Maintenance method for stable operation of a superconducting rotating-gantry

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1. Introduction

●NIRS outline

At National Institute of Radiological Sciences (NIRS), carbon-ion radiotherapy has been carried out since June 1994, and more than 10,000 patients were treated by now. Recently, the world’s first superconducting rotating-gantry was developed, and further installed in the new treatment facility at NIRS.

●Superconducting rotating-gantry

This gantry equips ten superconducting magnets, and can transport carbon ions to an isocenter over irradiation angles of ±180 degrees.

4-2nd temperature for each gantry angle

Cryocooler

We have to discover the cryocooler that the precursor of the cryogenic system for the superconducting gantry.

2. Method of exchange

Normally, maintenance of the cryocooler is performed during half-yearly shut down period. However, maintenance of the cryocooler generally requires a period of one month or more due to temperature rise and re-cooling. Therefore, it is impossible to complete the maintenance at half-yearly shut down period. So we performed the “cold maintenance”; the cold heads, as mounted in the gantry, were replaced while minimizing temperature increase.

The figures below show the actual time when cold maintenance was performed. The maintenance for the 4set of cryocooler can be made within 1.5days.

3. Early detection of failure

In the spring of 2017, we carried out the first maintenance of all the cold heads, while conducting the beam commissioning of the gantry before treatment operation starts. Having replaced and maintained all the cold heads, the superconducting gantry is now in clinical use since May 2017.

In this presentation, we will introduce the maintenance method for stable operation of the cryogenic system for the superconducting gantry.

4. Robustness

The superconducting rotating gantry of NIRS is designed so that the superconducting magnets can be operated even if one cryocooler per gantry stops. The figures below show the temperature data when one cryocooler per magnet stops at gantry angle of 0 deg.

5. Maintenance cycle

We will perform maintenance as shown in Fig.8.

We are confident that we can operate without interrupting the treatment schedule by implementing the following maintenance cycle.

1. Detection of failure

2. Treatment

3. Maintenance

We have to discover the failure of the cryocooler from the gantry angle and the cold temperature.

We 2. We complete maintenance on the weekend.

3. The removed cold head is overhauled to be spare parts.

6. Summary

●Summary

In the spring of 2017, we carried out the first maintenance of all the cold heads, while conducting the beam commissioning of the gantry before treatment operation starts. So the superconducting rotating-gantry is now in clinical use since May 2017.

From the experience we have maintained, we have established a method for early detection of failure and an early recovery method. By implementing this maintenance method, we convinced that long-term stable operate will be possible.

●Future plans

Improving the efficiency of the maintenance work of the cryocooler. We will be ready to complete maintenance work even at midnight on weekdays. Increasing the maintenance cycle by stopping one cryocooler in the middle of the night.

Table 1 Time table of the cold maintenance

<table>
<thead>
<tr>
<th>Day</th>
<th>Treatment schedule for NIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon</td>
<td>Day Maintenance</td>
</tr>
<tr>
<td>Tue</td>
<td>Night Maintenance</td>
</tr>
<tr>
<td>Wed</td>
<td>Sleep</td>
</tr>
<tr>
<td>Thu</td>
<td>Day Maintenance</td>
</tr>
<tr>
<td>Fri</td>
<td>Night Maintenance</td>
</tr>
<tr>
<td>Sat</td>
<td>Day Maintenance</td>
</tr>
<tr>
<td>Sun</td>
<td>Night Maintenance</td>
</tr>
</tbody>
</table>

※Half-yearly shut down
August 1 month
March 1 two weeks

Fig. 5 Temperature data when one cryocooler per magnet stopped

※2 Two magnets of BM09 and BM10 are cooled with eight one cryocoolers.

Cold heads (2nd)

Fig. 7 The cryocooler temperature for each gantry angle

This cryocooler has poor cooling capacity at a gantry angle of 0 deg and 180 deg.