Enhancement of zonal flow drive through equilibrium shear flows

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Turbulence generated zonal flows (ZFs) are known to be part of regulating turbulent transport and, therefore, are suspected to be involved in spontaneous transitions from low to high confinement regimes in toroidal fusion plasmas. ZFs are driven by radial gradients of the turbulent Reynolds stress (RS) $\langle \widetilde{v}_\theta \widetilde{v}_r \rangle$ which de facto measures the tilt of vortices. Therefore, equilibrium shear flows can constitute a seed flow for initially tilting vortices, initiating the ZF drive and stimulating its self-amplification.

In this contribution the dependence of the RS on the background flow shearing rates is investigated experimentally. To this end, the poloidal $E\times B$ background flow in the stellarator TJ-K is controlled via plasma biasing. A ring shaped electrode is positioned in the plasma and set on a positive potential with respect to the vacuum vessel. The current drawn from the plasma changes the equilibrium plasma potential profiles and therefore imposes strong $E\times B$ background flows. This application even allows to equalize the pressure driven $E\times B$ background flow and, thus, to minimize flow shear. The plasma potential $\phi(r)$, from which the shearing rate i.e. $\Omega = (RB_0)^2 B^{-1} \partial_r (RB_\theta)^{-1} \partial_r \phi$ is deduced [1], is measured with a radially moving emissive probe. For measurements of the poloidal RS distribution and related radial gradients, a specifically designed poloidal Langmuir probe array is employed, which consists of 128 probes with 32 tips each of four adjecent flux surfaces, measuring potential fluctuations. This way, the approximate flux surface averaged RS, the RS drive, and even zonal potential structures is analysed with respect to background flow shear experimentally.

Varying the bias voltages from 0 to 50V the shearing rates increase from negative to positive values in the kHz range. With the shear approaching zero also the RS vanishes. At this point the ZF power has a local minimum. The ZF power behaves similar to the RS and RS drive. Shear induced changes in the RS are considered a consequence of a modification in the nonlinear wave coupling process, in which the amount of coupling modes is reduced as to increase efficiency in the energy transfer into the zonal flow [2]. This paradigm is tested by means of bispectral analysis carried out on the measured RS data.

References

[1] Burrell et al., PPCF **40**, 1585 (1998).

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