Experimental Advanced Superconducting Tokamak (EAST) Design, Fabrication and Assembly

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Introduction

EAST is one of Chinese national fusion project
The main mission of the project is to develop an advanced superconducting tokamak

• Explore and demonstrate of steady-state operation with high plasma performance.
• Investigate of advanced tokamak physics and demonstration of stationary H-mode operation.
• Investigate of particle and heat fluxes handling on a time scale much longer than the wall equilibration time.

The construction begun in 2000 and will be completed in 2006, total budget is about 300 million Yuan.
ASIPP

Cryostat

Vacuum Vessel

Thermal Shield

SC coils

Major Radius $R_o$ 1.7 m
Minor Radius $a$ 0.4 m
Toroidal Field $B_o$ 3.5 T
Plasma Current $I_p$ 1 MA
Elongation $K_x$ 1.2 - 2
Triangularity $d_x$ 0.2-0.5
Pulse length 1000 s
Heating and Driving:
( first phase)
ICRF 3 MW CW
LHCD 3.5 MW CW
ECRH 0.5 MW
Configuration:
Single null divertor
Double-null divertor
ASIPP

Conductor design and R&D

<table>
<thead>
<tr>
<th></th>
<th>TF</th>
<th>CS and PF 7-10</th>
<th>PF 11-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>20.4 × 20.4</td>
<td>20.4 × 20.4</td>
<td>18.5 × 18.5</td>
</tr>
<tr>
<td>Number of SC strands</td>
<td>120</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Coating</td>
<td>Sn alloy</td>
<td>Ni</td>
<td>Sn alloy</td>
</tr>
<tr>
<td>Cu / non-Cu</td>
<td>4.91</td>
<td>4.91</td>
<td>8.23</td>
</tr>
<tr>
<td>Void fraction</td>
<td>0.34</td>
<td>0.34</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Total weight of NbTi strands: 20 tons
**ASIPP**

**Critical current $I_c$ (kA)**

- TF
- PF1
- PF2
- PF3
- Calculated

$B=4.5 \text{ T}$
$\frac{dm}{dt}=2.8 \text{ g/s}$

**Temperature $T$ (K)**

- TF: $5.8 \text{ T}$, $T=4.6 \text{ K}$
- PF1: $4.5 \text{ T}$, $T=5.8 \text{ K}$
- PF2: $4.5 \text{ T}$, $T=4.6 \text{ K}$
- PF3: $4.5 \text{ T}$, $T=4.6 \text{ K}$

**AC losses, mJ/cc**

- PF3
- PF2
- PF1
- Calculated

**Integration of $(dB/dt)^2 \cdot dt$, T2/S**

- TF: $4.5 \text{ T}$, $14.3 \text{ kA}$
- PF1: $4.0 \text{ T}$, $14.5 \text{ kA}$
- PF2: $4.5 \text{ T}$, $14.5 \text{ kA}$

**Transient stability against magnet field disturbance**

**Short Sample test**
CICC jacketing line
58 conductors (35 km) have been fabricated
Superconducting coils; CIC conductor; Uninterrupted multi-pancake winding; VPI; low rigidity support; Supercritical helium forced flow
TF coil

16 D shape TF coil

- Turns/coil: 130
- Size: 3.52 × 2.51 m
- Pancakes: 2× 6
- $I_{\text{nom}}$: 14.3 kA
- $B_{\text{max}}$: 5.8 T
- $T_{\text{in}}$: 4.5 /3.8 K
CS Assembly consists of 6 coils
Storage energy 30MJ

CS coil after VPI

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turns</td>
<td>140</td>
</tr>
<tr>
<td>Size</td>
<td>1.42×0.48 m</td>
</tr>
<tr>
<td>Pancakes</td>
<td>20</td>
</tr>
<tr>
<td>I_max</td>
<td>14.5 kA</td>
</tr>
<tr>
<td>B_max</td>
<td>4.3T</td>
</tr>
<tr>
<td>dB/dt</td>
<td>6.8T/s</td>
</tr>
<tr>
<td>T_in</td>
<td>4.5/3.8 K</td>
</tr>
</tbody>
</table>
PF7 and PF9 assembly

- Turns: 248
- Pancakes: 20
- $I_{\text{max}}$: 14.5 kA
- $dB/dt$: 3.5 T/s
- Storage energy: 19 MJ

- Size: 2.67×0.39 m
- Weight: 5.8 ton
- $B_{\text{max}}$: 5 T
- $T_{\text{in}}$: 4.5 /3.8 K
<table>
<thead>
<tr>
<th></th>
<th>Turns</th>
<th>Size (m)</th>
<th>Pancake</th>
<th>$I_{\text{max}}$ (kA)</th>
<th>$B_{\text{max}}$ (T)</th>
<th>dB/dt(T/s)</th>
<th>$T_{\text{in}}$ (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF 11-12</td>
<td>60</td>
<td>$6.05 \times 0.22$</td>
<td>10</td>
<td>14.5</td>
<td>1.5</td>
<td>0.7</td>
<td>4.5 / 3.8</td>
</tr>
<tr>
<td>PF 13-14</td>
<td>32</td>
<td>$6.65 \times 0.18$</td>
<td>8</td>
<td>14.5</td>
<td>1.5</td>
<td>0.7</td>
<td>4.5 / 3.8</td>
</tr>
</tbody>
</table>
Coil fabrication
- Full welded double wall structure
- 16 horizontal & 32 vertical ports
- Low rigidity gravity supports

**Volume**  38 m³ ;  **Ultimate Vacuum**  $1.3 \times 10^{-5} \text{Pa}$
In vessel components

- Divertor
- Feed back control coil
- Passive stabilizer
- cryopump
- Cooling & bake system
VV and CS Thermal shield

Consist of
- Vacuum vessel thermal shield
- Cryostat thermal shield
- Transition thermal shields

Insulation break: 8

Sandwich structure
- Wall thickness: 25/40 mm
- Panels thickness: 3/5 mm
- Cooling pipe: 19×19×2

Total surface area: 310 m²
Total weight: 22 tons
Cooling media: He gas
Mass flow rate: 110g/s
Inlet temperature: 60/80 K.
Pressure drop: < 0.4 bar
Cryostat

Consists of upper head, middle cylinder and bottom section.

Provide the vacuum environment and support for all of magnets, vacuum vessel and thermal shield

48 penetrations for the vacuum vessel ports extension

19 penetrations for feeder line and maintain access

Diameter: 7.6 M
Height: 7.1 M
Weight: 78 tons
Volume: 180 m³
Ultimate pressure: $5 \times 10^{-4} \text{ Pa}$
Coil Test

16 TF coils, one CS coil, CS assembly, PF 7-9, PF 8-10 and PFMC have been tested.

Test program:

• Insulation
• Cryogenic & thermal-hydraulic behavior
• Resistance of coil internal joints
• Coil exiting to nominal current
• Quench current measurement.
• Simulate Plasma initiation
• AC losses test

Test facility
TF coil in test facility
CS coil test

PF 7-9 coil test

CS assembly in test facility
Assembly
Cryogenic system

2kW/4.4K + 11kW/80K refrigerator

Helium distribution valve box
Power supply system for magnet

13 sets of power supply system for TF, CS and PF magnets.

36 group of 15 kA AC-DC convertor
total nominal power 210 MVA
Summary

- Except the in vessel components, the fabrication of all parts is completed. All of magnets, except 4 of big PF coils, have been tested and the results show that the magnets are accepted.

- It is planned to complete the assembly and make the first cool down around the end of this year. The commissioning will begin in 2006.

- The experiment in first stage will be focused on the steady state operation with 1 MA plasma, it will be a challenge for us and ASIPP welcome for cooperation.

- China participate ITER, the technology developed for EAST will be useful during the fabrication of ITER parts in China.