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Defocusing techniques for multi-pass laser welding of austenitic stainless steel

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Abstract

This study introduces an experimental work carried out in multi-pass laser welding with cold filler wire and laser-arc hybrid welding of thick section austenitic stainless steel. As it has been demonstrated earlier, hybrid and cold wire welding with a keyhole-mode can offer very efficient way to produce multi-pass welds in narrow gap thick section joints. However, when multi-pass welding is applied to one pass per layer method without e.g. scanning or defocusing, the used groove width needs to be very narrow in order to ensure the proper melting of groove side walls and thus to avoid lack of fusion/cold-run defects. As a consequence of the narrow groove, particularly in thick section joints, the accessibility of an arc torch or a wire nozzle into the very bottom of a groove in root pass welding can be considerably restricted. In an alternative approach described in this paper, a power density of a laser beam spot was purposely dispersed by using a defocusing technique. In groove filling experiments, a power density of defocused laser beam was kept in the range, which led the welding process towards to conduction limited regime and thus enabled to achieve broader weld cross-sections. The object was to study the feasibility of defocusing as a way to fill and bridge wider groove geometries than what can be welded with focused keyhole-mode welding with filler addition. The paper covers the results of multi-pass welding of up to 60 mm thick joints with single side preparations.

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Keywords: laser welding; defocusing; multi-pass; austenitic stainless steel

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1. Introduction

Laser welding is generally considered as a high energy density welding process, in which an ability to use a keyhole welding is exploited. In order to bring e.g. a steel alloy locally in the vapour phase for keyhole welding, the power density of laser beam at the surface of the work piece must be risen to the magnitude of 10^6 W/cm^2 or greater. This keyhole laser welding mode is also normally applied in hybrid or cold wire welding process, which results to a narrow, pinhead looking weld bead, where typical keyhole weld features like high depth/width ratio can be detected. It has been demonstrated in the previous studies of e.g. Arata et al. (1986), Jokinen et al. (2003), Rethmeier et al. (2009), Phaoniam et al. (2013) and Zhang (2013), that hybrid or cold/hot wire welding with keyhole mode can offer a very efficient way to produce multi-pass welds in very narrow gap thick section joints. In the alternative approach described in this paper, the used groove configurations (especially width of the groove gaps) were resembled like those used in conventional narrow gap arc welding processes (e.g. NG-TIG). One driving force for testing wider groove geometries was targeting to improve especially the accessibility and clearance of an arc torch or a wire nozzle in the case of root pass and lower passes welding of thick joints (~ 60mm). When the successful groove filling in above mentioned groove configurations is aimed, a keyhole mode welding alone cannot be used in filling runs, because gap widths are too wide to be bridged. Under the circumstances, a laser part (in terms of power density of the beam at the work piece) as well as filler wire feeding rate and welding speed has to be tuned in hybrid or cold wire process such that much wider weld beads can be produced. Therefore, it was decided to disperse a power density of a laser beam spot purposely by using defocusing and in that way bring the welding process towards or inside the conduction limited regime.

Nomenclature

NG-TIG	narrow gap – tungsten inert gas
P_L	laser power
F	focal point position
v_w	welding speed
v_f	filler wire feeding speed
MIG	metal inert gas
LF	lack of fusion

2. Experimental

2.1. Materials and test specimens

Base materials used in the experiments were austenitic stainless steel alloys with the different plate thickness between 10mm and 60mm as follows: AlloyX, PL=10mm, AISI 316L-A, PL=20mm, AISI316L-B, PL=60mm. Test specimens for the welding tests were rectangular pieces of 150 mm in width and 300 mm in length. Required groove geometries were made using machining and joints are prepared with tack welds in both ends and at the middle in order to achieve demanded joint configuration. Filler materials used were diam. Ø 1.0 mm ESAB OK Autrod 316LSi and diam. Ø 0.8 mm ESAB OK Autrod 308LSi stainless steel filler wires. The exact chemical compositions of the base and filler materials are given in Table 1.