COMPARISON OF ACOUSTIC AND CONVECTIVE DRYING

N. N. Dolgopolov, S. G. Simonyan, and B. I. Artamonov

Inzhenerno-Fizicheskii Zhurnal, Vol. 13, No. 4, pp. 575–576, 1967

UDC 66.047.37

An investigation is carried out into the process of the drying of a ceramic disk involving the use of an acoustic field produced by a gas-jet emitter fed by hot air (up to 140° C).

It has been demonstrated in a number of studies that the greatest intensification of the acoustic drying process is achieved when a moist material is subjected simultaneously to acoustic oscillations and heating by means of convective [1], conductive [2], infrared [3], and high-frequency [4] methods.

However, application of the indicated combined methods requires rather cumbersome equipment.

Particular interest has been expressed in the combination of two drying methods in a single apparatus.

Below we present the results from an experimental investigation of the acoustic drying process in which hot air was used to feed the gas-jet emitter.

Ceramic disks 120 mm in diameter and 20 mm thick were used for the experiment, and these had an initial moisture content of 0.34 kg/kg.

To ascertain the effect of the acoustic oscillations produced by the gas-jet emitters (with the latter fed with heated air) on the moist capillary-porous material, we set up an experimental installation which made it possible to carry out the drying operation in the presence of acoustic oscillations and without the latter (with conventional convective drying).

The installation (Fig. 1) consisted of air heater 1 with spiral 2 and regulating transformer 3; chamber 4 with gas-jet emitter 5 and specimen 6; manometer 7, flowmeter 8 and thermocouples with secondary instrument 9.

Two series of experiments were carried out: convective and acoustic drying.

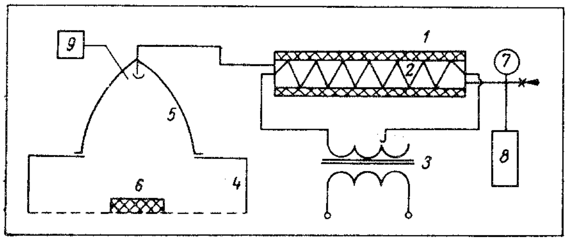

Fig. 1. Experimental apparatus.

Identical hydrodynamic conditions of flow past the specimen being dried were achieved by maintaining the air flow rate in the acoustic and convective drying at a constant 115 m^3/hr. In the case of acoustic drying this corresponded to a sound-pressure level of 160 dB at the emitter (at an air temperature of 20° C). In the convective-drying experiments, the whistling of the gas-jet emitter was recorded.

The air temperature was established by varying the voltage to the electric air heater by means of the regulated transformer and it was maintained for each series of experiments at levels of 20, 70, and 140° C.

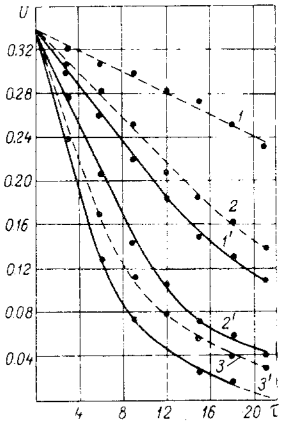

Fig. 2. Convective (1, 2, 3) and acoustic (1', 2', 3') drying of a ceramic disk at air temperatures of 20, 70, and 140° C, respectively (U, kg/kg; τ, min).

The moisture content was determined by weighing the specimen on analytical scales.

Figure 2 shows the curves of convective and acoustic drying of the specimen for various air temperatures.

Comparison of the convective curve (1) and acoustic curve (1') for drying at 20° C shows that the drying rate in the latter case is greater by a factor of 2.5 (with a change in the moisture content from 0.34 to 0.24 kg/kg). At 70° C the rate of acoustic drying (2') is greater than the rate of convective drying (2) by a factor of 2.2. With a higher temperature (140° C) the effect of acoustic drying (3') in comparison with convective drying (3) is diminished. Here the rate of acoustic drying is greater than convective drying by a factor of only 1.4.

REFERENCES

1. S. G. Simonyan, Sb. trudov VNII novykh stroitel'nykh materialov, no. 2, (10), pp. 34–35, 1965.

2. Yu. Ya. Borisov, N. N. Dolgopolov, and S. G. Simonyan, Akusticheskii zhurnal, vol. XI, no. 3, 1965.

3. N. N. Dolgopolov and S. G. Simonyan, Sb. trudov VNII novykh stroitel'nykh materialov, no. 2, (10), pp. 14–21, 1965.

4. S. G. Simonyan and N. N. Dolgopolov, IFZh [Journal of Engineering Physics], **10**, no. 4, 1966.

13 February 1967

All-Union Scientific-Research
Institute for New Structural
Materials, Moscow

SOLIDIFICATION OF A KILLED-STEEL INGOT

A. A. Zborovskii

Inzhenerno-Fizicheskii Zhurnal, Vol. 13, No. 4, pp. 577–580, 1967

UDC 536.421.4

An approximate solution is presented for the problem of the thickness of the diffusion boundary layer on solidification of a killed-steel ingot under conditions of natural thermal-melt convection.

The distribution of a soluble admixture in the case of normally directed crystallization, as is well known, is given by the effective distribution coefficient determined by Burton-Prim-Slichter [1]:

$$k = \frac{k_0}{k_0 + (1 - k_0)\exp(-\Delta)}, \tag{1}$$

where $\Delta = f\delta/D$, while the equilibrium distribution coefficient $k_0 = C_S/C_0$.

Of the three fundamental parameters f, δ, and D that determine the normalized rate of growth Δ and, consequently, the effective distribution coefficient k, the growth rate f, and the diffusion factor D in the liquid are generally known. If the conditions of the liquid flow for the solidification of the alloy are known, it is theoretically sometimes possible to calculate the thickness δ of the diffusion boundary layer. Solutions have been obtained for the thickness δ of the diffusion layer at the end of a single-crystal axis on vertical extraction from the melt [1] and with concentrated natural convection of the melt [2], defined by the differing density of the liquid in the boundary layer enriched by an alloying admixture, and in the main mass of the melt. Analogous solutions for heterogeneous transformations in a liquid, not accompanied by heat liberation, are given by Levich [3].

As we demonstrated earlier [4–6], the solidification of a killed-steel ingot is accompanied by the natural thermal convection of the melt, when the colder layers of the metal at the crystallization front, enriched with solid-phase nuclei, sink down, displacing the warmer but less dense layers of the melt upward along the axis of the ingot. The calculation of the diffusion-layer thickness under the conditions of natural thermal convection merits attention.

The integral balance equation for the admixture in the volume of the boundary layer [2]

$$v_n C_l^0 = \frac{d}{dx}\int_0^l C_l v\,dy + fC_s, \tag{2}$$

where the upper integration limit l is greater than both the thickness of the diffusion (δ) and the hydrodynamic (δ_0) boundary layers.

If we neglect the local values in liquid density and the difference between the densities of the liquid and solid phases, the velocity v_n of the liquid influx to the boundary layer normal to the solid-liquid interface is defined by the equation for the conservation of mass

$$v_n = \frac{d}{dx}\int_0^l v\,dy + f. \tag{3}$$

From (2) and (3) we obtain

$$f(C_l^0 - C_s) = \frac{d}{dx}\int_0^l (C_l - C_l^0)\,v\,dy. \tag{4}$$

The upper integration limit l can be replaced by δ, since when $y > \delta$, $C_l - C_l^0 = 0$.

Thus,

$$f(C_l^0 - C_s) = \frac{d}{dx}\int_0^\delta (C_l - C_l^0)\,v\,dy. \tag{5}$$

For an approximate solution of (5) let us express the velocity of the liquid flow in the case of natural thermal convection [7] and the distribution of the admixture concentration in the boundary layer [1] in the following form:

$$v = v_1 \frac{y}{\delta_0}\left(1 - \frac{y}{\delta_0}\right)^2 \text{ for } 0 \leqslant y \leqslant \delta_0, \tag{6}$$