Exploration of Compact Stellarators as Power Plants: Initial Results from ARIES-CS Study

Farrokh Najmabadi and the ARIES Team

Department of Electrical & Computer Engineering
and Center for Energy Research,
University of California San Diego, , La Jolla, CA 92093-0438
najmabadi@fusion.ucsd.edu

The optimum stellarator configuration is quite dependent on the engineering/technological constraints. In a stellarator, the majority of the confining field is provided by the external coils (poloidal field is generated by external coil as well as the bootstrap current). Because the external coils produce a multipolar field, the magnetic field intensity drops rapidly away from the coil. As such, the space used by the first wall, blanket, shield, *etc*. in a power plant plays a crucial role in determining the external coil design and physics configuration optimization. Fixed-boundary analysis of stellarator configuration may lead to high-performance plasma configuration which cannot be produced with any practical coils and/or cannot accommodate a power-producing blanket. Constraint imposed by magnet technology such as maximum bend radius, support structure, and inter-coil spacing needed for assembly as well as maintenance of in-vessel components play a critical role in configuration optimization. As a whole, there are a large number of tradeoffs among physics parameters and engineering constraints. These trade-offs play a crucial role in optimizing the compact stellarator configuration.

A detailed and integrated study of compact stellarator configurations, ARIES-CS, was initiated recently to advance our understanding of attractive compact stellarator power plants and to define key R&D areas. The stellarator configuration space is quite complex because of the large number of independent parameters (*e.g.,* β, α-particle loss, aspect ratio, number of periods, rotational transform, sheer, *etc.*). Furthermore, engineering requirements and constraints such as coil topologies and maintenance approaches (which will have a major impact on in-vessel components, blanket, and power systems) may depend on details of a specific configuration. As such, the study ARIES-CS is divided into three phases. The first phase of the study was devoted to initial exploration of physics and engineering options, requirements, and constraints. Several compact stellarator configurations such as quasi-axisymmetric and quasi-helical were considered. In each case, trade-offs among plasma parameters (*e.g.*, α-particle loss versus β) was explored and possible coil topologies (modular/TF/PF trade-offs) was studied. Initial estimates of device size, first-wall and blanket power loadings, divertor heat loads, *etc.* were made with a systems model. Promising configurations identified in phase 1 will be subjected to detailed self-consistent analysis and optimization. Detailed self-consistent analysis of this phase will allow us to identify critical high-leverage areas for compact stellarator research. One of the promising configurations chosen in this phase would be used for a point design study in phase 3.

We have completed phase of 1 of ARIES-CS study—our results are described in this paper. We have identified several promising stellarator configurations. The trade-offs among physics parameters have been explored by parametric system analysis. It appears that devices with an overall size similar to those envisioned for tokamak power plants are possible. Our examination of engineering options indicates that overall maintenance approach plays a critical role in identifying acceptable engineering paths and has a major impact on plasma dimensions and performance.