Recent Development of Engineering Design for Quasi-Axisymmetric Stellarator CFQS

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Abstract

The CFQS is a quasi-axisymmetric stellarator (GA) stellarator device, which is constructed on the joint project of National Institute for Fusion Science in Japan and Southwest Jiaotong University in China, and its design work has been performed. Based on OAS-pa design, the magnetic field configuration for CFQSs is determined. Typical parameters of magnetic field strength, major radius and aspect ratio are 1.0, 1.0 m, and 4.0, respectively.

Up to now, a mock-up modular coil having the most complicated shape was constructed to check feasibility and accuracy of modular coil build. Heat test was performed to check thermal increase of the conductor, and the capability of 1 T operation was confirmed. Construction of actual modular coils and vacuum vessel has begun since 2020.

In this paper, recent progress of the physics, the engineering design, and construction status of the CFQSs are presented.

Advantage of quasi-axisymmetry

Helical
• No inductive plasma current
• Steady-state operation

Tokamak
• Requiring plasma current
• Major disruption, pulse operation

Large neoclassical transport by ripple diffusion

Quasi-axisymmetry

Both advantageous points are combined

Quasi-axisymmetric stellarator has attractive features for future reactor.

Finite helix beta with bootstrap current

In GA, large bootstrap current is expected, because its neoclassical shear is similar to tokamak. Bootstrap current is calculated by bootstrap code based on JOREK analysis, and is 15kA. Magnetic field distortion at plasma boundary, which is 1.5-2.0% of the plasma boundary, which is 1.5-2.0% of the plasma, is neglected.

At the outside average beta of 1.2%, current of 15 kA is expected which makes a significant effect on equilibrium.

W. X. Wang et al., Nuclear Fusion 60 (2020) 103012.

Progress of engineering design

Completion of mock construction has begun

Coating for winding mounds are shown. Total of 18 coils will be used in 6 winding mounds.

Current status of vacuum vessel manufacturing

Vacuum vessel of 16 ton has been a doubled into 4 parts.

Summary

• The CFQS device is being constructed in the K-STAR site as the joint project of NIFS and SWJTU.
• Major parameters of CFQSs are R = 1 m, a = 1.5 and A = 4.
• CFQS has coil-on-cold plates of both stellarator and helical devices.
• Magnetic field strength of 1T is expected with HNT2 coils. Clear magnetic surfaces are maintained up to the volume averaged beta of 1.2%, which is attainable by NFI and experiments.
• Coil system of CFQS consists of MC, PFC, and TFC. By the control of rotational transform with TFC, investor configuration can be produced. 525 magnet rings in parabolic shapes can be used.
• Heat run test of mock-up coil was performed. Current of 1 kA for 38 ms was applied. Time evolution of temperature of cooling liquid and coil surface were measured.
• Expected cooling performance was achieved, therefore, 34 kA current for 2 s can be conducted for 1 T operation.

Vacuum vessel of 1 T modular coil was manufactured by KAI.

Part 1 plate was manufactured by pressing.

Molds for other parts of vacuum vessel

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• CFQS has coil-on-cold plates of both stellarator and helical devices.
• Magnetic field strength of 1T is expected with HNT2 coils. Clear magnetic surfaces are maintained up to the volume averaged beta of 1.2%, which is attainable by NFI and experiments.
• Coil system of CFQS consists of MC, PFC, and TFC. By the control of rotational transform with TFC, investor configuration can be produced. 525 magnet rings in parabolic shapes can be used. Simulation shows that the maximum stress is acceptable range.
• We will finish the construction of vacuum vessel in mid-2020.
• We will continue steady our work to achieve first plasma.