Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 83 (2016) 310 – 316

Physics Procedia

9th International Conference on Photonic Technologies - LANE 2016

Studies on the robustness of underwater laser cutting of S355J2+N using a Yb:YAG disk laser source

Jan Leschke[a,]*, Alexander Barroi[a], Stefan Kaierle[a], Jörg Hermsdorf[a], Ludger Overmeyer[a]

[a]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany

Abstract

In this paper, an underwater laser cutting process for maintenance and replacement operations is presented and investigated regarding process robustness for the application in rough environments. A Yb:YAG laser is used with 4 kW laser power in an active cutting process with oxygen as cutting gas. For 10 mm thick constructional steel plates a process window is determined with the focus on robustness for distance interferences. The examined parameter sets include the nozzle clearance, focus positioning and cutting gas pressure adjustment, as they are significant factors of influence in underwater laser cutting. By adjusting the developed parameter sets, sheets with thicknesses up to 50 mm, as well as plates that are fixed to a concrete backing are cut. The used equipment, which completely consists of standard components, is presented along with its preparation for underwater operation.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: underwater; laser cutting; robustness; oxygen; deconstruction

1. Introduction

There are over 7000 km of water canals used by the industry for transportation purposes, in particular bulky mass goods, solely in Germany (Ellrich, 2003). These structures are often made of sheet pilings which have an estimated operating life of 50 – 80 years (Heeling, 2010). Depending on the surroundings and the resulting effects of corrosion, their lifetime is often reduced to about 20 years (Binder & Gabrys, 2011). The maintenance often requires the removal of the whole structure which is usually done manually by divers. The average cutting speed that is achieved in those processes using oxyfuel cutting, is about $v_F = 0.06$ m/min (according to diver companies). Strong sea

* Corresponding author. Tel.: +49-511-2788-279 ; fax: +49-511-2788-100 .
E-mail address: j.leschke@lzh.de

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.032

currents that may occur, as well as miserable sight and low water temperature makes the work hard and dangerous to the divers. Additionally, commonly used cutting methods that use electrical current involve the danger of injuries by electrical shock. To increase process speed and diver safety an automated system needs to be developed.

Investigations concerning underwater laser cutting were primarily performed regarding nuclear decommissioning purposes. Studies using high power CO_2 lasers were carried out by Takano et al. Stainless steel plates were cut with thicknesses up to 150 mm using 20 kW laser power and a gas mixture of 20 % oxygen and 80 % nitrogen. In Khan & Hilton, laser cutting under water with a 5 kW Yb fiber laser is investigated in terms of dross formation and compared to laser cutting in air. One of the conclusions is that there is a significantly lower mass reduction when cutting under water due to a higher amount of adhering dross. Jain et al. obtained an underwater laser cutting process with a pulsed Nd:YAG laser that was able to cut 6 mm thick steel applying an average of 250 W laser power. The main purpose of these studies was to stick as much solidified melt on the cutting edges as possible to reduce nuclear contamination of the surroundings (Khan & Hilton, 2014).

As it can be seen, there are several studies regarding underwater laser cutting using different laser sources. For industrial applications, investigations concerning robustness and productivity still need to be carried out. To cover this issue, this paper describes the studies on process robustness which are performed using commercial components with the focus on positioning robustness. The first part of this paper is about the experimental setup and the preparation of the optical components for underwater application using a continuous wave laser with up to 4 kW laser power. In the second part it deals with common use cases in sheet piling deconstruction. A process window is developed for the cutting of 10 mm thick steel plates, focusing on the applied cutting gas pressure, focus position and nozzle distance. Further the cutting of sheet packages with thicknesses up to 50 mm and the process behavior of cutting 10 mm thick steel plates with concrete backing is investigated.

2. Experimental setup

The setup used for the studies is shown in Fig. 1 a. A 6-axis robot moves the optics via an extension to allow for vertical processing of the sheet piling specimens in a water depth of about 0.5 to 0.7 m beneath the water surface, depending on the position of the specimens. The specimens are secured by a mount which is able to lift the metal sheets out of the 1 m^3 water tank via linear drives. The deployed laser is a Trumpf Trudisk 16002 Yb:YAG disk laser with a fiber of 200 µm diameter attached. In order to develop a process with a low capital expenditure for the target group, including diving or maintenance companies, the optical system is constructed out of standard Trumpf D70 laser components with a limited laser power of $P_L = 4$ kW. The focus diameter is set to 200 µm. To satisfy the requirement of vertical processing, the beam is redirected by a mirror which is integrated in the connection cube between the collimation and the focusing tube. The diameter of the nozzle outlet is 1.7 mm. A tactile sensor, which is installed next to the nozzle, ensures the right positioning of the cutting head to satisfy the targeted nozzle distances and focus positions, respectively.

To obtain waterproofness several modifications have been made to seal areas that are critical for water penetration, as they are not sealed with O-rings as standard. These areas are the fiber coupling and the thread for the tip. To seal the coupling, a shrink tubing is applied directly above the O-ring sealing (Fig. 1 b, dashed line). Teflon tape is used to tighten the notch on the thread for the nozzle stock (Fig. 1 b, dotted line). Additionally, excess pressure is applied to the lens tubing between the focusing lens and the protective glass inside the tip holder. The used gas is compressed air with a pressure of about p = 2 bar.