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Problem 1: Plasma boundary parametrization

The solution of the Grad-Shafranov equation [1], which is at the basis of tokamak plasma MHD equilibrium computation, in the fixed boundary formulation first requires the description of the plasma boundary in terms of a few physical quantities. Typically, such quantities are the major (R) and minor (a) radius of the toroidal plasma, its elongation (k) and triangularity (d).

Limiter plasmas are characterized by a boundary that is a closed magnetic surface tangent to a material surface (e.g. poloidal or toroidal limiter). For this type of boundary, a common description is given by [2]:

r(t) = R + a*cos(t + d * sin(t))
z(t) = k * sin(t)

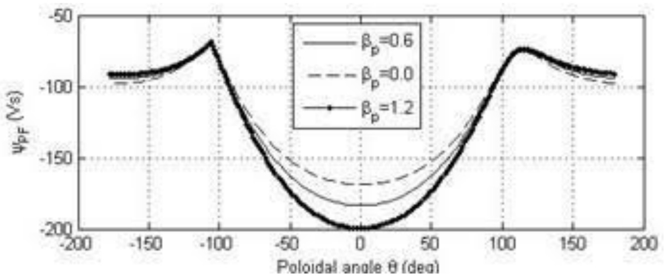
with t = [0,2*pi[the poloidal angle between the r-axis and the line connecting (R,0) and (r, z), which is the generic plasma boundary point in the poloidal plane.

Divertor plasmas are, on the other hand, characterized by a boundary that is NOT a closed flux surface nor tangent to any material surface, but it contains saddle point(s) at which the boundary has cusp(s) of 90 deg. For such a boundary (which is the most commonly used in burning plasmas) the parametrization above is NO longer valid.

A simple (i.e. in terms of R, a, k d, …) parametrization of divertor plasma boundaries would be most useful.

Problem 2: Plasma boundary control

The boundary of a tokamak plasma is controlled by acting on the currents flowing in the surrounding Poloidal Field (PF) coils. By solving the fixed boundary Grad-Shafranov equilibrium problem (see above) we easily establish the *target* flux function (ψ) along the *target* plasma boundary (Γ) that must be matched by the currents flowing in the external PF coils. A typical example of such functions for different type of equilibria is shown in the figure below.



Perfect matching is possible only if the set of PF currents are placed along the plasma boundary itself Γ [1], which is technically impossible. A common problem in tokamak engineering is therefore, to find a set of PF currents located on a different contour Γ^*, external to Γ, that match at best such target flux function ψ while minimizing a weighted functional of error (JE) and cost (JC) (typically expressed in terms of magnetic energy [1][3]).

An algorithm to compute the PF centres location and current along Γ^* to optimize a given functional J = JE + JC would be most useful

[1] T. Takeda and S. Tokuda, J. Comput. Phys., 1991, vol. 93, p. 1.
[2] R. Miller et al. Physics of Plasmas, 5, 973 (1998)
[3] Portone, A., "Magnet system optimization in tokamak engineering", In *Decision and Control (CDC), 2012 IEEE 51st Annual Conference on* (pp. 4328-4334). IEEE.