Design and material selection for a pressure controlled bellows actuator for the angular positioning of the steering mirror in the ITER ECRH upper port plug

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Abstract

The purpose of the ITER electron cyclotron resonance heating (ECRH) upper port antenna will be to provide localized current drive capability by accurately aiming mm-wave beams at chosen rational magnetic flux surfaces in order to stabilize neoclassical tearing modes (NTMs). ITER's reference design uses a front steering concept located in the upper port plug [1], with the moveable mirror close to the plasma. Among the relevant mechanical design aspects are the systematic reliance on frictionless and backlash free mechanical movements based on the elastic deformation of structural components to avoid the in-vessel tribological difficulties, increased by the high energy neutron flux present in near plasma regions. Among those structurally compliant components, a set of inert gas pressure and remotely controlled corrugated bellows function as actuators providing accurate angular positioning of the steering mirror. The selection, characterization and validation of the materials appropriate for the design and manufacturing of the bellows is discussed, as membrane structures such as the bellows are different from standard structural components. They are exposed to variable external pressure levels proportional to their expansion work against the load. Results of the cyclic fatigue tests are compared to the various standards and predictive codes applied for the given operating conditions, combining stress and strain controlled material fatigue properties. Industrially available bellows are manufactured by hydroforming or galvanic techniques, thus limiting the applicable materials to nickel base alloys, for which the available data on fatigue under irradiation combined with thermohydraulic and electromagnetic loads is scarce. Thermal treatment such as precipation hardening and cold work strongly influence the alloys microstructure and the resulting cyclic fatigue limits of the bellows. Other flexible components used in the mirror steering mechanism include flexure pivots, machined springs and helical water pipes. Material selection, experimental results and analytical methods used for life time prediction of these components are discussed.

[1] D. Strauß et al., this conference.