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

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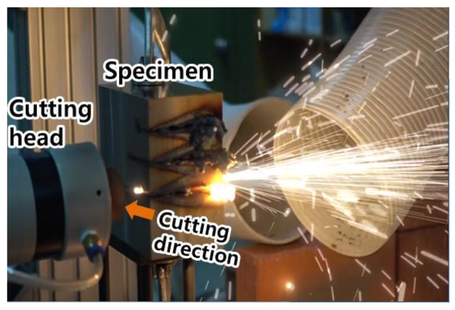
Abstract

Feasibility study of long-distance laser cutting for nuclear decommissioning was performed 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.

Introduction

- Laser cutting has the advantage of high-speed capability, and its miniaturization is possible through fiber delivery.
- Additionally, its minimal reaction force makes it well-suited for remote control applications.
- Due to these benefits, researchers have been exploring various laser cutting techniques for structural dismantling in nuclear decommissioning.



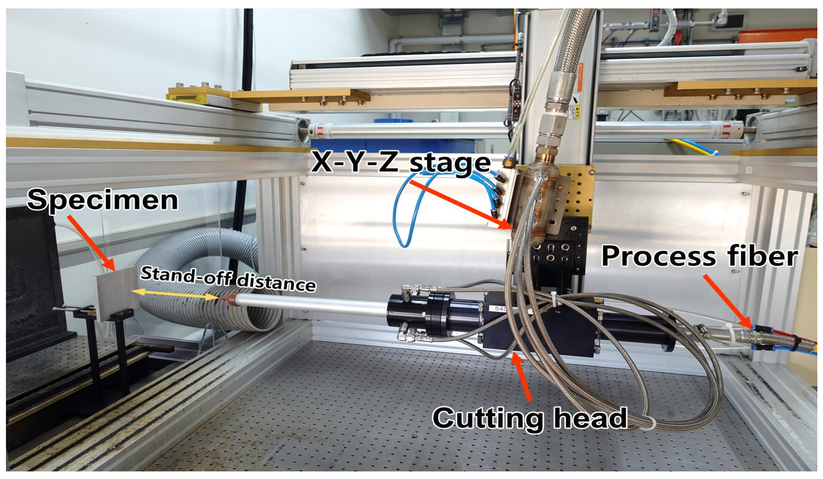
Laser cutting of stainless steel

- In scenarios involving complex structures in nuclear facilities, there may be situations where the cutting head cannot be positioned close enough to the target object.
- In this study, we investigated the feasibility of laser cutting at distances exceeding 300 mm from the target object.
- Through the conducted cutting tests, it was verified that cutting stainless steel with a thickness of 30 mm was achievable even at positions 300 mm or greater away from the target.
- Furthermore, cutting performance data was collected and organized through cutting tests on stainless-steel plate specimens ranging from 10 to 30 mm in thickness.

Experimental Procedure

Experimental Setup

- The cutting experiments employed a 6-kW ytterbium-doped fiber laser (IPG Photonics, YLS-6000) as the light source.
- The cutting head comprised a collimation lens with a focal length of 160 mm and a focusing lens with a focal length of 600 mm.



Experimental setup for the long-distance laser cutting

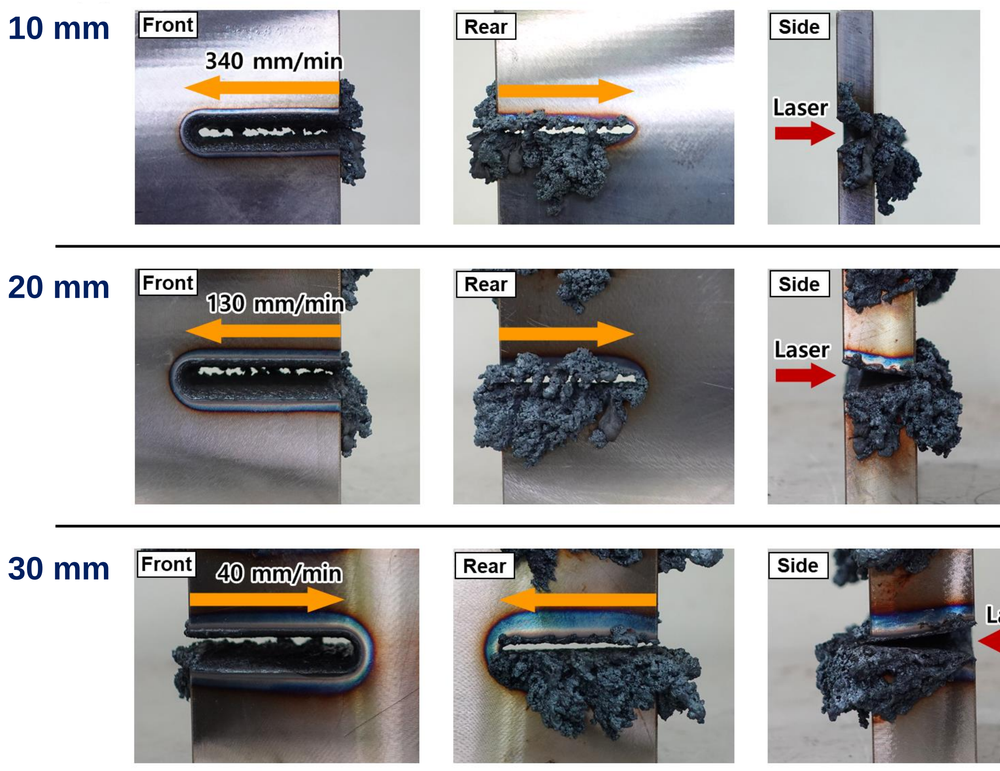
Cutting Process

- The cutting process started from the side of the specimen and proceeded inward as the cutting head moved.
- The cutting speed was determined by the speed at which the head moved and remained constant throughout the cutting process.
- In each test, a cut length of approximately 40 mm was achieved, and the success of the cut was determined by ensuring complete separation.
- Partial separation was considered a failure.

Results and Discussions

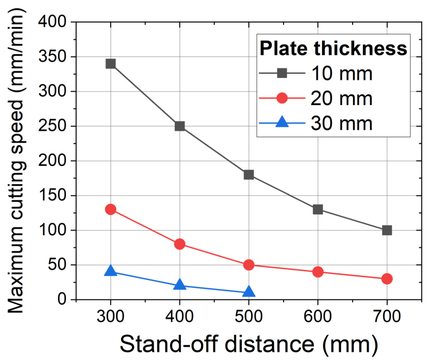
Experimental Results

- Successful cutting was achieved at stand-off distances ranging from 300 mm to 700 mm for 10 mm and 20 mm thick stainless-steel plates.
- However, for a thickness of 30 mm, cutting was only possible up to a stand-off distance of 500 mm.
- Nonetheless, this study experimentally demonstrated that long-distance cutting of more than 300 mm is viable even with a thickness of 30 mm.



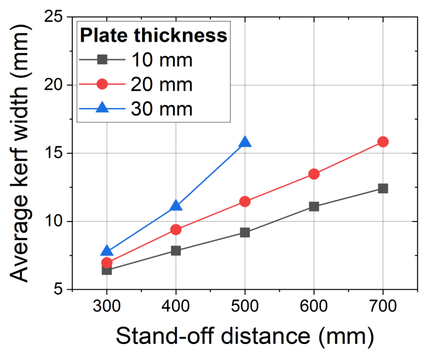
Front, rear, side surfaces of the stainless steel plates cut at the maximum cutting speed for the stand-off distance of 300 mm.

Maximum Cutting Speed



- The maximum cutting speed exhibits an almost linear increase with the reciprocal of the stand-off distance.
- The maximum cutting speed demonstrates a linearly increasing relationship with the reciprocal of the beam size at the front surface.

Kerf Width



- In nuclear decommissioning, the size of the kerf width is crucial as it is directly related to the amount of secondary waste generated.
- Both the kerf widths exhibited a linear increase with the expansion of the stand-off distance.
- The kerf width enlarged with an increase in the plate thickness.