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Influence of Pattern Geometry and Pouring Temperature on Fluidity in the Expendable Pattern Casting Process

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ABSTRACT

This report is an extension of the paper "Influence of Pattern Geometry and other Process Parameters on Mold Filling in the Aluminum EPC Process", by Yuan Sun, Hai-Lung Tsai and Donald R. Askeland (2). The increase in fluidity in the expendable pattern casting (EPC) process with pattern perimeter, volume to surface area (V/A) ratio, and pouring temperature was studied for a 700°C-900°C temperature range and for both aluminum and cast iron.

INTRODUCTION

Fluidity is the ability of liquid metal to flow and fill details in a mold. This paper deals with the first aspect of fluidity--the flow of liquid metal through a large cross-sectional area, or flowability. An equation that predicts the fluidity of liquid metal in the conventional empty mold casting process was developed by M. C. Flemings, E. Niiyama, and H. F. Taylor (1). It predicts that flowability is directly proportional to superheat and also to the ratio of the cross-sectional area to the perimeter of the cavity being filled. This ratio is approximately equal to the V/A ratio.

Like in conventional empty mold casting processes, fluidity increases with increasing pouring temperature and V/A ratio in the EPC process. It has also been observed that fluidity in the EPC process is related to the perimeter of the mold being consumed. The increase in flowability with increasing perimeter suggests that a controlling factor determining the flow of liquid metal in the EPC process is the production and elimination of gases, produced when consuming the mold (2).

Fluidity in this report is defined as the maximum height reached by the liquid metal in a rectangular pattern.

PRELIMINARY TESTS

An experiment was performed repeating the procedure followed in the paper "Influence of Pattern Geometry and other Process Parameters on Mold Filling in the Aluminum EPC Process" (2). The aluminum 319 experiment, was done in order to compare the results obtained in that paper with those presented here. A gating system composed of an 8 in. tall circular pouring cup, 13 in. x 1.25 in. x 1.88 in. rectangular sprue, and four 1 in. x 0.5 in. x 5 in. runners was used. The cross sectional area of the gates was 0.15 in2. A low permeability silica (Styro Kote 20.1) refractory coating was applied to the gating system by brushing and to the molds by dipping. 1.2 EPS foam was used to prepare the molds. The pouring temperature was 800°C, and the V/A ratio of the four rectangular molds ranged from 0.050 to 0.059. A bottom gating system was used. The dimensions of the patterns are presented in Table 1.

TABLE 1. PATTERN GEOMETRY

V / A	THICKNESS (in.)	WIDTH (in.)	HEIGHT (in.)
0.050	0.125	0.50	18
0.055	0.125	1.00	18
0.058	0.125	2.00	18
0.059	0.125	3.00	18

The results of the experiment are presented in Figure 1. The graph shows the high dependence of fluidity on the geometry of the mold, in particular to the perimeter. A mechanism to explain this phenomenon has been suggested (2) in which the products of mold decomposition in the EPC process escape through a small gap between the liquid metal front and the polystyrene left in the mold. If this is the case, fluidity should be almost directly proportional to the perimeter of the mold, if the mold is relatively thin.

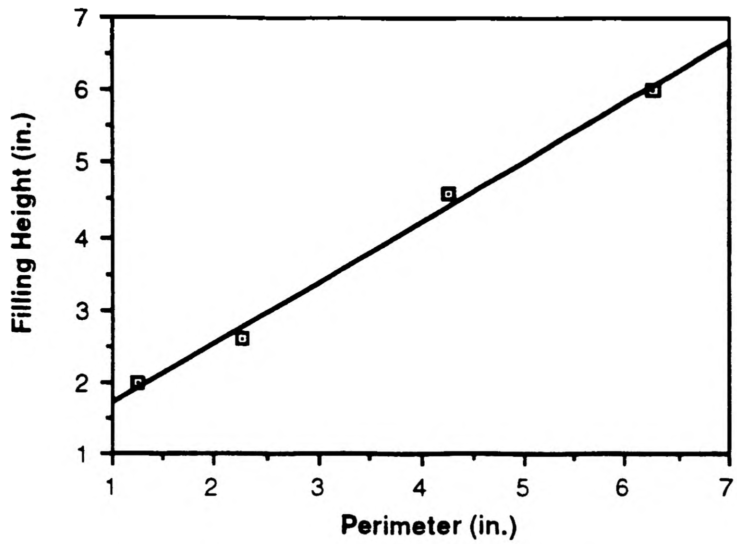

Figure1. The effect of pattern perimeter on fluidity

EXPERIMENTAL PROCEDURE

Five more experiments were performed, three with aluminum 319 and two with gray cast iron. The dimensions, material, and coating (Styro Kote 20.1) on the gating system were the same as those used in the preliminary test. The experimental setup and dimensions are shown in Figure 2. The only change made to the gating system, as compared to the one used in the preliminary test, was in the way the runners were glued to the sprue (see Figure 2). This change was made so that the liquid metal burning the mold would come in contact with the same amount of glue in the same position, and therefore its advance would be stopped by the same amount of time. This allowed for a more objective comparison between the molds.

To investigate the effect of superheat on fluidity, aluminum 319 castings of a V/A ratio ranging from 0.050 to 0.059 were poured at 700°C, 800°C, and 900°C. The dimensions of the molds can be found in Table 1. A low permeability silica coating (Styro Kote 20.1), applied by dipping, and a 1.2 EPS foam were used to produce the patterns.

In order to determine if the behavior observed for aluminum still holds at higher temperatures, two experiments were performed with gray cast iron. The composition of the gray cast iron was 3.5% carbon and 2.1%

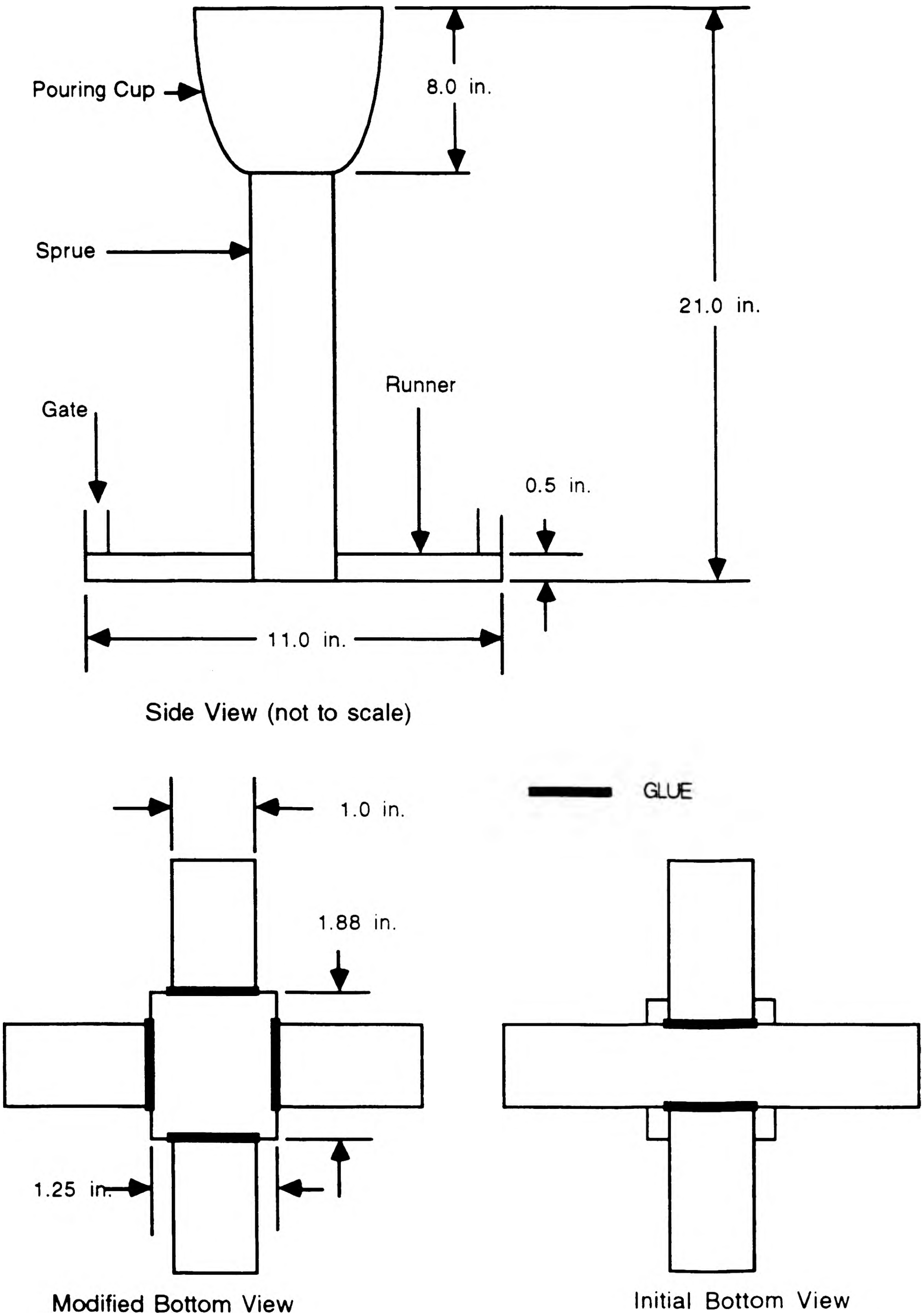

Figure 2. Experimental Setup

Si. This corresponds to a carbon equivalent of 4.2%. The 70 lb. of gray cast iron were prepared by melting 61.25 lb. of pig iron, then adding 6.34 lb. of steel (assumed to contain no carbon), heating to 2500°F, and adding 1.95 lb. of 50% FeSi. The liquid metal was tapped into the pouring ladle at 2600°F, while 0.46 lb. of inoculant (0.5% Si) was added to the stream. Finally, the gray cast iron was poured into the mold at a temperature of 2330°F.

Since limited information was available on the behavior of cast iron in the EPC process, two different V/A ratios were used. In the first experiment, V/A ratios ranging from 0.050 to 0.059 were used; the dimensions for the molds in this experiment are listed in Table 1. Table 2 lists the dimensions of the patterns used in the second experiment. The V/A ratios ranged from 0.080 to 0.087. A low permeability silica (Styro Kote 20.1) coating and a 1.2 EPS foam was used in both experiments.

TABLE 2. PATTERN GEOMETRY

V / A	THICKNESS (in.)	WIDTH (in.)	HEIGHT (in.)
0.080	0.188	1.20	18
0.083	0.188	1.60	18
0.085	0.188	2.40	18
0.087	0.188	3.00	18

RESULTS AND DISCUSSION

Figures 3 to 5 show the dependence of fluidity on the perimeter of the pattern. The almost linear dependence suggest that the flow of metal is controlled by the escape of the gases produced by the decomposition of the foam, probably through a narrow gap in the coating between the liquid metal front and the solid foam.

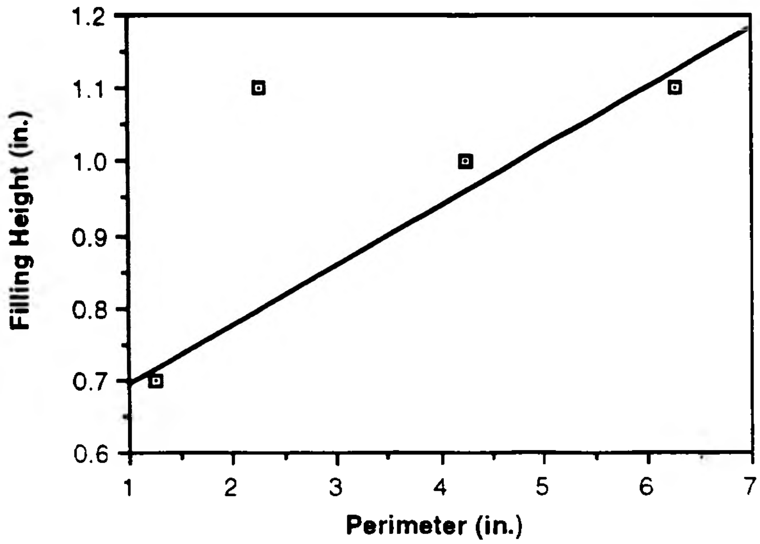

Figure 3. Perimeter vs. Fluidity in aluminum. Pouring Temperature 700 C.

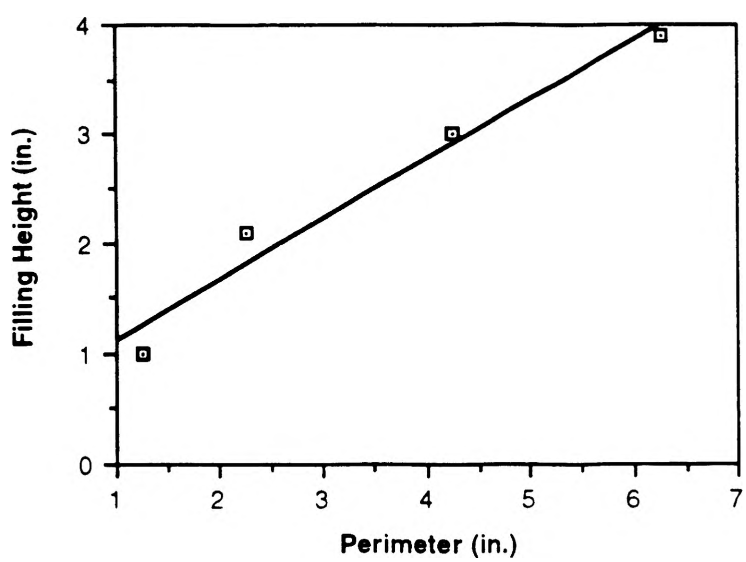

Figure 4. Perimeter vs. Fluidity in aluminum. Pouring Temperature 800 C.

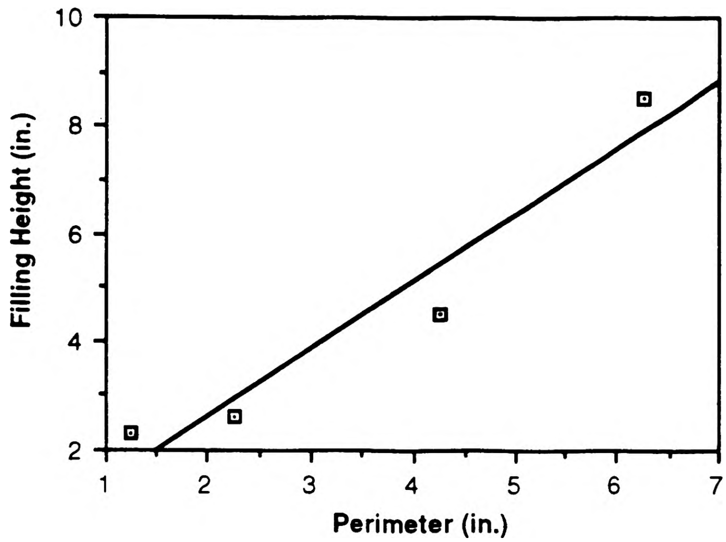

Figure 5. Perimeter vs. Fluidity in aluminum. Pouring Temperature 900 C.

The deviations from a straight line can be a result of an uneven amount of glue being used. The effect of the glue on fluidity has been shown to be a critical factor.

To see the effect of the pouring temperature on fluidity, the results shown in the three previous graphs have been combined and plotted in Figure 6. Fluidity and superheat are almost linearly related, as in the conventional empty mold process. The increase in fluidity with increasing temperature seems to be more dramatic as the perimeter of the pattern increases. This suggests that at higher temperatures the foam decomposes faster, but the perimeter controls how fast gases can escape. Therefore both the rate of production and elimination of gases are crucial factors governing the flow of liquid metal in the EPC process.

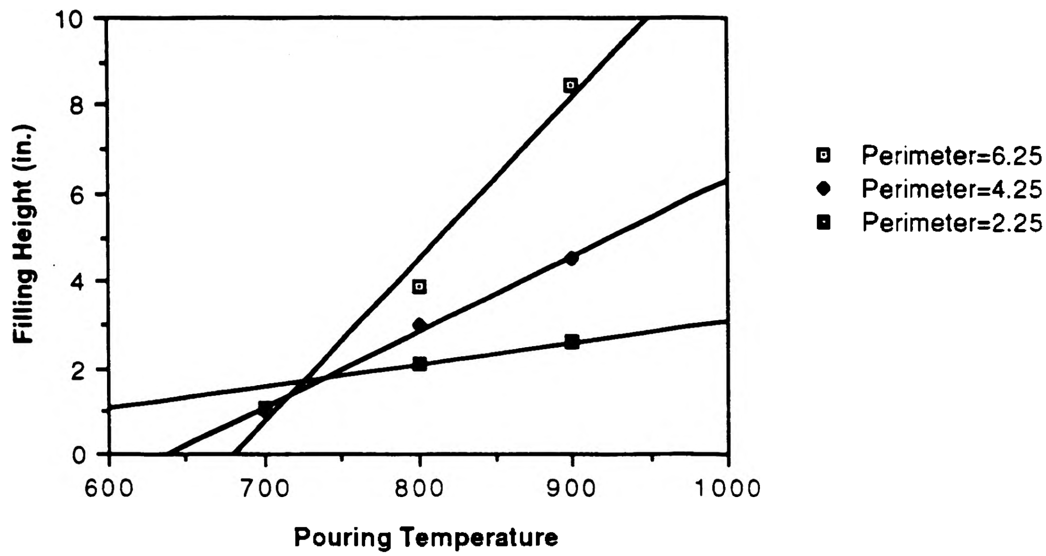

Figure 6. Effect of Pouring Temperature on Fluidity

The results obtained for both experiments performed with gray cast iron are shown in Figure 7. As expected, the fluidity of the cast iron increased with increasing pattern perimeter, holding the V/A constant. The fluidity also increased slightly with an increase in V/A ratio. This last result may indicate that another factor controlling the flow of metal may be its cooling rate. The longer the metal takes to reach a critical temperature, where it is no longer capable of decomposing the foam, the higher its fluidity. It's interesting to note that the plates made of cast iron show cracks at the end and a poor surface finish close to the metal front; this suggests that the flow of the metal was turbulent. The turbulent flow may have been caused by the high rate of production of gases due to the high temperatures necessary to melt cast iron.

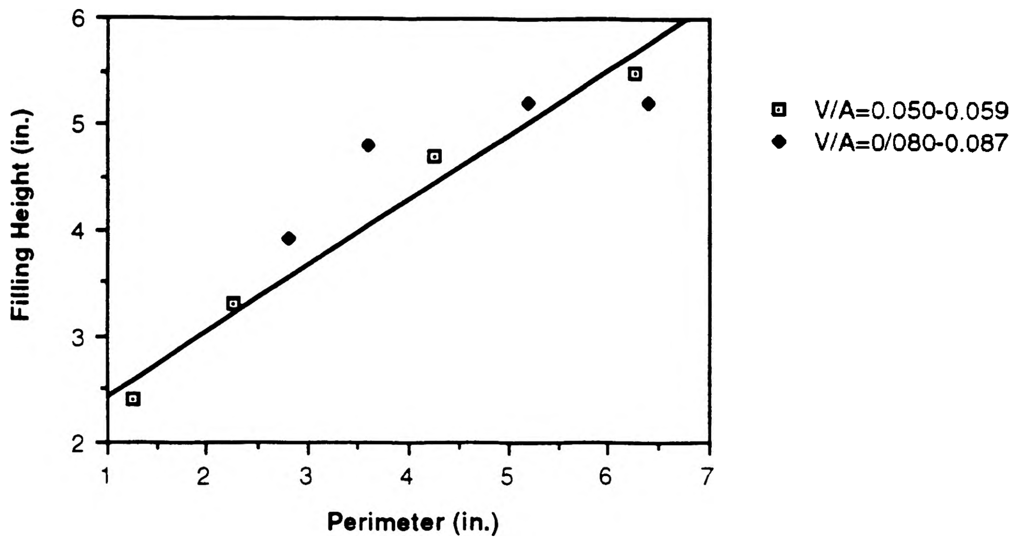

Figure 7. Perimeter vs. Fluidity. Cast Iron, Pouring Temperature 1300 C.

The effect of the V/A ratio on fluidity was investigated by interpolating the data presented in the article "Influence of Pattern Geometry and other Process Parameters on Mold Filling in the Aluminum EPC Process" (2). A constant perimeter of 4.5 in. was selected and a plot of V/A against Fluidity was made (Figure 8). The graph shows that fluidity is almost linearly related to V/A ratio, an effect which is also observed in the conventional empty mold casting process. The graph shows that the production and elimination of gases in the EPC process are not the only parameters controlling the flow of the liquid metal; the heat transfer is also a critical factor. The V/A ratio may also be a measure of the speed at which gases are produced, compared to how fast they can escape. The production rate is related to the area of the metal front, while the rate of escape of the gases is proportional to the perimeter of the pattern.

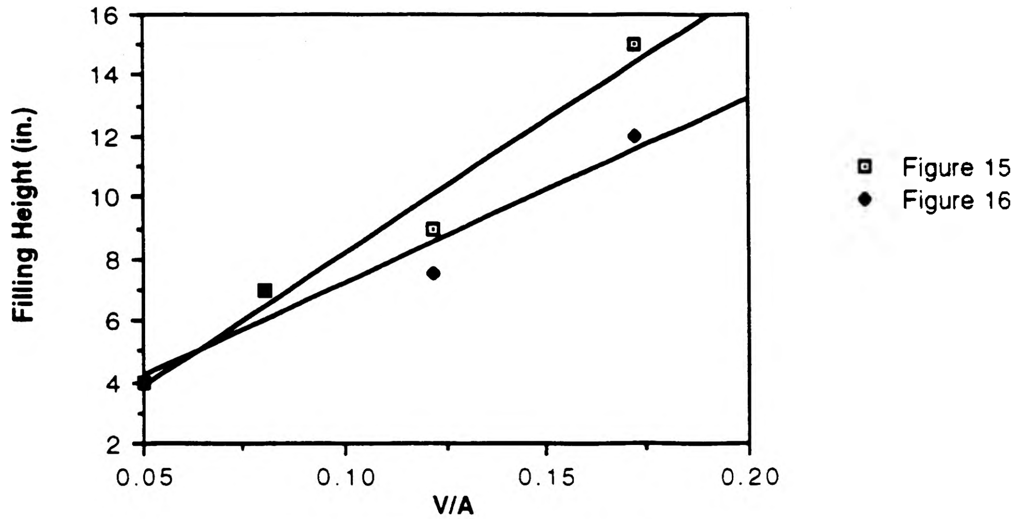

Figure 8. The Effect of The V/A Ratio on Fluidity

The figures mentioned in the graph refer to the figure from which the data was obtained in the original paper. In Figure 15, a 1.3 EPS foam with a high permeability dipped alumina coating (Styro Kote 270) was used, while in Figure 16, (1.3 EPS foam) a low permeability dipped silica coating (Styro Kote 20.1) was applied.

CONCLUSION

The flow of metal in the EPC process seems to be controlled by both heat and mass transfer. The temperature controls how fast the decomposition products are produced, the V/A ratio controls how fast the metal cools down, and the perimeter how fast the gases can escape. The V/A may also be a measure of how much gas is produced compared to the area available for these gases to escape. Fluidity in the EPC process seems to be proportional to the V/A ratio and the perimeter of the pattern. It also increases linearly with pouring temperature.

ACKNOWLEDGMENTS

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REFERENCES

1. M.C. Flemings, E. Niiyama and H.F. Taylor, "Fluidity of Aluminum Alloys", AFS Transactions. Vol 69, pp 625-635 (1961).

2. Yuan Sun, Hai-Lung Tsai, Donald R, Askeland, "Influence of Pattern Geometry and other Process Parameters on Mold Filling in the Aluminum EPC Process".