Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Development of KSTAR TF Coil Current Lead

N. H. Song, Y. J. Lee, Y. M. Park, Y. B. Chang, S. W. Kwag, C. S. Kim, K. S. Lee, E. N. Bang, and J. S. Park.
National Fusion Research Center, 52, Yeoeun-dong, Yusung-ku, Daejeon 305-333, Korea.
nhsong@nfrc.re.kr

1. Introduction

KSTAR project of National Fusion Research Center (NFRC) requires 14 pairs of current leads (CL) for the first plasma experiments. Current leads for toroidal field (TF) coils and poloidal field (PF) coils are to be charged up to 35 kA DC currents and 26 kA pulsed currents, respectively. A pair of prototype TF leads was developed on the basis of previous R&D process. The leads are vapor cooled type made of brass wires as the main conducting material. In making the leads, there are several technically important processes such as silver plating on the surface of main conducting blocks, making superconducting(SC) link, soft soldering processes, welding two different kind metal and alloy, and so on. Throughout the manufacturing processes, it was investigated and qualified the leak tightness and soft soldering quality.

2. Configuration

Current lead looks like Fig. 1 and the spec is presented in table 1. It consists of current flowing components, stainless steel encasing components, electrical isolator, and an electrical heater. Current flowing components consist of brass wires in the heat exchanger, two copper terminals connected both ends of the brass wires, and superconducting link.

The length of heat exchanger part that consists of brass wires and stainless steel encase is determined by the design parameter IL/A[1]. Where I, L, and A are design current, length, and cross sectional area of the leads, respectively. In case of TF leads, IL/A ≈ 1.83E-6 A/m and the design current is 17.5 kA. Two current leads are to be connected in parallel together with SC cables to supply 35 kA currents to TF coils. Efficiency of heat exchange between brass wires and helium coolants depends on the void fraction and the diameter of brass wires. The void fraction also influence to the helium coolant flow efficiency. Hence the design values of heat exchanger part presented in table 1 taken accounted such kind of factors.

All the current flowing components are to be soft soldered each others. Soft soldering regions of brass wires and all the copper blocks are to be silver plated before the soft soldering for the low electrical contact resistance and long term reliability of the soldering regions.

At the copper block center of SC link, there is a hole and inserted SC NbTi/Cu cable that developed for SC busline. In the cooled down states, the cold terminal temperature will maintain bellow 9 K in normal case to makes the SC link quench free. The cross sectional area of copper part also enlarged enough to carry 35 kA even when the link becomes normal.

Helium vessel can store around 10 liters of liquids. Liquid helium is supplied through a port placed bellow the vessel. Vaporized helium cool down the brass wires flowing through the spaces between brass wires and flow out to a port at the top of lead. The helium port at the top of helium vessel is for pressure balancing.

Electrical insulator has a role to isolate electrically from current lead box where the leads to be mounted. It was manufactured using G10 epoxy glass.

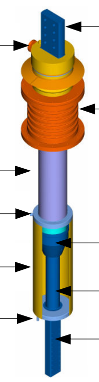

Figure 1. Current lead

Table 1. Spec of current lead

Item	Unit	Value	Remark
Overall length	m	2.4	
Weight	kg	280	
Design current	kA	17.5	
Diameter of brass wire	mm	1	
Length of brass wire	m	1.16	
Total cross sectional area of brass wires	mm^2	10000	
Number of wires	ea	12960	
Zinc contents of the brass wire	wt%	20	
Void fraction	%	50	
Heat exchanger diameter	mm	160	
Helium vessel diameter	mm	220	

3. Manufacturing Process

In Fig. 2 and 3, it is presented brass wires and copper blocks those were silver plated. Silver plating thicknesses of brass wires and copper blocks are 5~7 ㎛ and 10 ㎛, respectively. After then, it was pre-soldered the soldering regions to improve wetting property. SC NbTi/Cu cable to be inserted in the copper block of SC link is also silver plated with the thickness 5~7 ㎛. Since the NbTi/Cu strands are Cr coated with the thickness 1 ㎛, it was removed putting them in the acid like HCl before the silver plating.

Fig. 2&3. Silver plated brass wires and cold terminals.

In soldering the current flowing components, it was used two kinds of soft solders; 63Sn-36.65Pb-0.35Sb melting at 183 ℃ and 96.5Sn-3.0Ag-0.5Cu-0.12Sb melting at 221 ℃. The solder melting at 183 ℃ was used in connecting the SC links and cold terminals. In the other soldering region, it was used melting at 221 ℃. Hence, soldering SC link and cold terminal is the last soldering process.

In welding between stainless steel components, it was used the welding method GTAW. Where as, e-beam welding(EBW) method was used in welding two different materials. There is two places need to weld different material, cold terminal region and bottom plate of liquid helium vessel. To encase the cold terminal, a couple of rings, a stainless steel ring and a copper ring welded with e-beam, were used. Stainless steel part of the ring was welded to the case of brass wires and the copper part of the ring to cold terminal. Between lower plate of liquid helium vessel and SC link was e-beam welded.

Welded regions were inspected the defects during manufacturing. After assembly, it was pressurized using argon(Ar) gas up to 10 bars and sprayed bubbles at welded regions to check out visible leak. After then, the leads were vacuum pumped out up to 1E-6 mbar using turbo-pump and vacuum leak tested. Vacuum leak rates were bellow the requirements as presented in table 2. It also presented the photos of leak testing and manufactured leads in fig. 3 and 4.

Manufactured leads were charged up to 500 A at room temperature to measure electrical resistance and hence to investigate electrical contact at soft soldering regions. Measured resistance was around 7.8 μΩ and satisfied design criteria.

Table 2. Technical inspection.

Inspection item	criterion	result
EBW point	Defect	No defect
GTAW point	Defect	No defect
Pressurized leak	5 bar(bubble check)	No leak
Vacuum leak	1E-9 mbar-l/s	1E-10 mbar-l/s
Current charging	500 A, 8 μΩ	7.8 μΩ

Fig. 3. Vacuum leak test

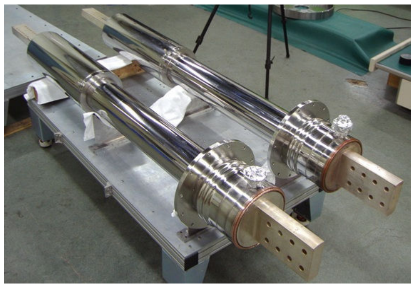

Fig. 4. Manufactured leads

4. Conclusion

A pair of prototype TF leads was manufactured and investigated detailed manufacturing procedures. During manufacturing, it was established the soldering process most important in lead development. Manufactured leads were qualified by inspecting welding defects, leaks, and low current resistance measurement.

5. Reference

[1] Y. J. Lee, "Numerical Analysis for the Development of Overloaded Current Lead", Korean atomic energy academic society spring thesis, 2003