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Structral Design of the Negative Triangularity Spherical Tokamak (NTST)

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ABSTRACT

- The NTST is the world's first originally negative triangularity spherical tokamak. It is designed to in-depth investigate the performance of negative triangularity plasmas and application prospects in fusion reactors.
- Within a 4.5m diamiter, and 7 m height overall structure space, we expect to achieve 1.4T@R=0.65m, Ip=1.3MA.
- The TU1(and Cr-Zr-Cu) coppers are used in the magnets on 77K temperature for low resistance, and Inconel625 alloys are used in vaccum vessels for high resistance.
- The main structural scheme derived from multi-physics optimization encompassing electromagnetics, thermodynamics, materials science, and structural mechanics is highly stressed.

BACKGROUND

- No originally negative triangularity spherical tokamak exists ever.
- The NTST has many advantages on plasma control and mechanical engineering feasibility.
- Thin vaccum is required for high circumferential resistance.
- Low temperature coils is to be used in future machine - we use the LN_2 temperature copper in NTST machine for experience.

CHALLENGES

- Compact spatial constraints and complex vacuum chamber geometries.
- High current-carrying capacity coils.
- High circumferential resistance of vaccum vessels.
- 77K Low temperature copper used in coils & supporting structure.
- 450K high temperature heated on vessels structure.
- Multiphysics coupling analysis & structure degin, including Electricity, Insulator, Thermal, Magnetic, Force, and Structural Strength, etc.

IMPLEMENTATION

Core Components

- Complete the development/iteration/optimization of the following key components based on the core parameters (I_P= 1.3 MA) provided by the physics team.

Magnet Coil & Support Structure

- Designed and optimized the coil positioning, current-carrying capacity, and installation framework.
- Conducted structural strength evaluations under electromagnetic forces, thermal loads (high-temperature baking), cryogenic cooling, vacuum conditions, and seismic impacts.

Vacuum Vessel & Cryostat (Dewar) Structure

- Ensured plasma operational space requirements while maintaining vacuum integrity.
- Integrated baking pipelines for vacuum vessel conditioning.

Cooling System & Thermal Analysis

- Optimized cooling flow and heat dissipation during current-carrying operations.
- Validated thermal performance under cryogenic conditions.

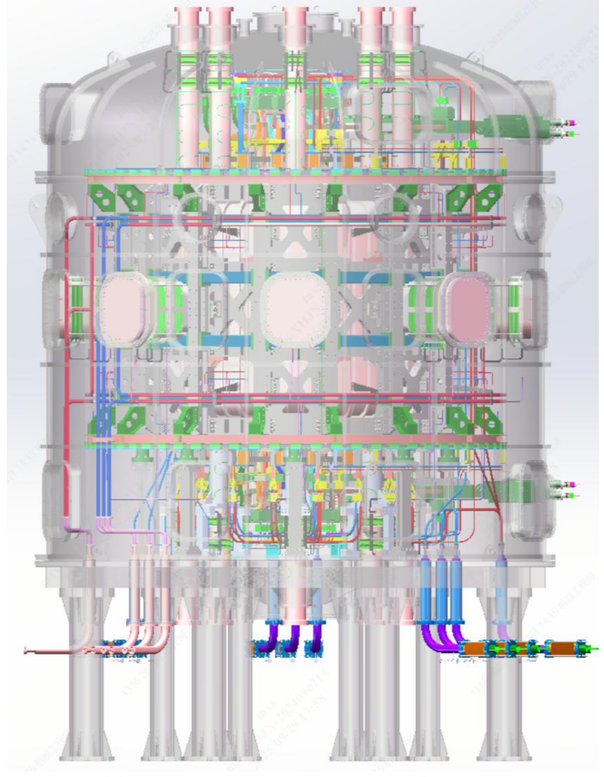
Material & Structural Testing

- Performed performance validation tests on critical materials and components to support fabrication, assembly, and maintenance.

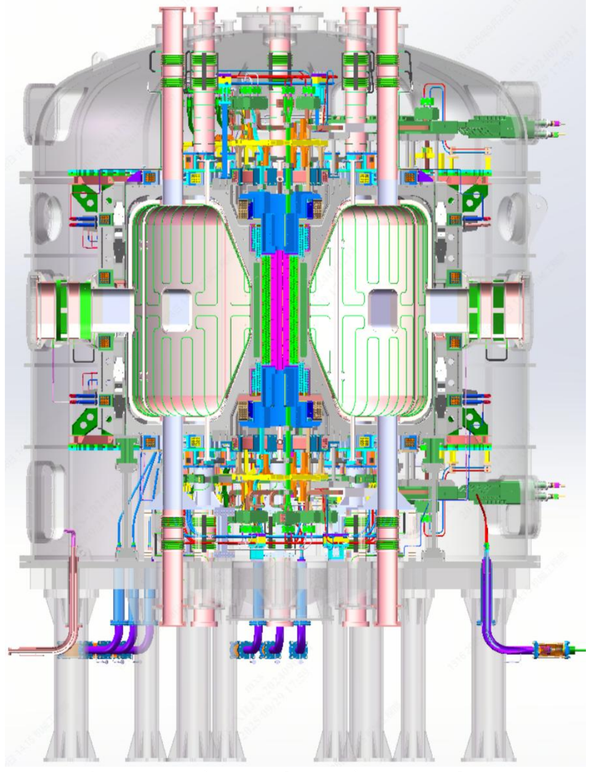
OUTCOME

NTST Device

- The NTST machine primarily consists of the following key components: Toroidal Field (TF) Coil and Its Support Structure, Other Magnets (CS, PF, CC Coils), Current Leads, Cooling& Heating pipes, Vacuum Vessel and Devar.



Host structure overview

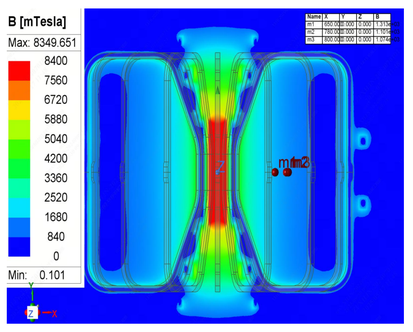


Internal sectional overview

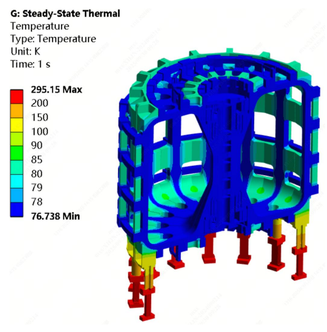
- The NTST is about 76.4t, and with the dimensions ~7081mm in height/ ~4900mm in diameter.

NTST Multi-physics Validation

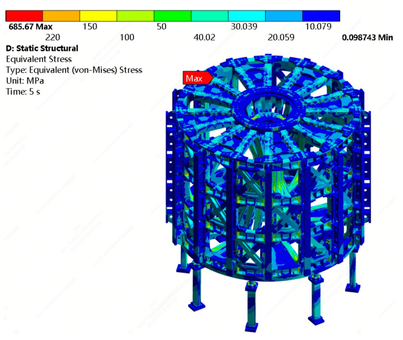
- Multiphysics coupling analysis, including Electricity, Insulator, Thermal, Magnetic, Force, and Structural Strength .



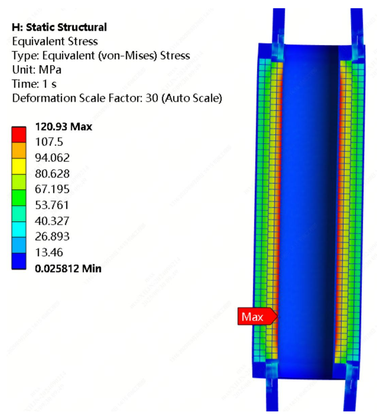
TF Coil Magnetic Field



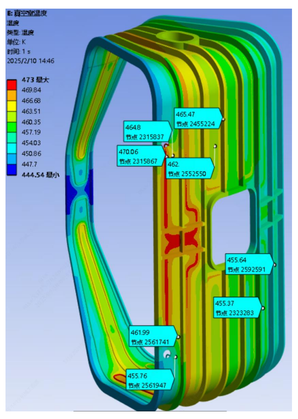
TF Structure Temperature



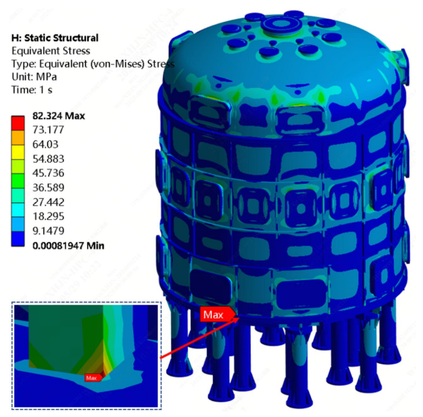
TF Structure Stress



CS1 Coil Stress



VV Temperature



Devar Stress

CONCLUSION & OUTLOOK

Conclusion

- The NTST **structural design** has been finalized.It meets the physics' specifications and is now ready for production orders.
- It develops the **ME's capabilities** in Tokamak structural design.

Outlook

- The NTST cold source cooling system is in design and development, validation activities are continuously ongoing.
- The entire NTST is expected to be installed and commissioned by the second half of 2026.

ACKNOWLEDGEMENTS / REFERENCES

- **Produced by Startorus Fusion ME Team.**