*Transactions of the Korean Nuclear Society Spring Meeting*
*Jeju, Korea, May 18-19, 2017*

# Laser cutting experiment of 100mm-stainless steel plate for nuclear decommissioning

Seong Y. Oh[*], Jae Sung Shin, Sangwoo Seon, Taek Soo Kim, Hyunmin Park, Lim Lee, Chin-Man Chung, Byung-Seon Choi, Jei-Kwon Moon and Jonghwan Lee
[a]*Korea Atomic Energy Research Institute, Daejeon 305-353, Republic of Korea*
[*]*Corresponding author: syoh73@kaeri.re.kr*

## 1. Introduction

In the nuclear decommissioning site, laser cutting as a dismantling technology can be superior to other conventional technologies in that it allows remote controllability and releases a small amount of secondary waste. Other dismantling technologies appreciable in nuclear decommissioning sites include plasma arc cutting, abrasive water jet cutting, and mechanical cutting. With regards to cutting performance, it should be considered that the internal structure of nuclear power plants contain metal components having a thickness over 100-mm. Recent studies demonstrate that laser cutting technology associated with a high-power fiber laser is sufficiently capable of dismantling metal plates that are over 100-mm-thick and up to 300-mm-thick. This result shows that laser cutting can be a convenient dismantling technology in nuclear decommissioning sites. 1,2)

In the laser cutting technology, focused laser beam heats up the local area of specimen above its melting point and assist gas jet passing through nozzle contributes to blowing the melted outside the specimen.3) The nozzle functions to increase the speed of assist gas jet. Therefore, the use of nozzle in the laser cutting is necessary to effectively blow out the melt. In this study, we have investigated the effect of a geometrical nozzle shape on cutting performance of stainless steel plate with 100 mm thickness.

## 2. Experimental Setup

Laser cutting system consists of 10kW fiber lasers (IPG, YLS 10000) and cutting heads, which are connected through 25-m-long process fibers. The high-powered laser beam is delivered to the cutting head through the process fiber having a core diameter of 100 m. Cutting head contain optical system delivering laser beam onto specimen and nozzle with 2 mm diameter. The optical system is made up of a collimation lens (f: 160mm), a parabolic focusing mirror (f: 600mm), and a reflector. The nozzle in the cutting head is connected to the high-pressure gas pipe so that the assist gas is introduced from the outside and injected into the specimen. The 10.0 bar gauge pressure of compressible air as an assist gas was used in this experiment. The cutting speed and direction were controlled by an x-y-z axis motion stage coupled with the cutting head. Because a large amount of dust is generated in the laser cutting experiment, it is sucked by the dust collector along the duct pipe installed near the cutting specimen, and then exhausted to the outside after passing through the filter.

## 3. Result and Discussion

### *3.1 Flow rate measurement*

Prior to the cutting experiment, flow rate measurement was carried out using a few of converging nozzles with different throat diameter. Four nozzles with throat diameters of 1.5 mm, 2.0 mm, 3.0 mm and 4.0 mm were prepared for flow measurement.

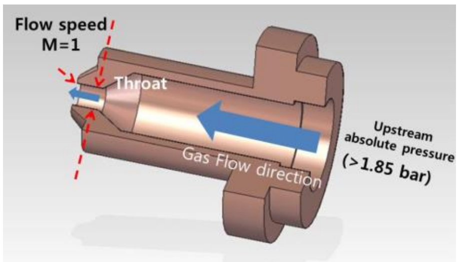


Fig. 1 Internal structure of converging nozzle.

Figure 1 shows typical converging nozzle. In the case of converging nozzle, when the upstream pressure is higher than the critical pressure (18.5 bar), the flow velocity at the nozzle throat reaches the sonic velocity (M = 1). Under the condition of upstream pressure above the critical pressure, the mass flow rate can be briefly expressed by the following mathematical equation.

$$\dot{m} = 0.685\frac{p_0 A^*}{\sqrt{RT_0}} \qquad (1)$$

$p_0$ is the upstream absolute pressure, A* is the throat area of the nozzle, R is the gas constant, and T0 is the assist gas temperature in the upstream. In this experiment, the back pressure becomes the atmospheric pressure. The mass flow rate is generally expressed by converting it into volume flow rate (Q). The volume flow rate is obtained by dividing the mass flow rate by the air density of the atmospheric pressure (1.0 atm) in standard condition. 4) Standard condition indicates atmospheric pressure, temperature of 20℃, relative humidity Based on the above equation (1), the flow rate discharging from the nozzle can be predicted theoretically as below:

$$Q(L/min) = \frac{0.685}{\rho_0}\frac{p_0 A^*}{\sqrt{RT_0}} \qquad (2)$$

Here, ρ refers to air density in standard condition and its value is 1.22 kg/m3. Four nozzles with throat diameters of 1.5 mm, 2.0 mm, 3.0 mm and 4.0 mm were prepared for flow rate measurement and flow meter (SMC Inc, PF2A703H-10-28) was used in this experiment. Table 1 shows the measurement result of flow rate as a function of upstream pressure and the diameter of nozzle throat. In Table 1, the flow rates values outside the parentheses are measured using a flow meter and another flow rates values inside parentheses indicate the values calculated from the above equation (2).

Table 1 Experimental results of flow rate measurement as a function of nozzle throat diameter and upstream gauge pressure. Measured value (Theoretical value)

| Throat diameter of nozzle | Upstream Gauge Pressure | | | |
|---|---|---|---|---|
| | 7bar | 8bar | 9bar | 10bar |
| 1.5mm | 155 (164) | 180 (184) | 200 (205) | 230 (225) |
| 2.0mm | 285 (291) | 315 (328) | 355 (364) | 390 (400) |
| 3.0mm | 620 (656) | 705 (738) | 790 (819) | 885 (901) |
| 4.0mm | 1075 (1167) | 1220 (1312) | 1330 (1457) | 1515 (1603) |

The theoretical values seem to be consistent with experimental values in the case of the nozzle with small throat diameter. For the case of the 4mm nozzle throat diameter, there is, to some extent, difference between the two values, It is attributed to the fact that the supply of compressible air at upstream is insufficient because of limited diameter of pipe line introducing assist gas to the nozzle.

*3.2 Effect of nozzle throat diameter on cutting performance*

The cutting performance of stainless steel plate with 100 mm thickness was evaluated as a function of the prepared four nozzles. Same experimental parameters except nozzle were employed and the same parameters include 9.5 kW laser power, 10 bar of compressed air and 1.0 mm stand-off distance. Stand-off distance refers to distance between nozzle exit and specimen surface.

Figure 2 presents the specimen after cutting. Laser cutting was carried out from left side of specimen toward right side and its entire cutting length was 40mm. The cutting speed was initially set at 5 mm/min until 10 mm cutting, after which, the cutting speed was increased to find the maximum cutting speed.

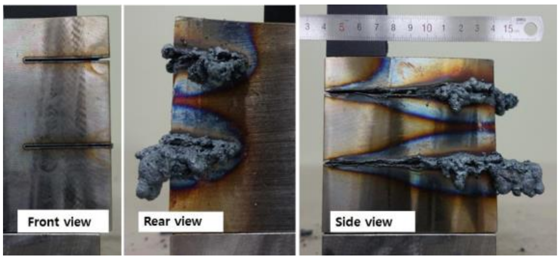


Fig. 2 Stainless steel after cutting (thickness: 100 mm, nozzle throat: 4mm, cutting speed: 45 mm/min and 50 mm/min)

The maximum cutting speed was 30 mm/min in the case of nozzle with 2mm throat whereas higher maximum cutting speed was found to be 45 mm/min and 50 mm/min in the cases of nozzles with 3mm and 4mm throat diameter, respectively. The values of maximum cutting speed were measured according to four nozzles and tabulated in Table 2. The increase of throat diameter in nozzle gives a rise to the flow rate of assist gas impinging on the melt during the cutting process. It improves the melt removal efficiency, which leads to better cutting efficiency for thick-section steel plate. In turn, it results in the increase of maximum cutting speed.

Table 2 Experimental results of maximum cutting speed according to nozzle

| Throat diameter of nozzle | Maximum cutting speed |
|---|---|
| 2mm | 30 mm/min |
| 3mm | 45 mm/min |
| 4mm | 50 mm/min |

## 3. Conclusions

For laser cutting a 100-mm-thick stainless steel plate, we observed that the larger throat diameter in converging nozzle leads to the increase of maximum cutting speed.

## REFERENCES

[1] K. Tamura, R. Ishigami, and R. Yamagishi, Laser cutting of thick steel plates and simulated steel components using a 30 kW fiber laser, J. Nuclear Science Technology, Vol.53, p. 916, 2016.
[2] K. Tamura, R. Yamagishi, Laser cutting conditions for steel plates having a thickness of more than 100mm using a 30 kW fiber laser for nuclear decommissioning, Mechanical Engineering Journal, Vol.3, p. 15-00590, 2016.
[3] C. Wandera, V. Kujanpaa, and A. Salminen, Laser power requirement for cutting of thick-section steel and effects of processing parameters on mild steel cut quality, Proceeding of the institution of Mechanical Engineer, Part B: Journal of. Engineering Manufacture, Vol. 225, p. 651, 2011.

[4] C. Chagnot, G. de Dinechin, and G. Canneau, Cutting performances with new industrial continuous wave ND:YAG high power lasers For dismantling of former nuclear workshops, the performances of recently introduced high power continuous wave ND:YAG lasers are assessed, Nuclear Engineering and Design, Vol.240, p. 2604, 2010.