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Increasing the Lifetime of Die Casting Molds by Additive Remanufacturing Applying Electron-Beam Deposit Welding with a Local Process Integrated Heat Treatment

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High pressure die casting molds are constantly exposed to high thermal, mechanical, chemical and tribological cyclic loads during the operation. These loads might cause different defects on or in the mold and thereby reduce the die lifetime significantly. In the case of an unexpected production stop caused by critical defects in the mold, repair welding by means of deposit welding is often the only way to reinstate the casting tool contemporary to the production.

Hence, the primary objective is the development of the electron-beam welding technology for an economic regeneration of locally damaged die casting tools.

Keywords: *HPDC, additive remanufacturing, electron-beam welding, permanent mold*

1. Introduction

The profitability of each die casting process is significantly influenced by the achievable lifetime of the die casting die.

Moreover, the surface quality of the cast component is directly correlated with the surface quality of the permanent mold. The process-related damages, like stress cracks, heat checkings and erosion increase constantly with every casting cycle and map onto to the so-called functional surfaces of the cast component. Damages have to be reworked manually, which is time- and costintensive. Due to the high costs for the production of a new mold insert, which can amount to at least 50 % of the initial cost of a new mold insert, repair welding instead of new manufacturing is a preferred approach. [1]

2. Repair welding of casting molds

Currently, the TIG or plasma welding processes are mainly used for such repair welding routines, because of their relatively low-cost system technology. Repair welding is also increasingly performed by using the semi-automated laser surface cladding. [2] Nevertheless, these conventional welding techniques manifest an insufficient process-reliability and therefore achieve an unsatisfactory increase in the lifetime.

The mold material mostly used in aluminum die casting is the hot-work steel H13. Due to its relatively high carbon, molybdenum, vanadium and chromium contents, this steel is not very well weldable. To avoid failures like hardening and cracking it is essential to heat the mold insert before welding to above the martensite start temperature. However, preheating temperatures should be avoided above 450 °C, as this may lead to embrittlement of the base material. [3]

As a consequence, insufficient preheating of the die or a too long cooling prior to performing the repair welding cause a very high hardness in the weld microstructure. This may also lead to macro cracks in the weld deposit. Tempering reduces the hardness in the weld structure within certain limits, by welding martensitic materials. Apart from the outstanding hardness peaks, also areas with hardness values in the heat-affected zone below the base material are noted. These are caused by annealing effects due to the heat input during the welding process. Because of the high hardness there is still a metallurgical notch in the heat-affected zone. Despite the final machining of the surface, this notch might quickly lead to a renewed crack and a failure of the permanent mold in the environment of the repair weld during the casting process.

3. Electron-beam welding

3.1 EB-technique

In addition to the laser beam method, electron-beam technology represents the second beam technology for the processing of thermal materials. Thereby, almost massless and thus inertia-less electrons for the thermal material processing are accelerated up to 2/3 of the speed of light by means of an acceleration voltage of 120 kV from an electron cloud in front of the cathode. The focusing and highly dynamic deflection of the electron beam is effected by a number of electromagnetic lenses. If the electrons impact on the workpiece surface, they will be braked. At this deceleration process, the kinetic energy of the electrons is converted into thermal energy and thus creates the possibility of melting the metal base or filler material. [4]

3.2 Researches on deposit welding by electron-beam welding

In the first part of the researches suitable filler materials were identified and tested under vacuum conditions. An under-alloyed, a similar and an over-alloyed material were tested. For possible buffer layers an additional filler material should be examined for Cobalt basis and on the basis of maraging steels with the standard designation 1.2709. Each filler material is fed as a filler wire with a diameter of 1.6 mm into the molten bath with an in the electron-beam system built-in wire conveyor. It has been shown that filler wires are not weldable in vacuum without a massive formation of weld spatters. That's why only massive wires were used for the further investigations.

In the main part of the investigations build-up tests were performed in extra pre-milled swales. The milled swale should simulate the real situation in the repair welding process in this connection, since any possible cracks in the die are milled and then back-filled with the filler material. The basic material is the hot work tool steel H13 (ESR-quality, annealed to 45 HRC), using SzFe3 as massive filler material.

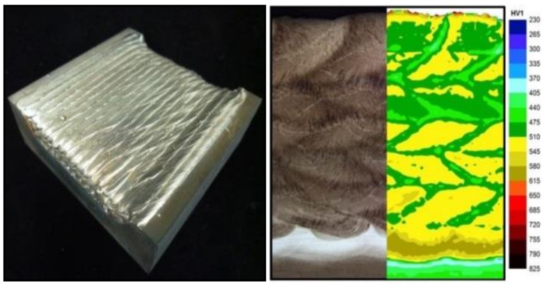

Fig. 1 Deposit welded filled test piece (swale)/ Cross-section polish and a hardness allocation of an EB-welded swale (without tempering).

It was welded with a torch directed toward the finished part of the weld, at which the sample was rotated to 180° by means of clamping. This was the reason that at the end of each track, a drop height of the weld took shape. A rotation after each layer compensated this situation. A total of five layers are required to fill the 10 mm depth of recess. Different heat treatment strategies were applied by adaption of the beam, simultaneously. Based on these experiments, it was found that a generative structure using the electron-beam system and an additional material is generally possible, as the test piece in figure 2 shows.

Furthermore, it could be shown that the connection between filler material and base material is well constituted with a relatively small heat-affected zone. Welding defects such as hot or cold cracking did not occur at all surfacings. Besides, figure 2 left shows clearly that the typical metallurgical notch in the heat-affected zone is less distinct than in conventional welded examples.

4. Conclusion and prospect

The conducted experiments show that the electron beam welding method is suitable for a generative development of metallic materials. For this purpose, multi-layer deposit weldings were realized with a typical hot work steel and suitable filler materials. Possible build-up strategies for three-dimensional bodies were demonstrated.

These results form the basis for an additive remanufacturing of permanent casting molds. A pre-and post-heating of the weld metal is hence essential in this or any case to avoid heat cracks.

Due to its multi-beam technology, the electron-beam welding technique allows in contrast to conventional welding methods a process-integrated pre-and post-heating. The next step of will be the application of the achieved results to real damaged die casting dies.

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