are 0.6 m diameter cylinders, 60 cm in height. The collector walls are 20.7 mm thick and have 196 coolant holes of 5.3 mm diameter. Each pair of adjacent coolant holes is connected in series to provide 98 cooling paths. The collector material is oxygen free high conductivity copper (OFHC) and the collectors are cooled by water at a design flow rate of 300 gpm. In order to reduce the peak thermal load on the collector walls, the beam is swept over the collector wall at 4 Hz and an amplitude of about 15 cm using an external coil. Sweeping reduces the effective peak heat flux from 1400 W/cm^2 to 600 W/cm^2.

During 2004 and 2005, some of the collectors failed due to stress cracks. In order to investigate reasons for these failures, a nonlinear elastic plastic thermal stress analysis of the collector was undertaken. The thermal stress analysis results indicated that the effective strain for OFHC material under the operating conditions limited the cycle life of the collector due to fatigue, resulting in failures.

The desired service life of more than 10^5 thermal cycles can be obtained by 1) operational changes, such as: increasing the frequency and amplitude of sweeping to reduce the average heat flux, 2) design changes, such as: increasing the height and/or diameter of collector, enhancing the heat transfer coefficient by roughening the coolant channel walls or 3) changing the material of the collector to dispersion strengthened copper such as Glidcop. The analysis and conclusions will be presented.

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