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Weldability of additive manufactured stainless steel

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Abstract

Part size in additive manufacturing is limited by the size of building area of AM equipment. Occasionally, larger constructions that AM machines are able to produce, are needed, and this creates demand for welding AM parts together. However there is very little information on welding of additive manufactured stainless steels. The aim of this study was to investigate the weldability aspects of AM material. In this study, comparison of the bead on plate welds between AM parts and sheet metal parts is done.

Used material was 316L stainless steel, AM and sheet metal, and parts were welded with laser welding. Weld quality was evaluated visually from macroscopic images. Results show that there are certain differences in the welds in AM parts compared to the welds in sheet metal parts. Differences were found in penetration depths and in type of welding defects. Nevertheless, this study presents that laser welding is suitable process for welding AM parts.

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Keywords: Additive manufacturing; laser welding; weldability; stainless steel

1. Introduction

Additive manufacturing is technology which enables creation of innovative and complex parts with good mechanical properties. These innovative geometries like deep helical cavities, integrated cooling channels and parts with unique design for the demanded applications are easy to produce. However, the part size in additive manufacturing, especially in powder bed fusion (PBF) technique, is usually relatively small. Joining of AM parts together or to existence construction is a way to overcome the part size limitation (Casalino et al. 2013). Joining of

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AM parts by laser welding is area of where very small amount of research have been published. It is commonly known that most materials that can be welded can be used in PBF process to build parts (Laitinen, 2014 & Järvinen, 2015). It is also known that PBF produced parts are almost porosity free, so this could indicate that PBF parts can be welded with laser welding (Yasa, Kruth, 2011). In principle PBF process is laser welding but in very small scale, so also this indicates that laser welding could be good method for joining AM parts together. (Tolosa et al. 2010)

Laser welding is an industrial joining process and used as an alternative to conventional arc welding processes nowadays. The advantages of laser welding are high welding speed, which enables low heat input, and deep and narrow weld with small HAZ (heat affected zone) (Lippold & Kotecki 2005). Laser welding can be executed as conduction limited welding or keyhole welding. In keyhole welding laser beam absorbs to the welded material surface, the material heats, melts and starts to boil. This boiling effect, in case of stainless steels, causes metal vapour cavity, a keyhole, mainly from the vapours from iron, nickel and chromium. When the welding head is moving, molten material flows around the keyhole, solidifies and forms the weld (Vänskä, 2014).

Nomenclature

AM	additive manufacturing	CCD	charge coupled device
PBF	powder bed fusion	ρ	material density [kg/ mm^3]
HAZ	heat affected zone	V_{WM}	weld metal volume [mm^3/s]
CR	cold rolled	c	specific heat of fusion [J/kgK]
Yb	ytterbium	T_m	melting temperature [K]
W	watt	T_0	room temperature [K]
°C	degrees in celsius	L	latent heat of melting [J/kg]

2. Experimental procedure

2.1. Geometry of the test pieces

The dimensions of the welding test specimen were approx. 50 mm x 100 mm x 3 mm for test pieces made out of cold rolled 316L and PBF manufactured 316L stainless steel sheets. In PBF sheets, the welding was performed in building direction. Dimensions of the test pieces and build direction of PBF test piece are shown in Fig. 1.

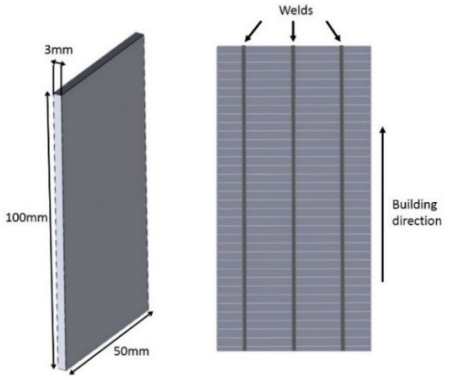

Fig. 1. Left: dimensions of the test pieces, Right: building and welding direction of PBF test pieces.

2.2. Materials used in this study

Two stainless steel 316L materials was used in the study. PBF sheets were manufactured from Höganäs Stainless Steel 316L powder and cold rolled (CR) stainless steel plates were Outokumpu 1.4404 (316L). Elementary analysis