ALL-ALUMINUM ALLOY VACUUM SYSTEM FOR TRISTAN e^+e^- COLLIDING BEAM RING

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ABSTRACT

Design and construction of all-aluminum alloy vacuum system for TRISTAN e^+e^- colliding beam ring has been presented.

INTRODUCTION

The first truely all-aluminum alloy vacuum system for large scale electron-positron colliding beam ring is described. The construction of the accumulation ring made of all-aluminum alloy was completed in 1983.[1~2] Electron beam was accelerated and stored 6.5 GeV.[3] We have no problem essentially in the all-aluminum vacuum system. The vavuum system and its components are basically the same as one of the accumulation ring. Much effort were paid to minimize the free space between the bending and the quadrupole magnets. Maximum line power density of the synchrotron radiation along the beam pipe is 1.3 kW/m for 30 GeV, 7 mA x 7 mA electron-positron beams. The critical energy of the synchrotron radiation is 256 keV and the penetration range is 34 mm for aluminum. Required operating pressure with beam is 5×10^{-9}Torr.

BEAM CHANNEL

Bending and Quadrupole magnets chamber

The aluminum alloy(6063-T6-EX) vacuum chambers in the bending and the quadrupole magnets are designed so as to accomodate the required beam clearence region and to allow an automatic welding between the chamber and a racetrack type bellows. The thickness of both chambers is 4 mm. The bending magnet has double line pumping slits(4 mm wide, 40 mm long and 60 mm pitch). The effective conductance of the slits is 250 l/s m. The curvature of the bending magnet chamber is 250 m. In bending and slit punching process of the bending magnet chamber, the beam chamber was filled with the argon and oxygen gas mixture to prevent the growth of oxide-hydride film on the inner surface.

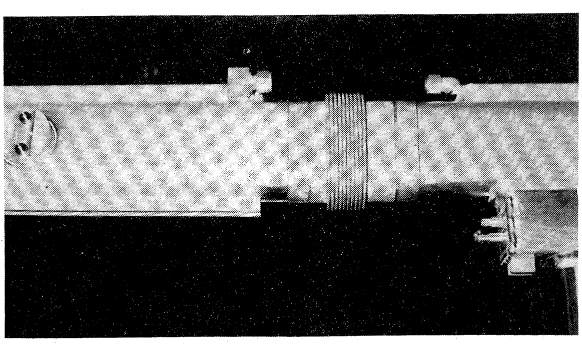

Fig. 1 Assembly of the bending and quadrupole magnets chambers with the bellows. Left side is electrode of beam position monitor.

Bellows

To absorb the mechanical tolerances, misalignments of the components and the thermal expansion due to the bakeout procedure, a bellows between these aluminum vacuum chambers is required. An aluminum alloy seamless bellows of racetrack shape is inserted between the aluminum chambers. Fig. 2. The bellows element is produced by the hydraulic forming of a 0.35 mm thick seamless tube. In our design, the seamless tubes have thick wall near the ends, but are thin walled everwhere else. The thickness of the corrugated part is reduced to 0.35 mm while the welding edge parts are thickness 4 mm. This contributes to both getting sound welds and better elastic performance of the bellows.

The rf insert made of Be-Cu, 0.35 mm in thickness is installed in the bellows to prevent the parasitic mode loss due to bunched beam. The surface of the aluminum alloy bellows is anodized to protect the corrosion due to NOx.

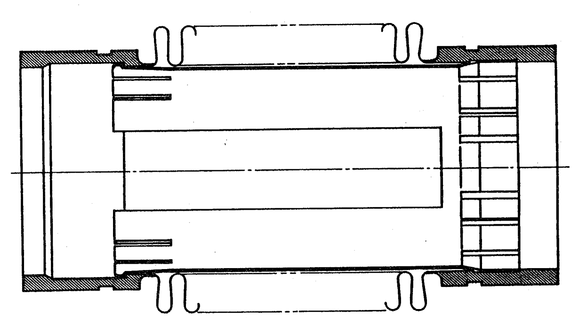

Fig. 2 Racetrack type, aluminum alloy(3004) seamless bellows with rf insert(Be-Cu).

Straight section chamber

For the rf sections and the experimental regions, the aluminum alloy(6063-T6-EX) circular pipes are used. Fig. 3. Tapered vacuum chambers are inserted between the racetrack and circular chambers for smooth wall current flowing. The vacuum chamber for the septum magnet is fabricated from the modified quadrupole magnet chamber. Fig. 4. Thickness of the wall of the septum side is 1 mm. The window of the injection is the beryllium foil whose thickness is 0.3 mm. Since the injected beam line is located inside of the ring, the moving mask against the synchrotron radiation for Be window is not required.

A ceramic chamber is bonded to aluminum alloy bellows pieces(3003) with a brazing sheet(4343-3003-4343) in vacuum furnace. For the metallization Mo-Mn with Ni plating is used. The ceramic chamber with bellows is welded directly to the aluminum alloy chamber. This type of ceramic chamber is used for the kicker magnet chamber and the beam intensity monitor. The inner size of the ceramic chamber of the kicker is 92 mm wide and 54 mm high in racetrack shape and 600 mm long. The inner surface of the ceramic chamber is coated with Ti-Mo for smooth wall current flowing. Fig. 5.

Gate valve

By relying on differential pumping between dual flat face seals , we developed a gate valve which has no gasket or knife edges. The sealing surfaces of the isolating plate are polished to a smooth mirror like finish by a flat diamond tool and coated with CrN for hardening. The valve seats, which are 0.1 mm thick aluminum, are pressed by compressed air against the sealing surfaces. A close-contacting, metal surface seal is obtained. The valve design employs dual-flat-faces together with a differentially pumped housing. The aperture of the gate valve has the same recetrack cross section as the vacuum chamber of arc section. When the valve opens, the bellows assembly closes on the aperture of the gate valve to assure smooth flow of the wall current. Fig. 6.

DC separators

16 DC separators are installed at both sides of the four collision points. These are 2 types of the separator: maximum operating voltage, +130 kV(Type 1) and +112 kV (Type 2), electrode size, 3500 mm long(Type 1) and 3300 mm long(Type 2), 145 mm wide(Type 1 and 2). The chamber is 4010 mm long and 300 mm in inner diameter for both

separators. A high voltage terminal is designed so as to be operated at maximum voltage, ±150 kV. TiN coating on the electrodes can be used to reduce unstable discharge due to high secondary electron emissions of aluminum oxides. It must be mentioned that the parasitic mode losses from a bunched beam to a vacuum chamber is not negligible in the storage rings. The estimated parasitic mode loss in our case is on the order of 100 W for 30 GeV, 7 mA x 7 mA and the single bunch. For cooling of the electrodes, heat pipes will be applied to simplify the structure of the separators.

Fixed mask

For physics experiments, it is necessary to reduce the background noises caused by stray electron or positron beam and X-ray emitted by Bremsstrahlung or by synchrotron radiation in various magnets. For this purpose couple of fixed masks should be set in long straight section. A fixed mask is installed in each insertion quadrupole magnets. The fixed mask consists of 100 mm long lead block surrounding the tapered aluminum alloy chamber.

Beam intensity monitor(DCCT) is installed in the ceramic chamber. A scraper, a beam stopper and a beam screen monitors utilize the straight motion driving mechanism. The driving mechanism is made of aluminum alloy. The dynamic bellows is also an aluminum alloy. The optical window for the visible light of synchrotron radiation consists of an aluminum alloy(3003) sleeve and a sapphire disk. X-ray window is made of Be and Al foil. The Be window is mounted on the aluminum alloy base flange. The Be foil(15 x 27 x 0.2 mm) is welded on the flange by electron beam. Al-window 0.08 mm in thickness is sealed with a Helicoflex gasket. Both of Be and Al-window are protected by helium gas from the corrosion due to NOx.

JOINING

The beam channels, the gate valves, the ceramic chambers and the bellows are joined by a fully automatic DCSP-TIG welder. Most of the joints are non-demountable. The automatic welder consists of a guide rail with gear and a moving stage. The moving stage is driven by a computer controlled servo motor. The welding torch, a filler wire feeder and an arc voltage controller are mounted on the moving stage. Fig. 9, Fig. 10

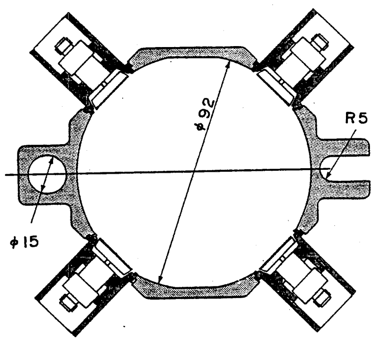

Fig. 3 Stright section chamber with beam position monitor electrodes.

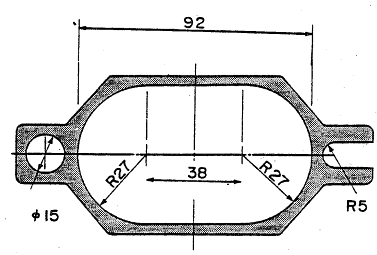

Fig. 4 Straight section chamber for septum magnet.

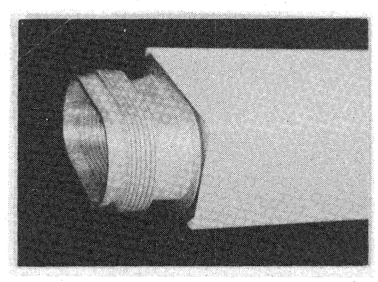

Fig. 5 Ceramic chamber with aluminum bellows for kicker magnet.

Cooling and X-ray shield

Cooled aluminum alloy block(10 mm high, 50 mm long) formed on the inside wall of the beam pipe protects the aluminum alloy bellows, gate valves and the ceramic chambers against intense and hard synchrotron radiation. All beam pipes are covered with lead of 10 mm in thickness to shield strong X-ray radiation. Fig. 7.

BEAM MONITOR

Four button type pickup electrodes to detect the beam position are installed in the quadrupole magnet chamber. SMA type vacuum feedthroughs are used. The feedthrough consists of ceramic-aluminum alloy seal using vacuum brazing. The beam position monitor electrodes mounted on the qoadrupole magnet chamber were fixed to the quadrupole magnet using the aluminum casting frame. Fig.8.

For demountable joints The Conflat type seal has been developed in which aluminum alloy flange coated with CrN or TiC and aluminum gaskets are used. Al-flanges(2219-T 87) and the gasket(1050-H18) are structually same as traditional Conflat types. The CrN or TiC treatment on the knife edge surface of the flange is performed for hardening. Anodized aluminum alloy bolts(2024-T4), non-anodized nuts (6061-T6) and hard-anodized washers(2017-T3) are used to tighten the flange.

PUMPS

The distributed sputter ion pump is installed in the bending magnet chamber. Its anode consists of five layers of polished and perforated aluminum plate. The cathode is made of special aluminum alloy(Al-Ti-Zr) rods 3 mm in diameter and is insulated from the vacuum chamber. Al-SHV feedthrough is used as high voltage connectors of the distributed ion pump. The feedthroughs are welded directly to the bending magnet chamber by electron beam. Fig. 11

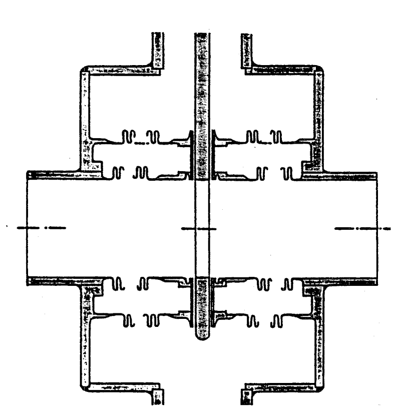

Fig. 6 Dual flat face seal with differential pumping type gate valve.

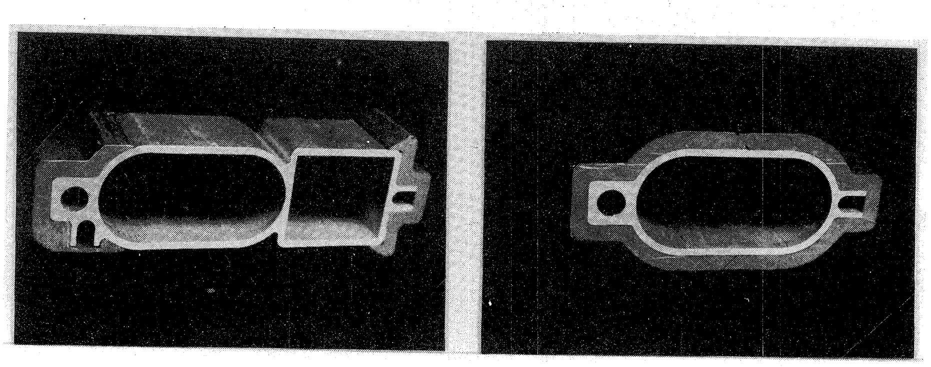

Fig. 7.a Lead shield against X-ray radiation for the bending magnet chamber. 7.b Lead shield for quadrupole magnet chamber.

Perforated and stacked anode cells for the stand alone sputter ion pump have been used with the aim of increasing the conductance and active pumping surfaces. The pump shell is made of the same extruded special aluminum alloy(Al-Ti-Zr) as the cathode. 30 l/s ion pumps are used for the arc sections. Fig. 12. 125 l/s and 250 l/s pumps are used for the straight section. 500 l/s ion pumps are used for the rf cavity.

The cartridge of non-evaporable getter(NEG) pump is mounted on the Al-Conflat flange with an Al-BNC feedthrough. The module of the NEG type ST-707 pump is installed in the insertion quadrupole magnet chamber.

ROUGHING PUMP

50 l/s and 300 l/s turbomolecular pumps are made of aluminum alloys. The flange is Al-Conflat type and the body is also aluminum alloy(6061-T6). Especially, 300 l/s pump has oil free magnetic bearing.

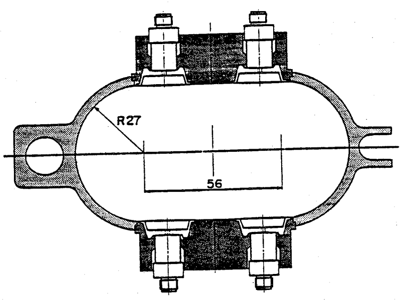

Fig. 8 Beam position monitor mounted on the quadrupole magnet chamber.

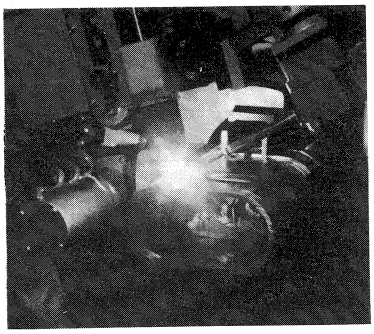

Fig. 9 Fully automatic welder

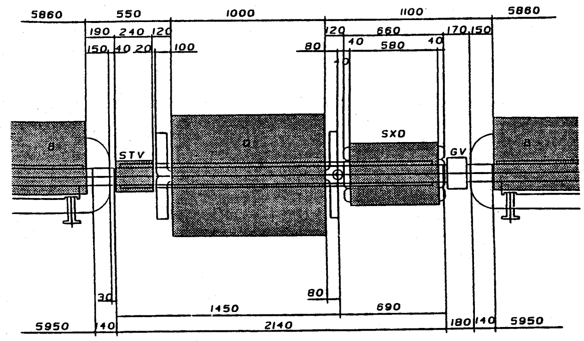

Fig. 10 Layout of the magnets and the vacuum chambers drawn by CAD system.

All-aluminum alloy right angle valves were developed using the sealing principle of the Helicoflex gasket. For semi-automatic operation, a right angle valve is equipped with a closing mechanism, which consists of a air motor. This ICF-114 type valve is useful as a safety valve for 50 l/s turbomolecular pumps in case of an unexpected power outage. Fig. 13.

300 l/s magnetic bearing type turbomolecular pump with the manual right angle valve ICF-152 type utilizes the automatic magnetic valve with the elastomer seal in the back of the turbomolecular pump. This is safety system for an unexpected power outage.

A seamless cross piece, a T-piece and a 90° elbow have been made of aluminum alloy(6063-T6) using a bulging method. Al-Conflat flanges are welded to these pieces.

CONCLUSION

The present system satisfied conditions such as high performance, high reliability, impedance matching, simplicity, low wasted space between magnets, small size, low residual radioactivity and low cost.

ACKNOWLEDGMENTS

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1. H. Ishimaru et al., IEEE Trans. Vol. NS-28, No. 3, June, 1981, 3320
2. H. Ishimaru et al., Journal of Vacuum Science & Technol. A2, April-June, 1984, 1172
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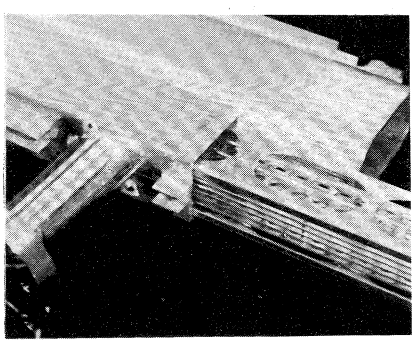

Fig. 11 Al-distributed sputter ion pump is housed in the bending magnet vacuum chamber. Left side is the pumping port.

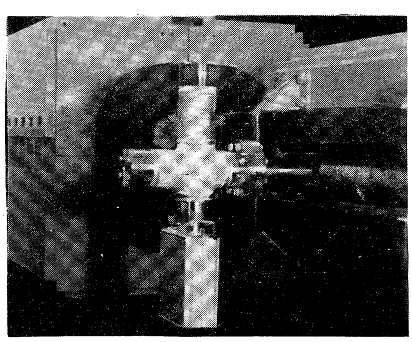

Fig. 12 Stand alone 30 l/s ion pump for the arc section.

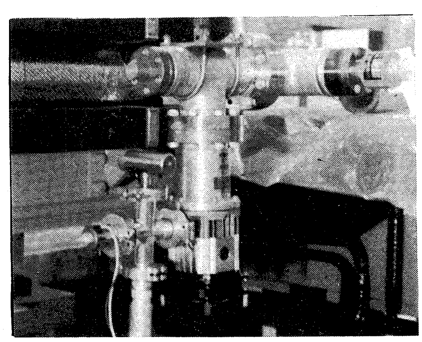

Fig. 13 50 l/s Al-turbomolecular pump for the arc section.