§1. Evolution of Magnetic Islands in a Heliac

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One of the critical issues in obtaining a high-β plasma for helical devices is the formation of magnetic islands induced in nonaxisymmetric finite-β equilibria. This issue has been studied by the 3D equilibrium code HINT, which does not a-priori demand the existence of regular nested magnetic surfaces. It has been discovered numerically that breaking of magnetic surfaces due to the finite-β effect occurs in a practical configuration of a toroidal helical system, such as heliotron/torsatron [1] and Helias [2], and often imposes severer limitation on the equilibrium beta than the Shafranov shift. In addition, unexpectedly good aspect, which can be called "self-healing", has also been discovered. The island issue is especially the case for the Heliac configuration, which has a small shear and contains a large number of Fourier harmonics in the magnetic field structure. In this paper, properties of magnetic islands induced due to finite pressure effects in a H-1 Heliac configuration [3] are studied using HINT. H-1 fields have a large degree of flexibility due to an $l = 1$ helical trim coil. In this study we examine a configuration which includes the island structure corresponding to the $\iota = 6/5$ resonance ($\iota = 2/5$ per field period) in the vacuum field and assume the existence of stellarator symmetry. The ι profile for the vacuum field is monotonous and the shear is quite small. As the increase of β, minimum of ι (vanishing shear) appears at around half the minor radius. Depending on the value of the minimum ι with respect to 6/5, the most dangerous (low order) rational surface relevant, a variety of topology appears for magnetic islands induced in finite β equilibria. At $\beta_0 = 1.5\%$ ($\bar{\beta} \approx 0.5\%$), the size of the $\iota = 6/5$ island should increase with plasma pressure to about 1/5 of the plasma radius. If the pressure is increased to $\beta_0 = 2.0\%$, the plasma appears to experience a form of self-healing, however the corresponding ι profile shows that this is because the 6/5 surface has been excluded from the configuration. It is possible that this exclusion might be due to some self-consistent plasma dynamics and, as such, could be considered as a (new) form of self-healing. In any case, it is a favorable property of the H-1 configuration that reasonably smooth flux surfaces can be obtained at these plasma β's.

As the pressure is increased further the HINT results show that the minimum value of ι remains just above 6/5, however the flux surfaces show marked signs of *near-resonant* deformation. When the equilibrium pressure has increased to $\beta_0 = 4.4\%$, the flux surfaces have reconnected to form a double island structure, indicating that the minimum of ι has decreased down to 6/5. The topology of the island is analogous to the homoclinic phase portraits observed for Hamiltonian dynamical systems after separatrix reconnection, but appears to be new in the context of stellarator magnetic fields. The possibility of separatrix reconnection occurring is due to the corresponding Hamiltonian being degenerate, which, in our case, corresponds to $\iota' = 0$ across a finite fraction of the plasma radius.

The behavior of islands shown in Fig. 1 suggests an existence of a new type of self-organizing process, which is driven by a pressure-driven instability.

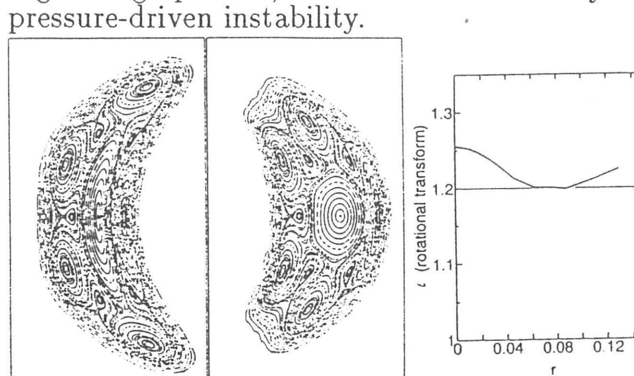

Fig. 1 Evolution of magnetic islands in a Heliac at $\beta_0 = 4.4\%$.

References

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[3] Hamberger, S.M., Blackwell, B.D., Sharp, L.E., Shenton, D.B., Fusion. Technol. 17 (1990) 123.