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Measuring the melt flow on the laser cut front

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Abstract

The flow characteristics on the laser cut front for 10mm stainless steel AISI 304 (EN 1.4301) are studied in this paper using High Speed Imaging (HSI). The laser cut samples were produced with a 6kW fiber laser with nitrogen gas assist. Previous work in this field has used unusual cutting parameters to make the experimentation easier. This work presents, for the first time, HSI results from standard commercially viable cutting parameters. This was made possible by the development of a new experimental technique. The results presented here suggest that the cut front produced when cutting stainless steel with a fiber laser and a nitrogen assist gas is covered in bumps which themselves are covered in a thin layer of liquid. Under the conditions shown here the bumps move down the cut front at an average speed of approximately 0.4m/s. The liquid flows at an average speed of approximately 1.1m/s. The average melt depth at the bottom of the cut zone under these conditions is approximately 0.17 mm.

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1. Introduction

In laser fusion cutting of metals a volume of melt is created (by absorption of the laser beam) and then blown out of the cut zone by an inert assist gas (see Fig. 1).

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I. Nomenclature

d	: Material thickness
D	: Cutting depth
Kr	: Kerf removal rate
Lr	: Liquid flow rate
u_{melt}	: Average melt flow velocity
t	: Average melt depth
V	: Cutting speed
W	: Average kerf width
ρ	: Material density

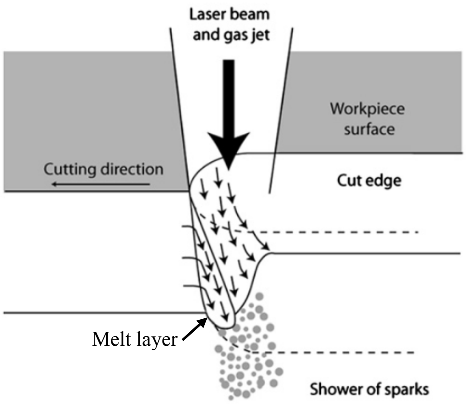

Fig. 1. The laser cutting process (Powell 2011).

During the process a thin layer of melt flows down the cut front, as shown in Fig. 1. Tani (2004) explains that the creation of both dross at the bottom of the kerf and striations on the cut edge (surface roughness) depend on the melt film condition throughout the kerf.

Schulz (1999) explains that dross formation is related to properties of the melt such as its thickness and velocity. He compared this to the experimental observations of viscous free surface flows around an edge, and the separation of the flow from the solid.

The importance of the melt film on the cut front is also emphasized by Chen (1999) who concludes that fluctuations in the absorbed laser power and the velocity of the high speed gas jet can create perturbations in the melt film which in turn could give rise to fluctuating striation patterns on the cut edge. It is therefore clear that information about the melt film thickness and velocity could give more insight into quality parameters in laser cutting.

Laser cutting of steels can be divided into two main subjects i.e. laser fusion cutting of stainless steel (usually with nitrogen assist gas) and laser oxygen cutting of mild steel with oxygen gas assist.

In both cases the assist gas is used as a source of mechanical energy to blow away the melt in the kerf. In laser oxygen cutting the oxygen assist gas also functions as a source of heat since the oxygen undergoes an exothermic reaction with the iron in meld steel. However, the gas pressures used in the two techniques are markedly different. Oxygen pressures tend to be less than 2 bar and nitrogen pressures are usually in excess of 10 bar. For this reason the melt film behavior for laser oxygen cutting and laser fusion cutting are separately discussed in section 1.1 and 1.2 respectively.