USE OF ELECTROMAGNETIC PYROMETERS FOR MONITORING
EQUIPMENT TEMPERATURES IN CASTING SHOPS

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It is important to monitor the temperature of steel parts in casting shops by contactless methods; this is particularly so in regard to moving equipment, which is involved in the production of molds or rods, or directly in casting, as in pressure diecasting.

An analysis has been given [1] for the systematic errors in optical methods of measurement in such shops; however, the errors arising from the blackness of the radiation from the metal surface are related to the degree of oxidation, the absorption of radiation, the scattering by dust, and other factors, so such methods cannot be efficiently used in casting shops on a number of materials.

Temperature measurements are performed by means of the correlations between the parameters of electromagnetic fields encompassing part of the component and the parameters of the part itself, such as the electrical conductivity and bulk magnetic susceptibility, which are temperature dependent. We have also examined the effect of the temperature of the equipment on an electromagnetic primary transducer with a U-shaped magnetic conductor at a distance up to 10 mm above the surface of the equipment.

When the electromagnetic primary transducer is collected in the bridge circuit, the ratios of the real and imaginary parts of the out-of-balance voltage to the input voltage are

\[
R_e = \frac{E_0}{E_{in}} = \frac{1}{2} \frac{R \Delta R + \omega L \Delta L}{R^2 + L^2 \omega^2},
\]
\[
I_m(\frac{E_0}{E_{in}}) = \frac{1}{2} \frac{R \omega \Delta L - \omega L \Delta R}{R^2 + L^2 \omega^2},
\]

where \( R \) and \( \omega L \) are the resistive and reactive impedances of the primary transducer when the object is present, when the initial values of the distance and temperature are such that the bridge is balanced. One of the main disadvantageous factors influencing the transducer parameters is variation in the gap between the transducer and the object to be measured. Figure 1 shows the observed relationship between the output voltage from the bridge and the specimen temperature when the gap varies, the initial parameters being \( T = 200^\circ C \) and \( d = 10 \) mm. The real and imaginary voltage outputs of the unbalanced bridge are as follows as functions of temperature:

\[
R_e = \frac{E_0}{E_{in}} = b_{11} \Delta d + b_{12} \Delta T,
\]
\[
I_m(\frac{E_0}{E_{in}}) = b_{21} \Delta d + b_{22} \Delta T,
\]

Fig. 1

where

\[
\begin{align*}
b_{11} &= \frac{1}{2} \frac{Ra_{11} + \omega LA_{21}}{R^2 + L^2 \omega^2}; \quad b_{12} = \frac{1}{2} \frac{Ra_{12} + \omega LA_{22}}{R^2 + \omega^2 L^2}; \\
b_{21} &= \frac{1}{2} \frac{Ra_{21} - \omega LA_{11}}{R^2 + \omega^2 L^2}; \quad b_{22} = \frac{1}{2} \frac{Ra_{22} - \omega LA_{12}}{R^2 + \omega^2 L^2};
\end{align*}
\]

and \(a_{11}, a_{12}, a_{21}, a_{22}\) are coefficients dependent on the material of the object, which respectively are

\[
\begin{align*}
a_{11} &= \frac{\Delta R}{\Delta d}; \quad a_{12} = \frac{\Delta R}{\Delta T}; \quad a_{21} = \frac{\omega \Delta L}{\Delta d}; \quad a_{22} = \frac{\omega \Delta L}{\Delta T}.
\end{align*}
\]

The relationships shown in Fig. 1 indicate that changes in temperature and distance cause unbalance voltages that differ in phase. The ratio of the unbalanced voltage \(E_0\) to the input voltage \(E_{in}\) is expressed by (1) and (2) as

\[
\frac{E_0}{E_{in}} = b_{11} \Delta d + b_{12} \Delta T + j (b_{21} \Delta d + b_{22} \Delta T)
\]

and the ratio is as follows to the input voltage when the distance and temperature vary:

\[
\frac{E_0}{E_{in}} = \sqrt{\frac{(b_{11}^2 + b_{21}^2)}{\Delta d} \Delta d} e^{j \arctg \frac{b_{11}}{b_{12}}} + \sqrt{\frac{(b_{12}^2 + b_{22}^2)}{\Delta T} \Delta T} e^{j \arctg \frac{b_{22}}{b_{21}}}.\quad (3)
\]

This unbalance voltage may be expressed in relation to a reference voltage in such a way that the projection of the components dependent on the distance change on one of the axes for the reference voltage in (3) will equal zero and the unbalance voltage will be influenced only by the projection of the temperature component on this axis. Then the ratio of this voltage \(E_0\) to \(E_{in}\) (3) may be put as

\[
\frac{E_0}{E_{in}} = \sqrt{b_{11}^2 + b_{21}^2 \Delta d} e^{j \left( \arctg \frac{b_{21}}{b_{11}} - \arctg \frac{b_{12}}{b_{11}} \right)} + \sqrt{b_{12}^2 + b_{22}^2 \Delta T} e^{j \left( \arctg \frac{b_{22}}{b_{12}} - \arctg \frac{b_{21}}{b_{11}} \right)} + j \sqrt{b_{12}^2 + b_{22}^2 \Delta T} \sin \left( \arctg \frac{b_{22}}{b_{12}} - \arctg \frac{b_{21}}{b_{11}} \right).
\]

Fig. 2