Remote Fiber Laser Cutting System for Dismantling Glass Melter – 13071

Takashi Mitsui, Noriaki Miura*, Katsura Oowaki, Isao Kawaguchi**,
Yasuhiko Miura, and Tooru Ino***,
*IHI Corporation, 1 Shin-Nakahara-cho, Isogo-ku, Yokohama, Kanagawa, Japan
** IHI Inspection & Instrumentation Co., Ltd, 1 Shin-Nakahara-cho, Isogo-ku, Yokohama, Kanagawa, Japan
***Japan Nuclear Fuel Limited, 4-108, Aza Okitsuke, Oaza Obuchi, Rokkasho-Mura, Kamikita-gun, Aomori, Japan

ABSTRACT

Since 2008, the equipment for dismantling the used glass melter has been developed in High-level Liquid Waste (HLW) Vitrification Facility in the Japanese Rokkasho Reprocessing Plant (RRP). Due to the high radioactivity of the glass melter, the equipment requires a fully-remote operation in the vitrification cell. The remote fiber laser cutting system was adopted as one of the major pieces of equipment. An output power of fiber laser is typically higher than other types of laser and so can provide high-cutting performance. The fiber laser can cut thick stainless steel and Inconel, which are parts of the glass melter such as casings, electrodes and nozzles. As a result, it can make the whole of the dismantling work efficiently done for a shorter period.

Various conditions of the cutting test have been evaluated in the process of developing the remote fiber cutting system. In addition, the expected remote operations of the power manipulator with the laser torch have been fully verified and optimized using 3D simulations.

INTRODUCTION

In the vitrification facility, HLW, which is generated from spent nuclear fuel reprocessing, is mixed with molten glass in the glass melter and the mixture is poured into the canisters as vitrified wastes.

A Liquid-Fed Ceramic Melter has been applied to the glass melter in the vitrification facility. The glass melter, of approximate outer dimensions 3.1 m long, 2.9 m wide and 2.8 m tall, consists of dual metal casings as the strength members, refractories as the inner wall, electrodes for joule heating of the glass, and accessories such as lid heaters and induction-heated nozzle. The overview of the glass melter is shown in figure 1.

The major components of the vitrification process including glass melters, off-gas treatment systems, and canister handling systems are placed in a large hot cell called "Vitrification Cell" which is a large hot cell approximately 40 m long, 15 m wide and 15 m tall (shown in figure 2). There are two complete process lines with duplicate pieces of equipment. In addition, two overhead cranes with power manipulators and some master-slave manipulators are also installed in the cell in order to remotely access and handle the equipment in the cell. The glass melter is dismantled in an enclosed area in the cell which is approximately 15 m long, 4 m wide and 7 m tall. This area is called the dismantling area and used for dismantling highly-contaminated solid wastes, not only glass melter. The basic equipment that is needed for the dismantling work such as an overhead crane, cameras, master-slave manipulators and ventilation systems have originally been installed in the area. However, the major equipment for dismantling the glass melter has not been installed yet and the development project is ongoing toward starting operation in 2014.

There is not enough time to dismantle the glass melter manually because the glass melter has to be periodically replaced and the used glass melter has to be remotely taken apart to small pieces in order that the debris are packed into designated waste baskets and carried out of the cell. In addition, the dismantling area is needed for dismantling the other used equipment in the cell, not only dismantling the glass melter as mentioned above. Therefore, high cutting performance, high remote controllability and robustness are required for the equipment during the dismantling work.

Two types of power manipulators will be applied as the major remotely-controlled devices in the dismantling area. They will provide a variety of operations for dismantling the glass melter using dedicated cutting and collecting tools.

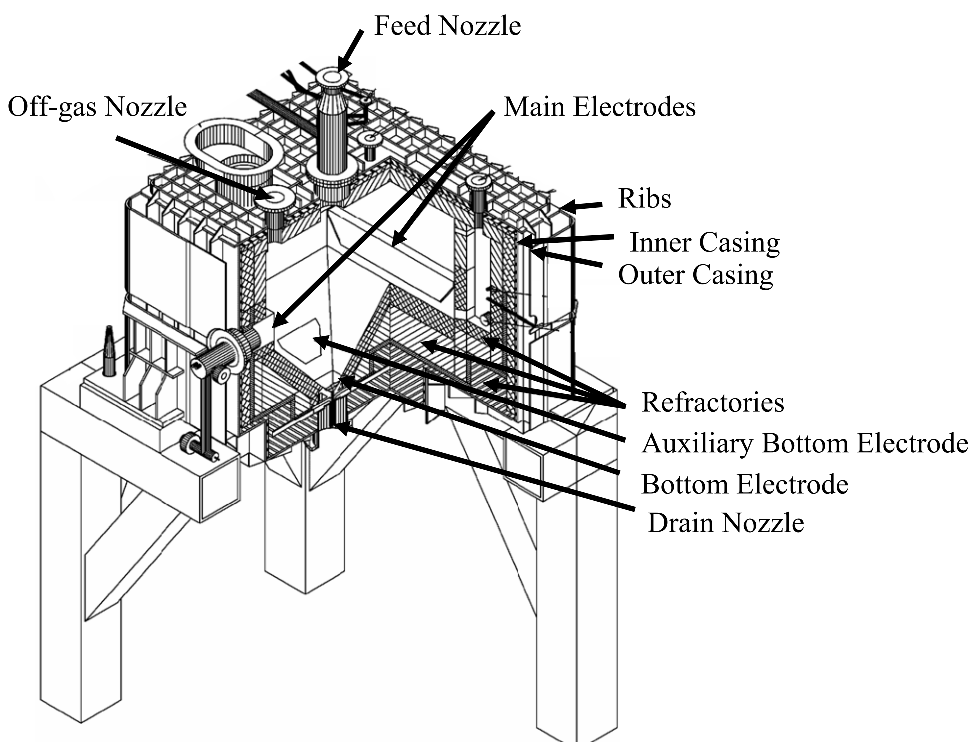

Figure 1: The Glass Melter (Liquid-Fed Ceramic Melter) [1]

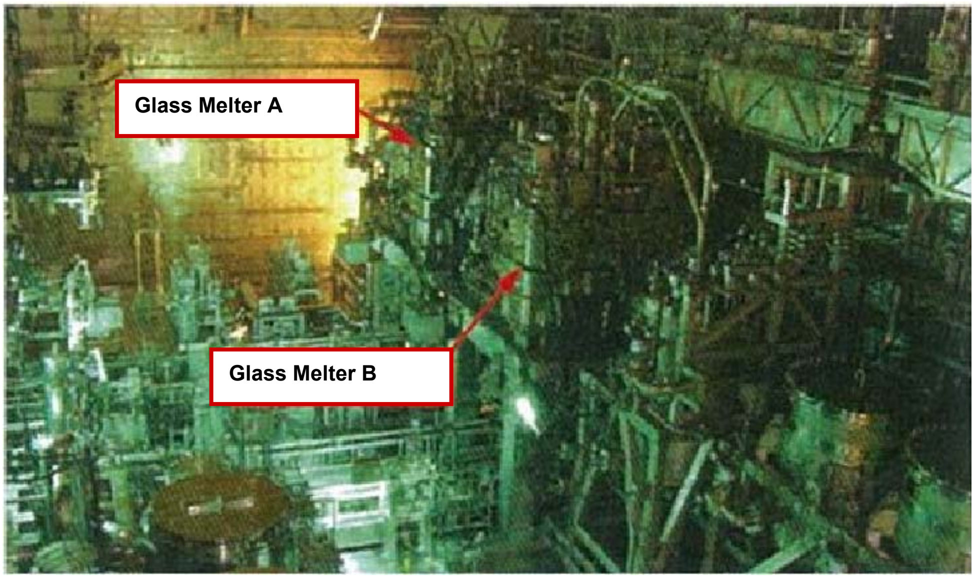

Figure 2: The Vitrification Cell [1]

DEVELOPMENT OF REMOTE LASER CUTTING SYSTEM

Selection of the metal cutting method

In order to select the most suitable metal cutting method for dismantling the glass melter, some typical methods were compared and evaluated. The results are shown in table 1.

First of all, the dismantling area has no drainage system. That means it is quite difficult to apply water jet cutting. The dismantling area also has so limited space that the large equipment like arc saw cannot be set in the area. As for the cutting performance, dismantling the glass melter requires cutting of stainless steel plate of approximately sixty millimeters in thickness. At this point a reciprocating saw and disk cutter looks unsuitable as the main tool of cutting. In addition, these types of tools, which are physically attached to the metal during cutting, may cause damage to the power manipulators due to the counterforce and vibration. Therefore, the use of these tools over a long time should be limited.

Laser cutting and plasma arc cutting are relatively similar method compared to other types of method. However, Plasma arc cutting requires more cables and hoses, and generates more fumes and dross than does laser cutting. Large current management is also required for plasma arc cutting.

For the reasons stated above, laser cutting has been selected as the most suitable method to major metal cutting for dismantling the glass melter.

Table 1: Metal cutting technologies for dismantling the glass melter

	Applicability to the facility	Cutting Performance	Secondary Waste	Contamination Spread	Safety	Remote Controllability
Laser cutting	M (Many cables and hoses)	H	L	M	H	M (Many cables and hoses)
Plasma Arc cutting	M (Many cables and hoses)	H	H (A lot of fume and dross)	M	M-L (Large Current)	M (Many cables and hoses)
Arc Saw cutting	M-L (Large space is needed)	H	L	M	M	L (Difficult to control arc)
Water jet cutting	L (No drain system in the cell)	H	H	H	H	M
Reciprocating Saw	H	L (Unsuitable for thick stainless plate)	L	M	M	M (Large counterforce)
Disk Cutter	H	M-L (Unsuitable for thick stainless plate)	L	M	M	M (Large counterforce)

H = High, M = Medium, L = Low

System Overview

A high-power fiberoptic laser has been applied to the remote laser cutting system. The laser oscillator of IPG Laser GmbH is used in the system and the output is 10 kW at the maximum. The optical fiber is doped with ytterbium and semiconductor laser is applied as the excitation light source. The main reasons of applying the fiber laser system are that stable and high output power can be provided and the size of system is compact compared to other types of lasers. A high power laser makes possible a smooth and speedy cutting work for dismantling the glass melter. Compact size of the system also meets the existing facility conditions.

Figure 4 shows an overview of the remote fiber laser cutting system. The laser oscillator, water cooling unit, assist gas unit and control panel are placed next to the vitrification cell. The optical fiber and hoses are put into the cell and connected with a laser torch which is remotely-controlled by power manipulators in the cell.

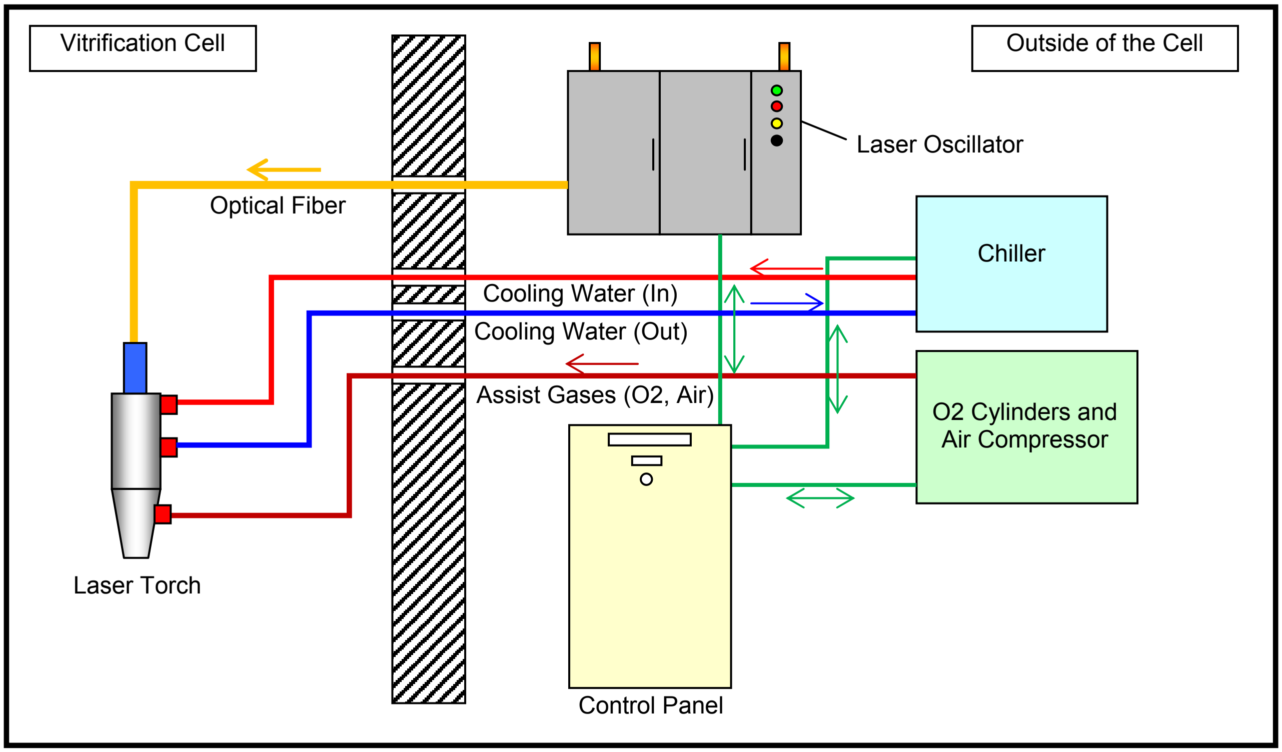

Figure 4: Overview of remote fiber laser cutting system

Cutting Test

Various conditions of cutting have been tested in the process of development of the remote fiber laser cutting system. An oscillator of IPG Laser GmbH and a laser torch of IHI Corporation (Figure 5) that were the same type as actual ones were used for the test. The laser torch was handled by using an industrial robot arm. Various thicknesses of stainless steel and Inconel plates were cut as simulated pieces of major metal parts of the used glass melter.

Figure 6 shows typical cutting sections of stainless steel and Inconel plate by the laser cutting. It was found that cutting performance (cutting speed) for Inconel steel is approximately twenty to thirty percent lower than for stainless steel.

Figure 7 shows a graph of thickness of stainless steel plate for cutting speed in case of the laser power of 8 kW and 10 kW. The 8 kW laser showed cutting performance to stainless steel of 60 mm in thickness at the maximum with enough cutting speed. In case of the 10 kW laser, it was 100 mm in thickness.

The system parameters which were necessary for the laser cutting such as defocusing factor, stand-off (nozzle distance), diameter of the nozzle and the flow rate and pressure of assist gas were optimized through this testing.

In addition, tendencies of temperature increase of stainless steel for laser power, irradiation time and distance from stainless steel were confirmed in another test. After one path of laser cutting is finished, a pierced laser may reach the stainless steel lining or structures in the dismantling area and cause damage to them. This result will be applied to parameters of the safety interlock composed in the remote fiber laser cutting system.

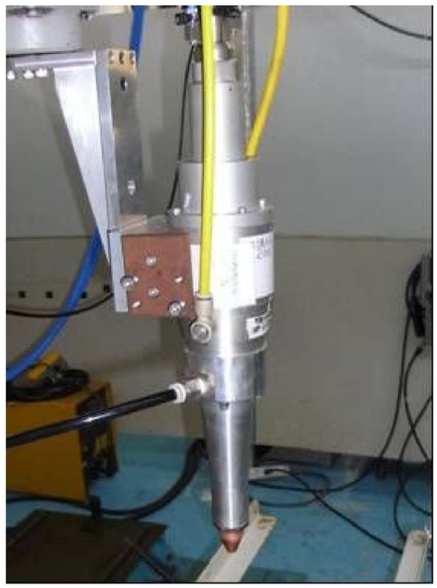

Figure 5: Laser Torch (used for cutting test)

a) Stainless steel (t = 20 mm)

b) Inconel (t = 20 mm)

Figure 6: Cutting section by the fiber laser

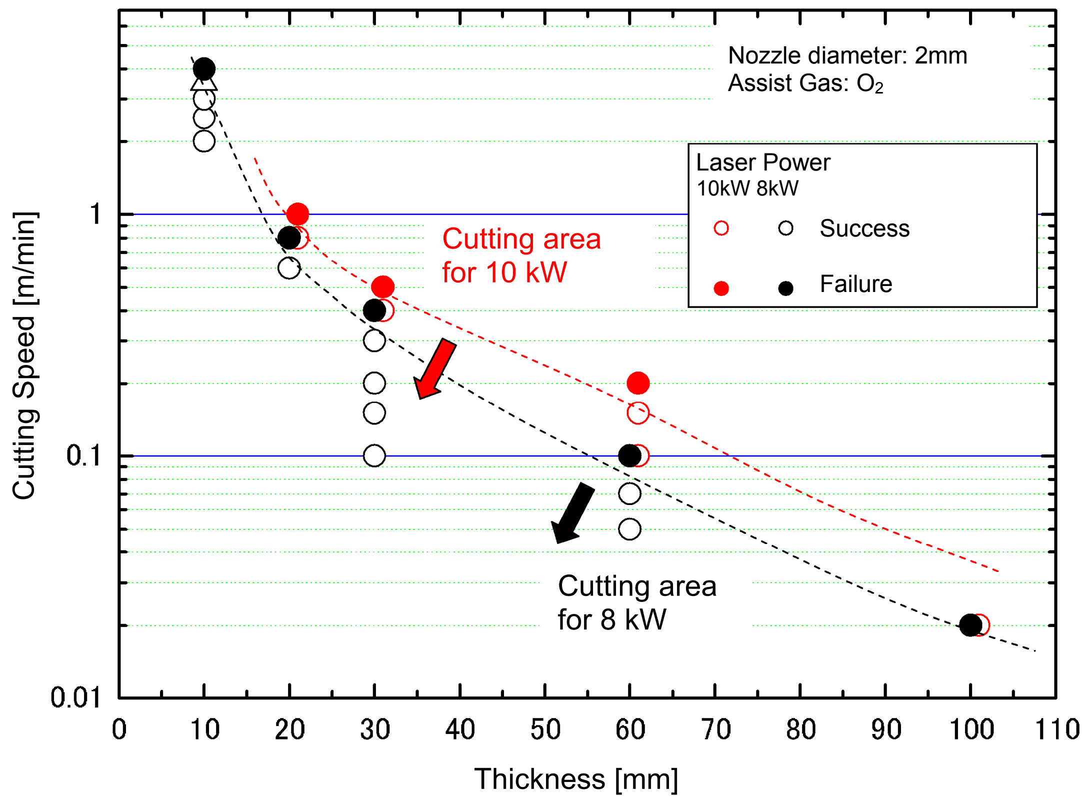

Figure 7: Cutting area for 8 kW and 10 kW laser

3D Simulations of Remote Operations

The expected remote operations of the power manipulators with the laser torch and the support devices in the dismantling area have been verified and optimized using 3D simulations. The results have provided feedback to design of the components for smooth remote operations.

The laser torch is connected with an optical fiber, some signal cables and hoses as mentioned above. Control of cables and hoses is very important for easy remote control of the laser torch. It has been also optimized using the dedicated bands and supports, however this was the most challenging issue and time consuming simulation. These remote operations will finally be demonstrated in the cold testing facility after finished the design and fabrication.

Next Steps

Detailed design and fabrication of the remote fiber laser cutting system is currently ongoing and will be done by the first half of the next year. After the demonstration of cutting performance and remote operations in the cold testing facilities, the system will be installed in the dismantling area by 2014.

CONCLUSIONS

A remote fiber laser cutting system which is one of the major equipment for dismantling the used glass melter in the HLW vitrification facility of the Rokkasho Reprocessing Plant has been developed.

The results of cutting test showed that the 10 kW fiber laser has an enough cutting performance that meets the requirement for dismantling the glass melter. Suitable cutting parameters and safety interlock conditions were also confirmed through the test.

Remote controllability of the laser torch and the support devices which consists of the system were verified and optimized using 3D simulations.

Through detailed design, fabrication and cold testing, the system will be installed by 2014.

REFERNCES

1. Japan Nuclear Fuel Limited: High-level Liquid Waste Vitrification Facility (Japanese) Information found on the internet at http://www.jnfl.co.jp