(90) Simulation of the Drainage of Two Liquids from a Blast Furnace Hearth

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I. Introduction

Previous studies on blast furnace liquid drainage have been undertaken with one liquid (1-4). These studies illustrated the fundamental factors which influence the drainage of the single liquid, but neglected the important influence of the second liquid phase and the subsequent interaction between liquid phases. The present work describes experimental and theoretical studies on the drainage of two immiscible liquid phases which simulate the flow of slag and metal.

II. Experimental Work and Theoretical Development

The study was undertaken on a two-dimensional Hele-Shaw apparatus (5) of geometry similar to that used in previous drainage studies (3,4). The dimensions of the apparatus were 0.8m wide and 0.6m high and glycerol and mercury were used to simulate the slag and metal phases respectively. The shapes and positions of the air-glycerol and glycerol-mercury interfaces as a function of time were measured photographically for a variety of drainage conditions. These results were compared with theoretical simulations, where the two liquids were assumed incompressible and of constant density (ρ_1, ρ_2) and viscosity (μ_1, μ_2). The gas-liquid and liquid - liquid interfaces were assumed to be abrupt and the hydraulic potential in each liquid was defined as:

$$\phi_i = \frac{p}{\rho_i g} + y \qquad i = 1,2 \qquad -(1)$$

The porous medium was assumed homogeneous and isotropic so that the hydraulic potential in each phase obeyed Laplace's equation:

$$\nabla^2 \phi_i = 0 \qquad i = 1,2 \qquad -(2)$$

At the gas-liquid interface, $y = h_1(x,t)$, the pressure was assumed constant (1) and across the liquid-liquid interface the pressure is continuous:

$$p_1 = p_2 \qquad -(3)$$

and the normal components of fluid flux are equal:

$$K_1 \frac{\partial \phi_1}{\partial n} = K_2 \frac{\partial \phi_2}{\partial n} \qquad -(4)$$

The above equations were solved numerically to yield the positions of both fluid-fluid interfaces as a function of time.

III. Results

A comparison between an experimental result and the theory is shown in figure 1.

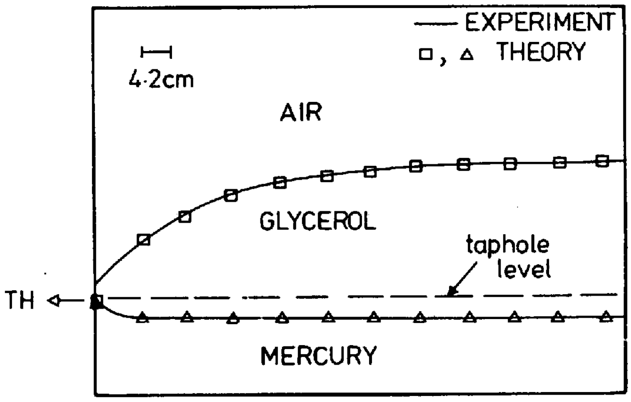

Figure 1. Comparison between theoretical and experimental surface contours for glycerol and mercury drainage in a Hele-Shaw apparatus.

The study revealed two important phenomena affecting liquid drainage. Firstly drainage of metal proceeded even when the average metal surface was substantially below the taphole level. This phenomenon was caused by pressure gradients developing within the draining glycerol phase. Secondly, "viscous fingering", resulting from instabilities in the air-glycerol interface, was observed when the velocity of the interface was high. This occurred when the drainage rate of glycerol or mercury was high and the latter was observed to occur when the initial mercury level was well above the tap point. The growth of the instability was most rapid in the vicinity of the taphole and this resulted in high residual glycerol volumes. These results have assisted in the analysis of an operating blast furnace.

IV. Conclusion

Drainage of two liquids has been studied experimentally and theoretically. The results have shown liquid interactions are important in the drainage process.

V. References

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