1. Introduction

Energetic particle populations such as fusion alphas, beams and RF tails can drive a wide variety of shear Alfvén instabilities in toroidal confinement systems. These instabilities lead to enhanced loss of fast ions and decreased heating efficiencies. Our gyrofluid stability model [1] has recently been extended to include sheared plasma flow velocities. We also discuss recent results from applying this model to ITER, TFTR, and W7-AS.

2. Velocity Shear Effects on TAE Instabilities

Advanced tokamaks are predicated upon improved confinement regimes, such as the H-mode and ERS (enhanced reversed shear) mode; these regimes rely upon the presence of sheared plasma flows to suppress turbulence and lower transport rates. Recent experiments on the JT-60U device [2] have indicated that TAE instabilities are also sensitive to velocity shear effects. Sheared flow effects have been introduced into our gyrofluid model by including the appropriate convective terms [1]; these flows have not, however, been included in the equilibrium (i.e., we assume $v_{\text{flow}} \ll v_{\text{sound}}, v_{\text{fast,ion}}$). Results for an $n = 5$ TAE instability in a circular cross section tokamak with $v_{\text{fast}}/v_{A0} = 0.85$ are shown in Figures 1 and 2.

![Figure 1 - Dependence of growth rate on position of peak poloidal velocity shear.](image1)

![Figure 2 - Dependence of growth rate on magnitude of poloidal velocity shear.](image2)

We have assumed a flow profile $v_0 = v_{\text{max}} (1 - \tanh [2\alpha (r - \lambda)])$ and have varied the parameters $v_{\text{max}}, \alpha,$ and $\lambda$ in order to study sensitivities to the level of flow shear and its...
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
Figure 3). In Figures 4 and 5 the mode structures for the two branches of TAE instability shown in Figure 3 are plotted vs. radius and poloidal mode number.

![Figure 4](image1.png)  ![Figure 5](image2.png)

**Figure 4** - $n = 5$ core-localized TAE eigenfunction.  
**Figure 5** - $n = 20$ high-$n$ TAE eigenfunction.

(b) **DT phase of TFTR**  
Alpha-particle-driven TAE instabilities were observed during the DT phase of TFTR [5] under special conditions which were predicted to lower the TAE instability thresholds. These included elevation of the central safety factor [6] (to align the gap structure with the peak alpha pressure gradient) and reduced central magnetic shear (to destabilize the CLM branch) [3]. In Figures 6 and 7 the dependence of TAE growth rates on $(\nu_{\text{fast}})/\nu_{\alpha0}$ and $\beta_\alpha(0)$ is plotted for an elevated $q(0)$ ($\approx 1.5$) DT discharge. A range of $n$'s can be destabilized and for $n = 1$ and 2, two different branches of TAE are present (the $n = 1$ and 2 branches at lower $(\nu_{\text{fast}})/\nu_{\alpha0}$ are more core-localized).

![Figure 6](image3.png)  ![Figure 7](image4.png)

**Figure 6** - TAE growth rates for an elevated $q(0)$ TFTR DT discharge vs. fast ion velocity at $\beta_\alpha(0) = 0.003$.  
**Figure 7** - TAE growth rates for an elevated $q(0)$ TFTR DT discharge vs. $\beta_\alpha(0)$ at $(\nu_{\text{fast}})/\nu_{\alpha0} = 0.7$.

(c) **GAE/TAE Instabilities in W7-AS**  
Stellarators which have been optimized close to quasi-symmetry generally have low values of magnetic shear. In such configurations the global Alfvén eigenmodes (GAE), which occur beneath the shear Alfvén continuum, have been observed in conjunction with neutral beam heating [7]. We have adapted our model to stellarators in a toroidally averaged sense in order to focus specifically on GAE and TAE instabilities (the helical Alfvén waves are excluded as they are expected to have higher energy thresholds). For GAE modes at low shear, the spacing between values of $k_\|_n$ at adjacent