Design and fabrication of the KSTAR Poloidal Field Coil Structure

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1. Introduction

The KSTAR magnet system consists of 16 toroidal field(TF) coils, 4 pairs of central solenoid(CS) coils, and 3 pairs of outer poloidal field(PF) coils. The TF coils are encased in a structure to enhance mechanical stability. The CS coil structure is supported on top of the TF coil structure and supplies a vertical compression of 15 MN to prevent lateral movement due to a repulsive force between the CS coils [1].

The PF coil system is vertically symmetry to the machine mid-plane and consists of 6 coils and 80 support structures(i.e, 16 for PF5, 32 for PF6 and 32 for PF7). All PF coil structures should absorb the thermal contraction difference between TF coil structure and PF coils due to cool down and endure the vertical and radial magnetic forces due to current charging [2]. In order to satisfy these structural requirements, the PF5 coil structure is designed base on hinges and both of PF6 and PF7 coil structures based on flexible plates. The PF coil structures are assembled on the TF coil structure with an individual basement that is welded on the TF coil structure.

2. Design and fabrication

2.1 Design

The PF structure is to protect PF coils from structural, electrical and thermal loads. In a structural aspect, the PF structures have to endure high magnetic force like radial force, vertical attractive/repulsive force and lateral force and to absorb differential thermal contraction between coils and structural parts [3]. Therefore PF structure is flexible along radial direction to compensate thermal contraction and rigid along vertical direction to resist the high magnetic force. Base material of PF structure is 316LN which has high strength and toughness at 4.5 K. Allowable stress of 316LN is 750 MPa at 4.5 K.

The PF5 structure consists of hinge-type connection block, cover block, inner block, outer block and bottom block. Dimension of PF5 structure is about W680D420 H520mm. The PF5 structure is assembled with basement of TF structure using link and pin connections. M20 Inconel718 bolts with pre-load are used to clamp bottom block and cover block.

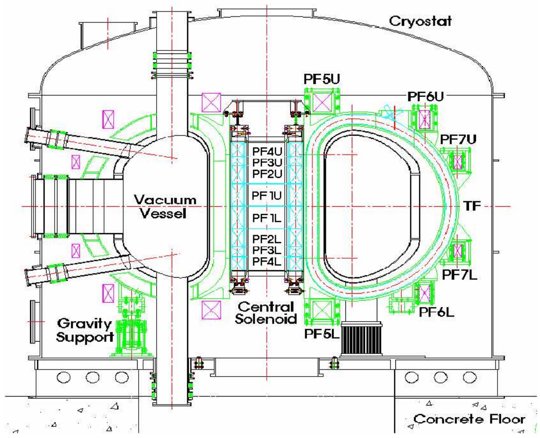

Figure 1. KSTAR magnet system

The maximum stress intensity of PF5 structure in bolt at room temperature is about 227 MPa that is 30% of allowable stress of Inconel718. During operation, maximum stress intensity of PF5 structure is 484 MPa and occurred in local link and pin connection. Maximum stress intensity of PF5 structure is under allowable stress of 316LN [4]. The link and pin connection of the PF5 structure which is freely motioned along radial direction and rigid along vertical direction, is designed to admit thermal contraction difference between the PF5 structure and the PF5 coil and endure vertical magnetic force.

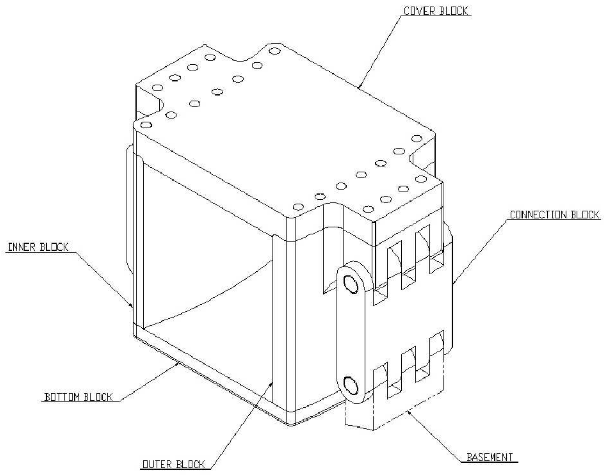

Figure 2. PF5 Structure.

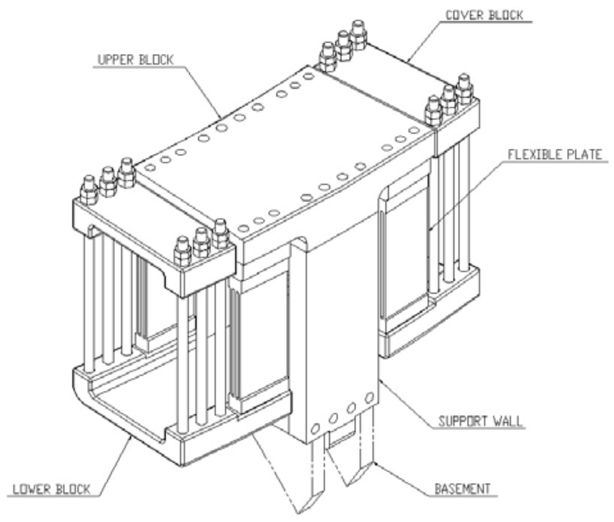

Figure 3. PF6 Structure.

The PF6 structure consists of flexible plates, upper block, lower block, cover block and support wall. The PF6 structure has 4 flexible plates welded on lower block and upper block. Cross section of flexible plate is internally hollow for flexibility along radial direction and rigidity along vertical direction. M20 Inconel718 bolts clamp support wall and the PF6 basement. Stud bolts clamp cover block and lower block. During operation, maximum stress intensity of the PF6 structure is 205 MPa and occurred in blocks [4]. Maximum stress intensity of the PF6 structure is under allowable stress of 316LN.

The PF7 structure consists of flexible plates, lower block, cover block, support wall, stud bolt and stiffener. The PF7 structure is similar to the PF6 structure without stud bolt and flexible plates directly clamped to cover block. The flexible plates of the PF6 structure are also designed same as flexible plates of the PF6 structure.

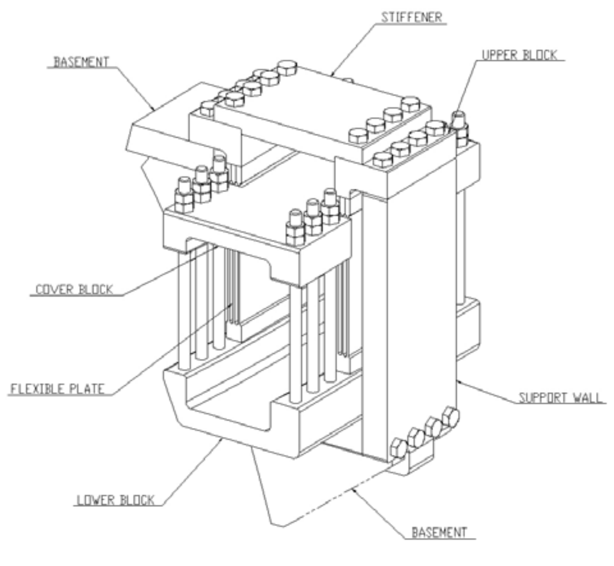

Figure 4. PF7 Structure.

To fix current leads of the PF coils, lead support structures are needed. Engineering design of lead support structure was finished and now is waiting for the fabrication process.

2.2 Fabrication

Major fabrication process of the PF structures are as follows. 1)Material cutting by plasma. Size margin of 5~10 mm is needed to absorb welding deformation and to get sufficient depth of cut for machining. 2)TIG welding with RT/UT nondestructive examination 3)Rough and finish machining 4)1st cleaning 5)Surface treatment such as buffing 6)2nd cleaning 7)3D measurement 8)Assembly of PF structure and basement 9)Installation PF coil into PF structure.

The 5 mm gap between the structure and PF coil is needed to clear the fabrication tolerance of the structure and PF coil. G10 shim plate is inserted into the gap. The flexible plates of the PF6 structure and the PF7 structure are machined by Electro Discharged Machining process and welded on blocks. Support pads for He manifold support are welded on the PF structure and cooling tube is also welded on the PF structure. All Inconel718 bolts are plated with silver to prevent seizing between bolt and nut contact surface and the Nordlock washers are applied for clamping the PF structures to resist loosening effects from vibrations and dynamic loads during cool-down and operation. The Nordlock washer uses tension to make the bolt self-locking.

3. Conclusion

The PF structures are now under fabrication. Doosan Heavy Industry & Construction Co started the fabrication of the PF structures in September 2004. Present progress of the fabrication is about 25%. The fabrication PF structures will be completed until January 2006 and PF coil structure will be assembled until June 2006. Engineering design of lead support structure was finished and will be fabricated until January 2006.

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