DEVELOPMENT OF LASER CUTTING METHOD FOR STAINLESS STEEL LINER

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1. INTRODUCTION
Concrete structures such as cells and fuel storage pools in nuclear facilities are lined with stainless steel liners in order to protect the concrete structures from radioactive contamination. In the decommissioning of nuclear facilities, such liners need decontamination and/or removal.

The present work is an attempt to develop a laser cutting method for cutting and removing stainless steel liners from concrete walls and floors in nuclear facilities.

The effect of basic laser cutting parameters such as energy, cutting speed, assist gas flow etc. were first studied through cutting experiments on mock-up concrete specimens lined with 3mm thick stainless steel sheets using a laser. These initial studies were followed by further studies on a new method of confining contamination during the cutting process using a sliding evacuation hood attached to the laser cutting head.

The results showed that laser cutting is superior to other conventional cutting methods from the point of view of safety from radioactivity and work efficiency when cutting contaminated stainless steel liners.

2.1 LASER CUTTING CONDITIONS
In this experiment 1kW Nd:YAG laser was used. Table 1 shows the laser cutting conditions.

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Nd:YAG laser-wavelength 1064nm</th>
</tr>
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<tbody>
<tr>
<td>Laser power</td>
<td>0.5–1kW</td>
</tr>
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<td>Cutting rate</td>
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<td>Cutting position</td>
<td>Flat, Horizontal, Vertical up and Vertical down</td>
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</tbody>
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2.2 EXPERIMENTAL RESULTS
To verify the gas jet effects on laser cutting of stainless liner, experiments were carried out under various cutting speeds and assist gas flow rates.

Removal conditions of the cut pieces from specimens were used in the estimation. The results are shown in Fig.1.

The symbols used in Fig.1 indicate the following.
- ●: the cut part of the stainless liner is easy to remove
- ▲: removable but not as easy as ● affected by the attached melt
- *: Not removable because of incomplete cutting

3. CONCLUSIONS
Laser cutting experiments on cutting 3mm thick stainless steel sheets on concrete with a 1kW Nd:YAG fiber-delivered laser yielded the following results.
- The laser achieved fast cutting rates of 2.5m/min.
- Flat, Horizontal and Vertical position cutting was possible at a cutting rate of 2.5m/min.
- The sliding exhaust hood attached to the laser head confined spatter and sparks efficiently.
- For stainless steel, oxygen is the preferred assist gas.

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ABSTRACT
The present work is an attempt to develop a laser cutting method for cutting and removing stainless steel liners from concrete walls and floors in nuclear facilities.

The effect of basic laser cutting parameters such as energy, cutting speed, assist gas flow etc. were first studied through cutting experiments on mock-up concrete specimens lined with 3mm thick stainless steel sheets using a 1kW Nd:YAG laser. These initial studies were followed by further studies on the effect of unevenness of the liner surface and on a new method of confining contamination during the cutting process using a sliding evacuation hood attached to the laser cutting head.

The results showed that laser cutting is superior to other conventional cutting methods from the point of view of safety from radioactivity and work efficiency when cutting contaminated stainless steel liners.

1. INTRODUCTION
Concrete structures such as cells and fuel storage pools in nuclear facilities are lined with stainless steel liners in order to protect the concrete structures from radioactive contamination. In the decommissioning of nuclear facilities, such liners need decontamination and/or removal. However, indentations, cuts and sharp scratches often exist on the surface of the stainless steel liners, making decontamination difficult. In many cases, therefore, it becomes necessary to cut and remove the liner. Therefore the development of safe and efficient cutting methods for stainless steel liners is important.

As baseline technologies, mechanical saw and plasma-arc techniques are available to cut stainless steel liners. However, mechanical sawing is slow (0.05~0.5m/min), and laborious. On the other hand, plasma-arc generates large amount of smoke, metal vapor and secondary waste, and, because of the presence of concrete on the underside of the liner, cutting is often obstructed by the molten metal that remains in the kerf.

Compared with these traditional methods, laser cutting is somewhat faster and has a number of advantages. The characteristics of laser cutting relate to the fact that the beam can be focused to a spot of 0.5~1mm diameter to achieve high power densities.

2. LASER CUTTING EXPERIMENT

2.1 MATERIALS AND SPECIMENS
Two types of 33mm thick concrete block lined with SUS304(JISG304, 18Cr-8Ni) stainless steel of 3mm thickness were made, representing liners most commonly used in the first stage nuclear installations.

The smaller specimens A(Fig.1) were used for laser cutting parameter study. Specimens B(Fig.2) are much larger ones and were used to determine the cutting performance.
2.2 LASER CUTTING CONDITIONS

The most common types of lasers are YAG and CO2. YAG laser uses fiber optic technology to deliver the laser beam to remote, hazardous cutting sites. Therefore the laser resonator, power supply, water chiller, gas assist supply, and operational controls are located in non-hazardous environment for protection and maintenance accessibility.

In this experiment 1kW Nd:YAG laser, laser-wavelength(1064nm) was used.
Table 1 shows the laser cutting conditions.

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2.3 CUTTING EXPERIMENTS

2.3.1 STAINLESS STEEL SHEET

Before the stainless steel lining cutting experiments, the relationship between thickness of sheet and cutting rate in single stainless steel sheet cutting (without concrete on the underside) by YAG laser was surveyed The results of experiment and literature survey are shown in Fig.3 for 1kW laser power. The cutting rate is dependant on several parameters such as laser spot size, optical alignment, chemistry of assist gas, gas flow rate etc. As shown in Fig.3, maximum cutting rates are between 4 to 5m/min for 3mm thick stainless steel under optimum conditions.

As will be mentioned later, in the case of stainless steel liners with concrete on the underside, the cutting rate is slower than the maximum cutting speed shown in Fig.3.

2.3.2 STAINLESS STEEL LINER

Figure4.1 and 4.2 show schematic diagrams of usual laser cutting single steel plate and cutting of liner with concrete on the underside.

In case of usual laser cutting, molten metal and oxides formed(dross) go through the kerf and the cutting progresses steadily. When cutting stainless steel liner with concrete on the underside, the molten metal and dross cannot go through the kerf. They are partially ejected out of the kerf, and one part will tend to remain in the kerf. The remains stick on the kerf will obstruct the progress of cutting.

There are three measures for counteracting this phenomenon.

1) Make the temperature of the melt higher, and lower its viscosity, and make it easy to eject.

2) Use oxygen as assist gas, and it delivers additional exothermic energy through chemical reaction between the assist gas and molten metal. Then the process temperature increases and the viscosity goes down.

3) Increase gas flow rate and the forcibly eject the melt from the cut zone by forced convection efficiently.
2.3.3 EXPERIMENTAL RESULTS

To verify the gas jet effects on laser cutting of stainless liner, experiments were carried out under various cutting speeds and assist gas flow rates. In the experiment oxygen was used as the assist gas. Cutting performance was estimated by cutting square openings on the specimen A. Removal conditions of the cut pieces from specimens were used in the estimation. The results are shown in Fig.5.

The symbols used in Fig.5 indicate the following.
- ●: the cut part of the stainless liner is easy to remove
- ▲: removable but not as easy as ● affected by the attached melt
- *: Not removable because of incomplete cutting

Figure 5 shows the cutting of liner is difficult when the assist gas flow rate is low. The higher the assist gas flow rate, the faster the cutting speed. The maximum cutting speed was 3.5 m/min, which is about 10 times higher than conventional mechanical cutting method.

Figure 6 shows a stainless liner stripped from concrete after laser cutting.

Air assisted cutting was conducted to characterize the effect of chemistry of gas. Stainless liner cutting was difficult when air was used as assist gas even at a low cutting speed of 1 m/min. Therefore, the use of oxygen, which creates additional thermal energy due to the exothermic reactions during the formation of FeO and other oxides is beneficial in stainless liner cutting process.
Figure 7 shows the generation of spatter and sparks during laser cutting of stainless liners. In this situation, hazards such as cross contamination by scattered particles, worker’s internal exposure, and injury or fire accident exist.

Therefore in the cutting of stainless liner by laser, simultaneous collection of spatter and sparks is necessary. A sliding hood with an exhaust blower system was designed to be attached to the laser head in order to prevent scattering of spatter and sparks. Figure 8 shows schematic diagram of stainless liner cutting with exhaust hood. The hood moves with the laser cutting head.

Figure 9 shows cutting with exhaust hood. By comparing with Fig. 7, it can be seen that spatter and sparks are restrained by the exhaust hood efficiently. The hood is also effective for cutting stability.

On site, a stainless liner is cut into size about 0.5 ~ 1.0 m square pieces and packaged in a container. Experiments on large sized specimen (specimen B 60 cm × 70 cm, see Fig. 2) were carried out to mock up floors and walls stainless liner removal.

The laser power was 1 kW, and the cutting speed was 2.5 m/min. Figure 10.1 shows stainless liner cutting in the flat position, and Fig. 10.2 shows the liner stripped from concrete after cutting in this position. This flat position cutting mocks up cutting of floor lining.
Figure 11.1 and 11.2 show stainless liner cutting in the horizontal and vertical up/down positions, mocking up wall lining. In all cutting positions, most of the melt was ejected and did not remain on or within the kerf, making liner removal easy.

Fig.11.1 Stainless Liner being cut in the Horizontal and Vertical Position

Fig.11.2 Appearance after Completion of Cutting in the Horizontal and Vertical positions

Fig.12 Appearance of Kerf after Cutting in the Flat Position

Fig.13 Appearance of Kerf after Cutting in the Vertical Position

3. CONCLUSIONS
Laser cutting experiments on cutting 3mm thick stainless steel sheet liners on concrete with a 1kW Nd:YAG fiber-delivered laser yielded the following results.
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REFERENCES


