Determining Laser-Welding Process Parameters
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Authors: Johannes Neuer, Markus Hofele, Prof. Harald Riegel; Aalen University, LaserApplikationsZentrum (LAZ), Germany

Date: February 2017

In order to determine the ideal laser-welding process parameters, it is necessary to conduct tests in which the relevant welding parameters are varied in order to subsequently analyze them, including an examination of microsections. These tests are conducted within the scope of a standardized process at Aalen University’s LaserApplikationsZentrum (abbreviated LAZ). With its “Routine Analysis” feature, the ZEISS Smartzoom 5 digital microscope is perfect for easily and efficiently creating high-resolution images of metallographic specimens for the analysis of laser welding parameters.

Introduction

Due to its numerous benefits, laser welding has become an integral part of industrial manufacturing processes across a variety of industries (such as automotive engineering, mechanical engineering, and tool technology, for example). Its key advantages compared to other welding techniques include a smaller heat-affected zone thanks to a comparatively lower level of heat transferred to the material and as a result, minimal deformation of the mating parts, the technique’s versatility when it comes to complicated welding contours, its ability to be used with a wide variety of different materials and material thicknesses, and the method’s excellent capacity to be automated. Although the technology’s development has already reached a fairly advanced stage, it still offers significant potential thanks to its versatility, for example in the manufacture of lightweight structures, where in the future, joining a variety of different and difficult-to-weld materials will play an increasingly important role.

In order to develop a new welding process, an analysis of process parameters needs to be conducted that includes laser output, feed rate, focal position of the laser beam relative to the part, and focal length of the welding optics (Figure 1). In addition, the use of supplementary wire or process gases can also be necessary, which then also need to be adapted to the respective process. For the tests conducted at LAZ, specimens of a standard size are fixed using mounting clamps (Figure 2), in order to then weld eleven different parameterized seams on the specimen. To quickly and effici-

Figure 1 Impact of focal position on seam geometry for S235JR structural steel, 1500 W laser output, and 6 m/min feed rate (macrosection and ZEISS Smartzoom 5 stitching feature)

Figure 2 Clamping device for laser welding
ently analyze the samples, macroscopic sections are manually prepared without embedding. The cross sections are etched with a ten percent nitric-acid solution (Figure 3). In order to analyze the seams, high-resolution microscopic images of cross sections of the seams are needed. With these cross sections, it is possible to study seam geometry, formation of hot and cold cracks, and the metallurgical structure. Since the specimens are always the same geometrically, the ZEISS Smartzoom 5, with its “Routine Analysis” feature, is perfect for capturing the images in a rapid and reproducible process. With this feature, recurring jobs can be programmed into the microscope and subsequently completed semiautomatically. These jobs can help significantly reduce the time it takes to capture the images and simultaneously ensure that image quality remains the same. This includes saving parameters such as illumination or brightness and contrast settings in order to always capture the images using the same settings.

**Generating a job**

Generating a job and subsequently repeating it in a semiautomatic process begins with the capture of an overview image (Figure 4). During the further course of the job, this image is displayed in the background of the user interface to serve as a guide. Positioning is made easier thanks to the stopper installed on the ZEISS Smartzoom 5’s motorized stage (Figure 5).

The microscope’s “Best Image” feature assists the user in the subsequent selection of the right illumination (Figure 6). Upon selecting this feature, the ZEISS Smartzoom 5 automatically captures images using different illumination modes that are offered to the user as an initial selection. The ZEISS Smartzoom 5 allows the user to select from the illumination modes ring light, coaxial bright field, or mixtures of the two modes with and without HDR and optional image sharpening. The user then only needs to make minor corrections, such as adjustments to brightness or contrast.

The structural steel weld (S235JR) specimens shown in the figures are captured using mixed illumination consisting of a ring light and coaxial bright-field illumination. Afterwards, image processing is used to increase the contrast.
The images are captured at 101× magnification. In this context, pixel size is equal to 2.5 × 2.5 µm. In order to fully capture weld seams with welding penetration depths between 980 µm and 1,700 µm, a stitching matrix comprising 2 × 3 individual images is created (Figure 7). During manual macroscopic preparation of the specimen, numerous factors can lead to the specimen not having plane parallel surfaces, which is why a Z Stack is superimposed over the stitching matrix to ensure sufficient depth of field. When the Z Stack feature is activated, the ZEISS Smartzoom 5 takes several images – depending on the setting – above the same position along the Z axis (at 20 µm intervals) at different distances from the specimen and uses them to generate an image that is sharp across the entire captured area, even if the surface of the specimen is uneven. Thanks to its intuitively designed user interface, the microscope’s features can be activated and configured quickly. In this context, it only takes a comparatively short amount of time to familiarize the user with the microscope and its features.

This programmed job can be saved in the archive. The settings and positions made by the user are also saved.

**Processing the job**

The jobs saved in the archive can be accessed at a later time and processed semiautomatically with new specimens. Upon loading a job, the microscope is preconfigured based on all of the job’s saved settings. The ZEISS Smartzoom 5 processes the job in the order that it was programmed – the microscope moves to the individual positions one after the other, the stitching matrix as well as the Z Stack are accessed, and any tools required, such as for measuring purposes, are displayed directly after the image is captured. When processing a previously saved job, the user may need to marginally adjust the positions and/or reposition the measuring tools at the correct points (if any corrections are needed at all). This not only saves a significant amount of time, but also means images can be captured by users who are not experts in the field of microscopy.

**Evaluating the microsections**

The image files are stored in czi format and can be subsequently processed further using the ZEISS ZEN 2 core software. In this case, excess weld metal, welding penetration depth, and seam width are measured at two locations to distinguish the seams from each other. In addition, an analysis is also carried out with regard to whether or not cracks tend to form at the center of the seam (Figure 8).