Design of blanket module in CFETR

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Object

- Analyze the design of materials for the components in ITER (requirement, standard).
- According to each sub-system, arrange the type of materials, rule for design, parameters for design, and process of materials fabrication.
- Provide suggestion to materials research in development of CFETR.

Design of blanket module

- Blanket: breeder blanket, shield blanket,
- Condition: thermal stress, electromagnetic force, pressure of coolant,

- Total neutron flux for superconductors : $1*10^{19}$ n/cm^2,
- = 40 years in a dose of $8*10^{9}$ n/cm^{2}s
- Welding between dissimilar materials
- Type of breeder blanket ?

- Structural materials (CLAM steel ?)
- Maximum of heat load : 1 MW / m^2 ?
- Maximum of neutron flux load: 5 MW / m^2 ?

Design method for materials in ITER

- There are 3 types of design method for materials in ITER : “by formula”, “by analysis”, and “by experience”.
- For example, use the design by formula for the pipe systems in tritium engineering ,use the design by analysis for the vacuum system.
- In general case, use ASME Sec.VIII(Su3.5). In special case, use ITER standard.

Energy sources and associated loads in ITER facility

Typical Enclosures	Energy Source	Associated Load
Vacuum vessel	・Fusion power (～500 MW) ・Thermal energy of plasma (～400 MJ) ・Energy injected to plasma (～50 MW)	Thermal loads caused by increase in fusion power (abnormal events of heat sources)
		Thermal and electromagnetic loads caused by loss of normal heat removal function
	・Decay heat of activated material (Max. 0.5 MW/m3)	Thermal loads caused by loss of normal heat removal function
	・Enthalpy of cooling water	Pressurization by water ingress due to damage of in-vessel components (categorized as experimental components)
	・Magnetic energy of plasma (～300MJ)	Thermal and electromagnetic loads caused by disruptions
	・Magnetic energy of superconducting magnet (50 GJ)	Deformation of superconducting magnet by abnormal events such as short circuit
Fuel processing and storage systems	Enthalpy of liquid hydrogen isotopes	Overpressure by deterioration of refrigeration function
Blanket and divertor primary cooling systems	Enthalpy of cooling water	Overpressure by malfunction of pressure control of cooling system

Key issues and approach for technical standards

Component	Key issues	Resolution	Groups
Vacuum vessel	☐Complicated configuration ☐Electromagnetic force ☐Limited accessibility for welding	☐Design by FEM analysis ☐Special configurations of partial penetration T-welded joints	Group C
	☐No accessibility for weld bead examination	☐Inspection-free automatic welding	Group D
Replaceable in-vessel components	☐Complicated configuration ☐Electromagnetic force ☐One-sided heating with high heat flux ☐Heavy neutron irradiation ☐HIPed bonding or brazing	☐Design by FEM analysis under a limited lifetime	Group E
Superconducting coils	☐Complicated configuration ☐Electromagnetic force ☐Cryogenic operation	☐Design by FEM analysis with a new design allowable stress limits	Group B
Tritium plant components	☐Low pressure operation	☐Reasonable requirement on examination/inspection	Group A

Major metallic mechanical components

Components	Safety System	Non-Safety System
Tokamak facility	- Vacuum vessel - Ports and extensions - Vacuum vessel supports - Suppression chamber - Shutoff valves (or isolation valves)	- Blankets- Divertors - Cry opump - Superconducting magnets -Cryostat
Tritium processing and storage system, and fueling system	-Cold box - Bellows and casing of bellows pumps - Shut off valves (or isolation valves) - Pipings	
Primary cooling systems for vacuum vessel, blankets, divertors and others	- Cylindrical vessels - Pipings - Pump casings - Supports	
Vented filtering and detritiation system	- Cylindrical vessels - Blowers - Shutoff valves and dampers - Pipings	
Other auxiliary systems		- Helium cryogenic system components

Major non-metallic mechanical parts

Components	Safety System	Non-Safety System
Auxiliary heating systems	- Alumina insulation breaks - CVD diamond for RF window	not specified yet
Plasma diagnostics	- Artificial sapphire - Fused silica - Synthesized quartz - ZnSe - Alumina	not specified yet
Cooling pipes	- Alumina for insulation breaks	not specified yet

Activities

- **Collect the standards for materials in ITER.**
- **Study the documents for materials and establish our database for materials.**
- **Include the process of fabrication, welding, non-destructive testing, transportation, maintenance.**
- **Provide the suggestion for materials development in China.**