A new generation of advanced polyurethane coldbox binders for aluminium castings

Introduction

When casting aluminium there are specific problems of core breakdown and removal, that are not found with ferrous castings. The lower pouring temperatures of aluminium result in lower core sand temperatures and reduced resin binder breakdown from thermal decomposition [1]. With less breakdown, the cores retain higher strength after casting and can be difficult to remove with mechanical vibration at shake-out (figure 1). Additional time and/or effort may be needed to completely remove cores from narrow passages, increasing casting costs [2]. Thin-walled castings prone to damage during shake-out and high sand-to-metal ratios can be particularly troublesome.

Complex internal cavities – difficult to shake out

Thin-walled casting and chunky core lead to poor thermal impact on the binder

Figure 1 Difficult shake-out in castings with bends and thin walls

A new class of binders have now been developed to meet the particular demands of aluminium foundries, addressing the need for improved breakdown after pouring as well as reduced emissions of hazardous compounds (figure 2).

Figure 2 Demands upon cores

Demands upon cores are:

☐ Low odour / less emissions
☐ Easy core breakdown
☐ No resin wipe off
☐ Good core release
☐ High as gassed strength
☐ Sufficient surface quality
☐ True to dimensions
☐ Low gas evolution

Health and environmental aspects have been taken into consideration and extensive studies of emission levels have been carried out during the work. Owing to a new solvent system it was possible to reduce the odour as well as lower the emissions of benzene, toluene and xylene, during the development.

Along with the development of the resins new methods to determine differences in terms of breakdown were established. Thus a reliable test, called the "dip test" was developed to determine the breakdown properties.

Experimental

The development work for a new generation of Urethane-Cold-Box-Binders focused on two major objectives: Initially the new binders had to meet the specific requirements of the Non-ferrous foundries to achieve better shakeout characteristics and secondly to reduce the environmental impact by the addition of less harmful materials.

To provide information for improved core removal a new test method had to be established which was both practical and reliable. The so-called "dip test" proved useful and is described overleaf.

The whole procedure is split into 6 steps the first three steps being as follows:

Step 1 (figure 3a) shows two dip test cores that are equal and will be tested simultaneously. The cores were produced by means of a small lab core shooter and are cylindrical but slightly conical. The density must be homogeneous and noted at the start of the test.

Figure 3a Core preparation

Step 2 (figure 3b) shows both test cores clamped in the dipping device. The cores are fixed and cannot be moved, additionally the outlet for core gases is placed in the upper part of the clamping device.

Figure 3b Clamping

Step 3 (figure 3c) shows the actual casting process. The clamping device with both cores has to be immersed into the aluminium manually or by means of an automatic device. The immersion length has to be constant and the dipping device must not be moved once it has been dipped into the melt. The melt temperature and the dipping time have to be recorded.

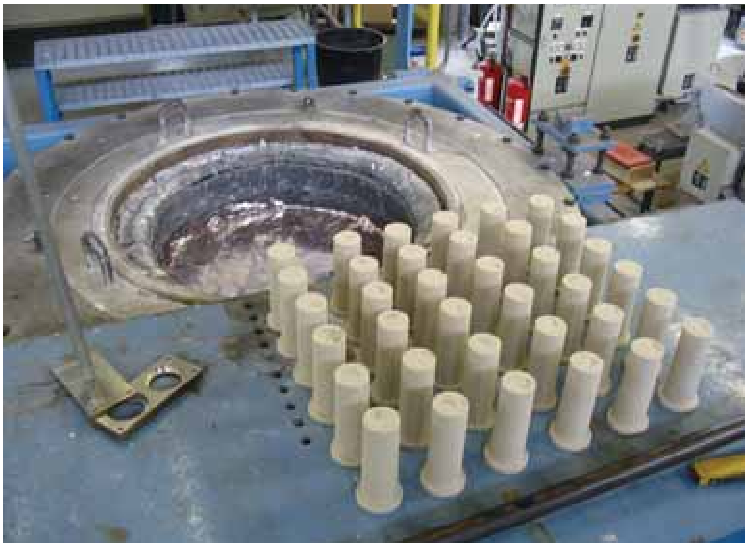

Figure 3c Casting

Additionally the evolution of gas and condensates is measured by means of the COGAS®-device (figure 4). The COGAS® equipment [3] simulates the casting process, where a test core is fully enveloped by molten metal.

Figure 4 COGAS-device for determination of gas and condensates

The gas evolved by decomposition of the organic binder is collected in a measuring tube (Figure 5a and 5b) and the quantity of gas produced during the various stages of decomposition is measured and recorded. A cooling trap precipitates condensable material, this can be weighed and analysed.

Figure 5a Clamped test core

Figure 5b Trap for condensates

Breakdown

Step 4 (figure 6a) shows two dipped cores after a given dipping time. The cores are covered with a thin layer of solidified aluminium during cooling.

Step 5 (figure 6b) has to be conducted very carefully: The dipped cores are un-wrapped, the thin aluminium foil being removed manually. It is important to remove the foil completely without damaging the core surface.

Step 6 (figure 6c) serves to assess the breakdown properties of the binder. Every core has to be brushed by means of a soft brush until every loose sand grain has been removed. This has to be done very carefully without use of any force. Afterwards every core has to be re-weighed.

Figure 6a After casting - cooling

Figure 6b Un-wrapping

Figure 6c Brushing and re-weighing

The figure to assess the breakdown is the ratio of core weight after casting divided by the core weight before treatment as a percentage. The statistical error is about ± 1,5 % related to the absolute value.

Figure 7 shows the appearance of cores made by means of a resin that has slightly better thermal decomposition properties than normal versus a core bonded with a resin from the latest development. Both cores were originally immersed for 120 s into molten Aluminium at 720 °C.

Figure 7 Stage 1 resin bonded core (left) vs. stage 2 resin bonded core (right)

Results and discussion

Figure 8 shows the results of a dip test for four different recipes. Each column shows the residual core percentage for four different dipping times from 60 to 150 seconds at intervals of 30 s.

The y-axis indicates the residual core in percent, and as described previously low figures indicate improved core breakdown.

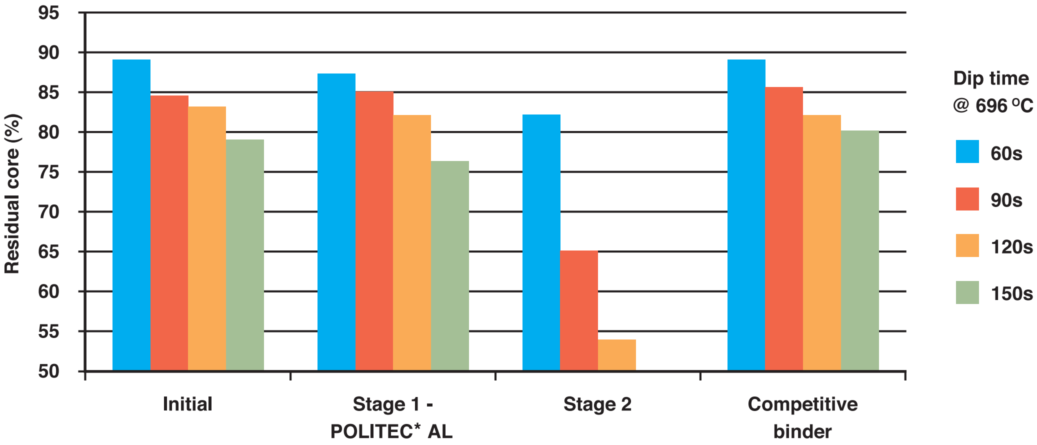

Figure 8 Breakdown properties for different binders at different dipping periods

As expected the core breakdown improves by prolonging the dipping time.
In Figure 8 the columns on the very left-hand side show the initial recipe with aromatic solvents, followed by the present low aromatic system and ending at the stage 2 low-aromatic binder with exceptional breakdown properties.

The replacement of solvents and the addition of special additives resulted in a significant improvement in breakdown performance. The reduction from 79 % residual core weight for the initial recipe after 150 s at 696 °C down to 75 % for the current system is in accordance with foundry practice where the theoretical figures were substantiated in reduced cycle time for shakeout. As is seen in Figure 8, the stage 2 resin provides a complete decomposition of the chemical bondings after 150 s.

Clearly all of the previously achieved benefits (sufficient strength, excellent core release out of the core box, and long bench life) were maintained while the breakdown properties were improved significantly and the emissions reduced dramatically.

COGAS® and environmental aspects

The binder residues collected in the cooling trap (Figure 9a) were weighed and afterwards analysed by means of the GC-MS-device shown in Figure 9b.

Figure 9a COGAS test: binder residues collected in cooling trap

Figure 9b Condensates / tar collected by means of COGAS and determined by GC/MS

Figure 10 shows the results of the quantitative determination of gas and condensates by means of the COGAS® equipment for four cores with four different binders after the immersion into molten Aluminium at 720 °C for a 3 minutes period.

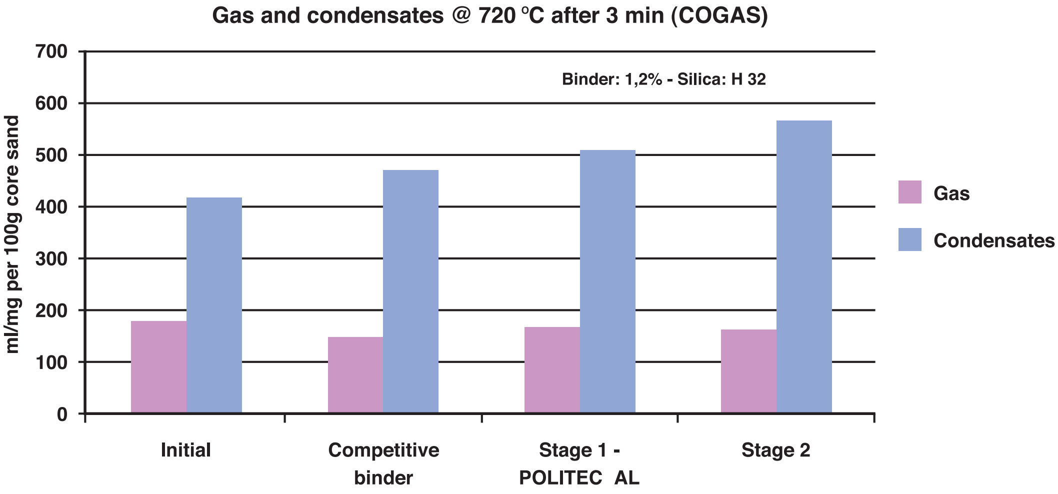

Figure 10 Slightly increased condensates due to better breakdown

Interestingly the amount of gas evolved during heating seems not to be affected by the modifications to the various binders that lead to improved breakdown, whereas the amount of condensates increased from the initial recipe with poor breakdown to the recipe with exceptional breakdown.

The loss of bonding power due to the thermal impact on the polyurethane molecule reduces the amount of binder left in the core (loss-on-ignition) at the expense of binder that has been converted either in gas or condensates.

Thus improved breakdown will always cause a difference in binder remaining in the core to an increased amount of released binder in the form of gas or condensates.

The graph (figure 11) shows significant improvement in the avoidance of harmful substances by comparing the initial recipe with aromatic solvents and the latest recipe with low aromatic solvents.

The orange (toluene) and green (m/p-Xylene) columns of the low aromatic based binder clearly indicate the successful results of the development work in order to achieve a more environmental friendly binder system, which can out-perform competitive Coldbox binders.

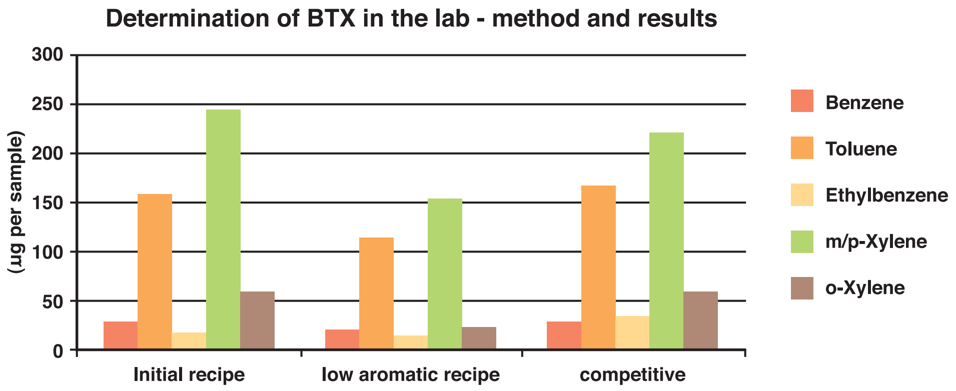

Figure 11 Determination of Benzene, Toluene and Xylene in the lab by means of gas chromatography and mass detection

Conclusion

This paper summarises the development of a new class of cold box binders for the non – ferrous foundry industry to improve both breakdown of cores after casting and improve environmental conditions.

The new binders have already proved successful at a number of foundries passing quite demanding quality control tests. Cores based on the new recipes are providing better breakdown and emmitting lower levels of harmful substances.

A “dip test”, using COGAS® equipment to measure emitted gas and condensates, has been established for quick and reliable quality control and to develop improved resins in the future.

References

1. Boenisch, D.: The Coldbox-Plus-Process: Higher Quality Cores with Lower Binder Levels , Research Development Reports 1986, RWTH Aachen

2. Simpson, B.: Recent developments in the application of the Polyurethane Cold Box process, Foundry Practice, Issue 243, p. 1-7

3. N.N.: COGAS-System, mk Industrievertretungen, Stahlhofen, 2004.