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Vacuum Tank Design Requirements

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Abstract:

Gas/air porosity constitutes a large part of the total porosity. To reduce the porosity due to the gas/air entrainment, vacuum can be applied to remove the residual air in the die. In some cases the application of vacuum results in a high quality casting while in other cases the results are not satisfactory. One of the keys to the success is the design of the vacuum system, especially the vacuum tank. The present study deals with what are the design requirements on the vacuum system. Design criteria are presented to achieve an effective vacuum system.

Introduction

The mechanical and thermal properties of parts produced in pressure die casting are often compromised by high porosity. Gas/air porosity contributes a significant part of the total porosity (shrinkage can also cause some porosity. A possible solution to reduce or eliminate this porosity is to apply vacuum and extract gas before it has the opportunity to mix with the liquid metal. Experiments (Booth 1992) have shown that commercial vacuum tank are insufficient for this purpose. Thus, die casters do not fully utilize vacuum systems. Air inclusion is significant for large parts where the pressure in the vacuum tank attains its critical value (or higher) for a large portion of the plunger stroke, and hence, the vacuum system capacity to extract air is reduced to a fraction of its potential. The aim of this paper is to study the relationship between the characteristic of a die cast system to the required vacuum tank.

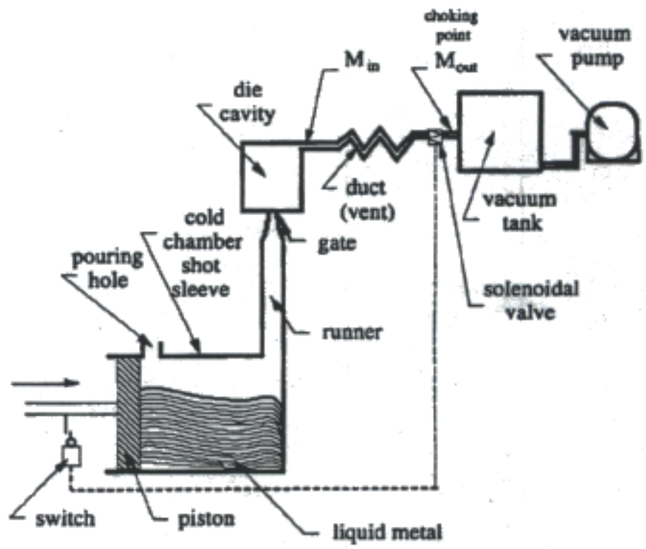

Figure 1 A schematic of an actual vacuum venting in pressure die casting arrangement

The non-continuous demand of vacuum (about 10 to 50 milliseconds compared to 1-2 minutes of a die casting cycle) suggests a system in which the pump is not directly connected to the cavity, but rather to a large vacuum tank which is connected to the die cavity (see Figure 1).This arrangement allows an efficient use of a smaller pump. An analysis (Bar-Meir, Eckert and Goldstein, 1996) indicates that to maximize the utilization of the vacuum, the pressure in the tank has to be lower than the critical value which is a function of the resistance in the vent design, 4fL/D. This value can be achieved either by installing a large vacuum tank or by increasing the vacuum. Large vacuum (low absolute pressure) is expensive to maintain and it is cheaper to build a larger vacuum tank. The authors (1996) have shown that the actual arrangement can be transformed to a simpler model and yet adequately represent the physical phenomena for a well designed runner and vent systems (see Figure 2).

It was suggested in the past (Bar-Meir, 1995) to use mass conservation. More conservative approach is to use energy conservation which permits comparison between states at two times, the opening of the vacuum valve and blockage (freezing) of the vent. In this case the heat transfer into and from the vacuum tank during this period is negligible, the air leakage into the tank and the die cavity is assumed to be neglected. Thus, the conservation equation can be written as the following.

$$[E_2 - E_1]_{tank} = E_{in} \qquad (1)$$

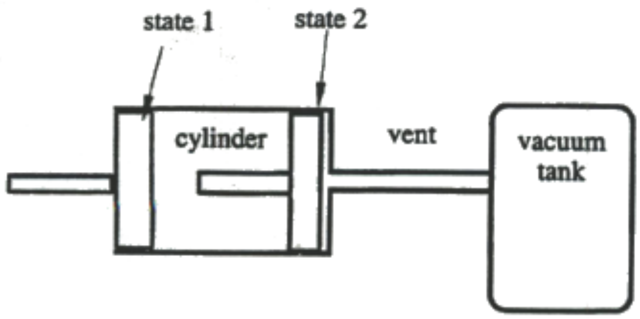

Figure 2 A schematic of the air volumes before and after the injection

Equation (1) states that the difference between the final energy and the initial energy is equal to the inflow energy. It was shown (Bar-Meir, 1995; Bar-Meir, Eckert and Goldstein, 1996) that the air/gas flow from the cylinder to the vacuum tank at constant flow rate, temperature and pressure (1atm). Hence, equation (1) can be rearranged,

$$[m_2 C_v T_2 - m_1 C_v T_1]_{tank} = m_{in} C_p T_{in} \qquad (2)$$

Utilizing the ideal gas model, the fact that the inflow is from the cylinder, and rearranging equation (2) yields

$$\frac{V_{tank}}{V(0)} = \frac{kP_{atm}}{P\left(\frac{4fL}{D}\right) - P_{vacuum}} \qquad (3)$$

where V(0) is the cylinder volume (unfilled shot sleeve, runner and die cavity.) The maximum pressure, P(4fl/D), in the vacuum tank is a function of 4fl/D and can be easily calculated Shapiro 1953 (see Figure 3a).

Results and Discussion

The results are presented in Figure 3b. As it was shown here the controlling parameter is the resistance in the vent system as represented by 4fL/D. The ratio of the required vacuum tank to cylinder (unfilled shot sleeve, runner and die cavity) volumes based on the energy equa-

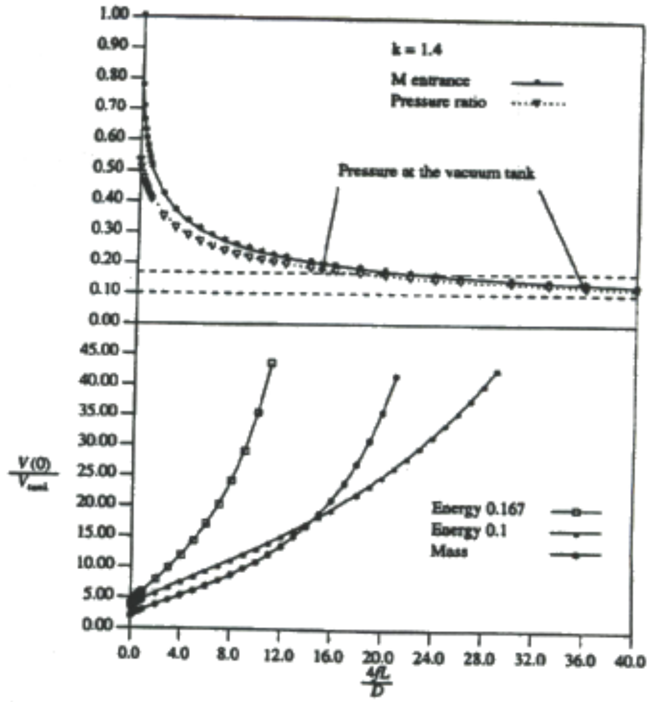

Figure 3 The ratio of the volumes as a function 4fl/D

tion is presented in of Figure 3b. The results for the energy equation are presented for two minimum vacuum tank pressures 0.167 atm and for 0.1 atm. The results (V(0) / V_{tank} obtained from the mass conservation also presented. As it can be observed, the ratio increases as the resistance in thevent system resistance increases. This increase is augmented as obtained by the energy conservation. The required volume ratio is not as large when the vacuum pressure is increased. Additionally, the ratio has to take into consideration the gas/air leakage and thus the ratio has to increase above the values given in Figure 3b. When the pressure in the vacuum tank is increased, the required volume does not increase as much as for a lower vacuum.

bibliography

1.Bar-Meir, G. 1995 On gas/air porosity in pressure die casting.

PhD thesis, University of Minnesota.

2.Bar-Meir, G., Eckert, E., and Goldstein, R.-J. 1996 Pressure die casting: A model of vacuum pumping. Journal of Engineering for Industry, 118:001 — 007.

3.Booth, S.E. 1992 Cookson technology centre. private communication.

4.Shapiro, A.H. 1953 The Dynamics and thermodynamics of Compressible Fluid Flow, volume I. John Wiley and Sons, New York.

Bibliographs

1. Genick Bar-Meir, E.R.G. Eckert, Goldstein, J. Richard, "On Gas/Air Porosity in Pressure Die Casting " PhD. thesis University of Minnesota, 1995, Dec,doi:10.5281/zenodo.5791072 url:https://doi.org/10.5281/zenodo.5791072

2. Bar-Meir, Genick, E. R. G. Eckert, R. J. Goldstein "Pressure Die Casting: A Model of Vacuum Pumping" may, 1996, 118, 2, p 259–265, Journal of Manufacturing Science and Engineering, doi:10.1115/1.2831019, url:https://doi.org/10.1115%2F1.2831019

3. Booth, S.E. 1992 Cookson Technology Center, Private communication

4. Shapiro, Ascher H. "The dynamics and thermodynamics of compressible fluid flow." New York: Ronald Press (1953).