Efforts on stable operation of the HIMAC irradiation system

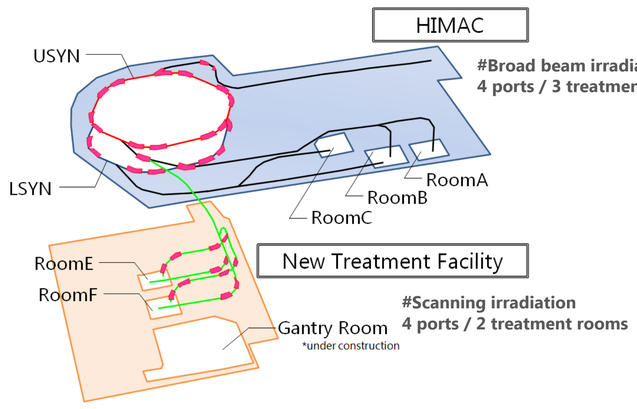
M. Katsumata[1], S. Fukuda[2], S. Yonai[2], H. Mizuno[2], E. Takada[2], T. Nakajima[1], T. Shimoju[1]

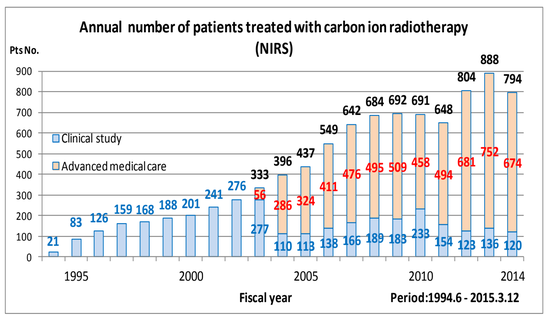
1) Accelerator Engineering Corp. 6-18-1-301 Konakadai, Inage-ku, Chiba-city, Japan 263-0043
2) National Institute of Radiological Sciences 4-9-1 Anagawa, Inage-ku, Chiba-city, Japan 263-8555

Introduction

HIMAC outline

Heavy Ion Medical Accelerator in Chiba (HIMAC) is the first accelerator in the world specially constructed for researches on heavy ion radiotherapy. Since 1994, HIMAC has carried out the clinical trial of cancer treatments using carbon beams. Treatment with scanned carbon beam was started in 2011 to provide more patient-friendly cancer therapy. The total number of patients is about 9,000 in March, 2015. HIMAC has 3 treatment rooms / 4 ports and a new treatment-facility has 2 treatment rooms / 4 ports.



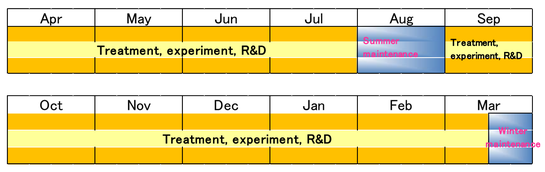


HIMAC annual schedule
- Treatment, experiment, R&D
- Summer maintenance (1 month)
- Winter maintenance (0.5 month)

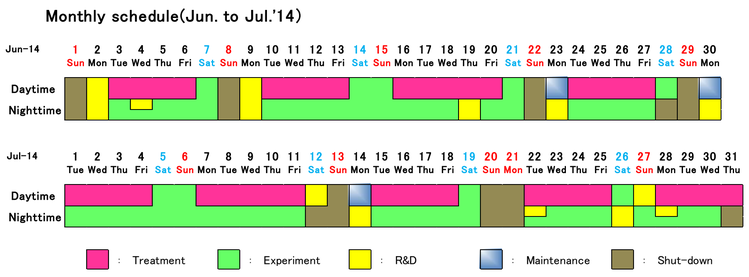
HIMAC typical weekly schedule
- Treatment
  Tue. To Fri. 8:30~19:30
- Experiment, R & D
  Tue. To Fri. 21:00～7:00
  Sat.
- Maintenance
  Mon. (every other week)

*Maintenance
Suspend accelerator operation for maintenance such as checking multiple equipment or replacing small parts.

Annual schedule (Apr.'13 to Mar.'14)



Monthly schedule(Jun. to Jul.'14)

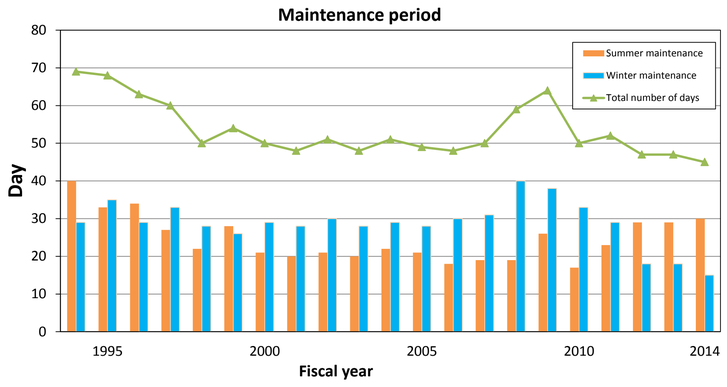


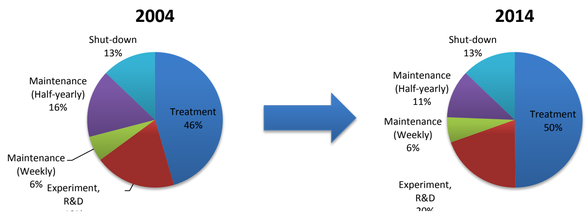
Stable operation is critical for the clinical use as normal treatment schedule continues for several weeks. In order to avoid irradiation interruption, HIMAC treatment room has two same ports for both horizontal and vertical ports within three treatment rooms. In case of machine trouble of irradiation system of one port, the other port act as backup port to perform treatment. Therefore, treatments have been successfully performed without interruption by rescheduling the treatment room in case of trouble. Through this 10 year's operation, there was almost no treatment that was postponed due to device failure. (There was one day interruption due to failure of power-supply unit of scanning system only at new treatment facility. And some treatments were rescheduled within a day due to machine trouble.) In this presentation, our maintenance program and some examples how we have improved the program are shown.

Overview of maintenance program

Maintenance program

At HIMAC, the period of semi-annually maintenance has become shortened in accordance with increase of treatment cases.
51 days (2004) → 45days (2014)
As a result, the ratio that can be assigned to semi-annually maintenance has decreased from 16% to 11%.





Transition of usage situation in HIMAC

We mainly implement three kinds of periodical maintenance program: daily, weekly and Semiannually in order to maintain the soundness of equipment within a limited time. We are using record sheets to perform each maintenance program.

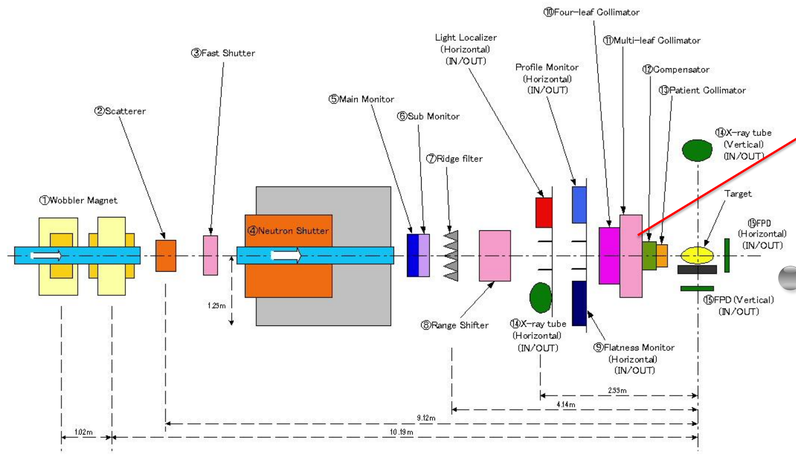
Daily maintenance (every morning 8:15 – 8:45 (Tue. – Fri.))
- Visual check of equipment
- Simple operation check of driving equipment
- Conditioning of X-ray tube and output check
- Check of imaging system
- Beam output check (Dose parameter and range check by irradiation standard condition)

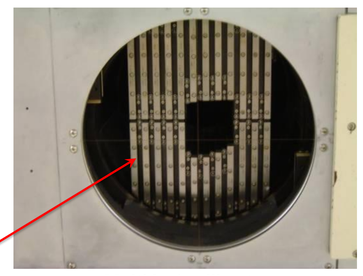
Weekly maintenance (Monday daytime)
- Visual check and operation check of equipment
- Simple check of alignment X-ray imaging using standard phantom
- Mechanical accuracy check (Precision check of reference parameters for driving equipment.)
- Required spot maintenance (parts replacement, etc.)

Semiannually maintenance (0.5 ~ 1 month work time/3 rooms)
- Accuracy check of equipment (speed of operation, driving force, stroke)
- Precise alignment
- Condition check, cleaning and adjustment of equipment by overhaul/decomposition

Example of maintenance program

Equipment layout





Multi leaf collimator

Multi leaf collimator (MLC)

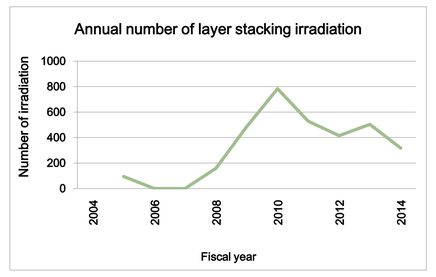
Field size 150 mm × 220 mm
Leaf pitch 6.5 mm
Leaf gap 0.25 mm
Leaf pairs 23 pairs
Stroke +110 mm ~ -55 mm
Driving speed 80 mm/sec

Maintenance program of MLC

Daily maintenance: Check of anomalous/collision sound by simple movement
Weekly maintenance: Numerical check of MLC control parameter,
Gap check between leaves in the completely closing position
Semiannually maintenance: Grease up of drive parts, Torque check of MLC motor,
Precise alignment of each leaf

Review of maintenance program of MLC

Layer stacking irradiation has been performed since 2008.
This irradiation required multiple field size variation using MLC.
It was clear that the frequency of MLC movement per day would increase.



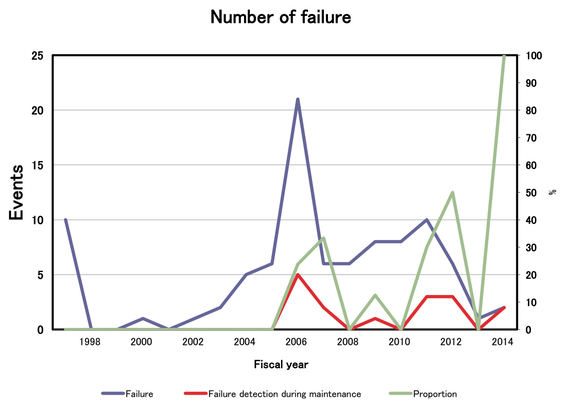
Lifetime review of MLC components
- Motor/Encoder → Already excess a shortest estimate of lifetime
  * A least lifetime recommended by manufacture assumes continuous moving operation. This assumption cannot simply apply to motor/encoder equipped in MLC. So we decided to keep using them.

Table 1 : Maintenance plan

Device	Parts	No. of pieces	Life-Time	Motion period /day		Motion period /year	Replace Interval (year)	Replace Interval (In the case of layer stacking irradiation)	Inspection Items	Inspection Interval
Multi Leaf Collimator (4set)	Motor	184	30000 h	24h		8544h	3.5	3.5	Step-out torque measurement	Semiannually
									Friction measurement	Yearly
	Encoder	184	20000h	24h		8544h	2.3	2.3	Friction measurement	Yearly
	LM guide	184	400km	6.6m	110 mm × 30 times × 2 stroke	1.3 km (200 days)	307	285 (+10mm/slice)	Friction measurement	Yearly
									Grease up	Yearly
	Rack-and-Pinion	184	10 million rev.	264 rev.	4.4 rev. (110mm) × 30 times × 2 stroke	53 thousand rev. (200 days)	18	17 (+10mm/slice)	Friction measurement	Yearly
									Grease up	Yearly

- Revised maintenance program (Check movement by following 2 methods)
  1. Friction measurement with combination of motor, encoder, LM guide, rack-and-pinion and arm
  2. Step-out torque measurement in leaf stop timing as a electronic aspects for assembly of motor and driver
  * Intension of the program revision is to detect serious failures beforehand. Therefore, we quantified the equipment conditions. In addition, daily/weekly maintenance has been performed in order to check subtle abnormalities.

Trouble of MLC



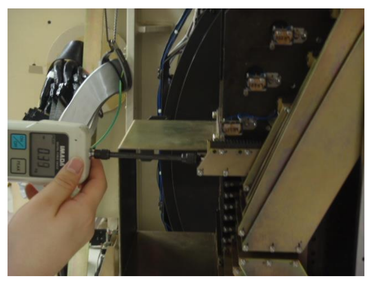
Main trouble
- Step-out of motor/collision
- Irregular (big) sound in leaf movement
- Failure of cooling fun for drive motor
- Failure of detected position

The revised maintenance program obviously reduced the frequency of failure during treatment.

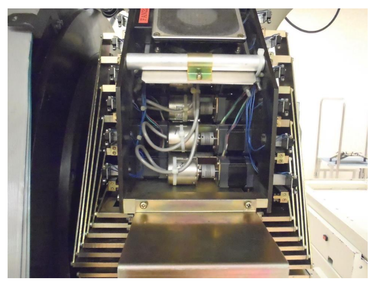
Example of failure detection during maintenance

Treatment room C (March, 2015)
Friction measurement failure (leaf R14: 4.0 kgf)
*Acceptability criteria at maintenance 1.5 kgf

Action 1: Condition check of equipment → grease up and visual check → still 4.0 kgf
Action 2: Replace motor → Improved to 0.6 kgf



Condition check



Setting position of the motors

Disassembly the motor and confirmed that bearing movement was irregularly heavy.
We concluded this was the cause.

Summary

We have succeeded to maintain the equipment for 20 years by performing and reviewing the maintenance programs. Recently, due to increase of frequency of use and aging of equipment, it was required to check many places in detail. It is crucial to detect equipment failures in routine daily/weekly check beforehand as the long maintenance span is less available.
Generally, our maintenance program is going well, however, we believe that it is important to revise the maintenance programs according to the frequency of equipment use etc.