Proposal and Development of A Cylinder Type Liquid Variable Compensator for Radiation Therapy

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ABSTRACT

In proton and heavy ion radiotherapy, compensators are required to modify the energy of heavy ion, to compensate the local difference of tumor depth. Conventional compensators have to be created, exchanged, and stored for each patient and for each irradiation directions. A Cylinder Type Liquid Variable Compensator is and is under development. Hexagonal cylinders will be arranged in honeycomb structure. In which air and fluid are divided by hexagonal pistons. The position of each piston will be changed in each cylinder for adjusting the thickness of fluid for variable compensator. The location of each hexagonal piston is determined by each controlling cylinder connected to the hexagonal cylinder by inlet pipes of fluid. Each controlling cylinder includes controlling a piston, which is moved mechanically. Each controlling cylinder is to be moved by a motor driven by a computer.

Keywords: Variable compensator, bolus, proton therapy, inverse treatment

1. INTRODUCTION

In proton therapy, a bolus or a compensator is used to change proton beam energy on position depending on the shape of a tumor to be treated. Figure 1 shows schematically the application of compensator. Compensators are created by machining from wax or resin. As the shape of the compensator is dependent on the shape of the tumor, it should be created for each patient and for each irradiation directions. To minimize damage to normal tissue, tumor had better be irradiated from many directions. For that purpose, many compemsators have to be created and have to be changed depending on the direction of the irradiation. And compensators should be stored approximately for one month during which each patient is irradiated. In this work, a novel compensator is proposed to overcome these difficulties.
The novel compensator is named cylinder type liquid variable compensator and is under development as is reported in the following.

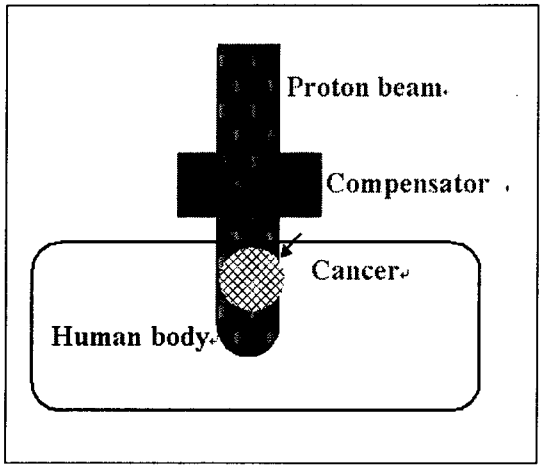

Fig. 1. Application of a compensator

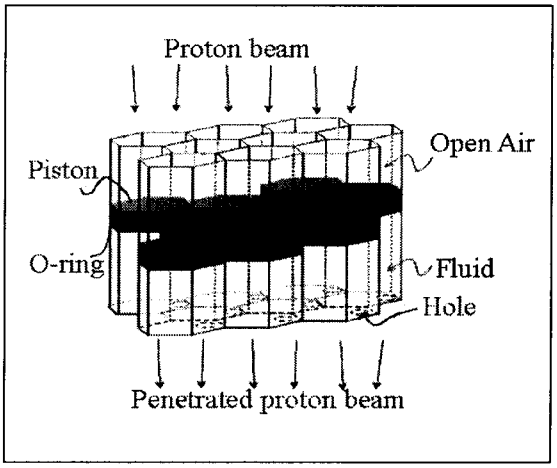

Fig. 2 Hexagonal cylinders

2. METHODS

A cylinder type liquid variable compensator is adjusted its liquid content in hexagonal cylinders by moving pistons that separate liquid and air. Proton beam passed through a cylinder with less liquid content lose less energy compared to that passed through a cylinder with more liquid content. The positions of pistons are controlled by the position of pistons in controlling cylinders (Figure 2.). The area of each hexagonal cylinder should be approximately 1 square centimeter. Figure 3 shows schematically the cross-section of one unit. Moving another piston in a control cylinder moves the position of the piston. In the previously plan, another liquid is to be filled in the upper part of the cylinder. We have simplified this structure that upper part of the cylinder is open. Figure 4 shows the total system from the upward. Control cylinders can be put around the hexagonal cylinder to shorten the pipe length connecting both kind of cylinders.

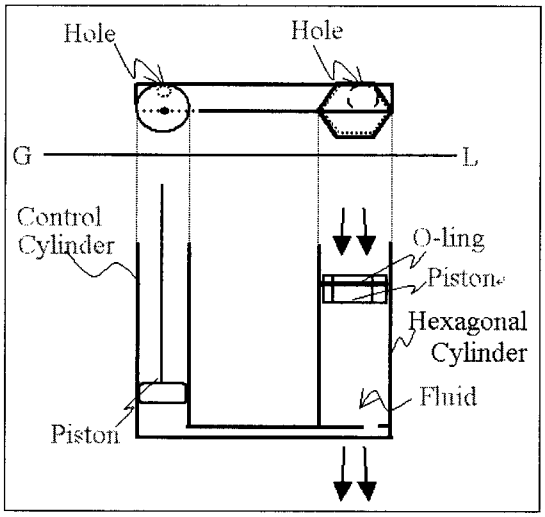

Fig. 3 Single unit

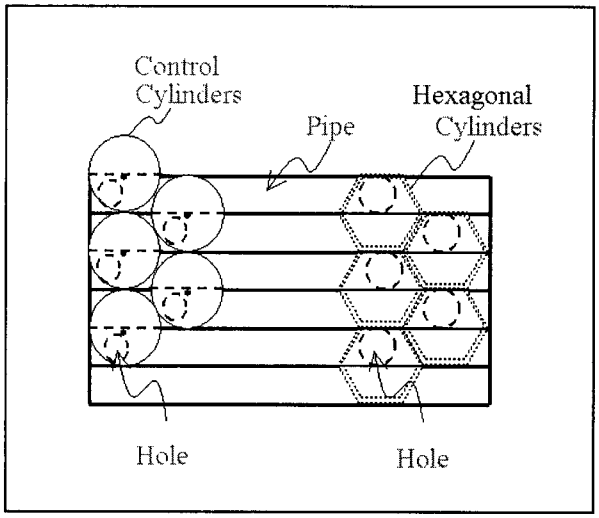

Fig. 4 Total system

3. X-RAY TRANSMISSION EXPERIMENT

Figure 5 shows honeycomb structure of hexagonal cylinders created by Epoxy-resin (47mmx52mmx60mm). In line -1 of this honey-comb structure were empty, line-2 was filled with 15mm depth of water, line-3 was filled with 30mm, line-4 was filled 60mm of water. S-ray radiogram was taken using Polaroid film. Figure 7 is an X-ray radiogram of actually used compensator (115mmx52mmxmaximum thickness of 73mm with minimum thickness of 3mm). Figure 6 shows the radiogram of honeycomb structure filled with above-mentioned depth of water. Figure 7 is a radiogram of actual compensator made of wax. From both radiograms taken in identical condition, absorption of X-rays by water of 60mm and epoxy-resin of 60mm was not so different, and approximately was the same with 73mm.

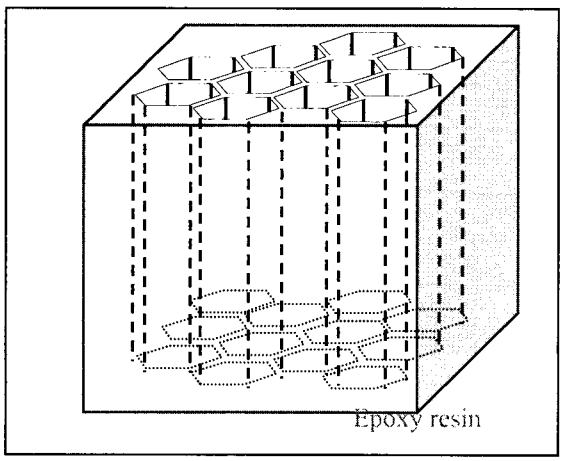

Fig. 5 Honey-comb Epoxy resin

4. CONCLUSIONS AND DISCUSSIONS

X ray-radiograms show the epoxy-resin absorbs approximately the same amount of X-rays as water, and if, in future, the amount of water in honey--comb cylinders is adjusted by control cylinders, it may be suitable as variable compensator. The endurance of hexagonal cylinders, hexagonal pistons, and control cylinders should be checked by motion of repetition. X-ray radiogram dose not show qualitative thickness of water, ultrasound echography will be applied in future experiment to monitor the depth of water in hexagonal cylinders. Above-mentioned compensator with mercury instead of silicon oil seems to be used to modify 2 dimensional X-ray distribution for Inverse Treatment (Patent pending).

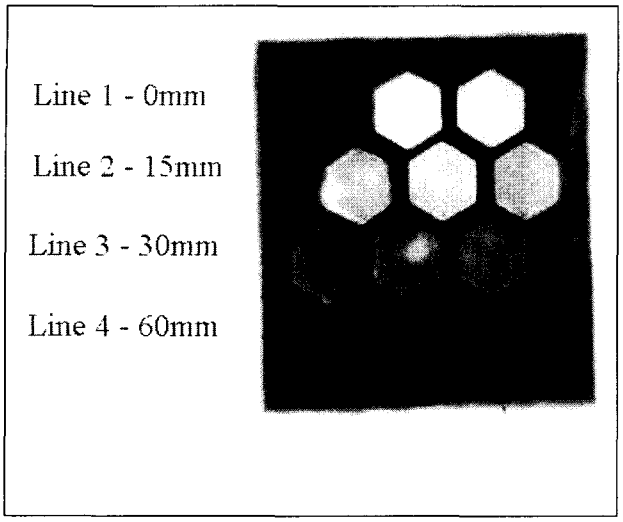

Fig. 6 X-ray radiogram of Epoxy and water

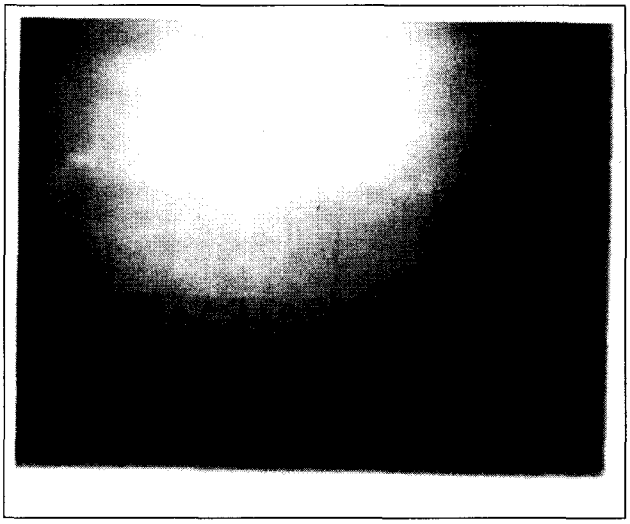

Fig. 7 X-ray radiogram of wax compensators

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