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Effect of Large Magnetic Island on Shear Alfven Continuum Crossing Points in Cylindrical Plasma

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Recently, much attention has been paid to the change of the continuous shear Alfven spectrum in the presence of the magnetic island in the tokamak. The resulting bound state shear Alfven wave (or MIAE) in the vicinity of the magnetic island can also be driven unstable by energetic particles without suffering continuum damping [1].

In the present paper, we explored change of shear Alfven spectrum near the crossing point when there is a large magnetic island somewhere else in cylindrical plasma. Detailed analytical work shows that continuum structure is destroyed and series of discrete spectrum arises near the crossing point with strong spatial localization. This result is different from the case of the toroicity where continuum formed a gap and also from the previous work [1] where authors are interested in the continuum near the magnetic island.

In cylindrical tokamak, large magnetic island with low toroidal and poloidal helicity usually induces perturbation with same helicity which covers from core to the edge. Also, inhomogeneity enables a continuous eigenstates of shear Alfven wave and frequency of the modes with different helicity can coincide in specific position. Near such points even away from the island, two shear Alfven propagating in opposite direction can resonantly interact with perturbations induced by magnetic island as long as their toroidal and poloidal mode numbers satisfy coupling condition.

To describe such mode-mode coupling process self-consistently, lagrangian theory of the ideal MHD is re-investigated and nonlinear equation of motion for the displacement is derived. Magnetic field, pressure and density is successfully expressed in terms of the displacements which is correct even in weakly nonlinear case. In such cases, instead of solving full set of MHD equations, three coupled nonlinear force balance equation for displacements are enough to get full solution of the weakly nonlinear MHD.

Coupling of shear Alfven continuum with magnetic island is analyzed in detail using the method described above. Two coupled equation for shear Alfven wave with different helicity is derived with additional coupling term introduced by magnetic island. Careful investigation of the solution indicates that near the crossing point of the shear Alfven continuum, continuum structure is destroyed by magnetic island and discrete eigen-frequency appears with localized spatial eigen structures. The system was similar to that of quantum harmonic oscillator and it turns out that poloidal components of the magnetic island provides each quanta of frequency gap while radial magnetic field contributes to the shift of the overall eigenfrequency. Such new types of bounded shear Alfven wave states can be also driven unstable through wave particle resonance with small continuum damping due to strong localization characteristics of the mode.

References

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