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Atlas for the TEXTOR-DED operations

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Introduction

The dynamic ergodic divertor (DED) of TEXTOR is presently under construction [1]. The concept was developed for a spreading the convective heat flux to a large plasma facing surface. The ergodization of the edge will be achieved by 16 perturbation coils placed on the high field side, inside the vessel (see Fig. 1) and covering about 30 % of a tokamak wall. The coils follow helically the magnetic field lines of the $q \approx 3$ surface. The DED can be supplied either by DC or AC current. Three types of operation are possible: static (with constant perturbation field), quasi-static (with 50 Hz rotation of the perturbation field) and with high frequency (1–10 kHz). This work concerns only the static and quasi-static scenarios. The structure of the magnetic field in the edge can be described as an "open ergodic system". Ergodic means that any field line passing through pre-selected starting point will come infinitely close to any target point [2]. The system is "open" in that sense, the field lines will cross tokamak walls. Such configuration provides three different regions in the tokamak:

(a) the almost unperturbed inner zone,

(b) the ergodic zone surrounding the inner one,

(c) laminar zone as the outermost one.

Some properties of these regions will be described in the next parts of the paper.

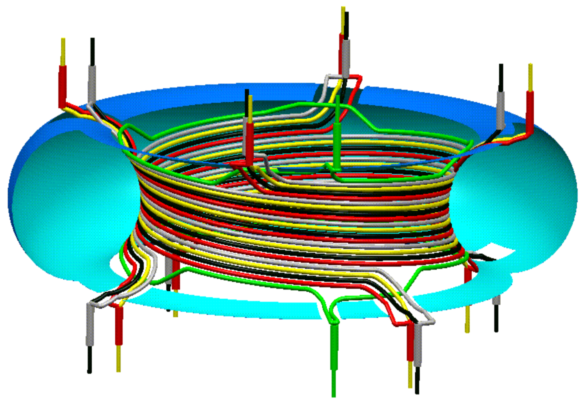

Figure 1: Sketch of the DED: sixteen perturbation coils located on the high field side plus two compensation coils.

Atlas

To investigate properties of the TEXTOR edge with the DED in operation, a special set of graphs was developed. This set, called *atlas*, consists of Poincaré plots, the laminar plots for the low- and high field side and the magnetic footprints plots. Calculations were made using analytical approximation depicted in [4]. Poincaré plots describe the topology of the magnetic field on a selected poloidal plane marking intersections of the field lines with that plane. The laminar plots are developed to visualise properties of the laminar zone, they extend information of the Poincaré plots by providing the field lines connection lengths, i.e. the distance between two intersections with the wall. They are in particular of interest for regions with the short connection lengths. The magnetic footprints plots were invented to investigate structure of the flux tubes striking the divertor target plates (see Fig. 4).

Parameters for the atlas are: the value of beta poloidal $(\beta_{pol} = 0,\ 0.5,\ 1.0)$ and the plasma current $(I_p = 350,\ldots,500\ \text{kA})$. It was found [3] that a perturbation spectrum strongly depends on β_{pol} and a position of the resonant surface varies with the plasma current.

The ergodic layer

For a sufficiently low perturbation current, magnetic islands centred on the resonant surfaces are created. With increasing the current, islands start to overlap creating the ergodic regions. If this happens, the field lines are no longer restricted on magnetic surfaces and "diffuse" over the whole ergodic zone; this process enhances the diffusive heat transport coefficient significantly. A typical situation for TEXTOR is shown on Fig. 2, where ergodic layers are separated by the islands chains. Because the system is "open", field lines passing close to perturbation coils intersect with divertor walls after few poloidal turns (one poloidal turn is about 30 m). Therefore this region has different properties then the ergodic one.

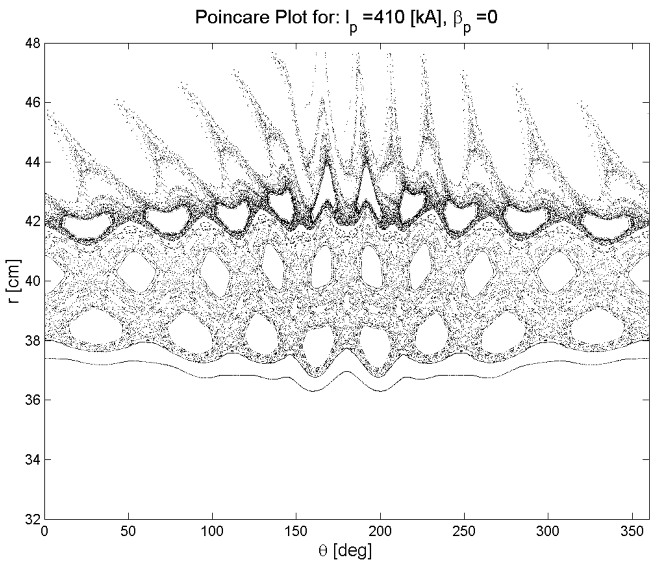

Figure 2: Poincaré plot for low ergodization case, three plasma regions are visible: good confinement region, ergodic and laminar zones.

The laminar zone

The laminar region has relatively simple boundary comparing to the ergodic zone. To investigate the properties of the TEXTOR-DED edge a new technique of visualisation was introduced [4]. At the poloidal plane field line with a given initial co-ordinates is traced clockwise and counter-clockwise until it reaches the d ivertor target plates; then a fractional

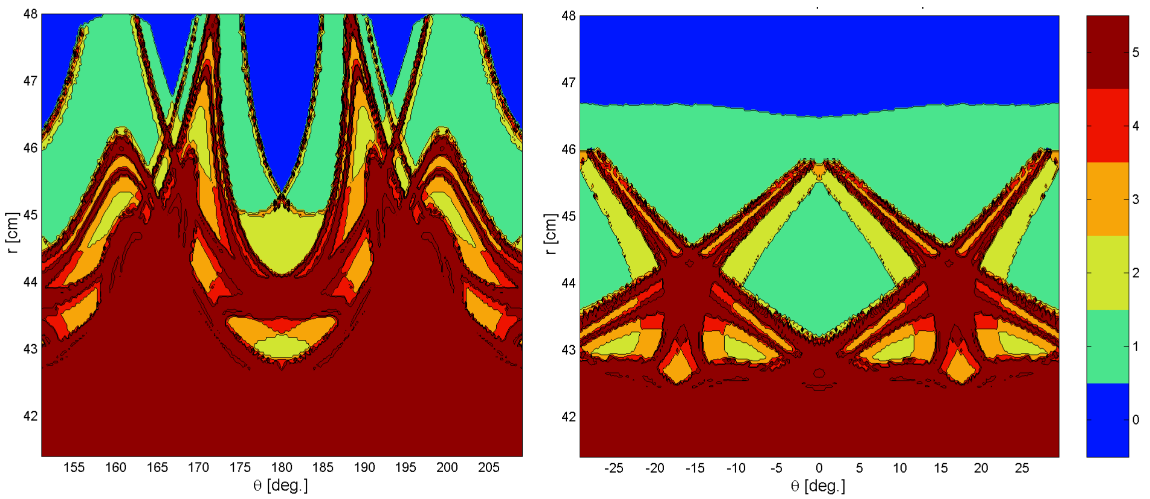

Figure 3: The laminar plot characterises the topology of the magnetic field in the poloidal reference plane. Two examples are shown for the $I_p = 410$ kA and $\beta_{pol} = 0.0$. Left: for the low field side; right: for the high field side.

number of poloidal turns is determined and marked at the position of initial co-ordinates. In the most outermost area of the DED plasma instead of the strong ergodization, the large continuous structures of single and double poloidal connection lengths were found. For this both the heat and the particle transports are dominated by the laminar zone in the plasma edge. It suggests to treat the plasma edge in a similar way as the scrape-off layer of the poloidal divertor. On Fig. 3 two examples are shown. Different colours mark different number of poloidal turns. The blue regions contain field lines with wall to wall connection lengths less then one poloidal turn – these areas will have similar properties to the private flux zone of the poloidal divertor.

Magnetic footprints

The structure of the laminar zone is reflected in the topology of the field lines intersections with the divertor wall. To visualise that special kind of graphs was developed. Fig. 4 shows an example of a *magnetic footprints plot*, which is created by tracing field lines starting from the wall until it reaches the wall again; then the connection length is calculated and marked at the initial position of the field line. One can see, that connection length changes very rapidly with change of the striking point co-ordinates. A relatively large area is formed by the private flux zone, it is expected that in high density discharges it provides a shielding of the confined centre of a discharge from impurities coming from the wall. The pattern is repeated after 90 degrees in toroidal direction (because of the four-fold symmetry of the system.

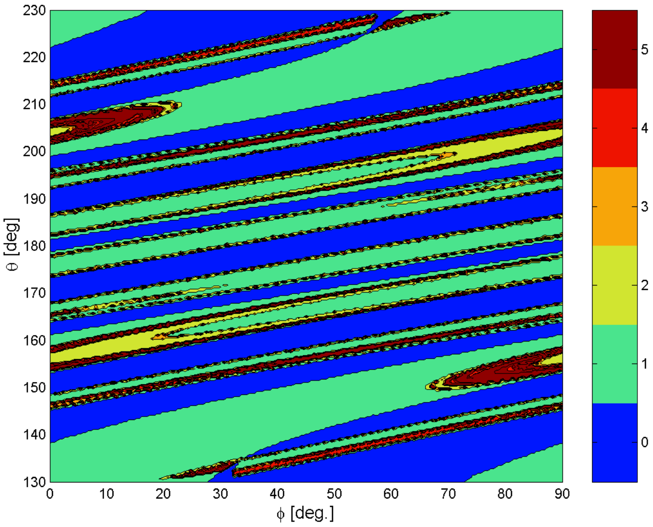

Figure 4: The structure of the magnetic field at the plasma wall r_d = 49 cm (I_p = 410 kA, β_p = 0.0); close-up view of the high field side. Different colours depict different connection lengths of the field lines.

Summary

Applying perturbation from DED to the TEXTOR plasma will leads to create a specific topology of the magnetic field in the boundary including ergodic and laminar regions. The laminar zone has physical properties similar to the poloidal divertor. The atlas is developed as a tool for analysis results obtained from TEXTOR with the DED in operation. As a parameters for atlas the value of I_p, β_p are chosen, because properties of the TEXTOR-DED edge strongly depend on both parameters. Further development of the atlas is planned.

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