§34. A Model for the Saturation of Pressure-Driven Modes in ATF and CHS

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High-beta experiments in ATF and CHS have provided first evidence for the transition to the second stability regime. In ATF it was observed [1] that the amplitude of the n=1 interchange increases with beta when $\beta < 0.3\%$ and it decreases towards higher beta when $\beta > 0.3\%$. In CHS we observed [2] that the amplitude of the magnetic fluctuations increases with beta when $\beta < 1\%$ but it does not increase any further when $\beta > 1\%$. In the present work we outline a model for the saturation of pressure-driven instabilities with a second stability regime, which may account for these results. In the presence of two stability bands for the equilibrium pressure gradient at $0 < -\nabla p_0 < G_{01}$ and $G_{02} < -\nabla p_0$, a perturbation ξ becomes unstable when $G_{01} < -\nabla p_0 < G_{02}$. For incompressible perturbations (with $\nabla\cdot\xi = 0$) the perturbed pressure gradient ($G = -\nabla p$) is given by

$$G = (1 + [\xi])G_0 \qquad (1)$$

where $[\xi] = d\xi_r/dr + \lambda\xi_r$, $\lambda = (dG_0/dr)G_0^{-1}$. Eqn. (1) implies that the perturbed pressure gradient G fluctuates about the equilibrium value G_0 approaching the stability limits (G_{02} and G_{01}). **In the present model the mode eventually saturates when the perturbed pressure gradient matches the stability limit which is closer to the equilibrium value,** i.e. when

$G = G_{01}$ if $|G_0 - G_{01}| < |G_0 - G_{02}|$,

$G = G_{02}$ if $|G_0 - G_{01}| > |G_0 - G_{02}|$.

This is illustrated in Figure 1. At mode saturation eqn. (1) becomes $G = (1 + \chi)G_0$ where $\chi = [\xi]_{sat}$ is the saturation parameter. In the above saturation principle the saturation parameter would be

$\chi = |1 - G_{01}/G_0|$ if $|G_0 - G_{01}| < |G_0 - G_{02}|$

$\chi = |1 - G_{02}/G_0|$ if $|G_0 - G_{01}| > |G_0 - G_{02}|$

The saturation parameter in the unstable region $G_{01} < G_0 < G_{02}$ is shown in Figure 2 for two different values of G_{01}/G_{02}. For $G_{01}/G_{02} = 0.33$ the saturation parameter has a "triangular" profile, such as the profile in ATF. For the much smaller value of $G_{01}/G_{02} = 0.06$, however, the saturation parameter grows very fast to a flat top (at χ of about 1), and it looks rather similar to the profile in CHS.

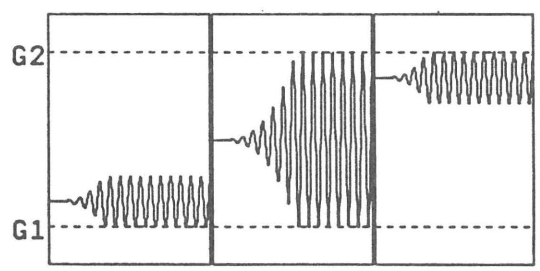

Fig 1. Illustration of the fluctuating pressure gradient in the unstable regime

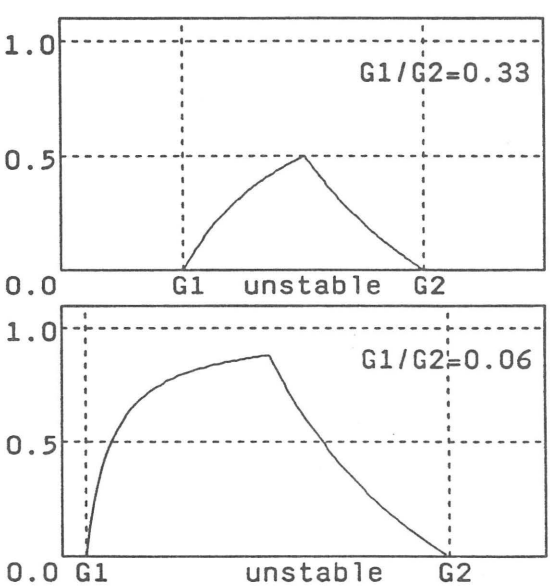

Fig 2. Illustration of the saturation parameter vs the pressure gradient

References

[1] Harris J. et al, PRL 63(12),1249 (1989)
[2] Okamura S. et al, NIFS - 280 (1994)