RADIATION OF A PERFORATED CYLINDER

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The generalized zonal method is used to find the energy radiated by a perforated cylinder. The existence of a range of geometric optical parameters is established, wherein the perforated cylinder radiates more energy than a continuous cylinder.

We will consider a cylindrical surface uniformly perforated by orifices. We will find the resultant energy flux (or surface density) radiated by the cylinder at specified temperature, optical properties, and surface geometry.

We make the following assumptions: 1) the cylinder is infinitely long; 2) the unperforated portion of the cylinder is diffuse-gray and homogeneous; 3) the surfaces, inner surface 1 and outer surface 2, are isothermal while T1 = T2 = T > 0; 4) the medium is diathermal.

We close the surfaces 1, 2 of the perforated cylinder with a coaxially located black (ε = 1) continuous cylindrical surface 3 of arbitrary diameter D3 and temperature T3 = 0°K. We now apply the generalized zonal method of [1] to this system of surfaces.

For the resultant fluxes from each zone, we obtain the following expressions:

\[ Q_{f1} = -\varepsilon_1 E_{13} \Phi_{12} (1 - \beta) F_0, \]
\[ Q_{f2} = -\varepsilon_2 E_{13} \Phi_{23} (1 - \beta) F_0, \]
\[ Q_{f3} = E_{13} (\varepsilon_1 \Phi_{31} + \varepsilon_2 \Phi_{32}) F_3, \]

where \( \gamma^{-1} = 1 - R_1 \Phi_{11} \); \( E_{13} = \sigma_0 T^4 \); \( \beta = 1/F_0 \); F is the area of the perforations; \( F_0 \) is the geometric area of the cylinder surface.

In Eqs. (1)-(3) the mean angular radiation coefficients (ARC) \( \Phi_{jk} \) can be expressed in terms of the average ARC \( \Phi_{11} \) of the perforated cylinder itself with the aid of the closure and reciprocity equations. Thus, the problem reduces to determination of \( \Phi_{11} \).

It follows from the physical meaning of the mean angular radiation coefficient that

Fig. 1. Ratio of energy radiated by perforated cylinder to energy radiated from continuous black cylinder; 1) function $\varepsilon_{ef}(\beta_{\text{max}})$; 2) $\varepsilon_{ef}(\beta)$.

Fig. 2. Ratio of energy fluxes radiated by perforated and continuous cylinders, the function $\varepsilon_{ef}/\varepsilon_2$.

Fig. 3. Ratio of energy fluxes of outer (curves $\varepsilon_{ef2}/\varepsilon_2$) and inner ($\varepsilon_{ef1}/\varepsilon_1$) surfaces of perforated cylinder to energy flux of solid cylinder. Curve 1, $\varepsilon_{ef1}/\varepsilon_1$ vs $(\beta_{\text{max}})$.

Fig. 4. Ratio of energy radiated by inner surface of perforated cylinder through orifices $\beta$ to energy radiated by outer continuous surface of area $\beta F_0$.

\[ \varphi_{11} = 1 - \beta. \]

Using this value for $\varphi_{11}$, for the remaining mean ARC's appearing in Eqs. (1)-(3) we will have

\[ \varphi_{13} = \beta; \quad \varphi_{23} = 1; \quad \varphi_{31} = \xi (1 - \beta); \quad \varphi_{32} = \xi (1 - \beta), \]

where $\xi = D/D_3$. Substitution of Eq. (5) in Eqs. (1)-(3) produces

\[ Q_{f1} = -\varepsilon_1 a_0 T^4 (1 - \beta) F_0 = -\varepsilon_1 a_0 T^4 F_0, \]

\[ Q_{f2} = -\varepsilon_2 a_0 T^4 (1 - \beta) F_0 = -\varepsilon_2 a_0 T^4 F_0, \]

\[ Q_{f3} = \varepsilon_2 a_0 T^4 (1 - \beta) \left( 1 + \frac{\varepsilon_1}{\varepsilon_2} \beta \gamma \right) F_0 = \varepsilon_2 a_0 T^4 F_0. \]