Viable Inorganic Binder Solutions for Ferrous Applications

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Abstract: The application of inorganic binder systems (IOBs) in serial production cores has gained significant traction in the aluminum automotive sector. However, the adoption of IOBs for ferrous applications remains limited. This study investigates the technical enhancements in IOB technology, particularly focusing on gray and ductile iron, to validate its efficacy for ferrous applications. Through semi-serial production of castings for various applications, the study demonstrates the benefits of IOBs. For ductile iron, high-quality castings can be achieved without the need for refractory coatings. Conversely, for gray iron, a waterborne coating is generally required to mitigate metal penetration. The findings underscore the feasibility of IOBs to maintain casting quality and efficiency in ferrous casting applications.

Keywords: Inorganic, Binder, Ferrous, Gray, Ductile.

1 Introduction

Inorganic binder systems (IOBs) have emerged as a well-established technology for serial production cores, particularly in the aluminum automotive sector. This success has bridged the use of these binders for core-making in ferrous applications, including gray iron, ductile iron, and steel castings. Despite their potential, the use of inorganic binder systems in ferrous foundries remains limited.

Sand cores using IOBs in ferrous applications must withstand temperatures around 1400°C, posing stringent demands. At these high temperatures, the lack of hot strength is a critical issue, as the waterglass-based binder softens due to its relatively low glass transition temperature. Additionally, the collapsibility or de-coring after the casting process becomes more challenging, requiring more complex binder system formulations. However, one significant advantage of IOBs in ferrous foundries is their lower sensitivity to veining formation.

The underlying study is dealing with the development of IOB systems for casting processes with ductile and gray iron. For ductile iron, a differential housing and a brake caliper were examined in detail, while for gray iron, a simple brake disc model was reviewed.

2 Experimental procedure

Sand mixtures were prepared using quartz sand and various inorganic binder systems, including liquid binders and powder additives. Recipes were engineered to achieve high-quality castings based on the specific requirements of the casting process and the type of metal. Laboratory-scale tests were conducted using a core shooter Laempe L1, which produces transverse bars (for strength measurements) and other small cores, such as cylinder-type cores and those for small brake discs.

Sand cores for semi-production trials were produced using a Mingzhi core shooter type 20 L, which produced cores for differential housings and brake calipers.

The ductile iron used was GJS600 for the brake calipers and GJS500 for the differential housings, while the gray iron used was GJL250 being used for brake discs.

Result and discussion

Casting trials on lab scale (GJS400-15)

Initial trials using existing IOB systems developed for the aluminum automotive sector on ferrous applications (GJS-400-15) resulted in the formation of amorphous silica deposits (see Figure 1 left IA001 0.0 wt%).

However, further laboratory tests revealed that adding a small concentration of IA001 led to a smooth, silica-free casting surface (see figure 1 middle and right) and improved collapsibility after the casting trials.

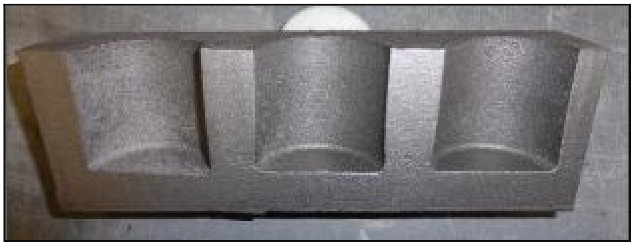

Figure 1: Casting surface after removing core residue (left: 0.0 wt% IA001; middle: 0.2 wt% IA001; right: 0.4 wt% IA0001).

Differential housings (GJS500)

Using the optimized IOB system, including a small amount of IA001 for ferrous applications, sand cores were produced using the Mingzhi 20L core shooter. Previous trials with coated sand cores, produced using the cold-box process principles, showed a smooth, sand-free and defect-free casting surface. This coating was necessary to prevent metal penetration and sand adhesion.

Figure 2: Complete differential housing (examples).

With the addition of a small quantity of the IA001, more than 100 non-coated sand cores were produced, and were casted on site. After de-coring, fettling and shot blasting, the inner surface of the castings was in all cases as-serial. Figure 2 shows two examples of differential housings.

Brake calipers (GJS600)

Ductile castings of brake calipers were manufactured without refractory coating application. After optimizing the core shooting parameters, cores were produced with smooth surfaces and no defects. Figure 3 shows a series of sand cores with on the right a macrograph of part of the inner surface of the casting.

Observations of the castings indicated no gas formation during the casting process. Other feature observed during the trials was the functional bench life of the sand mixture even after several hours, no issues occurred with manufacturing these cores: good flowability of the sand mixture, and high-quality cores with sufficient compaction and surface smoothness.

Figure 3: left: series of sand cores to be casted; right: smooth and sand-free casting surface.

Brake discs (GJL250)

Laboratory trials with small sand cores used for a simplified brake disc was coated with a waterborne dip-coating. After applying the wet coating layer, samples were dried in a pre-heated furnace set at 120 °C. No issues occurred with weakening of the cores during dipping and during the drying process. Figure 4 shows on the left 4 coated sand cores ready for casting and on the right the inner surface of the brake disc.

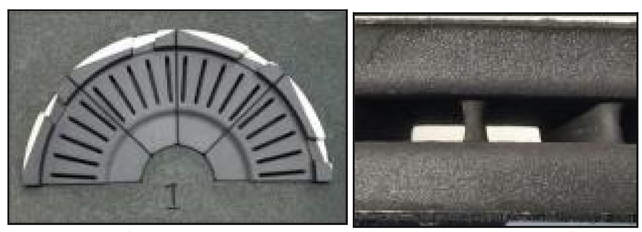

Figure 4: left: 4 coated sand cores; right: inner casting surface. Observations showed a high-quality casting surface: after easy de-coring a smooth, sand- and veining-free surface.

3 Conclusions

The findings from the presented case studies and through engineered formulations of the IOB systems, affirm the viability of IOB binder systems in ferrous applications, particularly in gray and ductile iron production. This study demonstrates that with appropriate adaptations, IOBs can produce ferrous castings with quality, consistency, and efficiency, reducing the need for refractory coatings and improving the overall work environment and carbon footprint associated to this metal casting segment.

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