Laser fusion cutting of thick-section stainless steel in underwater environment for nuclear decommissioning

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1. Introduction

Underwater dismantling works at decommissioning site has a considerable effect on trapping nuclear contaminants in the water environment, which can lead to significant reduction of those contaminants escaping toward the atmosphere. [1-2] Among the various underwater dismantling tools, laser fusion cutting technology coupled with fiber laser can be convenient approach due to remarkable advantages: remote controllability and the production of a small amount of debris. [3]

Laser fusion cutting technology basically uses the focused high-powered laser beam to melt the local area of metal specimen. Simultaneously, the pressurized gas jet is injected toward the melted local area to blow out laser-produced melt, which results in generating the kerf. Cutting process is achieved by along the path of the kerf, which is made by relative motion of the focused laser beam and the pressurized gas injection respective to the specimen position. It is noted that laser cutting in underwater environment adds more challenges than in atmosphere environment attributed to the fact that water has an intrinsic characteristics extremely absorbing the laser energy in infra-red region and greatly takes a conductive heat. The higher thermal conduction contributes to enhancing cutting efficiency through entirely heating up metal specimen during cutting process. Furthermore, in the scope of apparatus, there always exists on the possibility of water penetration into laser cutting head.

In this study, we have carried out underwater laser cutting experiments of stainless steel plate with 50mm and 60mm thickness. Cutting efficiency was investigated with the focus on variation of stand-off distance and the focal point position relative to specimen surface. The stand-off distance refers to the distance between the nozzle tip and the top surface of the steel plate. Furthermore, supersonic nozzle was used in this experiment. Supersonic nozzle with convergent-divergent is superior to subsonic nozzle with convergent shape in blowing out molten metal during the cutting process. It is mainly attributed to the fact that the gas flow of subsonic nozzle involves occurrence of strong oblique and normal shockwave under the high pressure condition. The strong shockwave leads to significant reduction of gas speed toward specimen. [4]

2. Experimental and Results

2.1 Experimental Setup

The high-powered 6kW fiber laser (IPG, YLS 6000, λ = 1070 nm) coupled with 25-m-long optical process fiber (core dia.: 100-µm) is connected with laser cutting head. The cutting head plays a role in effectively focusing laser beam toward specimen by collimation lens (f: 160mm), parabolic focusing mirror (f: 600mm), reflection mirror, optical widows installed inside it. The cutting head is also designed to introduce compressible air of 10.0 bar gauge pressure through gas pipe. The high-powered laser beam and high-pressurized gas jet coaxially pass through nozzle assembled at the end part of cutting head. The stainless steel block (SUS 304L) being immersed in the water tank is fixed by the clamp. The cutting head attached at X-Y-Z axis stage moves inside water tank in order to cut specimen along the computer-programmed path. Figure 1 presents the underwater laser cutting scene.

Fig. 1. Underwater laser cutting scene

2.2 Result and Discussion

In this study, the supersonic nozzle with a convergent-divergent shape was used in order to effectively cut the thicker stainless steel plate. [4] The supersonic nozzle has intrinsic characteristics of shockwave-free, uniform, and parallel flow. Therefore, the use of the supersonic nozzle can be desired in cutting thicker steel plate. Throat diameter of the supersonic was 2-mm and mass flow rate of compressed air was 400 L/min. Cutting head and specimen were fully immersed inside water. For a fixed specimen, cutting head was moved to perform cutting the fixed specimen in the water tank. The focal point of laser beam is placed 10 mm outside from the exit of nozzle. Figure 2 presents the front, side, and rear views of stainless steel with 60mm thickness after underwater cutting. X-Y-Z axis stage was programmed to cut 40mm length of the specimen. Cutting is started from the right with 5mm/min until 10mm had been cut, and then cutting speed was increased to 30mm/min until 30mm had been cut.

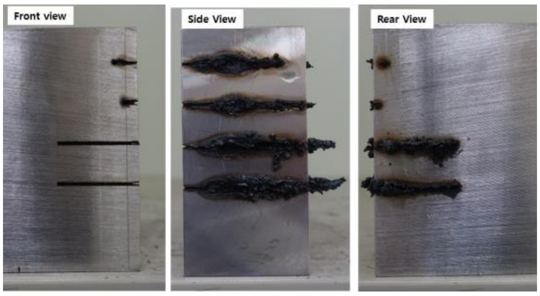

Fig. 2. Underwater laser cutting of 60-mm-thick stainless steel. Stand-off distances are 10mm, 10mm, 5mm, 2mm from top to the bottom. Focal point position correspond to 0mm, 0mm, -5mm, -8mm from top to the bottom

Standoff distance was sequentially varied from 2mm up to 10mm, which simultaneously involves the variation of focal point position from 0mm up to -8mm relative to specimen surface. Here, -8mm focal point position indicates that the focal point is located 8mm below the top surface of specimen. We have observed complete cutting under the condition of 2mm and 5mm standoff distance. It implies that focal point position of laser beam placing inside specimen is desirable to enhance cutting efficiency of thick stainless steel plate.

3. Conclusions

The conditions required for effective underwater laser fusion cutting of 60-mm-thick stainless steel were investigated, focusing on the effect of the focal point position and standoff distances. It was observed that the deeper location of focal point below the top surface of specimen is more effective to increase the melting rate of specimen, which results in enhancing laser cutting efficiency of 60-mm thick stainless steel plate. When cutting thicker metal plates in the water environment, the selection of proper standoff and defocus distances are necessary to obtain satisfactory cutting efficiency.

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