Fabrication and Welding of PF#4, 5 Superconducting Magnet Joint Boxes in SST-1

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Abstract

In SST-1 Tokamak there are four numbers of PF#4, 5 superconducting magnets for plasma shaping. These magnets are double pancake wound and consist of forties(40) turns. Each magnet consists of three interpancake joints. Low resistance joints have been made on each PF#4 and PF#5 coils with copper to SS welding. In order to make these joints helium leak tight in supercritical operating conditions of 5K and 4 bar joint boxes have been realised and fabricated. These joint boxes are being implemented over existing joints with optimised welding conditions. In order to protect superconductor from overheating temperature ~100 degree centigrade, argon gas flow ~7-8 lpm and welding current ~70-80 Amps are finalised. Helium leak tightness of these joint boxes are ensured at room temperature in vacuum and Sniffer conditions at 10^-7mbl/s and 12 bar. Details of joint box fabrication, implementation, its optimisation welding with cable in conduit conductor (CICC) and quality control have been discussed in this paper.

Introduction

Poloidal field (PF) magnets of SST-1 are made for plasma shaping. In SST-1 there are nine superconducting poloidal field coils. Out of nine PF SC magnets only four top and bottom PF#4, 5 magnets have twelve numbers of interpancake joints. Low resistance joints are already fabricated on PF#4, 5 magnets. Copper ï SS welding were adopted for helium leak tightness at two extremities of each IP joints. Copper ï SS welding being dissimilar metal joints, helium leak tightness of this joint is very challenging. In order to overcome this problem a joint box over the existing joint has been realised. These joint boxes have been implemented over the existing joint in such a way that its both ends have only SS-SS welding instead of copper-SS welding. In this joint box welding one end of the box has been welded with SS conduit of SC cable which requires welding process optimisation before actual welding. Superconducting CICC has to be protected from overheating in order to maintain its current carrying ability.

Joint box design

Joint box design is driven by operating pressure of 4 bar at 5K, availability of limited space between PF magnet winding pack and existing joint, its implementation feasibility without altering existing IP joint, welding feasibility in order to rotate welding torch during welding and protection of existing joint and cable in conduit conductor from overheating and leak tightness of the weld joints at 5K. Presently, each PF4, 5 magnet consists three numbers of interpancake shaking hand joints. The over all joint size comes out to be 360mm length X 37mm width X 29mm height. The existing IP joint is shown in fig. 1. and Joint box assembly over IP joint in fig.2.

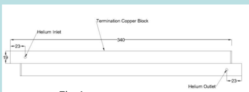

Fig. 1

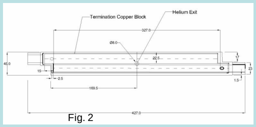

Fig. 2

Joint box fabrication

Joint boxes have been fabricated in IPR workshop from SS304L round bar of diameter 90mm and 400mm length using several stages of machining. Joint boxes have been fabricated in two parts called top cover and bottom cover respectively. Joint box fabrication stages of top and bottom covers are shown below in fig.3 and fig.4Fabricated top and bottom covers are shown in fig.5

PF# 4,5 top cover fabrication steps

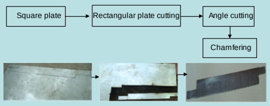

Fig.3

PF #4 ,5 joint box top cover fabrication steps

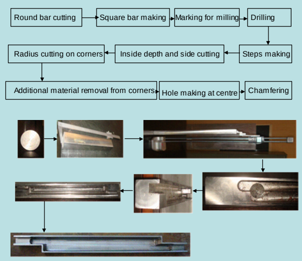

Fig.4

Joint box top and bottom cover

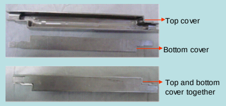

Fig.5

Welding parameter optimisation

Welding parameters for SST-1 cable in conduit were optimised after several laboratory trials, joint box welding on IP joints on spare TF coils and its testing at supercritical helium temperature in operating current condition.

Following laboratory trials were executed:

Å Conduit cutting and its fusion welding with and without filler wire
Å Insertion of SS sleeve over unconduited cable and its welding with CICC conduit
Å Insertion of two sleeves of same dimension over unconduited cable and its welding with/ without filler wire
Å Insertion of sleeve over small piece of CICC and its welding with conduit
Å In above mentioned trials welding current and temperature were also monitored with thermocouples.
Å After finishing welding SS foil and superconducting strands physical appearance verified. Average recorded current and temperatures were 70-80 amp and 100°C.
Å Laboratory scale optimised welding executed on spare TF coil IP and bus bar joint box welding. In this welding process additional argon gas purging also included in order to improve the welding quality and temperature control within acceptable limit. In order to limit temperature near 100°C average argon gas flow through CICC was 7-8 lpm.

Joint box assembly

Joint box assembly schematic over PF#4 IP joint and actual assembly of top and bottom covers along with helium exit stub are shown in fig.6

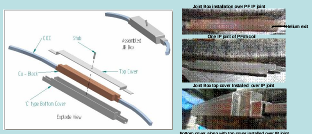

Fig.6

Joint box welding

Joint box welding over IP joints of PF magnet performed in following steps:

Å Acetone cleaning of existing IP joints and hydraulic path clearance
Å Installation of bottom cover over joint
Å Installation of top cover over joint
Å Dimensional checking of installed top and bottom cover as per drawing
Å Tack welding of top cover with bottom cover
Å Argon gas flow rate setting
Å Full welding with filler of top cover with bottom cover
Å joint box ends welding with CICC conduit

On going Joint box welding, welded joint box top, bottom and side views are shown in fig.7

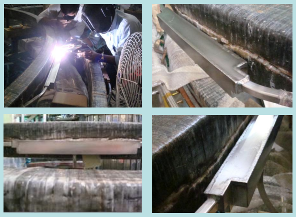

Fig.7

Quality control

UT test of round bar carried out before start of joint box fabrication. In this test no any significant defect detected. Chemical test was also carried out in laboratory in order to verify the elemental composition of round bar as per ASTM standard. Low manganese nil ferrite (LMNF) filler wire was used for all joint box tig welding. High purity (99.999%) argon gas was used for welding and purging. Leak test of joint box carried out at room temperature after welding at 12 bar pressure at 3.5 X 10^-7mbl/s background.

Conclusion

Joint box fabrication carried out in IPR workshop from round bar of SS304L with precise machining tools. Joint box welding parameters were optimised at laboratory scale and spare TF coil IP joints. Welding current ~70-80 Amps, argon gas flow~7-8 lpm were used in order to limit superconductor temperature ~100°C. Spare TF coil joint boxes leak tightness verified at 5K in fully charged DC current (10KA) condition. Hundreds of joint boxes of actual TF magnets were also tested at 5K in fully charged DC current condition. PF interpancake joint box welding carried out in optimised conditions. Joint box leak test carried out 12 bar pressure at room temperature.

Acknowledgement

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