Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2023

Fundamental Study on Long-Distance Laser Cutting of Stainless-Steel Plates for Demolition of Difficult-to-Reach Structures in Nuclear Facility Dismantling

Jae Sung Shin[a*], Gwon Lim[a]
[a]*Quantum Optics Research Division, Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon 34057, Republic of Korea*
[*]*Corresponding author: jsshin12@kaeri.re.kr*

***Keywords : Laser cutting, Laser processing, Nuclear decommissioning, Nuclear dismantling**

1. Introduction

A high-power laser can cut thick metal at high speed, while generating almost no reaction force. Additionally, laser cutting can be remotely operated through fiber delivery. Due to these significant advantages, there are ongoing attempts to apply laser cutting to the dismantling of nuclear facilities [1-15].

In traditional laser cutting, the cutting operation is performed by approaching the target object to be cut closely, aiming to minimize the size of the focused lase beam and efficiently remove the melted material using assist gas. However, in the complex structure of a nuclear facility, there might be instances where the cutting head cannot get close enough to the target object.

In this study, a fundamental experiment was conducted to assess the feasibility of laser cutting in scenarios where getting close to the target ins not possible. The long-distance applicability of laser cutting was experimentally confirmed by conducting tests on stainless steel plates. The tests involved cutting the specimens at a distance of more than 300 mm.

2. Experiment

A 6-kW fiber laser served as the cutting light source. The cutting head was composed of a collimation lens with a focal length of 160 mm and a focusing lens with a focal length of 600 mm. The specimens used for the experiment were 304L stainless steel plates with a thickness of ranging from 10 to 30 mm. For the assist gas ejection, a supersonic nozzle with a throat diameter of 3 mm was utilized. Compressed air was employed as the assist gas, with a gauge pressure of ~1 MPa, and ejected gas had a flow rate of 450 L/min.

During the experiments, the maximum cutting speed for each thickness of the specimen was determined by increasing the stand-off distance from 300 mm to 700 mm. The cutting was considered a failure if it did not completely cut through the specimen, and it was deemed successful only when the specimen was fully separated after cutting.

Figure 1 shows the front, rear surfaces of the stainless-steel plates cut at the maximum cutting speed for the stand-off distance of 300 mm. At the stand-off distance of 300 mm, it was confirmed that the 10 mm, 20 mm, and 30 mm thick stainless-steel plates were all successfully cut.

For the 10 mm and 20 mm thick stainless-steel plates, all cuts were successful across stand-off distances ranging from 300 mm to 700 mm. It was anticipated that cutting would also be feasible at a distance of ~1 m based on the observed cutting trend for these thicknesses. However, for the 30 mm thickness, cutting was only achievable up to a stand-off distance of 500 mm, and no successful cuts were obtained beyond that point. Nevertheless, it was confirmed that long-distance cutting from 300 mm to 500 mm is possible for the 30 mm thickness.

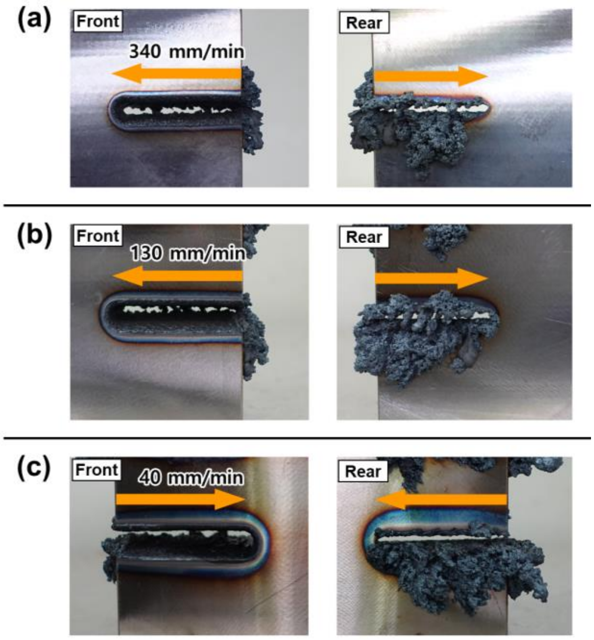

Fig. 1. Front, rear surfaces of the stainless-steel plates cut at the maximum cutting speed for the stand-off distance of 300 mm. The thickness of the specimens: (a) 10 mm, (b) 20 mm, (c) 30 mm.

In nuclear decommissioning, measuring the kerf width is crucial as it serves as an indicator of the amount of secondary waste generated. In short-distance laser cutting, the kerf width can be as small as 1 mm. However, in long-distance cutting, the kerf width tends to widen, resulting in average kerf width ranging from 6 mm to 16 mm.

3. Conclusion

In conclusion, the feasibility of long-distance laser cutting in nuclear decommissioning was successfully confirmed through experiments using a 6-kW fiber laser. Stainless-steel plates with thicknesses ranging from 10 mm to 30 mm could be effectively cut at stand-off distance of 300 mm or more. For 10 mm and 20 mm thickness, cutting was achieved up to 700 mm stand-off distance, and it was predicted that cutting would be possible at a distance of 1 m. However, for 30 mm thickness, cutting was limited to a stand-off distance of 500 mm.

The average kerf widths ranged from 6 mm to 16 mm, slightly wider than those in short-distance cutting. Nonetheless, it is expected to be a viable and suitable method for complex structures that are difficult to approach in nuclear facilities.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government(MSIT) (No. RS-2022-00155395).

REFERENCES

[1] K. Tamura, R. Ishigami, and R. Yamagishi, Laser cutting of thick steel plates and stimulated steel components using a 30 kW fiber laser, Journal of Nuclear Science and Technology, Vol. 51, 15-00590, 2016.
[2] K. Tamura, and R. Ishigami, Laser cutting conditions for steel plates having a thickness of more than 100 mm using a 30 kW fiber laser for nuclear decommissioning, Mechanical Engineering Journal, Vol. 3, 15–00590, 2016.
[3] K. Tamura, and R. Yamagishi, Observation of the molten metal behaviors during the laser cutting of thick steel specimens using attenuated process images, Journal of Nuclear Science and Technology, Vol. 54, pp. 655–661, 2017.
[4] K. Tamura, and S. Toyama, Laser cutting performances for thick steel specimens studied by molten metal removal conditions, Journal of Nuclear Science and Technology, Vol. 54, pp. 1011–1017, 2017.
[5] 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, pp. 2604–2613, 2010.
[6] P.A. Hilton, and A. Khan, Underwater cutting using a 1μm laser source, Journal Laser Applications, Vol. 27, 032013, 2015.
[7] A.B. Lopez, E. Assunção, L. Quintino, and J. Blackburn, High-power fiber laser cutting parameter optimization for nuclear decommissioning, Nuclear Engineering and Technology, Vol. 49, pp.865–872, 2017.
[8] N.P. Long, Y. Matsunaga, T. Hanari, T. Yamada, and T. Muramatsu, Experimental investigation of transient temperature characteristic in high power fiber laser cutting of a thick steel plate, Optics and Laser Technology, Vol. 84, pp.134-143, 2016.
[9] A. Choubey, R.K. Jain, S. Ali, R. Singh, S.C. Vishwakarma, D.K. Argawal, R. Arya, R. Kaul, B.N. Upadhyaya, and S.M. Oak, Studies on pulse Nd:YAG laser cutting of thick stainless steel in dry air and underwater environment for dismantling applications, Optics and Laser Technology, Vol. 71, pp.6-15, 2015.
[10] J. Leschke, A. Barroi, S. Kaierle, J. Hermsdorf, and L. Overmeyer, Studies on the robustness of underwater laser cutting of S355J2+N using a Yb:YAG disk laser source, Physics Procedia, Vol. 83, pp.310–316, 2016.
[11] J.S. Shin, S.Y. Oh, H. Park, C.-M. Chung, S. Seon, T.-S. Kim, L. Lee, J. Lee, Laser cutting of steel plates up to 100 mm in thickness with a 6-kW fiber laser for application to dismantling of nuclear facilities, Opt. Laser Eng. 100 (2018) 98-104.
[12] J.S. Shin, S.Y. Oh, H. Park, C.-M. Chung, S. Seon, T.-S. Kim, L. Lee, and J. Lee, Cutting performance of thick steel plates up to 150 mm in thickness and large size pipes with a 10-kW fiber laser for dismantling of nuclear facilities, Annals of Nuclear Energy, Vol. 122, pp.62-68, 2018.
[13] J. S. Shin, S. Y. Oh, H. Park, T.-S. Kim, L. Lee, C.-M. Chung, and J. Lee, Underwater cutting of 50 and 60 mm thick stainless steel plates using a 6-kW fiber laser for dismantling nuclear facilities, Optics and Laser Technology, Vol. 115, pp.1-8, 2019.
[14] J.S. Shin, S.Y. Oh, S. Park, H. Park, T.-S. Kim, L. Lee, Y. Kim, and J. Lee, Underwater laser cutting of stainless steel up to 100 mm thick for dismantling application in nuclear power plants, Annals of Nuclear Energy, Vol. 147, 107655, 2020.
[15] J.S. Shin, S.Y. Oh, S.-K. Park, T.-S. Kim, H. Park, and J. Lee, Underwater laser cutting of thick stainless steel in various cutting directions for application to nuclear decommissioning, Journal Nuclear Fuel Cycle and Waste Technology, Vol. 19, pp.279-287, 2021.