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Numerical and Experimental Analysis of Amine Flow in Foundry Sand Cores

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Extended Abstract

The PU (polyurethane) Cold Box System is a leading sand core-making technology. Sand cores are used to produce metal castings with complex internal structures. The core-making process consists of two stages: core shooting and curing [1]. In the first stage, the sand-binder mixture is filled into the cavity. The second stage is divided into two sub-stages: amine gassing and air purging. During the gassing, high-pressure compressed air carries the vaporized amine catalyst to the core box. The interaction between the amine and the sand binder initiates the polyaddition reaction, resulting in the curing of the sand in the core box. This is followed by purging, where compressed air is supplied to remove the condensed amine from the core.

In a multi-tool curing simulation study [2], the authors have identified the importance of amine and air flow on the core hardening behavior. The above study suggests that the core hardening depends on the distribution, concentration, and duration of the amine present in the local areas of the core, but does not consider the effect of the purging sub-stage. It is crucial to purge the amine from the core, as it can lead to the formation of surface defects on the respective castings [3]. On the contrary, a prolonged purging time can reduce core-making productivity.

The core hardening during gassing can be explained by the collision theory [4], which states that for the chemical reaction to occur, the particles (atoms or molecules) must collide at a certain concentration (the higher the concentration, the higher the reaction rate), with sufficient activation energy required for the transition from reactant to the product and proper particle orientation for the reaction to occur in the first place.

In order to experimentally verify the predictions made in [2] and to relate the core curing behavior to the collision theory using Arrhenius's law [5], a novel study of the polyaddition reaction time between amine and sand binders is being investigated. This study focuses only on the gassing sub-stage to explicitly investigate the amine flow and core curing behavior. A spiral core box (SCB) was designed to have unidirectional amine flow, as it can help track the amine flow and the core hardening behavior simultaneously. For comparative analysis, several numerical and experimental tests were conducted on the SCB at various sand-to-amine mass ratios of 1:0.25, 1:0.5, 1:1, 1:2, and 1:3. A standard amine concentration of up to 5% in the air was supplied at a system pressure of 1500 mbar.

Significant differences in the amount of cured core were found between the tests. Analysis of cured core quality and quantity using Arrhenius's law indicates that the observed differences in the curing behavior for different amine ratios are due to changes in the physical amine concentration in the local areas of the core during the gassing stage.

Continued research using the newly developed hybrid sensor system based on the on-line monitoring concept [6] is planned to determine the amine concentrations at the local locations in the core. Overall, these studies can enhance the understanding and further develop the curing stage in the core-making process.

Keywords
Spiral Cold Box, Fluid Flow Experiments, Core Curing Stage, Polyaddition Reaction, Sand Core Quality

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