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Angular Stability Margins for the Remote Fusion Cutting Process

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Abstract

The set of incident angles, that yields stable cuts when conducting remote fusion cutting (RFC), is of great importance when scheduling multiple cuts on a work piece. This is due to their ability to determine how much the laser beam can be moved by angling the cutting head instead of translating it. This paper investigates how the stability of the RFC process is affected by changing the incident angle when processing stainless steel sheets. This investigation was conducted as an experimental study in which the angle of incidence was decomposed into a work angle and a travel angle. The stability was evaluated by an automatic procedure based on images acquired by a programmable microscope and a computer vision algorithm developed in MATLAB. The results showed that the stability of the RFC process was dependent on the work and the travel angle. It was also seen that a coherent region of stable incident angles could be found. All experiments were conducted with a 3kW single mode fiber laser at the laser processing laboratory at Aalborg University.

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Keywords: Remote fusion cutting; Laser cutting; Remote laser cutting; Process Stability

1. Introduction

With the recent advances within the field of high quality, high intensity lasers, the remote laser cutting (RLC) processes have come closer to an industrial realization. One of the main benefits of using RLC is the remote position of the cutting head. This remote position reduces the risk of collisions with the work piece and enables the technologies to be combined with scanner mirrors that can reposition the beam by deflection. These scanner mirrors enables the RLC processes to increase processing speeds to levels that cannot be obtained by the linear drives that controls the cutting heads used in traditional laser cutting (Zaeh, et al. 2010, Lu og Kujanpää 2013, Lütke, et al. 2008).

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In remote fusion cutting (RFC) a cut is achieved by finding a parameter space where laser induced pressure phenomena ejects the molten material from the cutting kerf (Matti, Ilar og Kaplan 2013). This entails that the cut is achieved with only one exposure of the laser beam, in a process that resembles that of laser keyhole welding (Zaeh, et al. 2010). However, as the melt ejection principles are not fully understood yet and as RFC is sometimes described as being unstable for certain materials and parameters (Pihlava, et al. 2013), this reduces the industrial applicability of the process.

To increase the performance of RFC, research is currently being conducted to increase the understanding of the melt ejection principle by mathematical modelling (Schober, et al. 2012, Matti, Ilar og Kaplan 2013, Otto, et al. 2011), and experimental studies (Schober, et al. 2012, Kristiansen, Villumsen og Olsen 2015). In (Olsen, Hansen og Nielsen 2009) and (F. O. Olsen 2011) another approach is taken to improve the melt ejection principle. Here it is proposed that tailoring of beam patterns or multi beam cutting can increase the melt ejection, resulting in increased quality and cutting rates. However, this process is still in an early stage of development and more research needs to be conducted to verify its benefits (Villumsen, Joergensen og Kristiansen 2014).

The transition from traditional processing to remote laser processing has already happened with regards to the welding process in the automotive industry, where it has been shown that the transition from traditional resistance spot welding to remote laser welding (RLW) has the potential to reduce cycle times significantly (Park og Lee 2005). Recently research has been conducted in the field of developing automatic systems for scheduling of remote laser welds based on CAD/CAM technology to reduce the cycle times even further (Erdős, et al. 2013, Kovács 2013). These systems are however dependent on process knowledge obtained through experimental studies (Lu og Kujanpää 2013, F. Oefele og Zaeh 2008).

To create similar scheduling systems for RFC it is necessary to obtain similar process knowledge with regards to e.g. cutting speeds and focus position. Due to the similarities between RLC and RLW such systems could be evolved into integrated RFC/RLW scheduling systems (Musiol, et al. 2012, Schäfer 2010). Several studies have been conducted on RFC, revealing many of the necessary process parameters with regards to laser power, cutting speeds, work piece thickness and beam diameter (Schäfer 2010, Kristiansen, Villumsen og Olsen 2015). However, within the field of scheduling, a parameter of particular interest is the allowable angle of incidence as it directly determines to what extent the beam can be moved by deflection instead of translation. These parameters have to our knowledge currently not been determined for RFC. This entails that the main contribution of this paper is:

- To determine a set of incident angles that results in a stable RFC process that can be used in future planning frameworks

This set of angles is denoted as the angular stability margins. These margins will be determined experimentally by conducting a series of experiments designed to evaluate a set of hypothesis outlined in section 2.

The paper will be composed in the following way: In section 2 a set of working hypothesis and definitions will be presented. In section 3 the experimental procedure will be described. In section 4 the obtained results will be presented and finally, in section 5 conclusions will be drawn and the process itself will be discussed.

2. Hypothesis and definitions

As described in the introduction, the aim of this paper is to determine to what extent the RFC process remains stable when varying the incident angle of the laser beam. To do this it is necessary to define how the angle of incidence is represented and to determine how a measure of stability can be obtained. Finally a set of working hypothesis will be described that will be used for referencing in section 5.