Global beta-induced Alfvén-acoustic modes in JET and NSTX

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An area where up to now there has only been sporadic investigation [1, 2] but where pertinent wave particle interactions in burning plasma regimes need to be investigated, is the study of the linear interaction of two fundamental waves in MHD theory, the Alfvén and acoustic waves. The interaction is mediated by finite pressure, plasma compressibility and geodesic curvature. As a result of such interaction additional gaps in the coupled Alfvén - acoustic continuum emerge [2, 3] and here we present an analytic model for the structure of these gaps. In addition their Alfvén - acoustic continuum has extrema with respect to the radial position, which arise in the gaps or in the low shear regions. We find numerically that global modes may occur adjacent to these extrema points. We call these modes Beta-induced Alfvén - Acoustic eigenmodes (BAAE) and we find that these modes can arise in both relatively low and high beta plasmas.

Here we investigate whether unexplained data in JET (relatively low beta) and NSTX (relatively high beta) can be attributed to the excitation of BAAE's. Numerical calculations for monotonic and reversed q-profiles on JET (using the ideal MHD code NOVA) show that the BAAE modes evolve from almost zero frequency when q_0 or q_{min} crossed rational values to a maximum value around $f \simeq 40kHz$ in the plasma frame, limited by the Alfvén - Acoustic gap frequency. Although JET observations show a qualitatively similar frequency evolution, they are bounded by a lower frequency value of $f \simeq 14kHz$. Near the lowest possible frequency of the mode, the wave form is quite similar to that of a shear-Alfvén wave which is characterized by line bending polarization with a modified dispersion from the conventional shear-Alfvén wave dispersion.

In NSTX with plasma beta around 20% the same BAAEs are found numerically and there are oscillations in NSTX that can be explained as being due to BAAE instabilities. They are localized near the region of low shear in plasmas with a reversed magnetic shear profile as evidenced in both NOVA simulations and in the reflectometer observations. In this case the frequency is about half of the TAE frequency, which in NSTX is close to the geodesic acoustic modes (GAMs) frequency.

In contrast to the mostly electrostatic polarization of GAMs, the new global modes contain an electromagnetic component due to the interaction with the Alfvén branch. As these global modes have a substantial magnetic component, the resulting component of the phase velocity along the field line is substantially greater than the sound velocity. Consequently, the use of fluid equations is justified, but with an appropriate modification of the adiabaticity index which is determined by kinetic theory for a collisionless plasma which will also induce an intrinsic damping term.

By understanding the range of BAAE frequency excitation we may be able to extend the use of so-called MHD spectroscopy and by using frequency observations in this new regime to determine q_0. Such an observation would be a very important diagnostic tool for ITER and other burning plasma experiments. This observation would also help infer the central plasma beta and the ion and electron temperatures.

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