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ScienceDirect

Physics Procedia 56 (2014) 630 – 636

Physics Procedia

8th International Conference on Photonic Technologies LANE 2014

Thick-section laser and hybrid welding of austenitic stainless steels

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Abstract

Austenitic stainless steels are generally known to have very good laser weldability, when ordinary grades of sheets are concerned. But it is not necessarily the case, if special grades of fully austenitic structures with e.g. high molybdenum, or thick-section are used. It is also known that hot cracking susceptibility is strictly controlled by composition and welding parameters. If solidification is primary ferritic, hot cracking resistance is dramatically increased. It is also well known that laser welding needs a careful control of weld edge preparation and air gap between the edges. The dependence on edge quality can be decreased by using filler metal, either cold wire, hot wire or hybrid laser-arc welding. An additional role is high molybdenum contents where micro segregation can cause low local contents in weld which can decrease the corrosion properties, if filler metal is not used. Another feature in laser welding is its incomplete mixing, especially in thick section applications. It causes inhomogeneity, which can make uneven microstructure, as well as uneven mechanical and corrosion properties

In this presentation the features of laser welding of thick section austenitic stainless steels are highlighted. Thick section (up to 60 mm) can be made by multi-pass laser or laser hybrid welding. In addition to using filler metal, it requires careful joint figure planning, laser head planning, weld parameter planning, weld filler metal selection, non-destructive and destructive testing and metallography to guarantee high-quality welds in practice. In addition some tests with micro segregation is presented. Also some examples of incomplete mixing is presented.

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Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: Laser welding; Hybrid laser welding; multi-pass welding; austenitic stainless steel; solidification; thick-section; metallurgy; hot cracking

1. Introduction

Austenitic stainless steels can include a large variety of different grades, the most common of which are ordinary 18 Cr / 8 NI-type or their molybdenum alloyed versions. These conventional stainless steels are known to be very well weldable, in fact probably the best weldable metals of all. The weldability is one of the most important reason to make these grades so widely used. The other reasons are e.g. formability, quite good corrosion properties and their easiness to manufacture.

Recent development of demands of corrosion resistance in e.g. closed-circuits in chemical, oil or pulp and paper industry has increased the need for higher-alloyed stainless steels, where high contents of chromium, nickel and molybdenum are used. This has made the welding more challenging, because risk for hot cracking and control of corrosion properties of the welds needs more careful planning. In addition, other grades of stainless steels, as duplex stainless or ferritic stainless steels are more used today and their weldability needs also more attention than conventional grades. Lately, high price of nickel has made high-

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Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2014.08.056

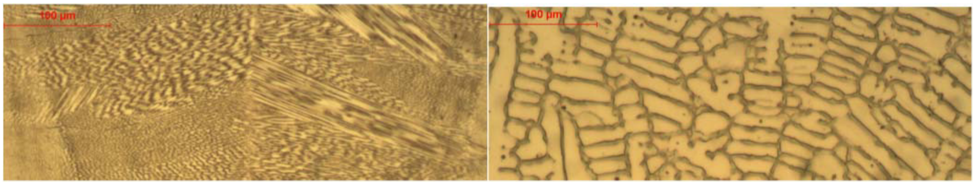
manganese grades of austenitic and duplex stainless steels also more interesting and their welding creates new features for welding procedures.

When considering laser or hybrid laser welding, the main advantages are high welding speed, low distortions, easiness to automation and the freedom for joint design. Anyway, it demands a strict control of joint preparation and high series to make it economical. In weldability point of view, high cooling rate makes changes in solidification behaviour and therefore it affects hot cracking susceptibility.

2. Solidification and micro-segregation

In laser and hybrid laser welding cooling rate is very high, around 1000-10000 ^{o}C/sec. High temperature gradient results in narrow heat-affected zone and no sensitization can happen. In addition with certain alloyed grades brittle phase zones do not exist to decrease the ductility.

High cooling rate affects also that the microstructure of the weld is very fine-grained, an order of magnitude finer than that of arc weld. In Fig. 1 shows an example of microstructure of laser and TIG (GTA) weld. It can be seen that laser welds are much finer than arc welds.



(a) (b)

Fig. 1. Microstructure of (a) laser weld, welding speed 10 m/min and (b) TIG weld, welding speed 0,25 m/min. Material 6 % Mo stainless steel. [1].

In Fig. 2 it is shown the effect of welding speed on distance of solidified primary dendrites. The microstructure size has an essential dependence e.g. on homogeneity and corrosion properties of the weld.

Austenitic stainless steel welds can solidify in different modes depending on composition and welding parameters: primary austenitic or primary ferritic ways. In addition five different solidification modes are differed depending on the fact if the secondary phase transformed from the remaining melt or in the solid phase, Fig. 3.

The solidification mode is strongly dependent on the composition, Fig. 4 It can be seen that the limits for the solidification modes can be calculated by chromium and nickel equivalents. Roughly, if the ratio of chromium and nickel equivalents is below 1.5, the solidification is fully austenitic or austenitic-ferritic and when it is between 1.5 – 2.0 it is ferritic austenitic. In the values over 2.0 solidification is austenitic-ferritic. These numbers depend a bit on equivalents used, Fig. 4.

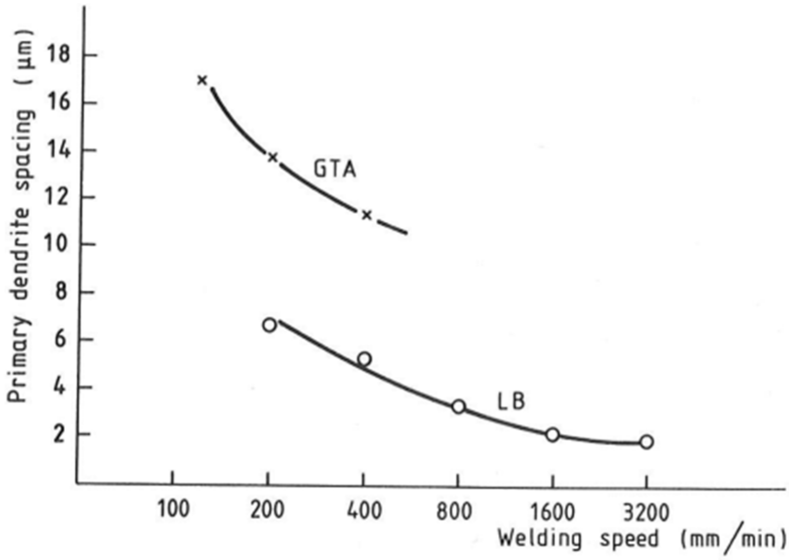


Fig. 2. The dependence of primary dendrite spacing on welding speed and method [2].

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