Underwater Laser Cutting Technology – 16491

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ABSTRACT

Underwater dismantling is advantageous for the highly radioactive apparatuses such as nuclear reactor internals. The most advantageous point of underwater dismantling is a radiation exposure reduction for workers. Underwater dismantling can take advantage of the water shielding. Then it can make the exposure reduction for workers and contamination reduction for work area be realized. And, underwater laser cutting technology has major three advantages. First advantage is lower action force. Therefore it can be possible that we can use a simple remote device for underwater dismantling operation. Second advantage is to reduce secondary waste. The cutting kerf size of underwater laser cutting is very narrow, so the amount of cutting dross is very small. Third advantage is very simple methods for dismantling. This advantage can reduce process time for cutting. On the other hand, the contaminated off-gas which generates during cutting should be taken care. IHI Corporation (IHI) developed the underwater laser cutting devices. The characteristic of IHI's laser cutting torch is that there is no air habitat. Therefore, the positions of the torch and the access to the narrow space have little limitation. Using the device the series of performance tests were performed in order to verify the ability of it. In the first Laboratory test at 0.2 meter depth of water, we evaluated the optimum cutting parameters. The next underwater demonstration test at 6 meters depth of water was performed. In the test the cutting performance, which the mild steel plate of the thickness of 12mm can be cut at the speed of 300mm/min with the horizontal and downward position of torch was verified. Then the hot bubble test using real radioactive test coupons was performed to evaluate the radioactivity carried as air borne and the decontamination factor (DF) of off-gas passing through water. This document provides an overview of the underwater laser cutting device that has been developed by IHI, and the advantage of these devices for the dismantling work of underwater apparatus.

INTRODUCTION of underwater laser cutting technology

The purpose of this development is to apply underwater dismantling structure like a SKIP (Spent Fuel Storage Steel Box) and furniture. There are 2 reasons that underwater dismantling suits. The 1st point is to reduce radiation exposure. In case SKIP can be dismantled in the water, there is not required to carry it out from the pond, and radiation shielding effect by water could be expected. The 2nd point is to be able to expect to contain most of radioactivity in the water. For this purpose, IHI developed underwater laser cutting technology, and IHI were subjected to various underwater laser cutting trial test.

IHI underwater laser cutting system is very simple system. (See Fig. 1.) This schematic diagram is general one, and as heat source, fiber laser oscillator and compressed air as assist gas are utilized. Adopting of non-habitat type compact laser torch head is our advantage point in the underwater laser cutting. And our torch tip can be accessed in narrow place by compact torch.

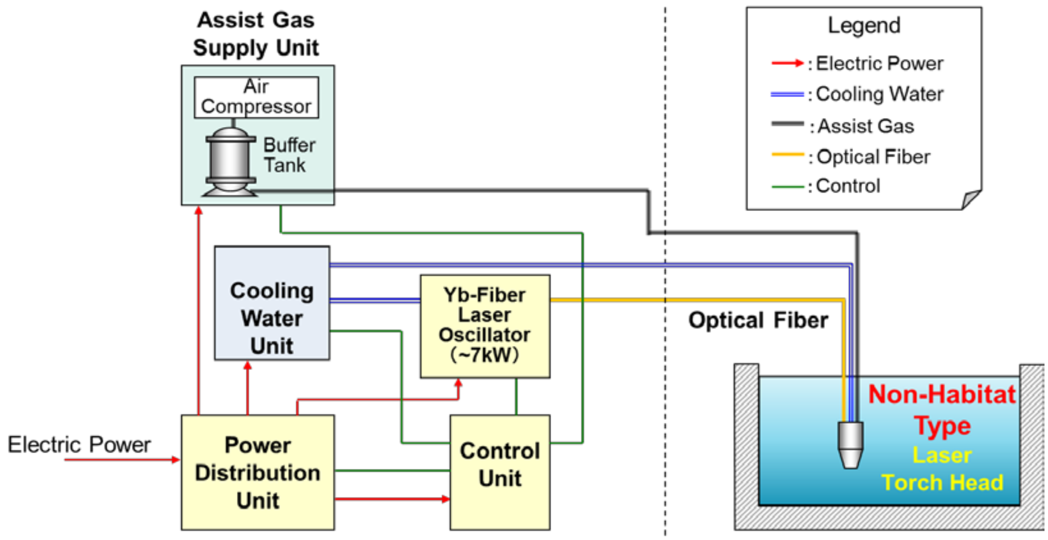

Fig. 1. Schematic diagram of underwater laser cutting system

We show underwater laser cutting situation. (See Fig. 2.)

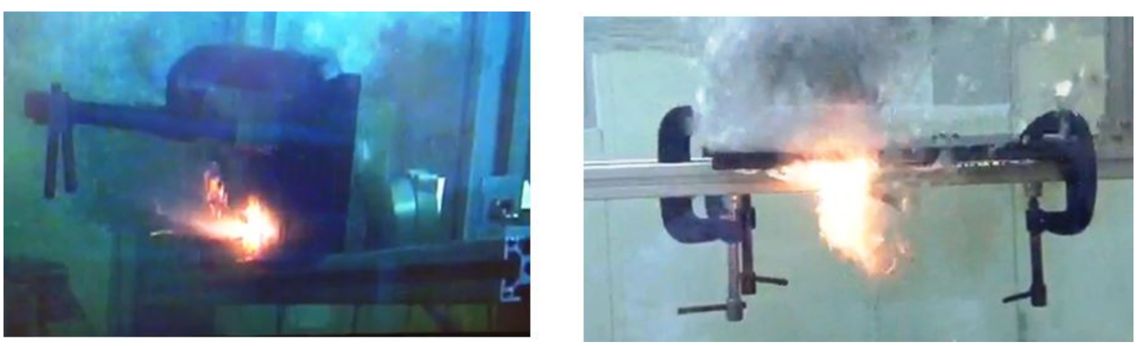

Fig. 2. Underwater laser cutting

We show merits of underwater laser cutting. (See TABLE I.) Since underwater laser cutting has a small reaction force, it brings the margin for decommissioning work. Various cutting technologies are compared by various situations and those comparisons are different, because the importance in the evaluation depends on the conditions of the facilities, the equipment to apply, the cutting conditions, and so on. This time, cutting technologies were compared by using dismantling 1 SKIP per day in the water, and being the equipment as cost effective and robust as conditions. As a result, the laser cutting which has few concerns, for example reaction force and generation of secondary waste, was selected.

We will report results of this IHI underwater laser cutting trial test on this paper.

TABLE I. Merits of laser cutting (for SKIP size reduction)

Method	Underwater Laser	Underwater Plasma	Mechanical Disc Saw	Abrasive Water Jet
Accessibility	Down/Side Posision Stand Off : ~15mm Average	All Position Good	All Position Good	All Position Good
Cutting Speed	~200mm/min Mild Steel t12mm Good	~300mm/min Mild Steel t12mm Good	~250mm/min Mild Steel t250mm Excellent	~60mm/min Mild Steel t100mm Excellent
Airborne Radioactivity	Kerf Size : 1mm Use Assist Gas Average	Kerf Size : ~5mm Use Assist Gas Fair	Kerf Size : ~10mm No Assist Gas Good	Kerf Size : ~3mm No Assist Gas Good
Secondary Waste	Small (Cutting Dross) Good	Large (Cutting Dross) Fair	Small (Cutting Chips) Good	Large [Abrasive Waste 500kg / day] Fair
Reaction Force	Low Good	Low Good	High Fair (N/A)	Midium Fair (N/A)
Device Size	Φ80×400 Torch Size Good	Φ80×300 Torch Size Good	Φ800 Disc Size Poor	Φ80×500 Nozzle Size Fair
Maintenance	Long Life Time Good	Long Life Time Good	per few days (Disk Change) Average	per few days [Nozzle & Abrasive System Change] Fair
Total	Good	Average	Fair	Fair

Result (summary)

1. Cutting speed:	200(mm/min)
2. Sand off of sectile range:	Wide range (1 – 15(mm))
3. Decontamination factor :	DF17
4. Cutting attitude:	Down Position (Vertical) Side Position (Horizontal) , (See Fig. 2.)
5. Sectile depth underwater:	0.2 meters – 6 meters

Laboratory test

In 2014 April, we did inactive trial test to survey underwater laser cutting condition at IHI R&D center. The purpose of this laboratory test is to understand the conditions that can be reliably cut by underwater laser cutting. It was possible to confirm the conditions that can be reliably cut at downward and lateral torch position in this laboratory test.

Laboratory test conditions and test results.

Test equipment
Water Tank: 1m(Depth)×2m(Width)×1m(Height)
Drive unit : Six-Axis Articulated Robot (See Fig. 3.)

Test Condition
Specimen Material : JIS SM490 (ASTM A572), Mild Steel
Water Depth: 0.2 meters

Laser torch position: Down Position (Vertical), Side Position (Horizontal)
Plate Thickness: 12 (mm)
Cutting Speed: 100 - 250（mm/min）
Stand Off: 1 – 20(mm)

Test result
Water Depth: 0.2 meters

Laser torch position:	Down Position (Vertical)	OK(Can cut)
	Side Position (Horizontal)	OK(Can cut)
Plate Thickness:	12 (mm)	
Cutting Speed:	100 - 200（mm/min）	OK(Can cut)
Stand Off:	Wide range (1 – 15(mm))	OK(Can cut)

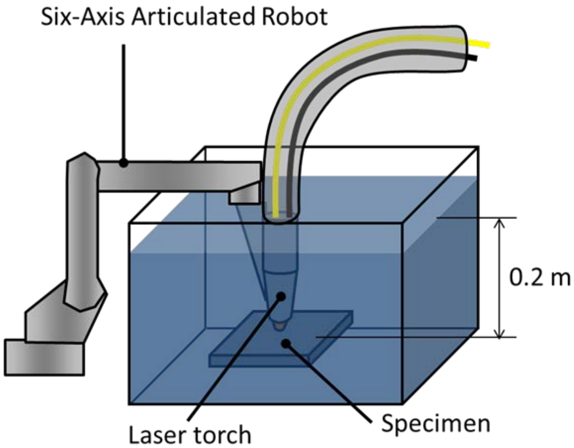

Fig. 3. Schematic illustration of laser cutting

Underwater demonstration test in 6 meters depth

In 2014 July, we did demonstration test in 6 meters depth at IHI Yokohama works in Japan. (See Fig. 4.)

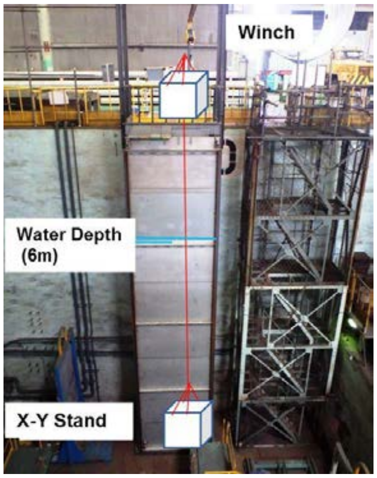

Fig. 4. Equipment of Underwater demonstration

Using already confirmed cutting condition of laboratory test, we did demonstration test in 6 meters depth. The purpose of this 6 meters depth test is to confirm whether can be cut in the actual depth of SKIP size reduction. Underwater laser cutting of 6 meters depth using 0.2 meters depth cutting condition was confirmed to be possible in same cutting condition.

Underwater demonstration test conditions and test results.

Test equipment
Water tank: 1m(Depth)×2m(Width)×10m(Height)
Water depth: 6 meters
Drive unit : X-Y Stand

Test condition
Specimen Material: JIS SM490 (ASTM A572), Mild Steel
Water Depth: 6 meters
Laser Torch Position: Down Position (Vertical), Side Position (Horizontal)
Plate Thickness: 12 (mm)
Cutting Speed: 100 ~ 250 (mm/min)
Stand Off: 1 – 20 (mm)

Test result

Water Depth:	6 meters	
Laser torch position:	Down Position (Vertical)	OK(Can cut)
	Side Position (Horizontal)	Ok(Can cut)
Plate Thickness:	12 (mm)	
Cutting Speed:	100 ~ 200 (mm/min)	Ok(Can cut)
Stand Off:	Wide range (1 – 15(mm))	Ok(Can cut)

Hot bubble test

In 2015 Feb, we did hot bubble test at IHI Southwest Technologies (ISwT). (See Fig. 5.) ISwT is located on the Southwest Research Institute (SwRI) campus, and in addition to Hot Par indicated in this picture.

Fig. 5. Hot Par (IHI Southwest Technologies (ISwT) in San Antonio)

To confirm the expansion of contamination prevention capability of water, we subjected to Hot bubble test. It shows in figure of hot bubble test. (See Fig. 6.)

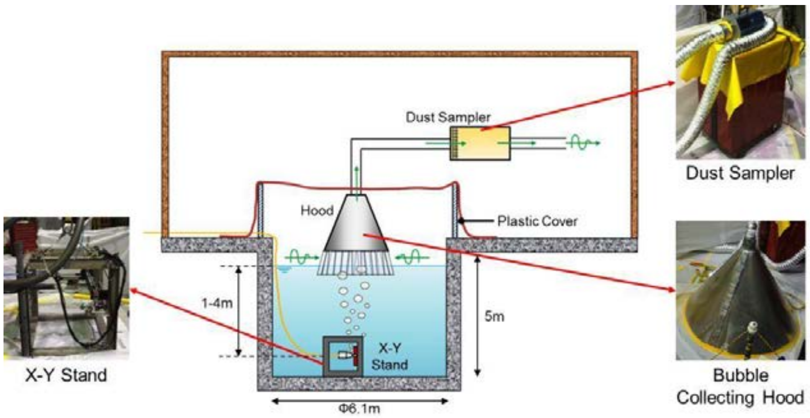

Fig. 6. Equipment of hot bubble test

To execute cutting in water depth of 1 meter to 4 meters, we also assembled the X-Y (See Fig. 7.) stand which can make laser torch move to straight as shown in the Fig. 7.

Fig. 7. Test stand

Hot bubble test conditions and test results.

Test Condition
Specimen : Mild steel
Specific Activity: 10.3 GBq/te
Dimension: 780mm × 510mm × t6.35mm
Water Depth: 1m, 2m, 3m, 4m

Laser Torch Position:　Side Position (Horizontal)
Cutting Speed: 200（mm/min）
Drive unit :　X-Y Stand (See Fig. 7.)
Test result
First, it was only Cs-137 that it was a significant measured value in both samples of air and water from measurement of the radioactivity amount of each nuclide. (See Fig. 8.) When the amount of radioactivity transfer to the gas and the water was standardized per cutting length of 1cm about Cs-137, this chart was obtained. Green line indicates the gas transfer ratio, and there was no clear correlation between gas transfer ratio and water depth from this chart.
Blue bar indicates activity transfer to gas, and brown is one to water in this chart. From this result, averaged Cs-137 activity balance per cutting length of 1cm is shown in the figure of the lower right.

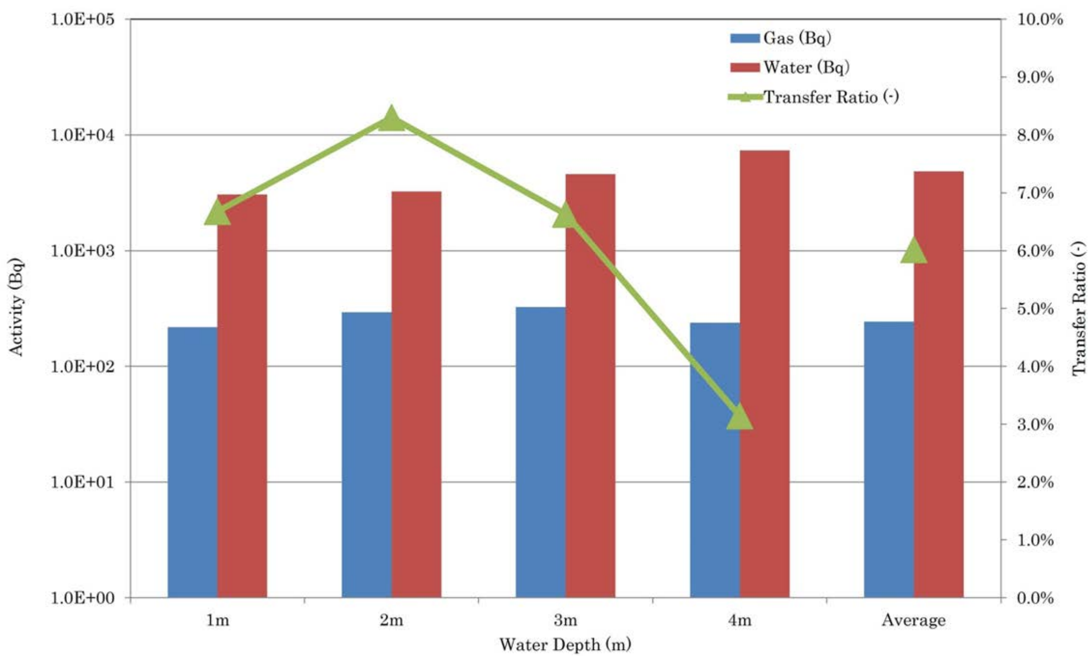

Fig. 8. Cs-137 Activities Transferred to Water and Air (per 1 cm Cutting)

From this result, averaged Cs-137 activity balance per cutting length of 1cm is shown in the figure. (See Fig. 9.)

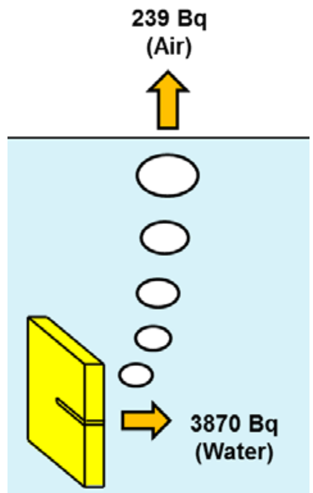

Fig. 9. Cs-137 Activity Balance (Average per 1 cm Cutting)

1. Only Cs-137 was detected in air and water samples at significant level.
2. Clear correlation was not seen between gas transfer ratio and water depth.
3. Activities transferred to gas and water were normalized by one cm cutting. (See Fig. 8, 9)

So decontamination factor can be confirm in DF17 (=100%/6%).
Applying the underwater laser cutting to decommissioning work, it is possible to prevent the expanding the pollution the working environment.

CONCLUSION

Underwater laser cutting technology has merits for decommissioning work. IHI has to take advantage of underwater laser cutting method, IHI would like to contribute to the reasonable decommissioning plan. We have to confirm the following result of the underwater cutting performance test and the hot bubble test.

Applicable cutting conditions for a mild steel plate of the thickness of 12mm

1. Cutting speed can be cut:	200(mm/min)
2. Sand off of sectile range:	Wide range (1 – 15(mm))
3. Cutting attitude:	Down Position (Vertical) Side Position (Horizontal)
4. Sectile depth underwater:	0.2 meters – 6 meters
5. Decontamination factor :	DF17

The decontamination factor (DF) of off-gas passing through water is approximately DF17.

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