Indigenous Development of HDR Source Assembly for Brachytherapy

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Abstract

Indigenous development of High Dose Rate (HDR) source assembly for Brachytherapy was taken up at the Division of Remote Handling & Robotics (DRHR) jointly with the Board of Radiation and Isotope Technology (BRIT). Recently, HDR source assembly was successfully qualified as per regulatory requirements and was approved for commercial use. The paper brings out the evolution of the design, development of gadgets for handling & welding inside the hot cell and its qualification.

Introduction

Treatment of cancer by using radiation emitted from radioisotopes or the radiation from the accelerators, is a well established procedure and is in practice for decades. Teletherapy and Brachytherapy are widely used for this purpose. In teletherapy, the cancerous tissue is irradiated by gamma rays emitted by radioisotopes. In brachytherapy mode of treatment, the radioactive source is kept near the cancerous tissue.

“Brachy” is a Greek word meaning short; hence Brachytherapy means short distance therapy. It is also known as internal radiotherapy or sealed source radiotherapy. This is a form of radiotherapy, where a radiation source is placed inside or next to the area requiring treatment. It allows use of a high dose of radiation, while reducing the risk of damage to nearby healthy tissues and increasing the likelihood of cancerous tissue being destroyed. Brachytherapy is commonly used as an effective treatment for cervical, prostate, breast, localized uterus, head and neck and skin cancers.

Applicators in the form of catheters are arranged on the patient. A high dose rate source (often Iridium-192) is then driven along the catheters on the end of a wire by a machine, while the patient is isolated in a room. The source remains in a preplanned position for a preset time, to allow controlled doses of radiation to be delivered to the cancerous tissues, without damaging the healthy tissues. Brachytherapy equipment requires accurate positioning of radioactive source of Ir192 within the close proximity of the cancerous area by ensuring safety of patient, operator, and general public with respect to radiation related hazards, achieving fail-safe, forward-backward movements of the radioactive source, etc.
The capsules that hold the radioactive ‘seed’ are only a few millimetres long, and about a millimeter in diameter and have a wall thickness of around 200 μm.

Description

The Brachytherapy source is sealed, so that the radioactive material is fully encapsulated within a protective capsule. HDR source assembly consists of radioactive material, miniature housings, end cover and metallic wire ropes. The assembly has five laser-welded joints between stainless steel wire ropes and miniature components. The component detailing and its design have evolved through ease of manufacture, assembly, handling and welding considerations. Laser welding parameters were finalized through several trials. Initially, laser-welded joints were studied through X-ray tomography for ensuring their quality followed by pull tests, to check the joint strength and its consistency.

A typical HDR source assembly is shown in Fig. 1. It has four miniature stainless steel micro-machined components viz.; machine end terminal, rope joining sleeve, source retaining capsule and cover and two stainless steel wire ropes of dia 0.91 and 0.73 mm. Overall size of the assembly is Ø1.1 mm X 2.1 metres long. There are four laser-welded joints between stainless steel wire ropes and miniature stainless steel components and one laser-welded joint, between two miniature stainless steel components. The weld that joins the source-retaining capsule with its cover, is needed to produce a hermetic seal, with a smooth weld bead. All the laser welding spots are very fine and perfect, devoid of any imperfections such as micro cracks, air bubble void etc. For each of these welded joints, laser welding parameters were optimized through series of trials at various stages.

Handling, Assembly and Welding

Considering miniature components and their handling inside the hot cell, laser welding was chosen. Wire rope end preparation went through several trials for avoiding flaring of wire rope strands and achieving ease of assembly with the matching part.

The welding system consists of industrial Nd:YAG laser, a motorised rotary unit, self centering holding device for miniature parts, inert gas purging arrangement, a CCD camera with 100X magnification to view the weld joint remotely.

Fig. 2 (a) shows laser welding system, Fig. 2 (b) shows welded joints and Fig. 2 (c) shows full-length welded HDR source assembly. In order to qualify the assembly, dummy source was used. In the final assembly, weld joint namely LW₅ (Fig.1) involving the source, is carried out inside the hot cell. In order to facilitate handling of miniature components during active welding inside the hot cell, assembly gadgets were developed and demonstrated for their capability in holding the assembly in position during...
laser welding. A motorized semi-automated welding unit for welding inside the hot cell was designed and manufactured for this purpose (Fig. 3).

Fig. 2 (a): Laser Welding System

Fig. 2 (b): Welded Joints

Fig. 2 (c): Full Length welded HDR Source Assembly

Testing and Qualification

Laser parameters were optimized and several samples were prepared to carry out load tests. Initially, a few samples were subjected to non-destructive examination through 3D X-ray micro-tomography, which provided a good insight into its three-dimensional spatial distribution. Some samples were tested for pull strength on the Hounsefield Tensometer, based on which weld parameters were finalized.

After finalizing the welding parameters of all the joints, four samples were randomly selected from the lot of twenty full-length HDR source assemblies and subjected to qualification tests as per AERB/SS/3/Rev. 1 and source classification C-53312. The qualification tests included high pressure, low pressure, high temperature, low temperature, impact and puncture tests. Fig. 4 shows the tested samples along with impact and puncture tools used for the test. After each of these tests, the samples were subjected to helium leak testing.

All the samples have successfully passed the tests. Based on the successful qualification, the Atomic Energy Regulatory Board (AERB) approved and granted permission for production and deployment of indigenous HDR Source assembly for commercial use.
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References

