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Increasing the Capabilities of Computer Process Modeling With Applied Programming Interface

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Abstract

Computer based process modeling has long been used for simulating the casting of metals. However, the majority of the analysis of the casting process has been limited to the metallic casting rather than the mold that contains the metal. High temperature characterization of molding materials has yielded an increased understanding of the condition of the mold and core during solidification. Properties such as thermal expansion, high temperature reactions, and changes in surface viscosity and decomposition gasses have yielded an increased understanding of the casting process. By using actual high temperature mechanical property data, the accuracy of the solidification modeling is improved and the range of capabilities is increased. The use of applied programming interface code can extend the software's capabilities and yield additional information on the condition of the mold before, during and after solidification. Although once limited in release, new versions of the process modeling software will include the capability to both optimize process variables and develop material specific datasets that increase both the accuracy and extend the capabilities of the analysis. Using applied programming interface code, the range of capabilities of the process modeling software can be extended to include information on veining defects, final casting dimensions, and decomposition gas generation.

Keywords: *Casting simulation, prediction analysis, veining, porosity, dimensional accuracy*

Introduction

Process simulation software is widely used in the foundry industry to predict and analyze the final casting integrity. Presently, the databases included in the software are generic and are limited with regards to the temperature dependent properties of sand. Improving the accuracy of the temperature dependent properties of molding materials will increase the overall accuracy of the process simulation software.

The material properties in this research were determined using a combination of direct measurement using analytical equipment and inverse optimization. Properties such as the coefficient of thermal expansion (CTE), specific heat capacity and surface viscosity were measured directly using advanced analytical techniques. Thermal conductivity, thermal diffusivity and heat transfer coefficients were determined by inverse optimization using automated software.

Veining defects are primarily seen in silica sand cores or molds, due to its thermal expansion profile. Previous research has determined that the volumetric contraction observed in silica sand after the alpha-beta phase transition at 573 C (1163 F) leads to a surface tensile stress that cause cracks in the mold or core surface [1]. The current research focuses on the use of application programming interface to predict vein strain and hence, the propensity of veining in castings. Thermal expansion data was used to calculate the differential volume in sand cores and an algorithm was developed to calculate the strain on the surface of the core at higher temperature.

Accounting for dimensional variation in castings has traditionally been performed using rules such as shrink rules, which fail to take into account the variation of the mold or core dimensions at high temperature. The current research uses a process simulation software to accurately determine casting dimensions from room temperature pattern dimensions. Although this method considers only one variable currently, it provides a valuable and for certain applications, accurate prediction of final casting dimensions.

Gas porosity in castings is often a result of gaseous combustion product from core or mold resin. A new testing methodology was developed at the University of Northern Iowa which measures the temperature dependent gas evolution based on weight loss. Although this methodology is in a developmental stage, it provides repeatable and quantifying data for gas generation due to organic sand binders.

Testing Methodology

Thermal expansion tests were run using the University's high temperature aggregate dilatometer. The samples were heated to 1650 C (3002 F) at a heating rate of 15 C per minute in a ceramic sample holder. Surface viscosity was calculated from the deformation recorded from the dilatometer. The specific heat capacity and sample weight loss was calculated using a high temperature Differential Scanning Calorimetry/Thermo gravimetric Analysis unit (DSC/TGA).

Surface strain was simulated in the MAGMASoft v4.4 casting simulation software using API functions, which uses the thermal expansion results. Dimensional accuracy of castings was calculated using thermal expansion and core displacement results from Magmasoft. Step-cone castings were poured to compare the predicted and actual results. A coordinate measuring machine was used to measure the dimensions of the cores and castings. Phenolic Urethane Cold-Box with a total resin content of 1.0%, 1.2% and 1.6% were tested for gas evolution. The sample weight loss results were used to calculate the gas evolution from the sand samples.

Discussion of Results

The vein-strain simulation and test steel casting results for baseline silica sand are shown in figures 1. The casting simulation indicates that the vein strain at the surface of the core is equal or greater to a value of 0.01 in/in. (cm/cm). If the sand at the surface fails to exhibit sufficient tensile strength, then the strain induced by the subsurface sand volume increase will raise stress above the tensile strength of the sand and cause cracking. A good correlation was observed between the predicted and actual casting results.

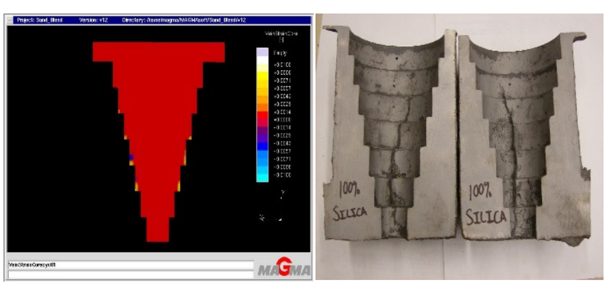

Fig. 1. Veinstrain comparison

Figure 2 shows the agreement in final casting dimensions using the modified thermal expansion data and the actual casting dimensions as determined by the CMM.

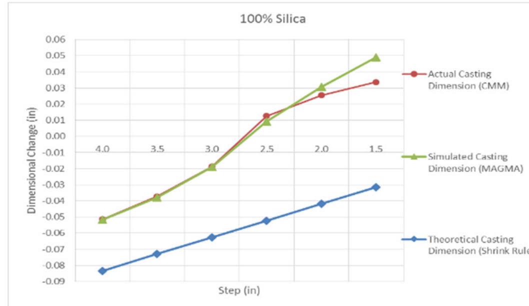

Fig. 2. Baseline silica dimensional accuracy

Figure 3 shows the comparison of gas evolution results between the traditional gas pressure tester and the new method for the 1.0% PUCB sand sample. Slight differences can be seen in between the two methods. The total gases evolved from the traditional method and the TGA method were 11.42 cc and 10.93 cc respectively.

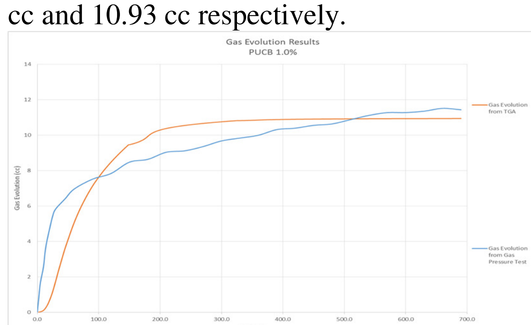

Fig. 26. Comparison of gas evolution results

Conclusion

The research demonstrated that veining defects can results from the thermal expansion of the molding aggregates. It was also shown that final casting dimensions can be estimated using accurate temperature dependent properties of molding aggregates. The measurement of the amount of gas emitted from organic material added to foundry sands based on the thermo- gravimetric analysis has the ability to directly compare various resins and organic sand additives. The results of the testing can also be used in process modeling software to serve as a predictor of gas porosity defects.

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References

1. J. Thiel, S. Ravi, Causes and Solutions to Veining Defects in Iron and Steel Castings, AFS Transactions 2014.