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CFD simulations for laser oscillation welding

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Abstract

Computational fluid dynamics (CFD) models have shown that laser keyhole welding at high speeds and powers can result in weld joints with reduced porosity. However, the process is limited by available laser powers (~6kW) and by insufficient penetration due to high welding velocities. To enable high speed welds with reduced porosity and optimal gap bridging, researchers have investigated laser oscillation welding. In this presentation, we look at some case studies where CFD models that simulate the laser-material interaction, melt pool dynamics and keyhole formation are developed to investigate laser oscillation welding in Zinc-coated steels. Additionally, these models helped identify zones of high Zinc vapor pressure that led to spatter and the data is compared to melt pool videos taken of the welding process. Such CFD models help develop welding schedules that limit the build of Zinc Vapor pressure in the melt pool and reduce spatter in laser oscillation welding.

Keywords: laser welding, CFD, simulations, oscillation welding

1. Introduction

CFD simulations help shed light on the laser welding processes at a fundamental level. By accounting for all the relevant physics, melt pool dynamics in a laser welding process can be studied in accurate detail, which help understand the role process parameters play on influencing weld bead dimensions, surface morphology and melt pool related defects such as porosity. The CFD software, **FLOW-3D**, has implemented relevant physics such as fluid flow, heat transfer, laser melting, phase change, recoil pressure and solidification, which makes it uniquely suited to analyze laser welding processes at the melt pool scale. In this paper, we discuss a case study on the investigation of spatter in remote laser spiral welding of Zinc-coated steels.

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It is known that high speed laser welding has many advantages related to faster product rates and reduced porosity formation. However, there are some common issues that arise from high speed laser welding

- Narrow joint width leading to poor tolerance for gap condition
- Large end crater when the laser is turned off
- High velocities can result in insufficient penetration
- Limited by available laser powers (6kW)

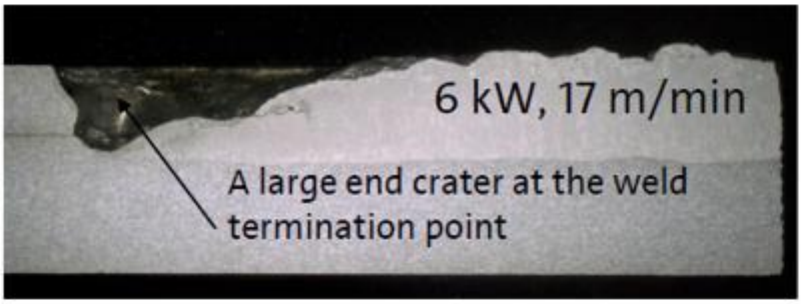


Fig. 1. Crater formation at the end of laser keyhole welding

With laser lap welding, we can enable high speed scanning that prevents keyhole collapse while minimizing porosity. It additionally offers flexibility in adjusting joint width at faying interface to bridge gaps. Additional benefits of laser welding with oscillation include:

- Improved first time quality through oscillation
- Enables high welding speed while avoiding keyhole induced porosity
- Alternates between keyhole and conduction modes within each cycle if no power modulation is used
- Enables adjustment of critical weld nugget dimensions and strength via changes of oscillation parameters
- Improves gap bridging between sheets

2. Case Study

Researchers from General Motors[1] found that during laser welding of Zn-coated Steels with zero gap, Zn coating vaporizes and accumulates between faying surfaces. If no venting channel was present, Zn vapor continued to build and entrained into the molten pool of Steel, potentially causing spatter. Zn vapor also affected keyhole dynamics and process stability. A simulation model was developed in FLOW-3D WELD to estimate instantaneous Zn vapor pressure and analyze keyhole dynamics.

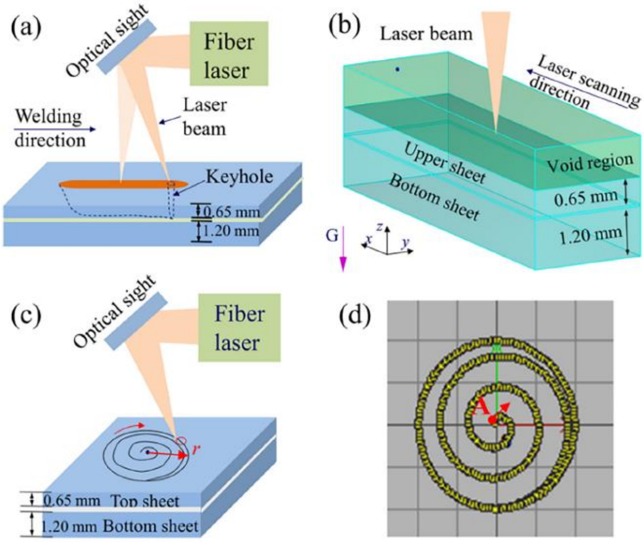


Fig. 2. Experimental and model setup: (a) laser stitching setup, (b) ***FLOW-3D*** **WELD** model setup, (c) laser spiral welding setup and (d) laser spiral scanning path

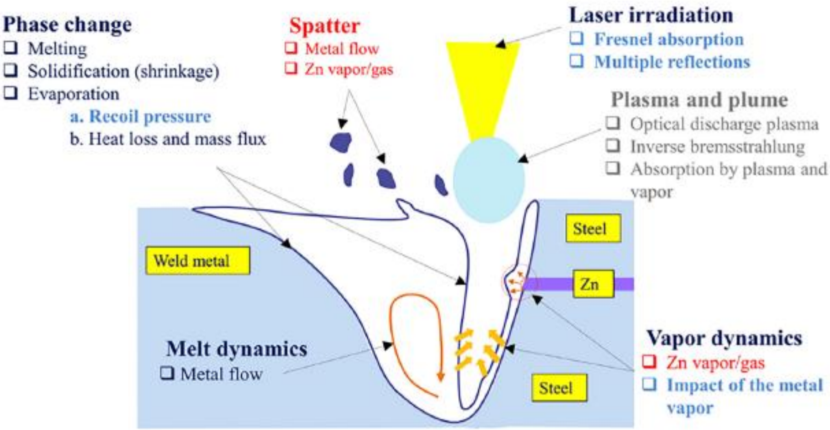
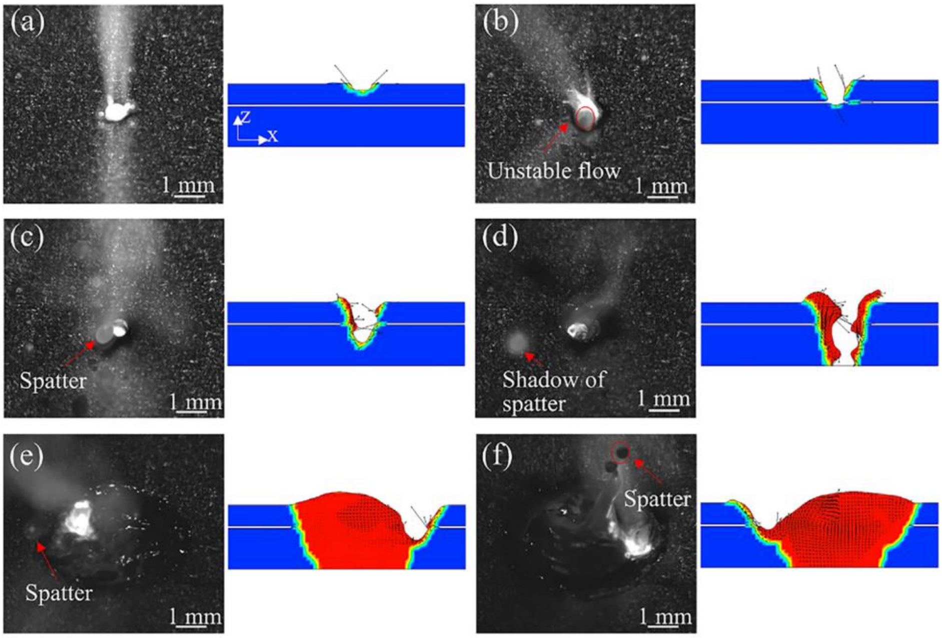


Fig. 3. Schematic representation of the physical phenomena occurring in the laser welding of zinc-coated steel

When the melting and keyhole cross the faying surface, the accumulated high-pressure Zn vapor acts on the melt surface at the gap and overcomes the keyhole pressure at the wall, resulting in spatter.



In conclusion,

- High instantaneous Zn pressure at faying interface leads to melt pool fluctuation and spatter formation
- The calculated Zn vapor pressure at faying interface can be an indicator of spatter formation, and can guide weld schedule design
- The initial line energy in the spiral welding is limited to avoid an increase of zinc vapor pressure that results in severe spatter when the laser penetrates through to the faying interface

References

1. Shengjie Deng, et al. *Investigation of spatter occurrence in remote laser spiral welding of zinc-coated steels.* (2019) https://doi.org/10.1016/j.ijheatmasstransfer.2019.06.009.