Influence of the Wire Feeding on the Wetting Process during Laser Brazing of Aluminum Alloys with Aluminum-Based Braze Material

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1 Abstract

This application note is based on the authors' article: “Influence of the Wire Feeding on the Wetting Process during Laser Brazing of Aluminum Alloys with Aluminum-Based Braze Material” published in the Journal of Manufacturing and Materials Processing 2019, 3(4), 83. The whole article can be found from: https://www.mdpi.com/2504-4494/3/4/83/htm. This document contains modifications and direct quotes from the article.

The wetting behavior in laser brazing can be designated as inconstant, caused largely by external process discontinuities such as the wire feeding. To reveal periodic melt pool propagation effects that occur during laser brazing of aluminum, and for a better understanding of those effects in laser brazing in general, the researchers analyzed high-speed recordings of the brazing process with aluminum alloy. It is demonstrated that two main effects of periodic melt pool behavior in different frequency scales occur during the process, both related directly to the wire feeding.

2 Setup

According to the article, the braze was done in a bead-on-plate configuration on a custom Power Automation CNC table with a moving specimen holder. An Nd:YAG laser was used as the laser source, emitting at a wavelength of 1064 nm. The filler wire was supplied to the workpiece laterally through a wire rope with a copper tip and argon was used to shield the braze from the surrounding atmosphere. The processing laser power of the Nd:YAG laser was 3 kW, the brazing speed was 2 m/min, and the wire angle was 30°. The wire feed rate was varied from 2.5 m/min to 3.5 m/min in 0.25 m/min increments.

The process was recorded with a Phantom VEO 410L high-speed camera, recording 768 × 312 px images at 18 kfps. CAVILUX HF illumination laser, emitting at 810 nm, was used as a light source for the recording together with an 810 ± 10 nm bandpass filter in front of the optics. This provided a controlled illumination of the process without disturbances from the surroundings.

The setup is visible in Figure 1. The created seam has a length of 100 mm.

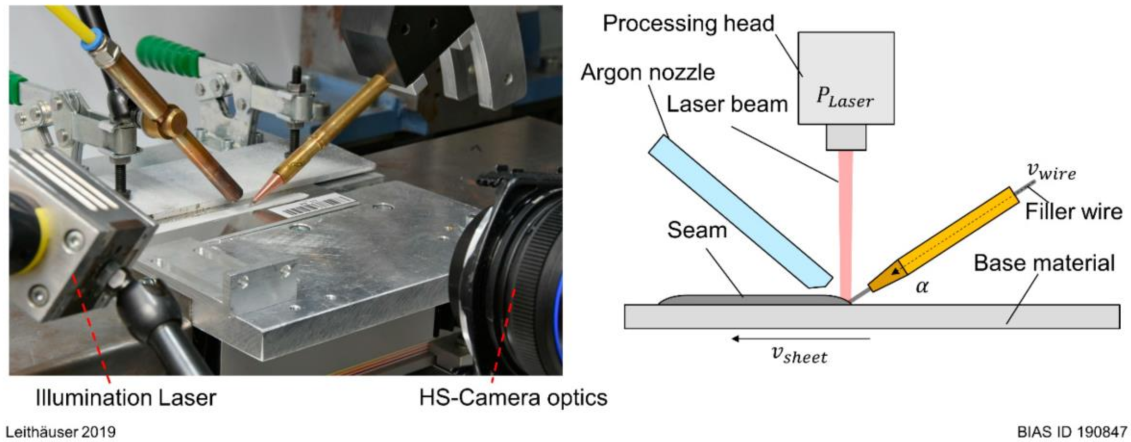

Figure 1: Setup to visualize the laser brazing process.

The tracking of the wetting front, as well as the capturing of process parameters such as the wire feed rate and wire angle, was achieved with image processing in MATLAB. In Figure 2, a circular object is noticeable at the front of the wetting melt pool. This can be recognized as the reflection of the wire nozzle. The fact that the melt pool is forming a spherical geometry at the wetting front brings the reflection to the camera. This circular shape was used for tracking the wetting front with a circle detection algorithm that uses a circular Hough transform.

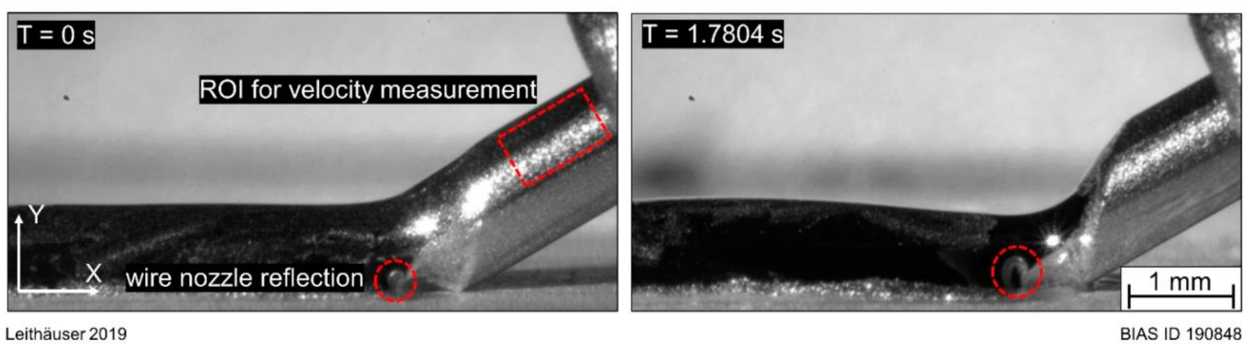

Figure 2: Image of the filler wire with reflection of the nozzle in the melt pool.

3 Results

During the imaging process all relevant process data were collected to study the wire feeding conditions during the brazing process.

Figure 3 demonstrates a representative sample of the wetting front deviation and the wire velocity signal. In the wetting front deviation, two periodicities are visible: one at 144 ± 3 Hz with an amplitude of 0.05 ± 0.01 mm, and superimposed a frequency of 13 ± 1 Hz with an amplitude of 0.12 ± 0.01 mm.

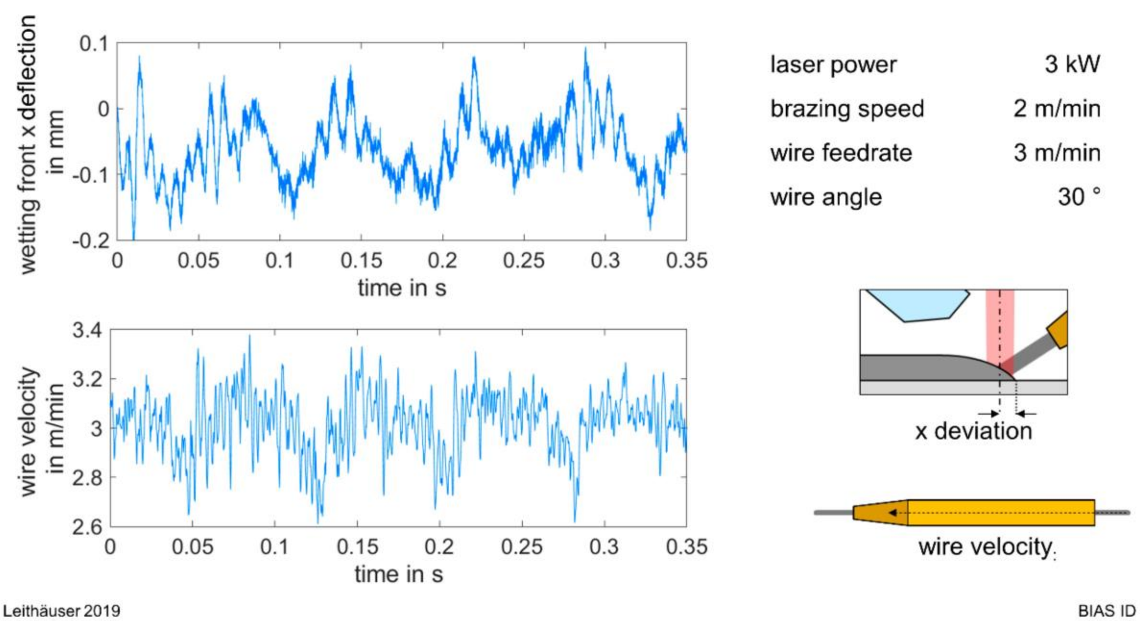

Figure 3. Section of the wetting front and the wire feed rate of a representative sample.

In Figure 4, periodic spikes of high velocity, of around twice the preset feed rate, are caused by a retained force that evolves when the wire is not sufficiently melted when it hits the base material. Due to a higher unmolten bottom edge of the wire in relation to the base material sheet, as shown in Figure 5, the load is smaller, resulting in a rather oscillating velocity signal. Finally, in Figure 6, the signal flattens when the bottom edge no longer touches the base material.

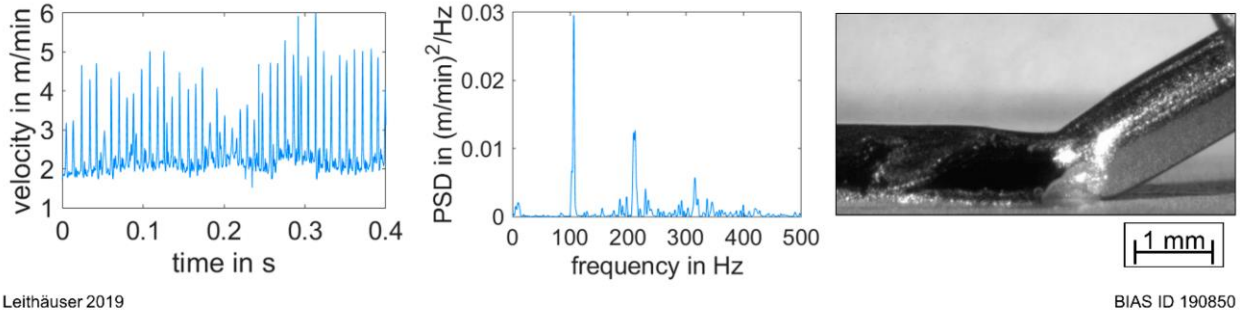

Figure 4. (Left) Wire velocity over time, when the wire hits the sheet and the retained force is released periodically. (Middle) Power spectral density (PSD) of the time signal. (Right) Snapshot of the high-speed recording during these events.

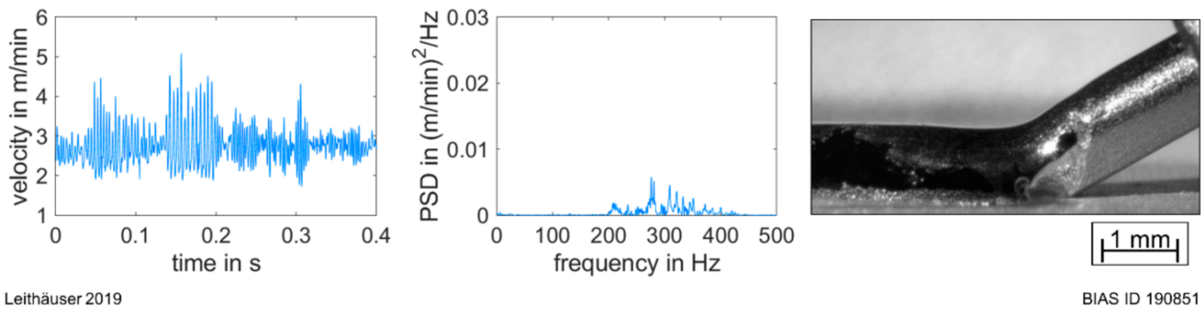

Figure 5. (Left) Wire velocity over time, when the wire feeding is hindered by the sheet. (Middle) PSD of the time signal. (Right) Snapshot of the high-speed recording during these events.

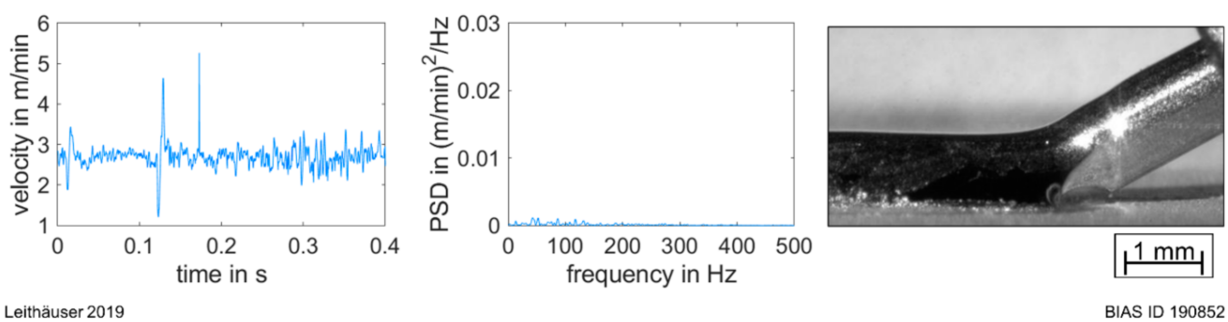

Figure 6. (Left) Wire velocity over time, when the wire feeding is uninfluenced by an interaction between the solid (unmolten) wire and the sheet. (Middle) PSD of the time signal. (Right) Snapshot of the high-speed recording during these events.

Based on the PSD (Power spectral density) of the feed rate velocity, each condition has a distinct amount of periodicity. During a strong interaction between the wire and the base material (Figure 4), the foremost frequency is at 106 Hz, accompanied by harmonics at 212 Hz and 318 Hz. In the second phenomenon (Figure 5), where there is less force between the wire and the sheet, there is no single dominating frequency but rather a range between 150 Hz and 400 Hz. When there is sufficient melting of the wire, and thereby no interaction in the wetting area, no frequencies are being noted, as in the PSD shown in Figure 6. It is feasible to classify the samples with dominant frequencies in the wire velocity as “noisy”, and those with a comparatively constant feed over the observed sequence as “smooth”.

More results from the measurements of the relation between wire velocity and wetting, as well as the influence of the wire feed rate on process frequencies, can be found in the original article.

4. Conclusions

The following conclusions can be drawn based on these studies:

Interactions between the unmolten wire and the base material cause oscillations in the wire feeding speed in the range of 160 Hz to 400 Hz and the oscillations being transferred to the wetting front movement with half of the frequency.

The oscillations of the wire velocity in the frequency range of 11 Hz to 15 Hz, caused by the wire feeder, affect the wetting front propagation with the same frequency.

5. References

M.Sc. Till Leithäuser, Dr.-Ing. Peer Woizeschke, BIAS - Bremer Institut für angewandte Strahltechnik GmbH, *“Influence of the Wire Feeding on the Wetting Process during Laser Brazing of Aluminum Alloys with Aluminum-Based Braze Material”* published in the Journal of Manufacturing and Materials Processing 2019, 3(4), 83 that can be found from: https://www.mdpi.com/2504-4494/3/4/83/htm.

Imaging technology

Camera: Phantom VEO 410L
Illumination: CAVILUX HF System by Cavitar Ltd

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