INTERPRETATION OF INTERFEROGRAMS IN STUDIES OF GASEOUS IMPURITY CONCENTRATION

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Relations are given for interpreting interferograms in terms of concentrations. The correction for achromatic fringe displacement is given for an air-carbon dioxide mixture determined on an IZK-454 interferometer.

Interferometers with large field diameters (up to 230 mm) can be used to study the laws of diffusion of gaseous impurities by an optical method. For this purpose, a model of the object to be observed is placed in one limb of the interferometer.

The interference pattern observed with the interferometer adjusted to give fringes of finite width, or the pattern with fringes of equal slope, gives a clear representation of the variation of concentration in an isothermal model from line to line, since the distortion of a fringe corresponds to the variation in concentration of the impurity in question. When the interferometer is adjusted to fringes of infinite width, the lines on the interferogram will join points of equal concentration.

The distortion of bands of equal slope and the appearance of bands of equal thickness are due to the difference in optical ray path length in the limbs of the interferometer [1]:

$$d\delta = l dn. \tag{1}$$

We shall express the difference in path length in (1) in terms of the number of bands affected by the displacement, and the refractive index in terms of the volume concentration of one of the components. Then, for a two-component gas mixture, the basic differential equation relating the displacement of the interference pattern with concentration and the refractive indices of the components will have the form:

$$\lambda dN = l d[n_1 + k_2(n_2 - n_1)]. \tag{2}$$

The refractive index of each of the components is determined by the temperature and pressure. When the temperature and pressure are known and steady within the limits of the experiment, the displacement of the bands will be determined solely by the concentration of the impurity. Integrating the left hand side of (2) from $N = N_1$ to $N = N_2$, and the right-hand side from $k_2 = K_1$ to $k_2 = K_2$, we obtain

$$K_2 = K_1 + \frac{\lambda(N_2 - N_1)}{l(n_2 - n_1)}. \tag{3}$$

Thus, the concentration of the investigated component in the mixture is linearly related to the displacement of the bands on the interferogram.

On the basis of (3), we can determine the impurity for any of the bands of "equal concentration," if the concentration at one of them is known. Accordingly, a reference point is fixed on the model, and an achromatic band is established as a point of departure for a system of known impurity concentrations. Then the achromatic band is displaced and brought back to the reference point with a compensator, a counter on the compensator determines the number of bands affected by the displacement and hence from (3) the impurity concentration.

For interpreting interferograms with bands of equal slope, Eq. (3) is written in the form

$$K_2 = K_1 + b\frac{\lambda}{l(n_2 - n_1)}, \tag{4}$$

where

$$b = d/B.$$

Let us evaluate the ability of the IZK-454 interferometer to determine the concentration of carbon dioxide in an air-CO_2 mixture. The refractive indices of air and carbon dioxide are given by the relations [2]:

$$n_a = 1 + 0.000294 \cdot 273p/1013T, \tag{5}$$

$$n_{CO_2} = 1 + 0.0004505 \cdot 273p/1013T. \tag{6}$$

Substituting (5) and (6) in (3), we obtain, for $\lambda = 5.46 \cdot 10^{-4}$ mm (green light):

$$K_2 = K_1 + \frac{1300}{l}\,\frac{T}{p}(N_2 - N_1). \tag{7}$$

Under normal conditions, the "value" of one band is

$$K = 375/l\,(\%). \tag{8}$$

Since the reading accuracy on an interferogram is 0.1 of a band [1], the minimum change of concentration that may be determined on the interferogram is

$$K_{\min} = 37.5/l\,(\%). \tag{9}$$

As there is air in the interferometer compensator, in an investigation of concentration fields the dispersion of the compensator is not equal to that of the medium studied [4]. In this case the zero maximum (when the picture is examined in white light) for wavelength λ_m will not coincide with the maximum for λ_r or λ_v. It will therefore be colored. At the same time a white band will appear among the other bands of the interferometer picture at the point where the maxima for λ_r and λ_v coincide. This new achromatic band will be displaced relative to the true position by a certain number of bands. The displacement will be the greater, the greater the difference in dispersion between the compensator and the medium investigated. The displacement of the achromatic band was determined experimentally for an air-CO_2 mixture in an IZK-454 interferometer, using a Zabelin compensator. The value of this displacement, referred to a path difference of one band in the limbs of the interferometer, was 1.025 units.

We carried out a number of experiments and obtained interferograms for the admission of carbon dioxide gas to the equipment. Figure 1 shows an interferogram with lines of equal concentration. A stream of carbon dioxide was supplied to a model 200 mm long, open at the ends. A channel 250 mm long, filled with carbon dioxide, is shown in Fig. 2. It is closed at the ends by glass guard plates. Air from the room enters the channel through slits located in the lower wall. The photograph was taken with adjustment for bands of equal slope.

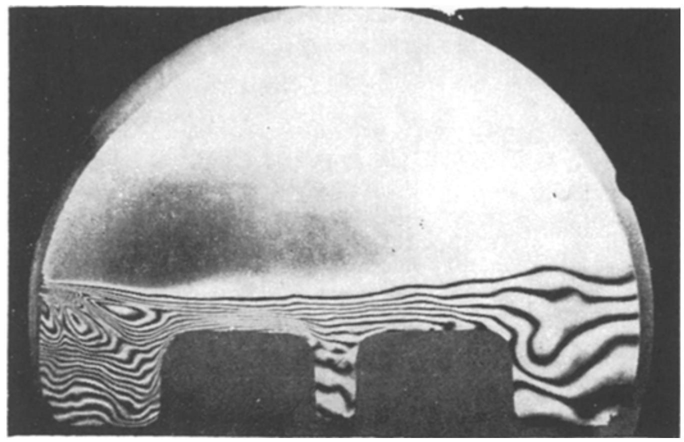

Fig. 1. Interferogram with carbon dioxide being supplied to the model. The photograph is taken with adjustment for bands of equal concentration.

A knowledge of methods of interpreting concentration interferograms considerably widens the scope of the interferometer in studies of thermal processes. By simulating heat transfer processes with mass transfer processes, thermal research may be done on models with guard glasses at room temperature. There is then no distortion of the interferometer picture due to heating of the glass and variation of its optical properties. The use of guard glasses eliminates the errors due to end effects in studying heat transfer processes in open models.

Fig. 2. Interferogram with air entering a model filled with carbon dioxide. The photograph is taken with adjustment for bands of equal slope.

NOTATION

δ – ray path difference in interferometer; l – ray path length in medium investigated; n, n_1, n_2 – refractive indices of mixture and each of its components; k_2 – concentration of component 2 in mixture; K_1, K_2 – concentration of component at different points in field investigated; N, N_1, N_2 – number of bands by which interferometer pattern is displaced; λ – wavelength of light (subscripts r, v, and m denote respectively red, violet, and mean for white light); b – relative distance between points on band of equal slope; d – distance between points on band of equal slope; B – width of band; T and p – temperature and pressure in space investigated.

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