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OPERATIONAL CHARACTERISTICS OF VACUUM SYSTEM FOR TRISTAN ELECTRON-POSITRON COLLIDER

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ABSTRACT

One year operational characteristics of the first truely all-aluminum vacuum system for an electron-positron collider is described. Problem of DIP characteristics was resolved by change of the cathode material from Al-Ti-Zr to ordinary Ti. Beam life time was reached to about 3 hours for 5 mA, 26 GeV beams. DC separators were improved for unwanted discharge due to beam. During next beam operation, improved DC separators will be examined.

INTRODUCTION

The first electron-positron colliding experiment was started in November 1986. Vacuum system performance in the first stage of the beam operation was as follows: average base pressure without beam was 10^{-6} Pa, average pressure with beam was 10^{-5} Pa, for 25 GeV, 2 mA beams. Life time was about one hour for 25 GeV, 2 mA beams.

During the following one year operation some vacuum problems have occured. First, distributed ion pump (DIP) with Al-Ti-Zr cothode did not exhibited efficient pumping characteristics. Second, DC separators could not be operated at the sufficient high voltage with beam. Much efforts have been done. The cathode material of DIPs was changed form Al-Ti-Zr to ordinary Ti. And the structure of the DC separators were improved. We have no problem about the cooling for radiated power of synchrotron light, the heating or unwanted discharge due to wall current, the corrosion of aluminum and the vacuum components. One year operational characteristics for the first truely all-aluminum vacuum system for the electron-positron collider is described.

BEAM OPERATIONS

Pressure rise due to beam

The requird pressure of 10^{-7} Pa with beam was not satisfied bacause of the pressure rise due to synchrotron radiation; that is, photo-induced gas desorption(dynamic gas desorption). Fig. 1 shows the pressure rise $\Delta P/I$ (Pa/mA) and η as a function of the time integrated beam current D(mA·h). The data based on the pressure of four arc sections are calculated. After a time integrated beam current of 10^2 mA·h, $\Delta P/I$ is approximately given by

$$\Delta P/I = 4.21 \times 10^{-3} \times D^{-1} (Pa/mA) \qquad (1)$$

This is shown by the straight line in Fig. 1. We have observed that $\Delta P/I$ is proportional to beam current as shown in Fig. 2. Relative amounts of residual gas species with beam were found to be $0.7(H_2)$, $1(CO)$at 5 mA, 26 GeV beams, at 4600 mA·h. The life time of the beam is mostly determined by the pressure of CO content. The content of CO has been decreasing by beam cleaning during one year period of operation.

Radiated power

A cooling circuit consisting of aluminum pipes servicing a bending and a quadrupole magnets. Power at bending magnet chambers is about 1 kW/m at 9 mA and 26 GeV beams. This is about 30% of the maximum designed power of 15 mA, 30 GeV. The aluminum bellows at each side of the bending magnet chamber receives about 300 W. To protect the 0.35 mm thick aluminum bellows, water cooled aluminum absorbers (5 mm high, 10 mm wide, and 50 mm long)were welded inside the chamber to shadow the bellows. The cooling absorbers of the gate valves and the ceramic chambers were the same system. Since the critical energy at 26 GeV beams is 150 keV, the penetration range is 20 mm which absorbs 80% of radiated power. The critical enargy at 30 GeV is 250 KeV, the penetration range is 35 mm. The temperature outside of the cooled absorber was measured. We have no problem for cooling system for radiated power of synchrotron light.

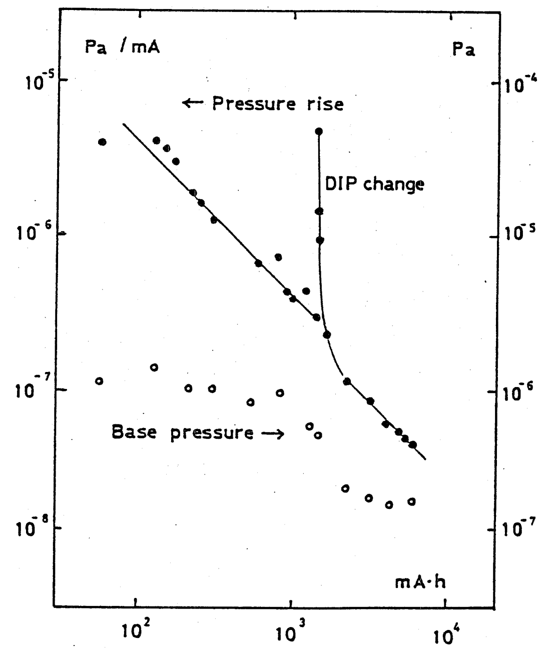

Fig. 1. The pressure rise and η as a function of time integrated beam current.

Wall current

In electron storage rings, the electron beam excites high frequency wall current inside the beam chamber. Therefore we took care to ensure a continuous current flow by using the gate valves to ensure a continuous conducting path. The vacuum chambers with racetrack aperture in the arc section and the circular aperture in the straight section were connected using tapered pipe to obtain smooth wall current flow. Both sides of three colliding points, DIPs which utilize the solenoidal magnetic field of particle detectors were installed. The tapered RF shields were inserted with welding inside the DIPs. To make good impedance matching for the racetrack shape bellows, and RF shield with fingers was inserted inside the bellows. The RF shield with fingers were made of Be-Cu alloy. For circular type bellows in the long straight sections including the RF cavity sections, the RF shield was not inserted. After one year operation, we have observed no problems such as an abnormal discharge due to wall current between the RF shield fingers and bellows. The ceramic chambers for the kicker magnet and the current transformer have racetrack inner shape just the same as the beam chamber. The ceramic chamber was bonded to an aluminum bellows which could then be welded to the aluminum chambers. A Ti-Mo film was coated on the inner surfaces to provide a continuous conducting path. The thickness of the film was 2 μm so that the magnetic field of the fast kicker magnet could penetrate in the beam region. No heating of these ceramic chambers was observed during one year operation.

Corrosion of aluminum

The temperature of the cooling water for the MR is controlled to be in the range about 20℃. When the temperature was set lower than the dew point, the surface of the aluminum vacuum chambers was covered with moisture. Corrosion has come due to forming a hydrooxide on the aluminum alloy chambers by moisture. Thus, temperature of cooling water was set higher and the humidity was lowered.

An influence of humidety was observed on the beryllium window which is used for X-ray extraction. Beryllium hydrooxide on the surface can be made by the interaction of X-rays with humidity and NOx. Some of the high voltage connectors for the ion pumps and distributed ion pumps deteriorated because of humidity. It was estimated that humidity accelerated abnormal discharges in the connectors carbonize the insulator. This was overcome by reducing the humidity in the MR tunnel. Therefore humidity control is very important.

Joining

The beam chambers of the bending and the quadrupole magnets, the gate valves with racetrack aperture, the ceramic chambers and the bellows with racetrack aperture were joined by a fully automatic DCSP-TIG welder. The joints of arc section were non-demountable. The joints of straight sections and the components were demountable. For demountable joints, an Al-Conflat type seal was used. During one year operational experience of MR, only one time leakage on the Al-Conflat flange was occured in beam operation. One Al-bolt 6 mm in diameter was broken, because of tightening force was too much. In RF cavities which were made of mild steel with copper plating and stainless steel flanges, an Al-flange and a stainless steel flange connection was used. We have no problems for joining using automatic welding and Al-Conflat flanges.

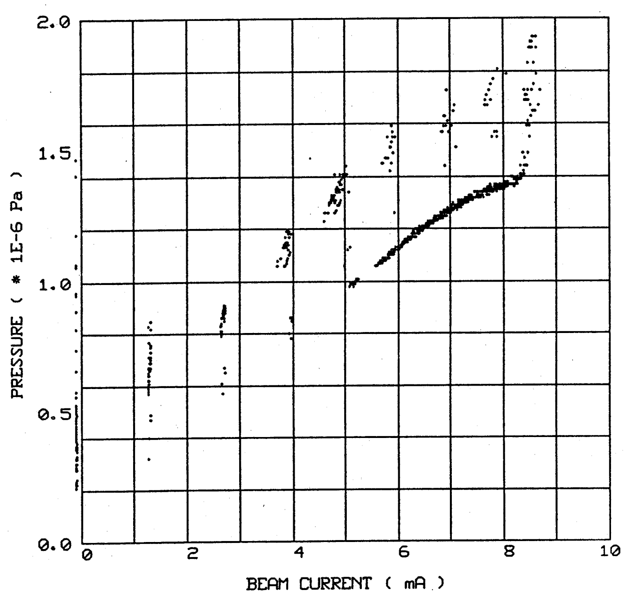

Fig. 2. Pressue rise is proportional to beam current.

PROBLEM AND IMPROVEMENTS

DIP

The cathode material of DIPs of the AR was ordinary Ti which has efficient pumping characteristics. However the DIPs with Al-Ti-Zr cathodes of the MR do not exhibit such efficient pumping characteristics. Especially, during the initial stage of DIP operation the pumping action was very weak and outgassing from DIP with Al-Ti-Zr cathode was observed. The main outgassing was hydrogen due to on hydrooxide film on the Al-Ti-Zr alloy. This hydrooxide film absorbed much water. The hydrooxide film had grown during holding process in two years which corresponded to the construction period. The DIPs were wrapped in polyethylene film without any desiccant. The data predict such hydrooxide film growth in high humidity atmosphere. All cathode material was changed from Al-Ti-Zr to Ti. DIPs change were done for 264 sets of DIP (1 m long/unit × 6 units) from 20th February to 20th April 1987. Changing for DIP was as follows: First, all-sextupole and correction dipole magnets were removed from the beam line. The bending and quadrupole magnets were not touched. Second, cutting was done between the bending and quadrupole magnets chambers. Cut bending magnet chambers were bended at racetrack shape bellows to take out the old DIP. Old DIP electrodes were replaced from Al-Ti-Zr cathode to Ti cathode in clean house inside the tunnel. Third, new DIPs were inserted in the housing of vacuum chamber and the end plate with the high voltage feedthrough was welded. And a bended vacuum chamber was fitted with the quadrupole magnet chambers. Welding and He leak test were performed. Eight or ten sets of DIP per day average were changed including re-welding.

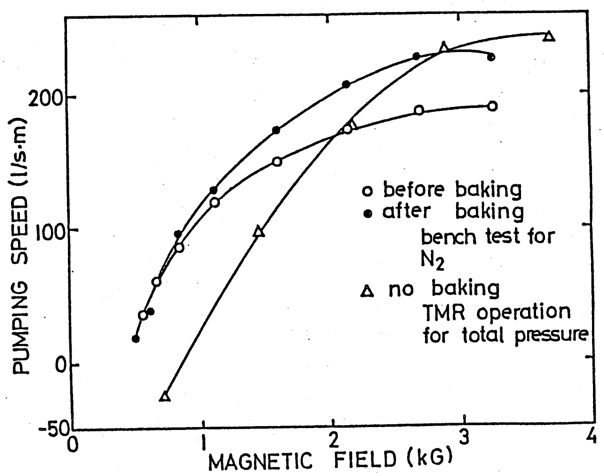

Fig. 3. Pumping speed vs. magnetic field on test bench and the ring.

DC Separators

The DC separator could be operated at the specified high voltage and had no problem without beam. Applied voltage for eight short and eight long type separators was ± 90 KV. However, DC separators had a big problem with unwanted discharge due to the beam occured at the connecting part between the pararell electrodes and the high voltage feedthrough and the small gap of these electrodes. The short type DC separator has two sets of pararell electrodes along the beam direction. The high RF voltage was induced between the small gap of the electrodes. Therefore the two sets of electrodes have been replaced by a one piece electrode to suppress unwanted discharge due to the beam. Old connection is not so good for high frequency wall current. Unwanted discharge was observed at this connecting part. The pressure rise due to the beam was observed. With DC separator off, the pressure rises linearly with the beam current for good performance DC separator, however the pressure rise is proportional to the square of the beam current for not good performance DC separator. Outgassing from the DC separator was dependent on unwanted discharge inside the separators. Then, the center conductor of the feedthrough was separated 5 mm electrically against wall carrent. The gap of pararell electrodes become from 80 mm to 70 mm.

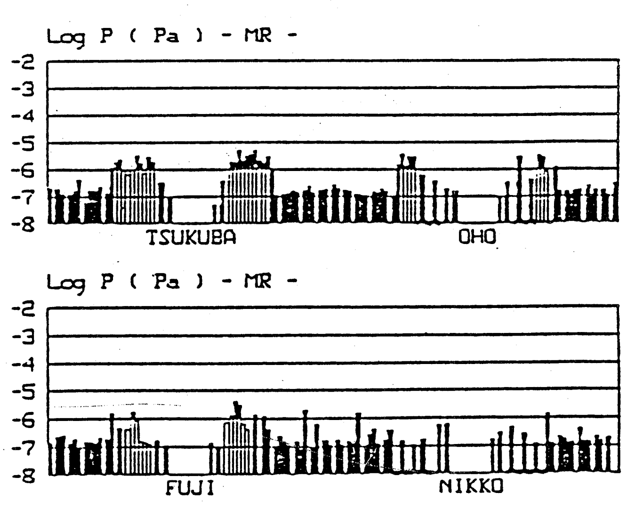

Fig. 4. The pressure distribution along the ring.

Beam operation

After the change of the cathode material, the pumping characteristics were improved to the extent that they were nearly the same as DIP of TRISTAN accumulation ring. Effective pumping speed in $10^{-4} \sim 10^{-6}$ Pa range was about 100 l/s·m on the test bench. Pumping speed vs. magnetic field on the test bench and the ring was shown in Fig. 3. Pressure rise with beam was reduced factor two as shown in Fig. 1.

The one year operational experience of the MR has shown that beam life time upto 3 hours for 5 mA, 26 GeV beams can be achieved without any baking and discharge cleaning. In the one year operation, the average pressure reducing in the ring with beam reached about 3×10^{-7} Pa. Obtained pressure rise of a value of about 4×10^{-8} Pa/mA for time integrated beam current of about 5000mA · h. The pressure distribution along the ring is shown in Fig. 4. At the RF cavity sections, average pressure was so high, bakeout is necessary to reduce the outgassing. Computer graphic display, Fig. 5, shows beam current, average pressure, and beam life time. The life time of the MR beam is mostly determined by the MR vacuum. Fig. 6 demonstrates a typical one-day operation of MR. On average, there were sixteen fills a day. In the end of June, we have attempted the colliding beam operation at 26 GeV successfully. In five weeks period in July, the MR vacuum system had completely no trouble.

CONCLUSION

The all-aluminum TRISTAN vacuum system has been operated for one year. The first 26 GeV electron-positron colliding experiment was done successfully. Luminosity was 6×10^{30} $cm^{-2}s^{-1}$, which was expected value. The problem resulting from DIP cathode material was resolved by changing of cathode material. And unwanted discharge of DC separators due to beam was improved. During next beam operation, the improved DC separators will be examined. We conclude that all-aluminum vacuum system suits for application of electron storage rings.

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References

1 H. Ishimaru, J. Vac. Sci. & Technol. , A2, 1171 (1984)

2 H. Ishimaru, T. Momose, K. Narushima, H. Mizuno, K. Kanazawa, H. Watanabe and M. Shimamoto, J. Vac. Sci. & Technol. , A4, 1762 (1986)

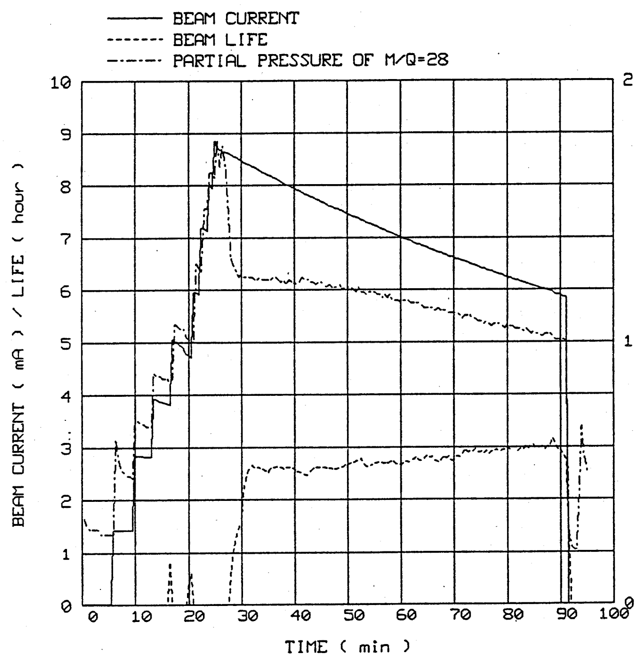

Fig. 5. Graphic display of beam current, average pressure and beam life time

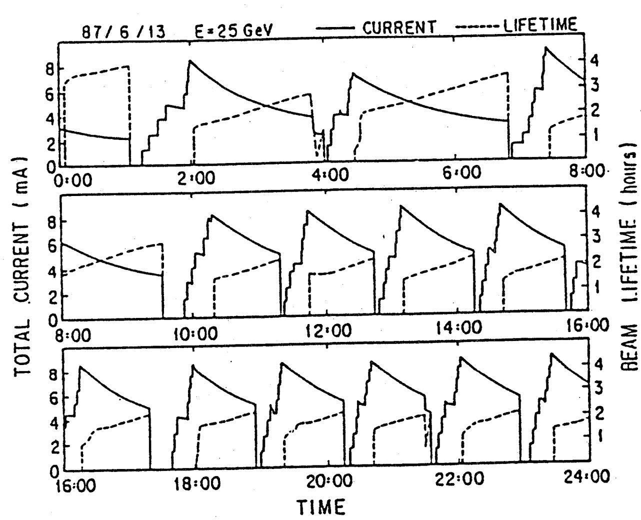

Fig. 6. A typical one-day operation of MR.