Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 83 (2016) 463 – 471

Physics Procedia

9th International Conference on Photonic Technologies, LANE 2016

Change of hot cracking susceptibility in welding of high strength aluminum alloy AA 7075

M. Holzer[a,*], K. Hofmann[a], V. Mann[a], F. Hugger[a], S. Roth[a,c], M. Schmidt[a,b,c]

[a]*Bayerisches Laserzentrum GmbH (blz), Konrad-Zuse-Staße 2-6, 91052 Erlangen, Germany*
[b]*Institute of Photonic Technologies (LPT), Friedrich-Alexander-Universität Erlangen-Nürnberg, Konrad-Zuse-Straße 3-5, 91052 Erlangen, Germany*
[c]*Erlangen Graduate School in Advanced Optical Technologies (SAOT), Paul Gordan Straße 6, 91052 Erlangen, Germany*

Abstract

High strength aluminum alloys are known as hard to weld alloys due to their high hot crack susceptibility. However, they have high potential for applications in light weight constructions of automotive industry and therefore it is needed to increase weldability. One major issue is the high hot cracking susceptibility. Vaporization during laser beam welding leads to a change of concentration of the volatile elements magnesium and zinc. Hence, solidification range of the weld and therefore hot cracking susceptibility changes. Additionally, different welding velocities lead to changed solidification conditions with certain influence on hot cracking.

This paper discusses the influence of energy per unit length during laser beam welding of AA 7075 on the change of element concentration in the weld seam and the resulting influence on hot cracking susceptibility. Therefore EDS-measurements of weld seams generated with different velocities are performed to determine the change of element concentration. These quantitative data is used to numerically calculate the solidification range in order to evaluate its influence on the hot cracking susceptibility. Besides that, relative hot crack length and mechanical properties are measured. The results increase knowledge about welding of high strength aluminum alloy AA 7075 and hence support further developing of the welding process.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: welding; high strength aluminum; vaporization; element loss; energy per unit lengt; hot cracking susceptibility

* Corresponding author. Tel.: +49-9131-97790-25 ; fax: +49-9131-97790-11 .
E-mail address: m.holzer@blz.org

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.048

1. Introduction

High strength aluminum alloys of 7xxx series are mainly used in aerospace sector Ostermann (2014). Due to its low applicability for fusion welding, those alloys have to be joined by gluing, friction welding, screwing, riveting or combinations of all these technics. Since the mentioned joining methods are hardly suitable for mass production, high strength aluminum alloys are not established in automotive industry. However, regarding their mechanical properties with nearly doubled strength compared to commonly used alloys of 5xxx and 6xxx series, they have high potential for light weight constructions in car manufacturing. There are different reasons for the poor weldability of 7xxx aluminum alloys. First, due to its contents of magnesium and zinc with their low boiling temperatures, high vapor pressure occurs during welding. Hence, keyhole is destabilized drastically with formation of spatter accompanied by loss of volume in fusion zone during process. Second, high hot cracking susceptibility occurs at typical concentrations of zinc (5.5 wt%) and copper (1.5 wt%) at these alloys Schulze (2010).

Some strategies can be used for increasing weldability. Regarding spatter formation, Holzer *et al (2015*) could partially stabilize the keyhole during laser beam welding by pulse shaping with a modulation frequency of 1 kHz, which also reduces spatter formation. To overcome hot crack formation, change of alloy composition in weld seam can be reached by using filler material. Due to an increased content of globular grains and decreased mean grain size during solidification, the permeability in semi solid state is expected to increase. This enables an increase of feed rate of liquid in the mushy zone and hence decreases hot cracking susceptibility Katgerman and Eskin (2008).

In order to reduce crack formation in arc welding of AA 6060, Coniglio and Cross (2013) used AlSi5 as filler wire with the effect of grain refinement in the weld. A higher content of Si leads to reduced solidification shrinkage and increased interdendritic liquid quantity, which decrease hot cracking susceptibility in the weld. Huang *et al. (*2015) investigated the influence of Sc content on grain refinement in a 7xxx series alloy welded by metal inert gas with AlMg6Sc filler. Due to an increase of Sc content from 0.1 wt.% to 0.25 wt.% in the base material, the grain size decreased from 120 µm to 50 µm. Due to fine coherent Al3 (Sc, Zr) particles heterogeneous nucleation was induced. Furthermore, Wloka (2007) reached grain refinement at laser beam welded AA 7050 with Sc-doped AlMg6Sc filler. Permeability of mushy zone increases if grain refinement is present; this improves liquid feeding during solidification with reduction of hot cracking susceptibility. Regarding the overview of Cross and Coniglio (2008) on hot cracking theories, hot cracking depends on a critical strain rate which is generated by the local thermal strain conditions and solidification shrinkage as well as liquid feeding. If the critical strain rate is reached, the pressure drop in liquid films between dendrites initiates crack formation. This suggests that besides alloying strategies, measures regarding system technology enable a decrease of hot crack formation during welding. In the work of Holzer *et al. (2015*) it was shown a reduction of hot crack formation in welding of AA 6082 and AA 7075 due to reduced thermal strain with decreasing focus diameter from 600 µm to 340 µm. Hu and Richardson (2006) implemented an additional heat source in order to reduce strain rate during cooling. Experiments with hybrid laser-gas metal arc welding of AA 7075 show decreased transversal crack occurrence of the weld by applying a heat source besides the weld. Also a reduced welding speed with least possible heat input was found to reduce hot cracks.

Also in pulsed heat conduction laser beam welding of AA 6016 Bergmann *et al.(2013*) could reduce hot cracking in bead on plate welds by using superimposed diode laser beam on welding area. In order of increased solidification time, the reduced hot cracking susceptibility is believed to occur.

This short summary of different methods for improving weldability of hard to weld aluminum alloys shows, that the use of filler material with the aim to change element concentration or alloying system in the weld seam can avoid hot cracking. However, especially for heat treatable aluminum alloys of 6xxx and 7xxx series, the change of alloying system softens the weld seam and inhibit hardening to the level of base material. Besides that, an increased heat input or extended solidification time during welding results in lower strain rate which decreases hot cracking susceptibility. With increasing heat input during welding, not only solidification conditions but also element concentration could change due to selective vaporization. In particular 7xxx aluminum alloys with high content of volatile elements Mg and Zn can be affected. Hence, the present work shows an investigation of element change due to differences in welding velocity which comes along with changed energy per unit length. The effect of both, the energy per unit length and the change of element concentration in the weld seam influence the hot cracking susceptibility.