Laser Cutting Experiment in Underwater Environment for Decommissioning a Nuclear Facility

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1. Introduction

Remote capability of dismantling tools at nuclear decommissioning site is an inevitable requirement to secure operator safety. [1.2] Furthermore, dismantling work at decommissioning site is, in some case, required to be done in the water circumstance to trap nuclear contaminants. [3] Underwater dismantling work contributes to considerable reduction of nuclear contaminants spreading toward the atmosphere. Laser cutting technology coupled with a high-power fiber laser can meet two requirements as a dismantling tool applicable at decommissioning site: highly remote capability and underwater dismantling performance. [4, 5] Also, laser cutting tools produce a small amount of secondary waste compared with other conventional dismantling tools such as water-jet and plasma cutting tools. Therefore, underwater laser cutting technology associated with a high-power fiber laser can be suitable candidate as a dismantling tool in nuclear decommissioning site.

Underwater laser cutting basically needs a gas jet column path to safely guide high-powered laser beam up to the steel specimen. It is attributed to the fact that laser beam is readily absorbed by water. It indicates that heavier loss of laser energy may occur by the absorption of water. Therefore, gas jet path in the underwater laser cutting should be constructed. Gas column path in underwater laser cutting experiment is generated by gas jet discharging from small-diameter nozzle. Cutting nozzle transforms high pressurized gas into gas jet with larger momentum. In the water environment, the high powered laser beam guided by the gas jet column heats up the steel specimen above melting point, after which, the gas jet with lager momentum also blows out the molten metal outside the steel plate. To sum up, underwater laser cutting is initiated through simultaneous steps: laser beam guiding, melting steel block and blowing molten steel. Cutting is accomplished by the spatial position of laser beam and gas jet moves together relative to steel specimen.

In this work, we have employed 10kw optical fiber laser system to cut thick-section stainless block in underwater environment. Also, supersonic nozzle having a convergent-divergent geometry was manufactured and used to obtain the gas jet with a larger momentum.

2. Experiment

2.1 Experimental Setup

Figure 1 shows experimental setup for underwater laser cutting experiment. Cutting system contains laser cutting head and fiber laser (IPG YLR-10000, λ = 1070 nm) whose maximum power is approximately measured to be 9.0 kW. Laser beam oscillated from laser system is transmitted into cutting head via 20m long process fiber. The core diameter of process fiber is 150 μm. Laser cutting head is spatially divided by two parts using optical window: upper and lower part. The upper part of cutting head incorporates collimation lens having 160 mm focal lengths and focusing parabolic mirror having 600 mm focal length. These two optical elements play a role in focusing the laser beam into stainless steel block (SUS 304L). Cutting head also incorporates supersonic nozzle assembled in its lower part. The compressed air is fed into the lower part of cutting head. And then, the introduced compressible air inside cutting head passes through the cutting nozzle and is discharged toward steel block. The gauge pressure of the compressed air applied in this experiment was over 1.0 MPa. Computerized numerical control (CNC) apparatus controls the spatial motion of cutting head submerged in the water tank.

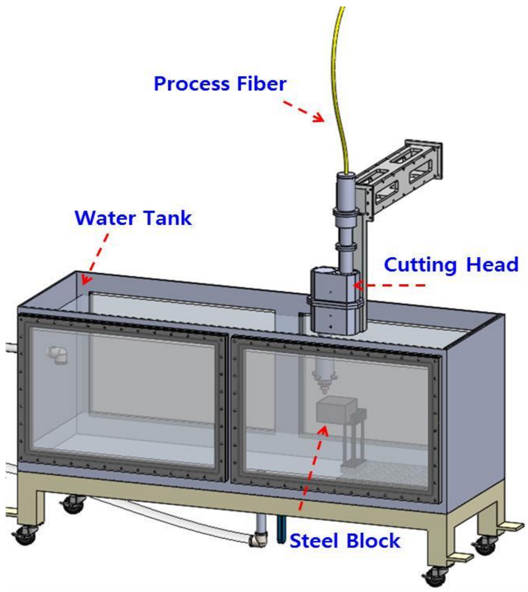

Fig. 1. Schematic of experimental setup for underwater laser cutting.

3. Result and Discussion

3.1 Underwater laser cutting of thick-section stainless block.

Cutting experiment is initiated from submerging cutting head into water tank. While submerging the lower part of cutting head, the compressible air keeps discharging from nozzle to protect the penetration of water inside cutting head. After cutting head automatically reaches the appointed position in the vicinity of steel block, 9kW high powered laser beam is directed toward steel block to melt. Cutting head move from left side to right side generating the kerf. It maintains constant distance between nozzle tip and top surface of steel block. Figure 2 presents the underwater laser cutting scenes of 80-mm thick-section steel block. The distance between nozzle tip and top surface of steel block was set to be 10-mm.

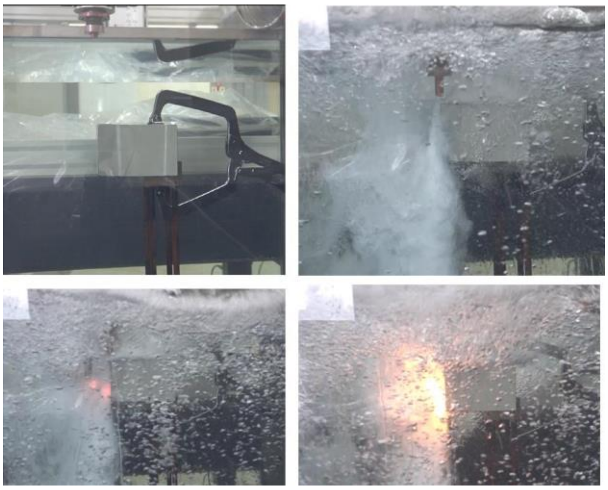

Fig. 2. Series of underwater laser cutting scenes in time order. Laser beam and compressible air emerging from nozzle are directed downward.

3. Conclusions

Underwater cutting experiment was performed using 10kW high powered fiber laser system. Experimental details such as cutting speed, steel specimen after cutting, the focal point position of laser beam, mass flow rate of discharging gas, and inner geometry of cutting nozzle will be explained in the presentation. In conclusion, fundamental study on underwater

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