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Quantification and Standardization of Pattern Properties for control of the Lost Foam Metal Casting Process

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UNIVERSITY HONORS PROGRAM

SENIOR PROJECT - APPROVAL

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PROJECT TITLE: Quantification and Standardization of Pattern Properties For Control of the Lost Foam Metal Casting Process.

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

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QUANTIFICATION AND STANDARDIZATION OF PATTERN PROPERTIES FOR CONTROL OF THE LOST FOAM METAL CASTING PROCESS

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ABSTRACT

The thermal degradation of expanded polystyrene (EPS) foam patterns was studied by simulating the lost foam casting process. A LFC system was designed and built to replicate the actual process. A hermetically sealed chamber was built with the capability to measure pressure and temperature changes during the degradation process. Using a metal rod to simulate the molten metal being poured, the physical characteristics of the degraded EPS foam were determined. Varying the plunging speed, the temperature distribution of the evolved gas was determined. The results indicated that the LFC system designed was not hermetically sealed. There were numerous leaks present in the system, even after steps were taken to seal the leaks. Although the system was not adequate enough to measure pressure changes, the temperature of the evolved gas was determined. The evolved gas reached a temperature of 90°F after 510 seconds of testing.

INTRODUCTION

The lost foam casting process is a new technology that is experiencing rapid growth. This latest form of casting is commonly used in the automotive industry to produce various car parts, such as engines blocks. An expanded polystyrene foam pattern is coated with a refractory coating and is packed in sand. Liquid metal is then poured through a gating system unto the foam pattern. Upon filling, the EPS foam degrades and the metal hardens to precisely duplicate the intricacies of the foam pattern. During the degradation process there is an amount of gas evolved. The amount and composition of the evolved gas is believed to be related to the quality of the casting.

The importance of this undertaking is that no one has yet to fully understand the lost foam casting process. There is no detailed information about the chemical and physical properties of the foam during degradation. As a result industry is unable to improve the estimated that 65 percent of defected cast that results in scraps. Without a clear understanding of what happens during the process it becomes impossible for manufacturers to come up with effective solutions. It is therefore, the goal of this research project to relate the casting outcome to measured pattern properties in order to model and control the LFC process and thereby increasing the yield rate for castings and lowering the environmental burden of the LFC process.

In this study a system was designed to simulate the actual lost foam casting process in order to understand the physical properties of the EPS during degradation. The pressure changes in the system were measured in order to calculate the amount of gas evolved during the process in relation to plunging speed and temperature.

EXPERIMENTAL

Samples

The samples used in the testing were EPS foam blocks donated from Saturn Corporation, in Spring Hill, Tennessee.

Instrumentation

In order to simulate the LFC process, a system had to be built that could accurately duplicate the procedure. The system consists of a chamber built to hold the sand and the EPS foam. The chamber was designed to be hermetically sealed in order to prevent gas to escape during the degradation process. The dimensions of the chamber are 4x4x6 inches. The chamber is displayed in the following figures.

Figure 1. Picture of the chamber and valve attachments

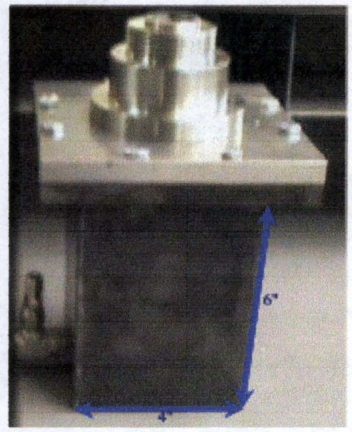


Figure 2. The chamber and its dimensions

The chamber was equipped with two valves. Valve 1 was closed initially to measure the temperature of the exiting gas prior to pressure readings to ensure that the gas temperature was less than 70°C (158°F). The temperature was determined using a thermocouple that was affixed to the chamber outlet. The thermocouple was also used to determine the temperature changes during the degradation process. Valve 2 remained close until the completion of the test, when it was opened to release the gas. To measure the changes in pressure of the system during the degradation process, a pressure transducer was attached to the system as shown below in Figure 3.

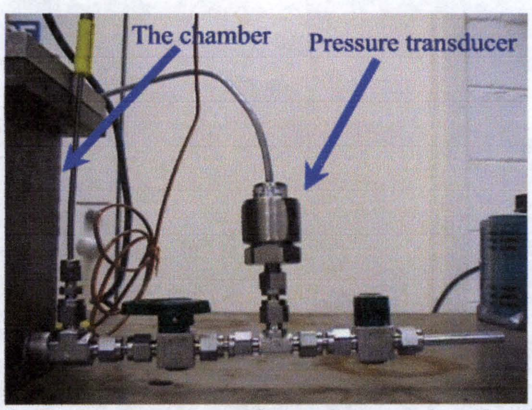


Figure 3. The pressure transducer connected to the chamber

The output of the pressure transducer was then attached to a high precision voltmeter that read 0 to 50 mv. A 5-volt DC power supply was also connected to the pressure transducer. The voltmeter was used to observe the changes in voltage during the degradation process. The voltage readings were then converted to pressure values.

In order to replicate the actual pouring of the liquid metal unto the foam, a heated metal rod was used to simulate this process. The rod was 9" in length and 1" in diameter. The metal rod was designed with a heating tube inside of it in order to have the capability of heating the rod to the desired temperatures. The heating was restricted to the end of the rod to accurately depict the liquid metal front in the actual LFC process. In order to control the temperature that the rod was heated, a thermocouple was placed inside the heating area as diagramed in Figure 4.

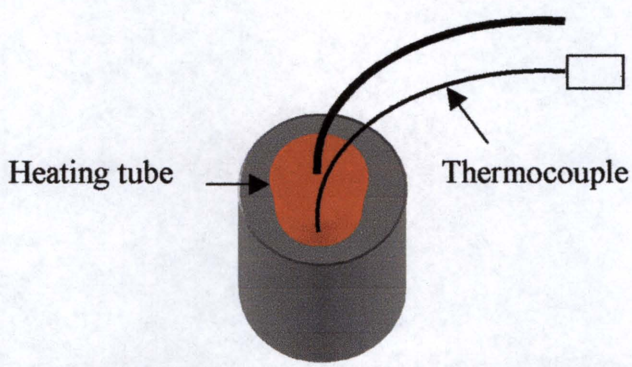


Figure 4. 3-Dimensional diagram of the inside of the heating system of the rod

In order to minimize the amount of gas that could escape during the degradation process, the top of the chamber was designed to increase the pressure around the metal rod as it is inserted inside the chamber, sealing the entire system and ensuring accurate alignment. The rod is shown in the following figures.

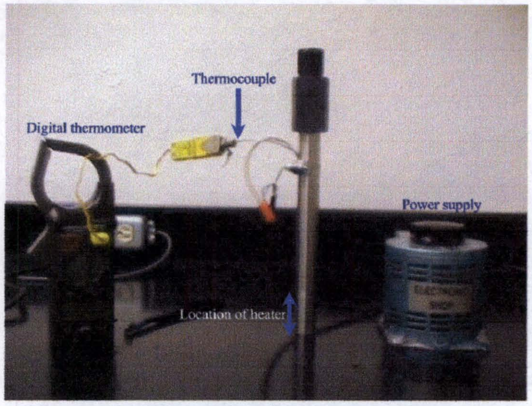


Figure 5. The rod (middle) connected to the thermocouple (left) and the power supply (right)

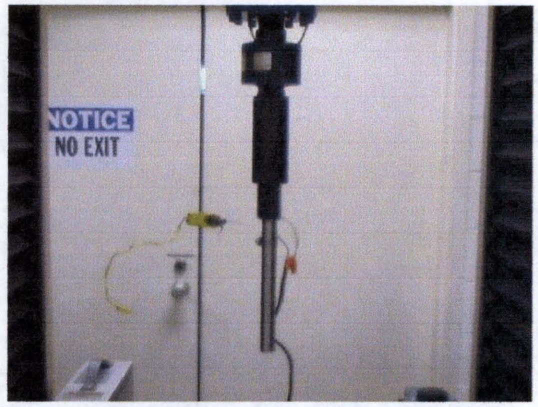


Figure 6. The metal rod attached to the SATEC machine

A SATEC® tensile testing machine was used to control the plunging velocity of the metal rod. The metal rod was attached to the SATEC® machine and the NuVision program was used to control the velocity at which the metal rod plunged the EPS foam. The NuVision program provided the capability of inputting different plunging rates of in/sec. Figure 7 shows the complete experimental setup.

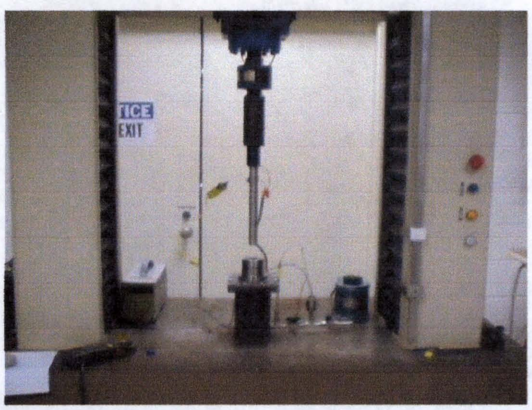


Figure 7. The experimental setup prepared for testing

Test to Determine Chamber Efficiency

Before any tests could be conducted on the LFC system, it had to be verified that the system indeed was hermetically designed and sealed vacuum tight. Tests were performed on the system to check to see if there were any leaks in the system that would cause the gas to escape.

First, the system was pressurized in order to determine if there were any leaks. From pressurizing the system, leaks were found in four corners of the chamber and on top of the chamber. These leakage areas are shown in the figures below. Figures 8 and 9 show the view of the chamber from the bottom. All four corners of the chamber were leaking; however, the most significant leaking occurred at the areas circled in Figures 8 and 9. Figures 10 and 11 are pictures of the leakage on the top of the chamber. Looking at Figure 11, one can clearly see the problem area.

Figure 8. Bottom view of the chamber, the leakage areas are circled

Figure 9. Closer view of the leakage areas

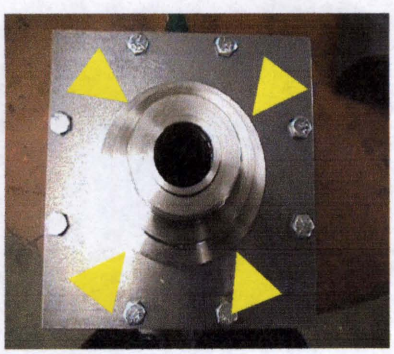


Figure 10. View of the top of the chamber where leakage occurred

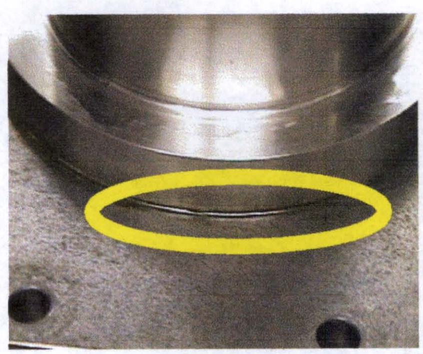


Figure 11. Closer look at the leakage area

After noticing these leaks, the areas of the chamber that had leaks were welded shut. The top of the chamber was dismantled and the screws were re-tightened and silicon seal was placed over all the screws to insure no leakage. The system was then pressurized again and there were no noticeable leaks. So the procedure was taken a step further to ensure this. The pressure was cut off and the chamber's valve was close, sealing the entire system. Now if the chamber was indeed completely sealed, the pressure would remain constant. However, after this was done the pressure dropped rapidly, drawing one to conclude that there still were leaks present in the system.

Another test was conducted this time using a vacuum. Assuming that the leaks were still from welded areas, the top of the chamber was detached and the bottom of the chamber was placed on a flat surface as shown in Figure 12, attached to a vacuum. The vacuum was turned on. Soap water was poured on top of the chamber.

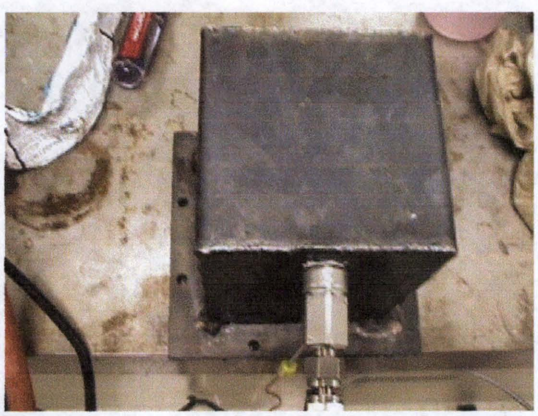


Figure 12. The chamber placed on a flat surface

Now if the chamber had leaks the soap water would start bubbling and get sucked inside the chamber. And this is what exactly occurred. Water leakage was noticed in two specific areas of the chamber as shown in the figures below.


Figure 13. Leakage area


Figure 14. Another leakage area

After this test was conducted the chamber was lifted and there was a considerable amount of water under the chamber. This is shown in Figure 15 below.

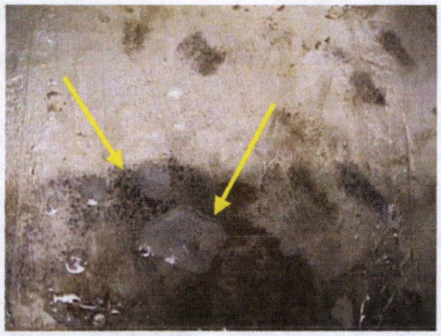


Figure 15. Water observed under the chamber

From the tests that were conducted on the LFC system, it was clear that the system designed is not adequate to perform the necessary tests one desires. The system has several significant leaks that would give us very inaccurate pressure measurements and would allow a large amount of gas evolved to escape.

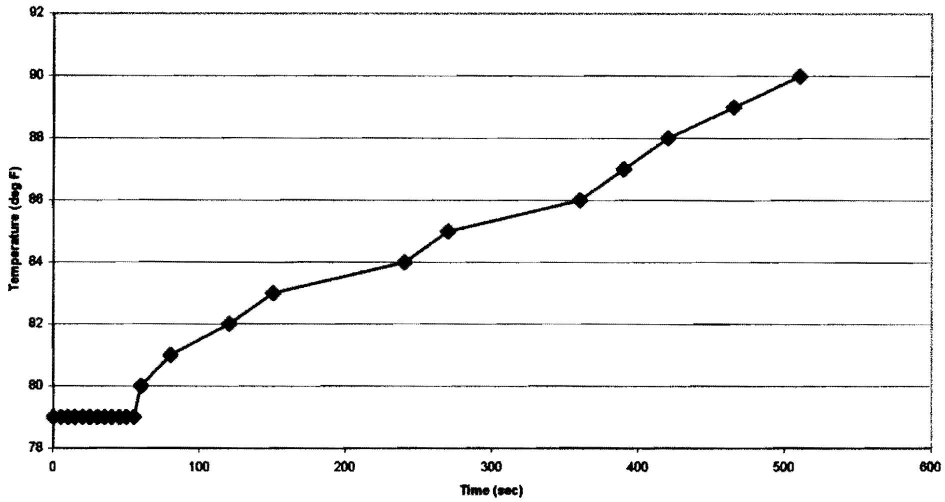
Procedure for Evolved Gas Temperature

Although we have concluded that the system was not efficient for pressure measurements, one can still perform a test using the system to determine the temperature of the evolved gas during the degradation process.

The rod was heated to an initial temperature of 700°F. The EPS sample was then loaded into the chamber and sealed. Valve's 1 and 2 were opened and a vacuum was attached to the chamber to pull and collect the gas. The rod was then lowered into the chamber at initial velocity of 0.2 in/sec. While the foam was being degraded, the temperature of the gas at the exit outlet was observed during the degradation process over a period of 510 seconds. The experiment was repeated at plunging speeds of 0.6 in/sec and 1.0 in/sec.

RESULTS

All three plunge rates had the same evolved gas temperature over time. As can be seen from Figure 14, the gas temperature is constant for the first 60 seconds, then it gradually increases. The test was stopped after 510 seconds. The temperature reached at this time was 90°F.



Temperature Distribution of Evolved Gas During Degradation

CONCLUSION

One must take into consideration that this is the starting point of a long-term process. Although the LFC design had too many leaks and was unable to measure pressure changes, the design was an efficient initial model to start from and learn through. However there is a lot of room for improvement. A system must be designed that is vacuum tight with no leaks. A new design might have to be implemented that requires little to no welding. Or one must come up with better solutions to cover up the leaks in the current system. Also, a more effective design is needed to measure pressure changes in the chamber.

One also determined that the temperature distribution of the evolved gas was equal at all three plunge rates; however, the speed ranges might have been too small to show significant changes.

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REFERENCE

Industrial Analytics Corporation project proposal