The 8th Symp. on Accelerator Science and Technology, 1991, Saitama, Japan

Development of High Intensity Beam Handling System

Part IV, The technical details of Beam Handling System

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ABSTRACT

We have constructed the new counter experimental hall at the KEK 12 GeV Proton Synchrotron (KEK-PS) in order to handle high intensity primary proton beams of up to 1×10^{13}pps (protons per second), which is one order of magnitude greater than the present beam intensity of the KEK-PS, 1×10^{12} pps. New technologies for handling high-intensity beams have, then, been developed and employed in the construction of the new hall. A part of our R/D work on handling high intensity beams will be reported.

INTRODUCTION

In recent years high-intensity proton beams become important particularly for very precise experiments of nuclear and particle physics. The new counter experimental hall of the KEK-PS was at first designed for dedicated high intensity experiments. Most construction work of the new primary beam lines (EP1) of the north counter experimental hall of the KEK-PS was completed by the end of 1990. The first primary proton beam was extracted to the north hall on January 23rd, 1991. The fine tuning of the new secondary beam line (K5) is now under way. The schematic illustration of the primary and secondary beam lines are shown in Fig.1. The components of EP1 are the twenty of electromagnets, vacuum beam ducts, beam profile monitors, beam intensity monitors, and production-target stations. We designed those components to be used at the day, in the future, when the beam intensity of EP1 becomes ten times higher than the existing primary beam lines (EP2) of the east counter experimental hall [1),2)]. When some trouble occurred on the components, we might carry out the maintenance work in the very high radiation field, which is a strong risk for our life. Therefore the most important and essential characteristic of the components is that it must not break. In other words, the apparatus should be maintenance free. However, in the case of need, maintenance should be carried out quickly from a distant location in order to reduce the absorbed dose during the maintenance work. So the most components of the apparatus are made of radiation resistant materials and are equipped with the quick disconnect-connect system. Since the power supply, the electric signals, the cooling water port, the pumping port and the beam duct are connected to the magnet, the special apparatus for the quick disconnect-connect system are required. In this paper, details of each apparatus developed are summarized.

I. Connectors for electric power and interlock signals

The magnets are mounted on the base plates, which are aligned on the beam tunnel floor. The connection between the magnet and the base plate has to be made exactly by the remote operation. On the way of the development, three types electric power connectors were considered. The maximum current/voltage required is DC 3000A/200V. The 1st type was the press-conductor type where two

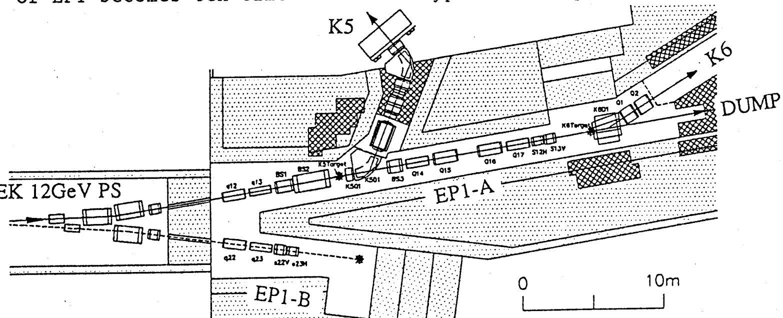

Fig.1, Schematic illustration of the primary beam lines of the new counter experimental hall conductor plates with spring contact fin are compressed each other. This type has the widest allowance on the axial imbalance between female and male connectors. But there may happen the deterioration of the electric contact because of a dust gotten between two plates. The 2nd type was the knife-switch conductor type and was just likely a standing one of the 1st type. This type required, however, very accurate positioning at least for one direction. The 3rd type was the plug-sockets structure, which conquered weak points appeared at the 1st and the 2nd types. The structure of this type is shown in Fig.2.

This 3rd connector was constructed with plugs and sockets with 100 μm silver plating. The socket-side structure consists of separated 14 fines bound in a bundle, therefor this connector has the ability of self-cleaning at each time of connecting and disconnecting. This fin structure can absorb the axial imbalance and the mechanical impact between male and female parts in the connection stage. It has also the very good cooling effect so that the maximum temperature rising is under 65 ℃. The electric insulation (⑤in Fig.2) is made of the machinable ceramic plate impregnated by polyimide resin. This impregnated plate keep the performance of pure ceramics, e.g. electric insulation and compressed hardness. The flexural rigidity is, however, ten times better than pure insulator.

The temperature of the magnet cooling water was measured at the exit of each cooling path of the magnet coil and was included in the interlock diagram of magnet power supply. Other apparatus driven electrically also needed the electric signal connector. Therefor we developed the signal connector which has 49 contacts of 7x7 matrix structure. The connector are automatically joined by using the magnet weight. All of the parts of the connector under the magnets are made of inorganic materials against radiation damage. Each contact consists of a spring contact pin which is gold plated and a flat contact plate made of stainless steel at the other side of the pin. The maximum current and the electric contacted resistance are 70 A and less than 0.002 ohm. The axial imbalance over 5 mm cam be permitted at the joining stage.

II. Cooling water port and pumping port

Connectors of cooling water port and vacuum pumping port require a great deal of skill to join each other more then electric power connector. The connector sizes developed are 2 inches in diameter for cooling water and 1 inch in diameter for vacuum, respectively. We developed the two-arms toggle-link structure for both connectors, which combines a set of facing flat plates. The mechanical concept of this apparatus is shown in Fig.4. The actual procedure of connecting and disconnecting is only to turn of a top screw bolt of apparatus by the remotely operated tool. The power magnification generated by the toggle-link structure is at least 4.3 per one turn of a screw bolt.

The gasket material used for water is stainless steel O-ring (helicoflex) to prevent from corrosion in the cooling water. The O-ring is attached on the magnet side, so that it is also brought to the hot sell and replaced easily by the manipulator. It is compressed between the plates by means of increase of a fastening force. The cross section of the metallic O-ring is shown in Fig.5. The outside and inside skin was made of SUS304(JIS) of stainless steel. The inside of O-ring tube is made of inconel spring. The characteristic curve of stress-deformation of the metallic O-ring and necessary driving force of the link are shown in Fig.6. The pressure of the cooling water employed in the new experimental hall is 20 Kg/cm^2 . The connector was tested according to the JIS 20 Kg flange standard and no water leakage was found up to 50 Kg/cm^2. In this case, the compressive force is 12,651 Kgf. In practice this metallic O-ring can used two times. For three times the water seal is not sufficient. The outside skin and spring of O-ring for the vacuum pumping port was made of Aluminum and inconel. The helium leak test was carried out and less than 10^{-8} Torr·l/sec was found. The compressive force is 1,658 Kgf about the vacuum port.

III. Connecting devices for vacuum beam duct

When the magnets is placed in the beam line and in the maintenance room, we have to connect and disconnect the vacuum beam duct at the both sides of the magnet. The structure of the remote handling apparatus for the vacuum beam duct is shown in Fig.7. The actual mechanical operation are, (1) extend 80mm of bellow duct length to fit the facing flange along the linear guide rails; (2) fasten these flanges by automatic flange collar using toggle-link structure. In order to avoid the influence of strong residual radiation in the beam line, the force of fastening procedure is transmitted from one screw bolt placed at the top of the apparatus.

We have selected also the metallic O-ring (Helicoflex) as a vacuum seal because the rubber seal will be deteriorated by strong radiation effect. So we have designed the new type of vacuum flanges, i.e., KEK-K flange standard, which has the similar characteristics of the ISO-KF flange and is more suited for the metallic seal. For the KEK-K flange, the size of the metallic seal used is shown in table 1. The flange collar is fastened by the six separeted V-coupling made of "Devametal" which is containing a fine carbon powder in a brass body, and is ensuring very low friction at the surface of the metal. Most parts which needed lubrication are also made of Devametal. MoS_2 was not used because of its long-term instability.

This V-coupling pressed up metallic seal to steel belt which is a width of 40 mm and a thickness of 0.8 mm. The actual tensile stress of the steel belt at K370-flange is shown in Fig.8. In this case, the total compressive force is necessary 33,993 Kgf and the tensile stress is minimum 40 Kg/mm^2. The maximum driving torque is 3.3 Kg·m at a screw bolt by hand. The helium leak test was carried out and less than 10^{-8} Torr·l/sec was found even after two times of fastening.

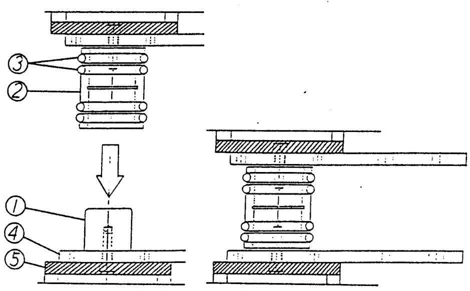

Fig.2, Structure of plug-type electric power connector
① plug conductor ② 14 segment of finny conductors ③ garter spring band ④ terminal plate ⑤ electric insulation plate

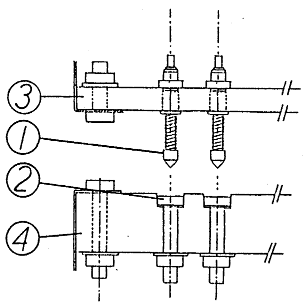

Fig.3, Structure of the signal connector board
① 7x7 matrix contact pin conductor ② plate conductors ③ and ④ ceramic base plate

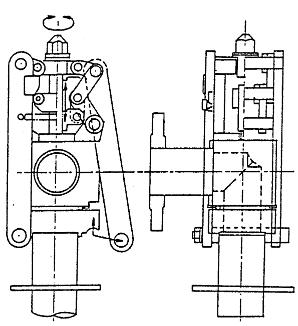

Fig.4, The actual procedure of fastening connector flange connection and fastening device

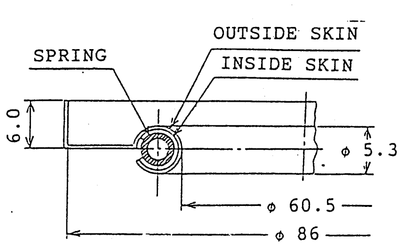

Fig.5, The cross sectional view of a metal gasket(Helicoflex)

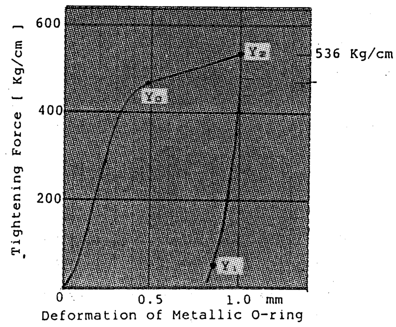

Fig.6, The characteristic curve of stress-deformation of the Helicoflex
Y_0: initial sealable point
Y_1: working point
Y_2: minimum sealable point

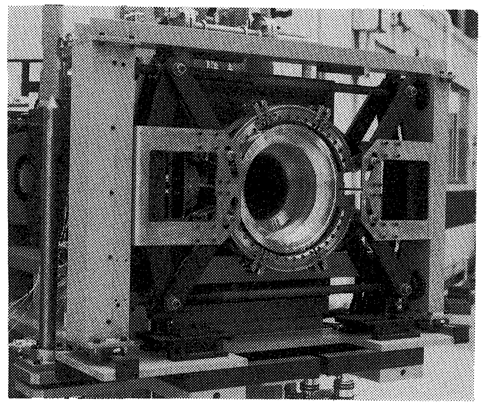

Fig.7, The structure of the vacuum flange disconnect system.

TYPE	OUTER dia.	TUBE dia.	OUTSIDE SKIN	INSIDE SKIN	USE
K160	113.2	φ 8.4	A11050P	SUS304L	Beam Duct
K210	163.2	φ 8.4	A11050P	SUS304L	Beam Duct
K260	213.2	φ 8.4	A11050P	SUS304L	Beam Duct
K310	263.2	φ 8.4	A11050P	SUS304L	Beam Duct
K370	323.2	φ 8.4	A11050P	SUS304L	Beam Duct
2inch	60.5	φ 5.3	SUS304	SUS304L	Water Port
1inch	31.0	φ 3.5	A11050P	-	Vacuum Port

Table 1, The new standard flanges size and metallic seal size.

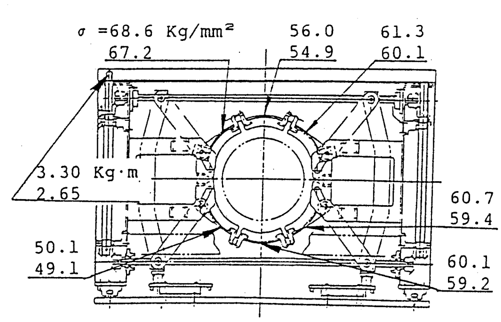

Fig.8, The actual tensile stress of steel belt at K370-flange. The indication of upper law is at the first trial and the one of lower law is at the second.

ACKNOWLEDGMENT

This work was partly supported by a Grant-in-Aid for Scientific Research (C), No.03640287, of the Japan Ministry of Education, Science and Culture. It was performed also as a part of a Grant under the Monbusho International Scientific Research Program, No.01041095.

REFERENCES

(1) Y. Yamanoi et al., Development of A High Intensity Beam Handling System at KEK-PS New Experimental Hall, Proc. of 7th Symp. Acce. Sci. and Tech., 318 (1989)

(2) K. H. Tanaka et al., The Beam-handling Magnet System of the KEK-PS New Experimental Hall, Proc. of 12th Int. Conf. on MT-12 (1991), in press.

(3) Helicoflex, the product of Usui Kokusai Sangyo, Co., Ltd.

(4) Devametal, the product of Daido Metal Co., Ltd.