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Laser Welding of High-Strength Aluminium Alloys for the Sheet Metal Forming Process

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Abstract

Laser beam welding of similar and dissimilar joints made of 7075-T6 and 5182-O sheets is conducted. A new approach of the Helmholtz-Zentrum Geesthacht is used to solve the problems of weldability and softening. The microstructural characteristics and the mechanical properties of the joints are evaluated. With this information it is possible to initially assess the formability of the tailored blanks. Finally the formability of the welds will be validated via a sheet metal forming process. Owing to the good formability of the base materials, the results obtained for the welded joints are compared with base material properties.

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Keywords: high strength aluminium alloys; Al-Zn-Mg (Cu) ; laser beam welding; tailor welded blanks; sheet metal forming.

1. Introduction

In the recent years the economic and political pressure on the automotive industry to reduce the fuel consumption and the CO_2 emissions increased more and more. Hence, the efforts for a lightweight automotive design become more important [1,2].

One possibility for reducing weight is the substitution of steel by aluminium alloys in automotive sheet applications. In this regard, medium strength 5xxx (Al-Mg) and 6xxx (Al-Mg-Si) series alloys are already widely used. This is mainly due to their high strength-to-density ratio, good formability, weldability and corrosion resistance [3,4]. Although 7xxx (Al-Zn) series alloys exhibit an even higher specific strength, there is no widespread use of these alloys. The key obstacles for this disregard are weldability problems like hot cracking and porosity in the weld, but also the softening of the fusion zone (FZ) and the heat affected zone (HAZ) [3].

Yet another possibility for reducing weight of automotive structures is the use of tailor welded blanks (TWB), which also allow an improvement of structural integrity of the joined and formed sheet component. Laser beam welding (LBW) is an efficient method for producing joints with high weld quality as a prerequisite for a successful sheet metal forming process of the tailored blanks.

Aluminium tailor welded blanks with high specific strength in conjunction with a good formability might fulfil the demands of the automotive industry once the weldability problems were overcome.

2. Materials and experimental procedures

2.1. Base and filler materials

Two different combinations of aluminium alloys were joined by laser beam welding:

- the similar joint made of 7075 and
- the dissimilar joint made of 7075 and 5182.

The chemical composition of the both aluminium alloys used in this study is given in Table 1. The heat treatable aluminium alloy 7075 was used in the peak-aged T6 temper condition whereas the non-heat treatable aluminium alloy 5182 was used in the annealed O temper condition. The sheet thickness of the both aluminium alloys was 2.0mm. Before welding the oxide

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layer on the sheet surface was removed by mechanical grinding and the resulting surface was degreased with alcohol, in order to avoid hydrogen induced porosity in the weld.

The new approach for solving the problems of weldability and softening of the Al-Zn alloys - referring to a recently granted patent of the Helmholtz-Zentrum Geesthacht - includes the use of vanadium in combination with a conventional filler wire [5]. For this purpose a 99.8% pure vanadium foil with a thickness of 40µm was used. Because the general recommendation of 5xxx series alloys as filler material for welding 7xxx series alloys, a 5087 filler wire with a diameter of 1.0mm was used for laser beam welding of the joints. The chemical composition of the aluminium alloy used as filler material is also given in Table 1.

Table 1. Chemical composition (wt.%) of the used aluminium alloys

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
7075	0.4	0.5	2.0	0.3	2.9	0.28	6.1	0.2	Bal.
5182	0.2	0.35	0.15	0.5	5.0	0.1	0.25	0.1	Bal.
5087	0.25	0.4	0.05	1.1	5.2	0.25	0.25	0.15	Bal.

2.2. Laser beam welding

The laser beam welding of the butt joints of both alloy combinations was performed using 3-axial CNC machining centre which is connected to a 2.2kW Nd:YAG laser. The used welding configuration is shown in Fig. 1. For retaining the position of both sheets during welding a vacuum clamping device was used. And for an accurate positioning of the vanadium foil, a foil strip was laser tack welded on the face (joining zone) of one of the sheets. The filler wire was supplied by a dragging wire feed. Argon was used as shielding gas in order to protect the molten weld metal against oxidation. It was provided on top and bottom side of the weld.

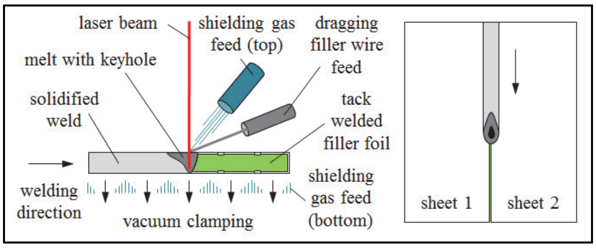

Fig. 1. Laser beam welding configuration

The laser beam welding process was first optimised with respect to the subsequent properties of the joint like for example the weld seam appearance and the porosity of the weld. Therefore, the following welding parameters were varied:

- the laser power,
- the welding speed,
- the feed rate of the filler wire and
- the focal position.

The properties of the laser welded blanks were initially evaluated by preceding inspections and the optimized welding parameters which resulted from the parameter variation are given in Table 2.

Table 2. Optimized process parameters for laser beam welding

Parameter	Unit	Value
Laser power	kW	2.0
Welding speed	mm/min	3500
Filler wire	-	5087
Feed rate of filler wire	mm/min	3000
Shielding gas	-	Argon
Flow rate of shielding gas	l/min	20
Focal position	mm	0 (specimen surface)

2.3. Preceding inspections

The preceding inspections allowed a quick and easy determination of the joint properties and served as an initial evaluation of the joint quality.

Visual inspection was used to determine the outer appearance of the weld seam. Hereby weld imperfections like incompletely filled grooves, surface cracks, undercutting and excessive penetration can be detected.

In contrast to that, X-ray inspection was used to determine inner imperfections like porosity and with this procedure the amount, the distribution along the weld and the size of the pores can be determined.

2.4. Determination of microstructural properties

The microstructural properties of laser welded blanks were investigated by optical microscopy. Therefore extracted microsections of the weld were etched with Kroll's reagent.

In addition, selected welds were investigated by the use of scanning electron microscopy (SEM) on polished microsections. The local chemical composition was determined by energy dispersive X-ray (EDX) analysis at the same time.

2.5. Determination of mechanical properties and formability

The local mechanical properties of laser welded blanks were determined by the use of Vickers micro-hardness testing (HV0.2). Therefore several hardness indentations were made at all important regions of the