Experimental studies of diffusion welding of YBCO to copper using solder layers

Y. Xie¹,², Z. Ouyang¹, L. Shi¹, Z. Kuang¹, M. Meng¹

1. High Magnet Field Laboratory, Chinese Academy of Science, Hefei, China
2. University of Science and Technology of China, Hefei, China

Introduction

Joint techniques of YBCO to copper are essential for its practical applications. It can be usually seen on the superconducting devices. When it’s used as current lead joint, it’s important to reduce the resistance because the critical current density Ic would be reduced due to the high joint resistance and also the high joule heat may cause great mount of liquid helium usage during the magnet operation. Compared with the 1st generation high temperature superconducting material Bi2223, the 2nd generation YBCO has a more fragile property which is it could not stand a temperature above 200°C and it would get a performance degradation and be totally damaged when it is over 300°C. In a superconducting tape, there is no resistance causing losses, however, because of soldering, things like tin/indium/welding are the causes of losses in a realistic joint which lead to a dropping efficiency of superconducting apparatus[2]~[5]. In this research, a closed facility for fabricating the joints was built and made several YBCO-COPPRE/YBCO-SS (stainless steel) joints with different solder tin. The joints were tested in liquid nitrogen bath using four-probe method.

Experiments

YBCO coated conductors used in the present experiment were prepared in Shanghai, China and it has no copper coating, so the base face and the silver face can be easily recognized. A fabricating system has been designed and built which is shown in Fig 1. This designed facility for welding can supply the maximum pressure of 2 ton, and set different welding temperature for different solder. Take a notice to that after the displayed temperature reach the set point, heater stop working while the temperature still rise 10°C~15°C because of copper thermal inertia, and it would be tested by PT100 temperature sensor. So that we should choose the proper setting temperature before we get started. After fabricating, nitrogen gas is ventilated to cool the sample down to room temperature.

![Fig.1 Photograph of the welding facility we built.](image)

We made each joint sample through the following steps: (1) prepare two copper blocks connected by stainless steel tube (used as current divertor), they are soldered, (2) cut a plane on the tube height leveling with the copper blocks, (3) apply soldering flux on the copper and stainless steel plane, (4) place the YBCO tape with a piece of solder in between on the copper, (5) put copper with tape on the holder which is made by aluminum foil, (6) place a piece of PTFE shim over the joint and put joint over the heater, (7) vacuum the working zone and apply an 1500 kg load right before the joint temperature reaches the solder melting point, keep for 10mins and 8) turn off the power supply and inlet Nz to cool down in case of get oxidized in air. Fig 2 shows one of the samples we made. It just like a small sized HTS current lead with stainless steel in between worked as the current divertor.

![Fig.2 Photograph of one sample.](image)

Results

Three different solder tin with each melting points are 138°C, 183°C and 217°C were chosen in our experiment, which made the joints marked as sample 1, 2 and 3 separately. The length of welding joint is unified to 14cm among which 10cm is connected to stainless steel and 2cm is connected to copper joint both ends each. Fig 3 shows the V-I curves of the samples using different solders. It is clear that the Ic value decreased with several rubbing times with a hot heater. Surprisingly, the heat applied to the samples has an adverse effect on the superconducting layers in the YBCO tapes. Compared the resistances in table 1(The resistances is calculated per mm² area), it is clear to figure out that the joint welded by solder with a higher melting point has a better property, containing higher Ic and lower resistance. So when we need to make a YBCO joint, while the melting temperature is limited, it is suggested that we use the soldering tin with a higher melting point within the temperature limit. One thing we should take consideration is that, according to Q. Qu[1], YBCO tape can’t bear a temperature above 200°C, so the validity of the curve of sample 3 should be doubted and we shall not offer analysis.

For how long time the welding process takes does an influence to the joint property which is showed in Fig 4. The Ic decreased about 6% if welding time took twice as long. As we predicted that heat does harm for the tape, so the welding time should be shortened as much as possible in prerequisite of having ideal connection.

![Fig.3 V-I curves of the different sample joints.](image)

![Fig.4 V-I curves of the same joint with different welding time](image)

Discussions

We tried to make the joints perfect, somehow there was Ic decrease remained. This paper showed the facility we designed for processing and examined the characteristics of various YBCO-COPPRE/YBCO-SS joints. The joint resistance was decreased by using the solder tin with higher melting point. And shorter the welding time was good for YBCO remain higher critical current. The idea that YBCO tape gets a great performance degradation when the welding temperature is higher than 200°C should be more specific and responding, for the reason that in our experiments, the degradation is lower than other temperature processes.

In addition, the facility we designed for welding still needs to be improved for having the following defects: 1) the welding temperature can not be precisely controlled which makes the process less reliable; 2) it takes at least 1 hour to make one sample and samples can only be made one by one, which is far away from efficient; 3) the facility needs an intelligent control system instead of people’s full time watching. We are looking forward to improve the design and make better joints.

References