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Comparison of Component Properties between HPDC and Rheocasting Applying the RheoMetal™ Process

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Abstract

Since the 1970s, there has been increasing interest in semi-solid processes, allowing improved mould filling with lower gas porosity and lower melt temperatures with improved tool life compared to the standard HPDC process. Challenges lie in the process know-how and the precise temperature control to ensure process stability and reproducibility. In contrast to other semi-solid processes, the RheoMetal™ process achieves the semi-solid state by stirring in an enthalpy exchange material (EEM). This work compares component properties (engine mount) produced by standard HPDC and rheocasting, applying the RheoMetal™ process using an AlSi7MnMg alloy. The results of component testing and radioscopic examination reveal promising outcomes regarding process stability, pore formation, and component properties compared to the standard HPDC process.

Keywords:

semi-solid processing, enthalpy exchange material, AlSi7MnMg, component testing, radioscopic examination

1. INTRODUCTION

Since the discovery of globular solidification in the 1970s by the research group led by M.C. Flemings [1], there has been strong and continuous interest in rheocasting processes. Advantages such as improved mould filling with reduced gas porosity, lower melt temperatures, and an increased tool life compared to the standard high-pressure die casting (HPDC) process have driven efforts to develop reliable and industrially scalable processes. These processes can generally be divided into thixocasting and rheocasting. The essential difference between thixocasting and rheocasting lies in the fact that thixocasting requires two separate process steps. Before the casting step, billets must be produced. These billets are then heated into the semi-solid region and cast into the mould. In contrast, rheocasting achieves the semi-solid state directly during the cooling phase of the melt, which is subsequently cast into the mould [2]. Compared to standard HPDC, rheocasting offers several significant advantages. The first positive aspect is the higher viscosity compared to fully liquid melts. This promotes the transition from turbulent to laminar flow, resulting in improved mould filling with fewer air and oxide inclusions. Secondly, less superheating is required. Consequently, the melt temperature can be kept lower, resulting in an increased tool lifetime, reduced sticking tendencies, and shorter solidification times. Another advantage is the formation of partially solidified melt, which can reduce volumetric shrinkage and enable near-net-shape production. Furthermore, castings with varying wall thickness can be produced more easily. Finally, the lower amount of gas porosity improves the suitability for heat treatment [3]. Among the challenges is the specific process know-how that is required in applying the rheocasting technology. Furthermore, precise temperature control is required, which is necessary because both the solid fraction and the viscosity are strongly dependent on the temperature [2], making rheocasting processes challenging with regard to process stability and reproducibility. Furthermore, slurry fabrication may result in an increase in production time [4]. To overcome the challenges of standard rheocasting processes, the RheoMetal™ [5] process was developed, which does not rely on complex temperature control but achieves the semi-solid state by stirring in an enthalpy exchange material (EEM). A liquid and solid alloy system is mixed together and with the help of stirring, the solid alloy a new alloy system (slurry) are produced with the targeted solid fraction. The initial temperature and composition of the melt and the EEM, and furthermore the amount of EEM, determine the final solid fraction, making precise temperature control during the process unnecessary. Furthermore, due to the rapid heat exchange between the cold EEM and the liquid melt, large amounts of semi-solid material can be produced in a short time [6, 7].

This work focuses on a comparison of component properties of parts produced by the RheoMetal™ process and the standard HPDC process.

2. MATERIALS AND METHODS

In this work, an AlSi7MnMg (Silafont®-33) alloy was used. Standard impeller degassing was applied with argon as the purge gas. The Bühler SC D/53 HPDC machine was equipped with a slurry maker to produce a maximum of 2 kg of slurry material (Comptech i Skillingaryd AB). An example engine mount (Fig. 1a, b) was cast both by standard HPDC and rheocasting. For the standard HPDC process, the machine is equipped with a vacuum dosing system using a dosing robot. In the case of rheocasting, a ladle is mounted to the dosing robot. Spraying of the die was performed with an automated spraying system, and the parts were removed manually.

The rheocasting process comprises the following steps:

1. casting of the required amount of melt around a steel rod to produce the EEM with a diameter of 40 mm and a height of 37 mm,
2. removal of the feeder and gating system,
3. extraction of the required amount of melt for the casting using a ceramic ladle,
4. stirring of the EEM into the melt,
5. homogenisation at a second stirring station, equipped with a non-dissolvable stirring rod,
6. filling of the semi-solid melt into the HPDC chamber,
7. cleaning of the steel rod.

The slurry maker is shown in Figure 1c. A stirring program was applied to produce slurry material with a solid fraction of approx. 24%.

The piston velocity of the second phase of the standard HPDC process was approx. 2.2 m/s. In contrast, rheocasting allows a lower piston velocity of the second phase due to the structural viscous behaviour of semi-solid melts. A piston velocity of the second phase of approx. 0.4 m/s for the rheocasting process was found to be appropriate for the engine mount used in this work.

A universal testing machine (Zwick 250 kN) for static applications was used for component testing of the individual casting parts. Each individual casting part was fixed on the clamping plate with 5 bolts. A press ram mounted on the universal testing machine was used to apply a compressive force on the opposite side of the engine mount (Fig. 1d). An initial load of 50 N and a testing speed of 20 mm/min were applied until failure of the individual casting part occurred. Above a piston stroke of 15 mm, the parts tend to be supported by the edge of the clamping plate. This effect is indicated by the increase in the compressive force, as shown in Figure 2a. Therefore, the compressive force at a piston stroke of 15 mm was used for the comparison of the individual casting parts.

Individual casting parts were also examined by radioscopic examination (v|tome|xc with a 240 kV microfocus X-ray).

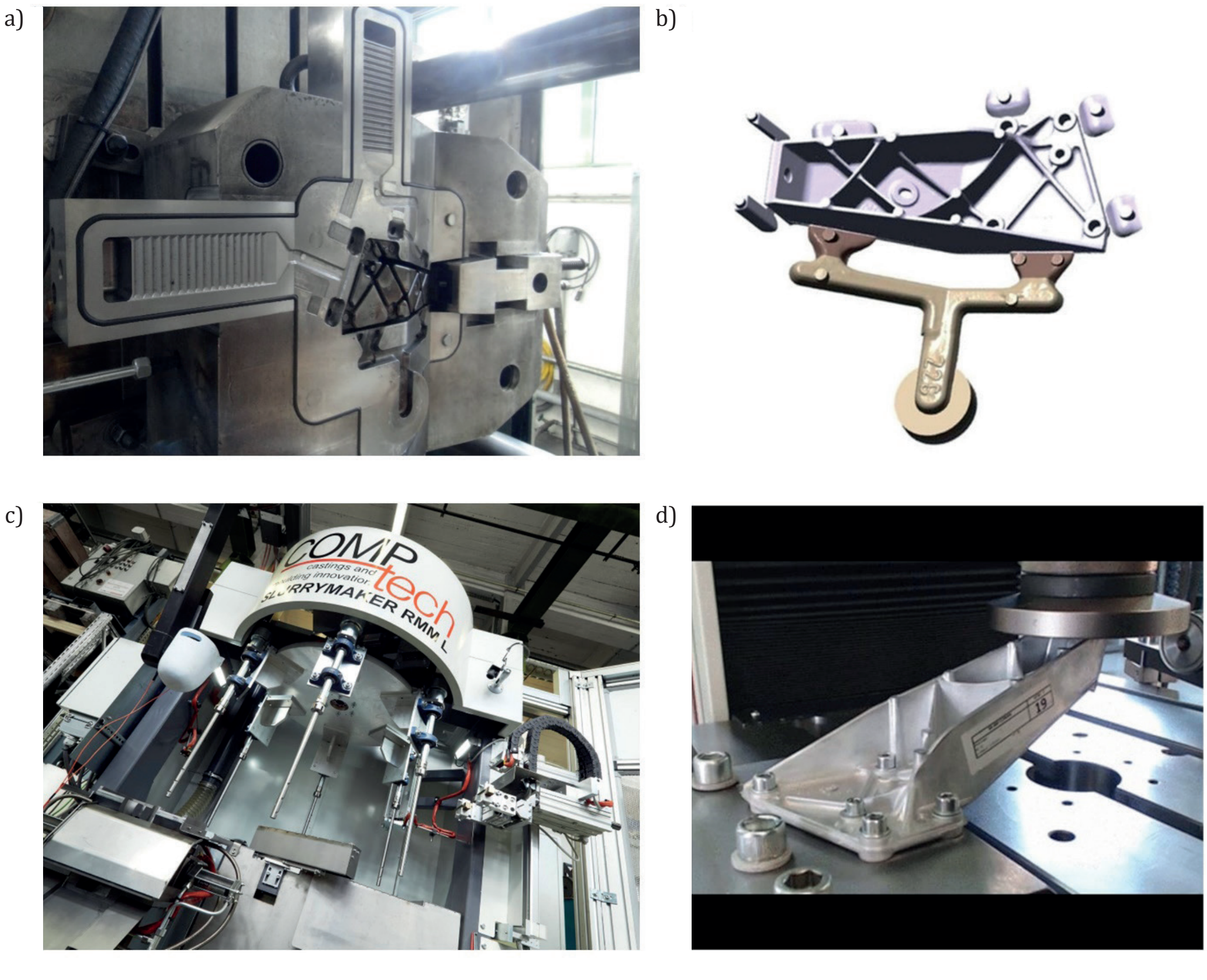

Fig. 1. Experimental facilities used in the present work: a) movable part of the mould; b) geometry of the engine mount; c) slurry maker from CompTech AB; d) engine mount component testing

3. RESULTS AND DISCUSSION

3.1. Component properties

The results of the component testing are shown in Figure 2. The compressive force of one individual casting part is shown versus punch stroke. The compressive force at a punch stroke of 15 mm was chosen for evaluation, as mentioned above; however, supporting the component on the specimen holder leads to an increase in compressive force beyond a piston stroke of 15 mm.

The results indicate that the parts produced by standard HPDC show a higher scattering compared to the parts produced by rheocasting applying the RheoMetal™ process. The mean value of the individual castings shows slightly higher component properties of the parts produced by rheocasting. The low scattering indicates that the RheoMetal™ process allows stable process conditions.

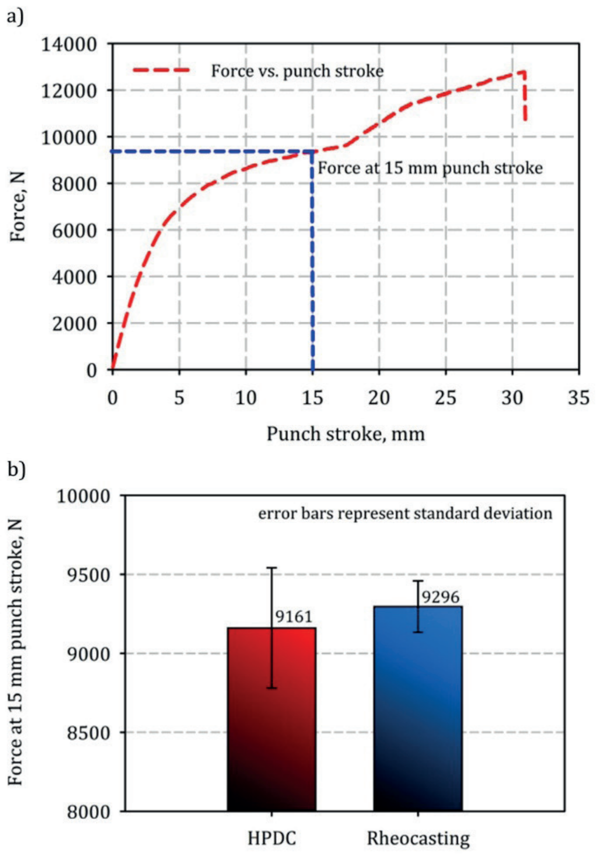

Fig. 2. Comparison of component testing between standard HPDC and rheocasting applying the RheoMetal™ process: a) schematic depiction of the compressive force vs. punch stroke; b) compressive force at 15 mm punch stroke of the individual castings produced by HPDC and rheocasting

3.2. Radioscopic examination

The results of individual castings investigated via radioscopic examination are shown in Figure 3. Oxide films and crack formation can be observed in both castings. (Fig. 3a, b for HPDC and Fig. 3c, d for rheocasting). In the HPDC part, oxide film formation can be attributed to turbulent melt flow in the region indicated by the blue arrow in Figure 3b.

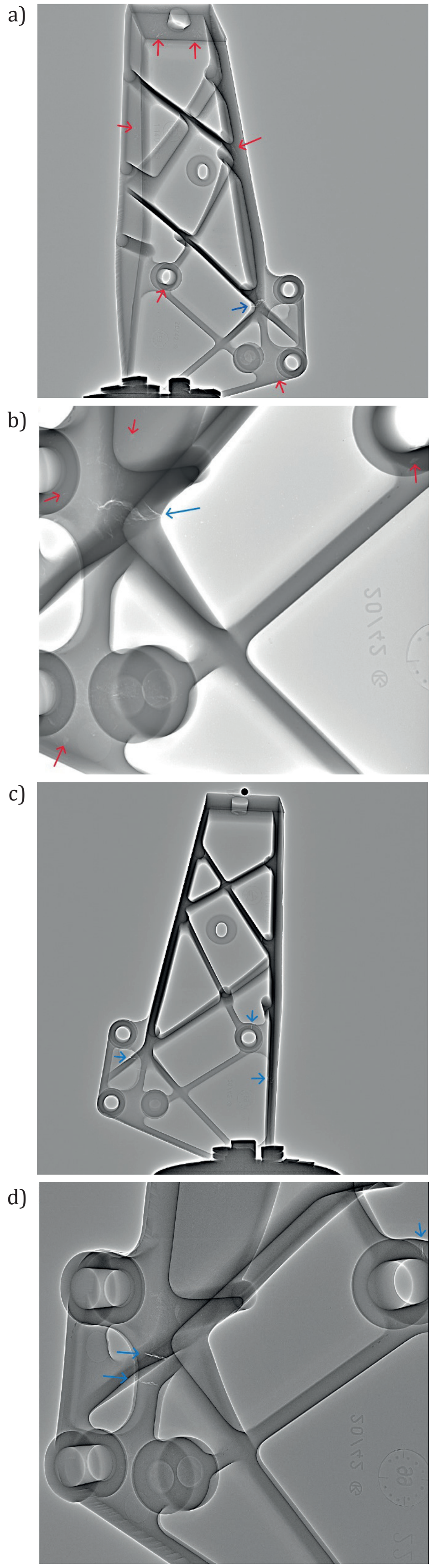

Fig. 3. Radioscopic images of individual casting parts: a) and b) standard HPDC; c) and d) rheocasting; less porosity in castings produced by rheocasting can be observed, indicated by red arrows; blue arrows indicate potential oxide films and crack formation, probably as a result of chilled melt fronts in the part produced by rheocasting

Crack formation in the part produced by rheocasting can be assumed to be a result of cold shut formation. Defects attributed to chilled melt fronts in rheocasting parts are also reported in the work by Richter et al. [8]. However, less gas porosity can be found in the part produced by rheocasting, which can be attributed to the more laminar melt flow of the rheocasting process. In the HPDC part, gas porosity, potentially associated with shrinkage porosity, is distributed across the entire component. This is also supported by the work of Granath et al. [9]. HPDC parts are prone to gas porosity, potentially connected with shrinkage porosity, whereas in parts produced by rheocasting, only shrinkage porosity potentially associated with oxide films can be observed.

4. CONCLUSION

Component testing of an engine mount was performed on samples produced by standard HPDC and rheocasting. The following conclusions can be drawn from the present work:

- Rheocasting enables a smoother mould filling compared to standard HPDC, with lower piston velocity – 0.4 m/s for rheocasting in contrast to 2.2 m/s for standard HPDC, resulting in a more laminar mould filling and less gas porosity, which also contributes to an increase in die lifetime.
- Component properties are comparable, showing a reduced scattering of the parts produced by rheocasting, indicating stable process conditions of the RheoMetal™ process.
- Lower porosity can be observed in castings performed by rheocasting.

The experimental investigations applying the RheoMetal™ process demonstrate promising outcomes and create scope for continued research and further optimisation efforts.

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DECLARATIONS

The author declares no competing interests of a financial or personal nature.

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