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Multiple Spot Electron Beam Welding of Aluminium Die Castings

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When welding aluminium high pressure die casting (HPDC) parts metallurgic pore formation is a main challenge. In particular welding of thin-walled, pressure-proof housing parts, such as heat exchangers for vehicle application, is mainly performed using laser or electron beam welding (EBW). A novel approach is the application of multiple spot EBW to achieve good degassing conditions through remelting in a low pressure environment. Moreover high speed beam deflection enables the generation of multiple melt pools at spatially divided locations. The present investigation focuses on the influence of the number of melt pools, the distance between them and power distribution (PD) on porosity. In addition the results are related to the HPDC process and its influence on EBW.

Keywords: *Electron beam welding, multiple spot, aluminium casting, aluminium high pressure die casting*

1. Introduction

The demand for thin-walled aluminium die castings for lightweight and medical applications is steadily increasing. In many applications these parts need to be welded to fulfil their purpose. The main challenge in welding aluminium HPDC parts is porosity. The applied welding technique, the surface condition, the total hydrogen content and the casting porosity are key factors regarding the formation of weld porosity. According to literature hydrogen bonded in hydrides and hydrogen dissolved within the casting material is carried into the melt pool by diffusion during the welding process. After solidification the hydrogen is trapped inside the weld metal and forms porosity. An opportunity to avoid metallurgical pore formation is multiple melting with different penetration depths. At each run the weld metal melts again and trapped porosity, which was formed during a former run, can rise to the surface of the melt pool where is leaves the thaw. In state of the art welding this is achieved by repeating the welding process several times. In order to increase process efficiency the long term goal is to use the capability of EBW for multi spot welding to achieve remelting during one run. Subsequently the current investigation aims to find basic relations between weld bead quality, power distribution and the distance between the melt pools. [1,2]

2. Materials and Methods

2.1 Materials

All trials performed were carried out on material casted at the institute for joining and welding (ifs) on a Bühler B53 Evolution HPDC machine. Alloy AlSi10MnMg was casted as sheets with dimensions of 260 x 110 x 4 mm. The HPDC process was performed using the wax free release agent HERA EU DC-120918A, plunger lubricant ChemTrend Power-Lube 766. All plates were casted with vacuum assistance (150 mbar, evacuation after shot sleeve filling 1.5 s)

2.2 Methods

The welding process was performed on a pro-beam K-26 electron beam welding machine. Welding speed and acceleration voltage were kept constant at 60 mm/s and 60 kV in order to ensure production related welding speeds and avoid high voltage discharge. The energy input per unit length was set to 162/234/288 J/m for 2/3/4 spot welding. The focal position, deflection pattern, number of melt pools and the power distribution between the melt pools were varied (see Table 1).

Table 1 Welding parameters alternated

Parameter	**Range**
Focal position	+20/+10/0/-10/-20
Pattern [-]	Spot/Circle
Frequency [Hz]	1667/1111/1000
Number of melt pools [-]	2/3/4
Melt pool distance [mm]	10/20/30/40

All weld paths were created as 3 mm bead on plate welds of 210 mm length, containing a 10 mm slope in/out region. Moreover stop action welds were produced for each set of parameters, in order to distinguish the influence of each weld pool. Photographs were taken from each weld and longitudinal as well as cross sectional metallurgic sections were taken from chosen weld beads. The stop action welds were additionally CT-scanned and analysed for porosity.

3. Results and discussion

3.1 Melt pool distance

The weld paths performed with small gaps between the melt pools showed a strong tendency to surface defects. These defects were identified as overheating driven surface porosity. The occurrence of these defects was further observed as dependent on the number of melt pools. Thus a lower bound for the melt pool distance was defined for each number of melt pools. For the current conditions a lower bound of 5 mm melt pool distance was found. It was further observed that the penetration depth of the following melt pools drops with increasing gaps between the keyholes, as expected. Fig 1 gives an example for this observation. The metallurgic cross-section each show two nail head formed welds, where the upper one is caused by the second keyhole and the lower one by the first melt pool. As a result of the increasing gap about 20 mm the penetration depth drops as shown.

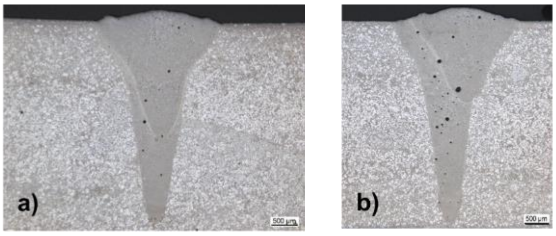

Fig. 1 Cross-sections for a) 20 mm and b) 40 mm melt pool distance for a two spot weld path

As an additional outcome the penetration depth must be carefully set by beam power, distance between the melt pools and power distribution to avoid melting base material at the repeating runs.

3.2 Power distribution

The influence of power distribution was observed by analyzing the stop welds performed. Fig 2 shows a longitudinal section taken from the stop action welds performed. The areas highlighted areas show the target location of the different melt pools. Area (A) for example shows the area where only one melt pool passed the joint. As the comparison of area A, B, and C shows, the amount of porosity decreases after each melt pool passed a specific place within the weld path. From the areas highlighted in Fig 2, it is apparent that the power distribution should be decreased slightly from the first to the last keyhole. The weld bead shown in Fig 2 was welded with three spots and a 78/17/6 % power distribution, a frequency within the deflection pattern of 1111 Hz and 3900 W beam power. As Fig 2 shows, the decrease of power used for this specific example was too sharp. Area A is much bigger than area C but C is the area with the lowest porosity content.

Fig. 2 Longitudinal section, three spots, PD 78/17/6 %

3.3 HPDC process influence on welding

The trials although confirmed that the casting quality is a key factor for the quality of the resulting weld bead. Vacuum assisted casting, the use of wax free release agent as well as low density indices were confirmed to be a good casting strategy for weldable HPDC Parts.

4. Summary and conclusion

In this investigation, the aim was to assess the influence of power distribution and melt pool distance for multiple spot EBW of aluminium HPDC parts. It was shown that the melt pool effects penetration depth and porosity content and is effected by the power distribution used. It was confirmed that the power distribution has to be decreased counter to the direction of welding slightly.

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References

[1] S. Wiesner: *Wirtschaftliche Herstellung von gasarmem, schweißbarem Aluminium-Druckguss*. (Shaker-Verlag, Aachen, 2003)

[2] R. Winkler: *Porenbildung beim Laserstrahl-schweissen von Aluminium Druckguss*. (Herbert Utz Verlag Wissenschaft, München, 2003)