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Magneto-Hydro-Dynamic Instabilities in Tokamak Plasmas

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Magneto-Hydro-Dynamic (MHD) instabilities are responsible for some important operational limits in tokamak plasmas, notably the limit on the total pressure and total current in the plasma. These global MHD stability limits are well known and usually avoided in experiments. The limits are accurately described by the linearised ideally conducting MHD model.

Even well below the global ideal MHD stability limits, MHD instabilities are a common feature in the standard tokamak operating scenarios. Examples are the so-called sawtooth collapses in the plasma centre, Edge Localised Modes (ELMs) and neoclassical tearing modes (NTMs). The ELMs are fast (~200μs) MHD instabilities, driven by a large pressure gradient and current density at the plasma edge. The ELMs cause significant energy losses with a high peak load. This is a real concern for possible damage to the ITER first wall.

The NTM modes are tearing modes driven by the local pressure gradient. They lead to the formation of islands in the plasma thereby reducing the energy confinement. The NTMs may cause a limit on the total pressure well below the ideal MHD stability limits.

The MHD model is not just used to describe (unwanted) MHD instabilities; it is also used as a means of diagnosing the plasma. The response of the plasma to small magnetic perturbations yields information on the MHD stability limits while the plasma is still stable. The observation of MHD waves, excited by fast particles or by an external antenna, gives information on the profile of the current density distribution.

The numerical calculation of the MHD stability limits is well advanced, taking into account the exact plasma geometry and high values of the magnetic Reynolds number. The non-linear simulation of the MHD instabilities is very challenging due to the very high Reynolds numbers and large heat conduction parallel to the magnetic fields.

Examples of the MHD instabilities in tokamaks will be presented together with the progress made in the numerical simulation of these instabilities.