Recent Progress in Sawtooth Control

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It is now well known that sawteeth with long periods can trigger neoclassical tearing modes at relatively modest plasma beta, thereby reducing energy and particle confinement at best, or leading to a disruption at worst. Sawteeth are expected to be long in ITER due to the stabilising role of trapped alpha particles. Over recent years there has been renewed interest in the theoretical understanding of sawteeth, and the experimental implementation of control techniques. In these studies, control refers to objective of deliberately manipulating the period of sawteeth, and usually the objective is to shorten it. An important advance has been to show that energetic ions have a significant, and moreover, a controllable effect on the stability of the internal kink mode, thought to underlie the sawtooth phenomenon. As well as the established stabilising effect of trapped fast particles, it has recently been shown [1, 2] that passing fast ions with a large orbit widths also strongly influence sawtooth stability, due to the radial drift excursion of the energetic ions which are distributed asymmetrically in the velocity parallel to the magnetic field. Such distributions occur naturally when unbalanced neutral beams are applied, or ICRH is employed with asymmetric antenna phasing. Analytical techniques [1, 2] and numerical modelling [2, 3] have enabled not simply interpretation of observations, but the prescription of conditions required for the desired sawtooth period. There have been notable advances in sophisticated experimental control techniques. Recent results exhibiting destabilisation of sawteeth by steerable electron cyclotron resonance heating (ECRH)in TCV [4] and TORE-SUPRA [5] have included real-time feedback schemes and robust control of the magnetic shear via electron cyclotron current drive and localised heating. Dramatic changes in sawtooth stability have also be achieved in JET [6] by the application of off-axis ICRH with toroidally asymmetric antenna phasing. Consistent with theory [2], ICRH has been shown to control sawteeth due to kinetic effects even under conditions where the modification to the magnetic shear is minimised [6]. It is concluded that various robust control schemes have been established, and ever more sophisticated analytic and numerical modelling are helping define the requirements of sawtooth control actuators in ITER.

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