PROPOSAL OF 99.99%-ALUMINUM/7N01-ALUMINUM CLAD BEAM TUBE FOR HIGH ENERGY BOOSTER OF SUPERCONDUCTING SUPER COLLIDER

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Abstract:

Proposal of 99.99% pure aluminum/7N01 aluminum alloy clad beam tube for high energy booster in Superconducting Super Collider is described. This aluminum clad beam tube has many good performances, but a eddy current effect is large in superconducting magnet quench collapse. The quench test result for aluminum clad beam tube is basically no problem against magnet quench collapse.

I. INTRODUCTION

To design for high energy booster vacuum system in Superconducting Super Collider with low cost and high performances, we propose 99.99% pure aluminum/7N01-aluminum alloy clad beam tube. We have related aluminum vacuum/ cryogenic components.

II. HIGH ENERGY BOOSTER RING [1]

The primary function of the high energy booster (SSC-HEB) is to furnish 2.0 TeV/c beams of protons for injection into the collider. Circumference of the HEB ring is 10.89 km. Since the HEB and collider magnets are similar superconducting magnet, it is to be expected that their vacuum system will be alike. A topic of concern in the collider is the effect of synchrotron radiation. These phenomena do not concern the design of the HEB vacuum system. Many of the collider rule apply to the HEB cold beam tube vacuum system.

III. REQUIREMENTS FOR BEAM TUBE OF HEB [2]

The beam tube for all cold components such dipoles, quadrupoles, spool pieces, and empty cryostats shall be seamless and have an inner diameter 41.4 mm. The beam tube outer diameter shall be 44.4 mm. There shall be no welding at liquid helium flow and beam tube vacuum interfaces. The beam tube shall be cleaned and handled in a manner consistent with a vacuum system pressure in the 10^{-11} Torr range.

Ion pumps will be provided for reliable valve interlock and pressure sensing in the event of a quench. Small ion pump will be installed every full cell in the HEB. Pumpdown of the cold beam tube regions will be initiated while the magnets are warm through the use of portable turbomolecular pump and dry-pump combinations.

The reliable performance of the Tevatron has established practically a cold beam tube cryogenic pumping system. Tevatron experience indicates that desired pressure can be readily achived in the absence of the beam. However, the intense beams will initiate a number of mechanisms that can increase the residual pressure or partially neutralize the beams, leading to lowered lifetime and to unwanted changes in the betatron tune. The mechanisms that might increase the pressure are gas desorption by pressure bump phenomenon, and beam induced multipactoring. Operational experience at Tevatron has shown no advantage in removing condensable gases from the beam tube beyond a rough vacuum prior to cooldown.

A. Beam impedance

The vacuum beam chamber components must present a low electrical impedance to the beam in order to avoid instabilities. The beam tube has a 0.1 mm thickness high conductive material on the inside surface.

B. Beam induced multipactoring

Electrons released in beam-gas ionization events can be accelerated by the beam itself. These electrons strike the wall, emitting secondary electrons that can be accelerated by the electric field of subsequent bunches. If the secondary emission coefficient is large enough, a particular relationship between the bunch spacing an desceleration can cause a resonant buildup of the secondary electrons leading.

C. Quench collapse by superconducting magnet

A beam tube subjected to eddy current load in quenching dipole requires an optimum diameter design to provide maximum aperture and adequate cooling space for the liquid helium flow to cool the beam tube.

IV. ALUMINUM CLAD BEAM TUBE [3)]

To satisfy these requirements, 7N01 aluminum alloy tube which is clad inside by aluminum over 99.99% pure is proposed for the beam tubes for the HEB ring. From the experiments up to now, it is found that the electrical resistivity of aluminum over 99.99% pure is lower than that of 99.99% pure copper at temperatures below 100K. The residual resistivity ratio of copper is 300; on the other hand, that of aluminum is more than 1000. Wall current, however, has a wide frequency range of up to several GHz. The surface resistivity of pure aluminum is lower than that of pure copper even in the condition of anomalous skin effect[4)].

A 20 m long clad tube with a diameter of 44 mm and a thickness of 2 mm was produced by an co-extrusion clad method as shown in Fig.1. The average thickness of 0.1 mm which is thick enough for the skin depth of the high frequency wall currents induced by the bunched proton beam. To ensure good properties as a material for ultrahigh vacuum the tube was co-extruded in oxygen and argon atmosphere. There is no defect such a separation between the pure aluminum and high strength aluminum alloy.

The aluminum has high secondary electron emission coefficient. To avoid the multipactoring effect the titanium-nitride coating has been considered.

V. QUENCH TEST [5)]

The distortion due to quench in superconducting magnet was tested. Aluminum clad tube was installed in 1 m long superconducting magnet. The aluminum clad tube is joined stainless steel tube using the aluminum alloy-stainless steel transition with exprosion method. Two strain gauges for horizontal and two strain gauges for vertical positions were installed. Another one strain gauge was installed with floating as a reference. Three signal wires for each strain gauge were twisted to suppress induced electromagnetic noise. Before installation in the superconducting magnet, strain gauges ware tested in the vacuum and the cryogenic temperature in liquid nitrogen. The superconducting magnet was quenched at the current of about 7000 A. After quench collapse the aluminum clad beam tube was deformed elastically. The plastic deformation was negligiblly small.

VI. RELATED ALUMINUM ALLOY COMPONENTS [3)]

A. Bellows with rf-shield

An aluminum alloy bellows was developed. Its flexibility and durability were ontained by using 6951-T6 heat-treated aluminum alloy. To reduce the resisitivity of the inner surface, both ends of the bellows should be made of pure aluminum clad. For impedance matching an rf-shield which is made of berillium-copper alloy is inserted.

B. Gate valves

A large cryogenic vacuum system should be divided into many sections by gate valves. For this purpose, an all-metal gate valve workable at low temperature was developed. At low temperature, sealing by knife edge loses reliability. So a double seal by mirror surface with differential pumping, which shows good results in TRISTAN ring, was adopted. Helium leak tests across the gate seals were conducted on the valve while operating at 77 K for the required design life of 5000 cycles. The seal leak rate at room temperature is less than 10^{-11} Torr l/s. The gate valve was tesed at 77 K with a differential pressure of 0.6 MPa helium and held 60 minutes [6)].

C. Beam position monitors

Beam position monitors of strip line electrode type will be installed in every spool pieces. A coaxial vacuum feedthrough which will be used for strip line electrode of a beam signal in the GHz region at low temperature was made from a titanium center pin, aluminum alloy 6951-T5 sleeve with nonmagnetic. and alumina ceramics insulation. Hundred coaxial SMA type feedthroughs were tested hundred times thermal cycles in liquid helium and room temperature.

D. Pressure measurement

Pressure distribution over a circumference of about 11 km can be measured by new gas ionization monitor. A gas ionization monitor is an application of a nondestructive beam profile monitor for a proton synchrotron [7]. Residual gases ionized by the proton beam are collected and the current is converted into pressure. This new method needs only ion collection electrodes and and an already stated SMA feedthrough. It is very simple and does not contain any heat source in contrast to usual hot cathode gauge.

E. Isolation vacuum

We have extremely low thermal emissivity film $\varepsilon = 0.002$ [8] between liquid helium and liquid nitrogen temperatures. This film is very useful for insulation vacuum instead of multilayer super insulations.

VII. OPERATIONS OF VACUUM

A. Chemical process removing water adsorption [9]

We developed new chemical treatment removing water adsorption on the aluminum surfaces using dicloropropane gas. This chemical process can be nearly replace against ordinary baking process.

B. Fast pump-down process [10]

Extremely fast pump-down process has been developed. A key element of the system is a moisture trap (three-stage sintered metal filter) to produce super-dry nitrogen gas, with a water content of about 10 ppb. The ultrahigh vacuum system can be vented to atmospheric pressure, with the use of super-dry nitrogen gas, without degradation of the fast pump-down time.

VIII. CONCLUSION

We have been proposed 99.99% pure aluminum/7N01 clad beam tube and related vacuum components for high energy booster in Superconductive Super Collider. Eddy currents are large for high conductivity aluminum alloy. We measured magnetic field collapse deformation for aluminum clad beam-tube using strain gauges in superconducting magnet. The collapse deformation for the aluminum clad-beam-tube is negligiblly small.

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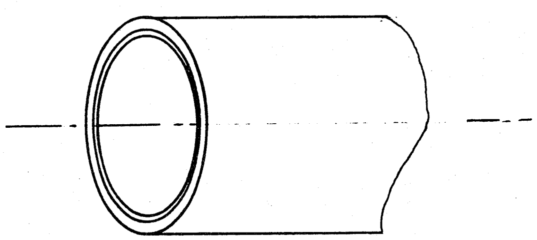

Fig.1. 99.99% pure aluminum/7N01-aluminum alloy clad beam tube. inside: 99.99% pure aluminum, outside: 7N01 aluminum alloy, inner surface: titanium-nitride coating.