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# Reference Magnetic Coordinates (RMC) for Toroidal Confinement Systems

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# Reference Magnetic Coordinates (RMC) for toroidal confinement systems

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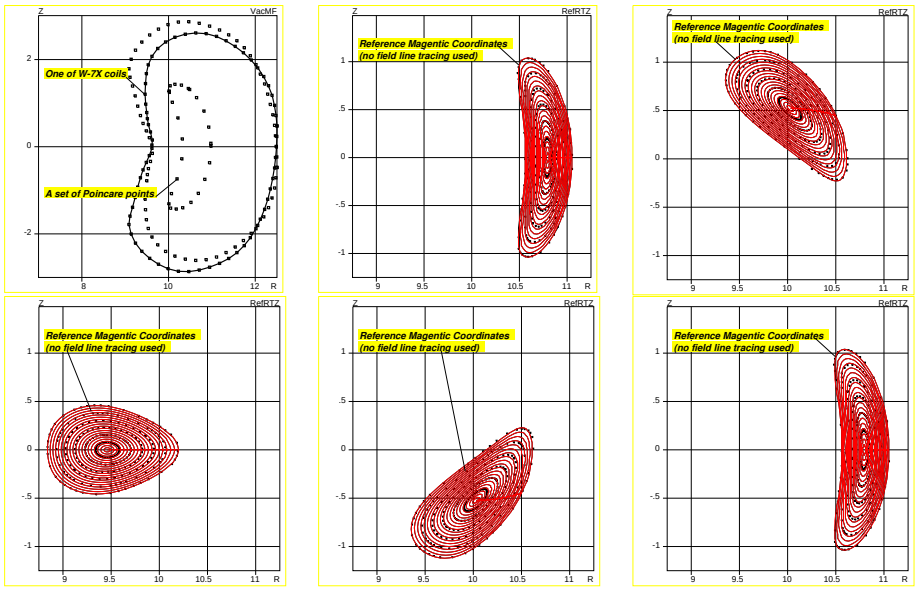
Intrinsically high anisotropy of the fusion plasma creates serious problems in simulations of plasma equilibria in stellarators and plasma dynamics in tokamak disruptions unless adaptive coordinates aligned with the magnetic field are used. While in axisymmetric case the poloidal flux function $\Psi(r,z) = const$ determines proper flux coordinates, in 3-D, such a function does not exist. The destruction of nested magnetic surfaces even by small 3-D perturbations leads to a sudden change of topology of magnetic field. As a result, the coordinate systems can no longer be based on tracing the magnetic field lines resulting in difficulties for theory and 3-D numerical simulations.

The RMC coordinates $\hat{a}, \hat{\theta}, \hat{\zeta}$ presented here (introduced in 1998 [1] but not really used) are nested toroidal coordinates, which are best aligned with an ergodic confinement fields. In particular, in RMC the vector potential of the magnetic field has an irreducible form

$$\mathbf{A} = \bar{\Phi}_{00}(\hat{a})\nabla\hat{\theta} + \left[\bar{\Psi}_{00}(\hat{a}) + \bar{\psi}^*(\hat{a},\hat{\theta},\hat{\zeta})\right]\nabla\hat{\zeta},$$

where 3-D function $\bar{\psi}^*$ contains only resonant Fourier harmonics of angle coordinates. The remarkable fact is that RMC can be generated and advanced using a fast (Newton) algorithm not involving the field line tracing.




Example of W-7X vacuum field: 3-D RMC were generated by ESC code within 1 sec on an early Sun workstation (1998) with no line tracing. The red contours are RMC generated using 24 boundary Poincare points, the black squares in the core are the Poincare points used for illustration.

Implementation of RMC opens an opportunity for fast stellarator equilibria calculations and for resolution of the existing problem with singular currents at the resonant surfaces in calculations using flux coordinates.

RMC can initiate transition to adaptive, plasma physics based numerical schemes in fusion MHD simulations where plasma anisotropy has to be addressed by the appropriate choice of coordinates.

At present, the ESC code [2], is being modified for 3-D equilibria calculations and its 3-D results will be presented.

[1] L. E. Zakharov. "Reference magnetic coordinates (RMC) and the theory of 3D plasma equilibria". Bull. Amer. Phys. Soc. (1998)

[2] L. E. Zakharov, A. Pletzer. "Theory of perturbed equilibria for solving the Grad-Shafranov equation", Phys. of Plasmas, 6, p. 4693 (1999)

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