Development of ITER diagnostic upper port plug

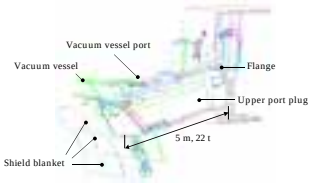
Kazuyoshi Sato, Junji Ohmori, Katsuyuki Ebisawa[1], Yoshinori Kusama, Yuzuru Neyatani
Japan Atomic Energy Agency, 1AITEL Corp.

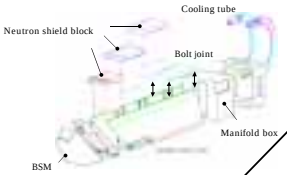
Summary

The studies of the upper port plug for No.11 have been performed to integrate the diagnostic components for procurement in Japan.
The design progresses of the upper port plug are as follows.

- The manufacturing processes were studied both forging structure and rolling structure to compare the cost and manufacturing period.
- It is necessary to discuss for the mechanical strength of the port plug structure, which includes the diagnostic devices, for decision of the structure.
- The labyrinth of optical path, the driving mechanism and cooling systems for shutters and mirrors, the maintenance space and the interaction of each other were arranged.
- According to the E-M analyses, maximum moment was appeared at the support flange about 1 MNm, which is about half of the design guideline.
- From the results of the effect of the slits on BSM, at least three slits on BSM are necessary for reduction of the EM force.
- The dose equivalent rate at the outside of the port flange was estimated to ~ 6 μSv/h.
- Though this estimated value is 80 % probability, it is within the design guideline in the ITER maintenance phase.

ITER upper port plug





Required Functions

- Provides neutron and gamma shielding to the SC coils and port region.
- Supports the first wall armour and shielding blanket material located in front of the port plug.
- Closes the vacuum vessel ports.
- Supports the diagnostic equipment within the primary vacuum, on the primary vacuum boundary and in the port interspace.

Diagnostics in Port Plug #11
- Edge Thomson Scattering,
- Visible-IR TV Divertor Viewing
- Neutron Activation (encapsulated foil)

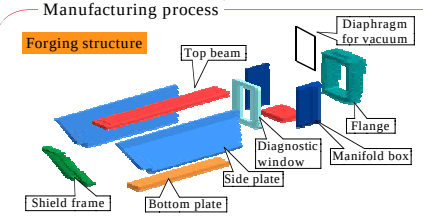
Apertures in Blanket Shield Module, Neutron Labyrinth are necessary

Issues : Reporting by this work

- Manufacturing process is not considered
- Layout plan included all diagnostic components is not indicated
- Maintenance scenario is not cleared
- Support structure of the port plug is not completed
- E-M analysis which include the detailed structure of port plug is not performed
- Neutron shielding analysis which include the aperture and optical path is not performed

Manufacturing process

Forging structure



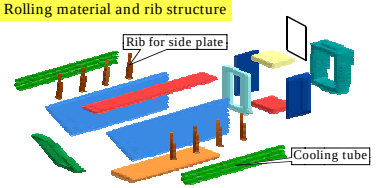
The upper port plug should has high stiffness since the port plug is cantilevered structure.
To achieve such high stiffness, the upper port plug is designed to compose of forging material.

- ✓Parts: machining, welding, drilling,
- ✓The flange will be divided into two pieces perpendicular to the port axis to finally adjust precisely
- ✓Decision of number and size of the cooling channel by the thermal analysis
- ✓An assemble procedure from these parts was projected rationally with inspection at each process.

An alternative structure using commercial base rolling material have been also studied to reduce the manufacturing cost and period.
To satisfy high stiffness, the combination of rolling plate and rib were considered.

- ✓The manufacturing process is almost same as that for the forging structure
- ✓For the cooling channel, it needs cutting groove for the cooling tube
- ✓For the rib structure, it needs long welding length

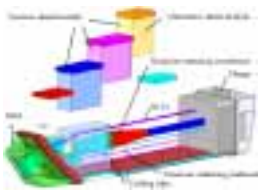
Rolling material and rib structure



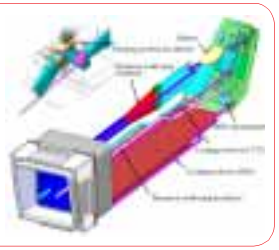
- The man-hour of the rolling material and rib structure is about 1.5 times longer than that of the forging structure.
- It was not considered the procurement lead time for the forging material and this material is not circulated generally in the market.
- The cost of the rolling material and rib structure is a little lower than that of forging structure.
- It is necessary to discuss the decision of the port plug structure from the engineering point of view.

Preliminary Mode analysis for the forging structure: 18.6 Hz (1st) 22.5 (2nd)
These values are too low to support the structure. It might be have another support point.

Layout plan

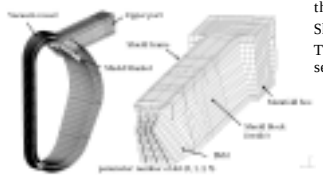


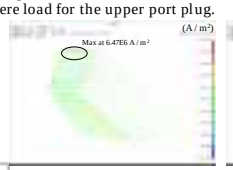
- The labyrinth of optical path, the driving mechanism and cooling systems for shutters and mirrors, the maintenance space and the interaction of each other were considered.
- A change in the design of the diagnostic/shield module just behind the blanket shield module (BSM) was proposed in order to keep a space enough for maintenance and installation of diagnostic mirrors and a shutter mechanism. <A>
- The neutron shield in the module is moved in front of the vacuum flange instead to maintain shielding performance.
- The structure and the position of BSM supports, which is a main component concentrate E-M load induced on the BSM, have been arranged to space out optical path inside the BSM.

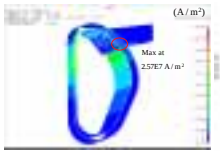


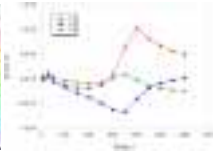
Electro-Magnetic analysis

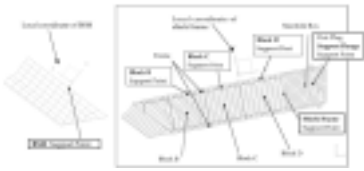
Three-dimensional model of partial vacuum vessel, port and blanket module, located around the port plug, was constructed for the electro-magnetic analysis.
Shield frame is integral type structure with top beam. Isolation to BSM and shield block
The upward fast VDE was selected to calculate the EM loads because it produces the most severe load for the upper port plug.

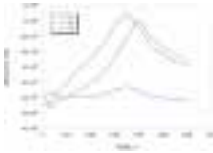








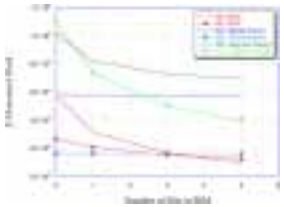




Local coordinate and support point of port plug components

Components	Fr [N]	Ft [N]	Fp [N]	Mr [Nm]	Mt [Nm]	Mz [Nm]
BSM	3.39E4	-9.33E4	2.67E4	5.76E5	6.83E4	2.63E5
Shield frame	6.89E4	3.44E4	-2.04E4	5.82E5	-3.46E4	1.62E5
Block B	4.20E3	-3.00E3	-3.59E3	4.78E4	-1.62E3	2.68E4
Block C	-4.91E2	1.49E3	-3.52E2	4.76E3	5.10E2	8.11E2
Block D	-1.13E2	6.76E1	-8.38E1	1.88E2	1.90E2	4.40E1
Support flange	1.03E5	-6.70E4	-2.41E4	1.02E6	1.49E5	1.10E6

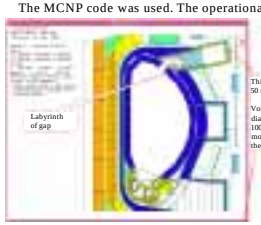
EM forces are related to local coordinates

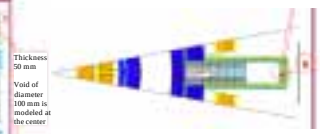


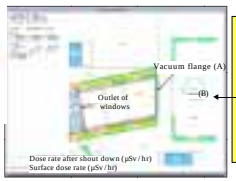
- ✓The E-M force of the support flange reaches to their maximum at 35 ms, which plasma current corresponds to 0.
- ✓Maximum moments are appeared at support flange with Mx of 1 MNm and Mz of 1.1 MNm, which are about half of the design guideline of the port plug. (DDD1.5)
- ✓The E-M moments of BSM decrease with the increasing of number of slit.
- ✓The E-M moments of the shield frame, on the other hand, are almost constant.
- ✓From the figure, at least three slits on BSM are necessary for sufficient reduction of the EM force.

Neutron shielding analysis

Dose equivalent rate at the outside of the port flange after 11days from shutdown was calculated. In the analysis, the gap between the vacuum vessel port and the upper port plug of 20 mm was assumed based on the ITER design. The labyrinth of optical path for the edge Thomson scattering was also modeled as the voids.
The MCNP code was used. The operational scenario I defined in Nuclear Analysis Report was used for the neutron condition.







Nuclear heating
Total ~550 kW on BSM, about half of the specification
(maximum input, ~95 % of the port plug)
First mirror: 16 mW/cc

The dose equivalent rate at the point A was estimated to ~ 6 μSv/h and that at the point B was estimated to ~4.5 μSv/h. (80 % probability)

These estimated values were within the design guideline in the ITER maintenance phase.

Future plan

Three dimensional structure analyses should be performed to confirm stiffness and deformation within the allowable limit of the upper port plug.
To improve the precision of the neutron shielding analysis for comparison between the present design and the proposed design changed the location of the neutron shield module, additional analyses are planned.