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Original Research Article

Susceptibility for extrusion welding of AlMg alloys

Dariusz Leśniak [a,*], *Alicja Wassermann* [a], *Mateusz Dziki* [a], *Krzysztof Zaborowski* [a], *Henryk Jurczak* [b]

[a] AGH University of Science and Technology, Faculty of Non-Ferrous Metals, 30-059 Krakow, al. Mickiewicza 30, A-2, woj. małopolskie, Poland

[b] Albatros Aluminium Sp. z o.o., ul. Południowa 36, 78-604 Wałcz, woj. zachodniopomorskie, Poland

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ABSTRACT

The extrusion of hollow profiles from high strength aluminium alloys through porthole dies causes serious problem in practice. Mainly, this is due to low weldability of these alloys and high extrusion force. The present paper discusses the investigations undertaken to determine the weldability of hard AlMg alloys using the original method and device. Main advantage of the proposed method is that it allows for the reflection of real welding conditions occurring in a welding chamber of the porthole die. Weldability tests were performed for alloys: 5754 (3.5% Mg), 5083 (4.5% Mg), 5019 (5.6% Mg) and 5xxx (7.1% Mg) in a wide range of temperature, unit pressure (normal compressive stress) and duration of welding. Microstructure and strength properties of the welds were examined. Most favourable welding conditions for the tested alloys, allowing for obtaining high strength welds were defined. To validate the laboratory experiments the extrusion trials were performed in the industrial conditions, in which the round tubes from 5754 alloy were produced using the porthole dies. The tensile strength of the welds in the extruded tubes is comparable to that for the solid material. Strength of the welds as well as of the solid material strongly increases with magnesium content in the alloy.

1. Introduction

Production of the hollow profiles from aluminium and its alloys is based mainly on the hot extrusion (so called extrusion welding) with the use of the porthole dies. The use of the extrusion welding in practice depends on the ability of particular alloy to welding. As results from the outgoing experience, the aluminium alloys of 1xxx, 3xxx, and 6xxx series are susceptible for extrusion welding process [1]. In last year's 5xxx, 8xxx and partly 7xxx series alloys can be also included to the group of extruded with welding [2]. Currently, major problem in extrusion through the porthole dies is with the 2xxx alloys [3] containing Cu, which impede the welding process. The high yield stress of the 2xxx alloys is an additional difficulty in this case. Above limitations determine the process assumptions for extrusion welding and are base for the selecting process parameters which will

* Corresponding author. Present address: 30-059 Krakow, al. Mickiewicza 30, A-2, woj. małopolskie, Poland.
E-mail addresses: dlesniak@agh.edu.pl (D. Leśniak), awojtyna@agh.edu.pl (A. Wassermann), dzikimateusz@agh.edu.pl (M. Dziki), kzaborow@agh.edu.pl (K. Zaborowski), h.jurczak@albatros-aluminium.com (H. Jurczak).

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be favourable for obtaining good weldability in production of the hollow sections.

Analysing the factors determining the weldability of aluminium alloys the following issues should be considered:

- welding temperature,
- hydrostatic pressure in welding region,
- duration of contact needed to welding,
- shear strain in the welding region.

Theoretically, by proper choice of the mentioned above factors, the strong welds can be obtained for any aluminium alloy. However, in practice we have different difficulties in obtaining assumed level of the deciding factors and because of that, 2xxx and partly 7xxx series alloys cannot be extruded through the porthole dies [4].

Having a fundamental knowledge on the role of the mentioned factors we can control the extrusion welding process to obtain the expected result. Describing the assumption in analysis of the extrusion welding process we will consider hypothetically the particular factors.

The extrusion temperature, and to be precise, temperature at the region of welding is a crucial parameters influencing quality of the weld [5,6]. Generally, it can be stated that the higher temperature in the location of weld the better conditions for good strength of weld [7,8]. To obtain the high temperature level at the region of weld, it is recommended to heat up the billet to possibly high temperature, however, the negative influence of higher temperature on maximal extrusion speed should be also taken into account [9]. The heat balance of the process, including temperature-speed parameters would be helpful here to properly determine the extrusion temperature.

The hydrostatic pressure within the region of weld also plays important influence on weldability. The higher hydrostatic pressure the better is quality of weld. To reach high hydrostatic pressure at relatively high temperature, it is important to design the welding chamber in a die correctly [10]. Generally, the higher extrusions pressure the higher hydrostatic pressure value within the welding chamber [11,12]. It suggests that the extrusion welding process should be carried out with relatively high extrusion ratio, guarantying suitable level of the hydrostatic pressure within the welding chamber [13]. Bingöl and Bozaci [14] investigated the influence of extrusion speed on the ratio of normal pressure to effective stress (P/σ) which is responsible for the strength of the welding in porthole extrusion.

Duration of contact of metal streams for which the welding occurs is connected with an extrusion speed. The higher extrusion speed, the shorter is time of contact and the condition for welding became worse. Theoretically, the longer duration of contact of the metal streams, the better is the effect of welding [15]. To improve in practice the welding conditions, it is recommended to apply such shape of the welding chamber which will provide the longest duration of contact of the metal streams within the welding chamber [16].

The shear strain within the welding chamber is a very important parameter influencing the weld quality [17]. The shear strain at the region of weld leads to exposure the contact surface of metal streams, and because of this, aids the adhesive joining. The high deformation level at the region of weld can be affected by rising the extrusion ratio, but more effectively may be caused by proper design of the porthole die, and particularly by the shape of both the inlet channels and welding chamber.

Alharthi et al. [18] analysed the extrusion welding of AM30 magnesium alloy. They revealed two types of extrusion weld seams; the first seam type does not show a weld line which indicates perfect solid state bonding. The second type contains a weld line, which could be a potential source of imperfections in the extrudates.

Having knowledge on the weldability of a particular aluminium alloy, received form the custom-designed testing device, by proper selection of process parameters of the extrusion welding in connection with the die design, it is possible to obtain the expected effect, i.e. a hollow section with very good quality of the welds.

The objective of the present study is the evaluation of ability of AlMg alloys of high content of magnesium to extrusion welding process, in which the hollow sections with longitudinal welds are produced.

2. Procedure of experiments

Research program includes following experiments:

- Tests of weldability.
- Microstructure and mechanical investigations of welded samples.
- Industrial extrusion of tested alloys.
- Examinations of microstructure and mechanical properties of extruded tubes.

Research on weldability of AlMg alloys of high content of magnesium was carried out using a developed authorial device (Fig. 1, [19]). This device enables repeating conditions of joining of a metal which are expected to exist in a porthole die during extrusion of hollow sections (shearing and compression without the air admission). The weldability test consists on to stages: in the first stage the shearing of two contiguous samples occurs, in the second these samples are axially compressed (welded) at the assumed both temperature and unit pressure (hydrostatic pressure) (Fig. 2).

The samples are previously preheated in a heating chamber and then deformed in a tool cassette equipped with a hydraulic drive. The axial pressure which causes the welding of a material is realised by an upper compressing stem, acting perpendicularly to the surface of joining. The weldability tests with using the proposed device were carried out for the following AlMg alloys: 5754 (3.5% Mg), 5083 (4.5% Mg), 5019 (5.6% Mg), and 5xxx (7.1% Mg) at temperatures 450, 500 and 550 °C and under the pressures of 100, 150, 200, and 250 MPa. The assumed temperatures of weldability tests are determined by the values of solidus temperatures of AlMg alloys with different Mg content (EN AW-5754, 3.5% Mg, EN AW-5083, 4.5% Mg, EN AW-5019, 5.5% Mg, 5xxx, 7.1% Mg)). The higher the Mg content in the alloy, the lower solidus temperature of the alloy — safe limit temperature above which the material structure may melt. Generally, for alloys with the lowest Mg