# KINETIC AND CURRENT PROFILE EFFECTS OF ALFVEN WAVES IN THE TCA TOKAMAK

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Recent Alfvén wave experiments in the TCA tokamak show new evidence of the importance of kinetic effects and the influence of plasma conditions on the Alfvén wave. The R.F. magnetic field measured at the plasma edge reflects unambiguously the resonance of the kinetic wave eigenmodes in the plasma centre. The measured values of the resonance Q-factor of the principal eigenmodes are lower than predicted by the code by a factor of 3 to 20, although all expected damping mechanisms are included in the code. Alternative damping mechanisms are discussed and the best candidates proposed after quantitative evaluation. The R.F. itself modifies the plasma in such a way that the coupling strength can change very strongly. The experimental observations and the results of the code show that the current profile is certainly the best candidate which can affect the coupling in this way, implying that the R.F. pulse is able to influence the plasma current profile.

Observations of kinetic effects at the edge : In the kinetic description of AWH, the surface compressional wave mode converts to the KAW in the vicinity of the Alfvén Wave resonance layer (ARL). As the ARL moves outwards, standing waves of increasing order are formed due to reflection at the plasma centre. These standing waves, which occur for all (n,m) modes, appear as a sequence of resonances on the loading and edge plasma wavefield at a higher density than the principle DAW.

A comparison between experiment and the cylindrical kinetic code ISMENE [1] for the n=2 edge plasma wavefield is shown in Fig. 1, where the experimental, cold and kinetic theory fields have been plotted in the complex plane. From the figure it may be concluded that the resonances are a kinetic effect. The resonances disappear when the KAW is damped before reaching the plasma centre and so indicate approximately when energy deposition ceases to be central.

Width of the DAW resonance peaks : An important discrepancy between theory and experiment is the value of the quality factor, Q, for the DAW resonances. Figure 2a shows the experimental (2,1) Q as a function of plasma current and R.F. power and Fig. 2b shows the theoretical Q for two representative current profiles as a function of plasma current. According to Fig. 2a, the DAW affects the plasma in such a way that its Q increases with R.F. power.

A comparison of the figures shows that the experimental Q is about 10 times lower than the theoretical Q, even though the kinetic code includes those damping mechanisms, electron Landau damping, transit time magnetic pumping and electron-ion collisions, known to be important for the damping of shear Alfvén waves. The theoretical Q is not a strong function of the electron temperature, or its profile.

Three mechanisms have been proposed which could lead to a lower Q than predicted and which are not contained in the model of a hot quiescent plasma.

Enhanced collision frequency due to MHD turbulence has been observed to lead to lower than predicted Q's for magnetoacoustic waves [2]. Calculations using the kinetic code with 1000 times the electron-ion collisionality revealed a negligible change in Q since the kinetic damping mechanisms dominate for TCA conditions. Turbulence enhanced electron-ion collisions do not therefore explain the low observed Q.

In toroidal geometry a DAW may couple to KAWs of several different surfaces already present in the plasma. This coupling, not contained in the cylindrical theory, could provide an additional energy loss channel for the DAW. Analysis of such coupling would require a 2D kinetic code. However, we have made numerical simulations based on coupled circuits, using the experimental observation that the KAW $n_e$ at the (2,0) resonant layer increases by a factor of 5 during the passage of the (2,1) DAW. These reveal that the power transfer is insufficient to explain the observed Q. Until toroidal coupling is properly modelled, however, the energy loss of the DAW cannot be determined unambiguously.

Since the DAW resonance is density and plasma current dependent, a noise modulation of the average values of these parameters, or their profiles, will modulate the resonance condition and lead to a smearing of the resonance curve. Changes of ~ 3 % in $\overline{n}_e$ and ~ 10 % in $I_p$, required to reduce Q enough, would be too large. Plasma current and density profile wobulations are, therefore, most likely responsible for the low observed Q.

Effect of R.F. power on the Alfvén Wave spectrum : At high power levels in AWH, discontinuities are observed to occur in the plasma parameters at the continuum thresholds [3]. At the thresholds, the rate of density rise decreases or even changes sign and a drop in the plasma internal inductance ($l_i$) has been proposed to accompany a transient drop in $R_{pl}$ [3,4].

Further evidence for a drop in $l_i$ is shown in Fig. 3a. The density begins to decrease after the (2,1) threshold, however, the DAW fails to reappear due to a drastic loss of loading as the spectrum is reswept. This is surprising since the DAW is relatively insensitive to plasma parameters provided the profiles of density and current are held fixed. The DAW loading decreases very rapidly for flat density profiles as the profiles become flatter; however, the change in density profile required to completely eliminate the DAW is larger than measured. Numerical calculations show that the DAW loading and coupling ($R_{ant}/Q$) are also strong functions of the plasma current profile, increasing linearly with $l_i$ as shown for the coupling in Fig. 3b for the (2,1) DAW over a wide range of current profiles. Fig. 3b indicates that a flattening of the current profile can cause the DAW coupling to become vanishingly small, however, the interpretation is complicated by the presence of $\beta$ in the experimental $\Lambda = (\beta + l_i/2)$ measurement. The problem of current profile modification is also treated in [5].

Conclusion : Results have been presented which show clear evidence that certain effects of Alfvén waves cannot be explained by the simple quiescent cold plasma MHD theory. Kinetic effects must be included to fully describe the standing KAWs observable in the edge plasma wavefield. Current or density profile wobulation appears the best candidate to explain the low observed Q. Static current profile changes occurring at continuum thresholds seem the best candidate to explain a markedly reduced DAW loading in experiments where the spectrum is reswept by a descending density.

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References

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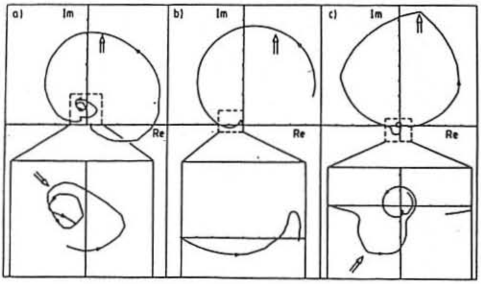


FIG. 1. The RF magnetic wavefield of the (2,1) DAW and KAW resonances plotted in the complex plane: a) experiment b) cold model c) kinetic model.

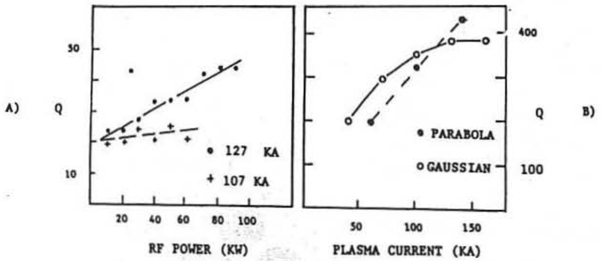


FIG. 2 A) measured Q of (2,1) DAW vs RF power.
B) Calculated Q of (2,1) DAW vs plasma current. using a parabolic and a Gaussian profile.

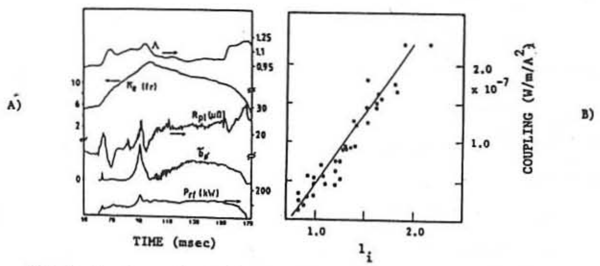


FIG. 3 A) Loss of coupling to DAW during density fall. Note change in lambda.
B) DAW coupling vs plasma internal inductance calculated from code using a wide range of plasma current profiles.