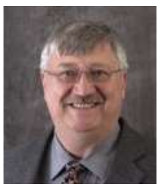
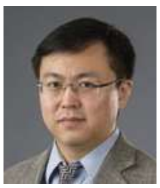
Distributed Temperature Monitoring of Tundish Refractory Lining Using Optical Fiber Sensors



Distributed temperature monitoring can provide useful insights into thermal conditions in the continuous caster tundish that can affect operating stability and cast quality, such as pre-heat conditions, superheat uniformity, fill height and refractory wear. In the current study, fiber-optic sensors were embedded into the refractory lining of a lab-scale tundish to record the temperature profiles during dry-out, pre-heating and direct molten steel exposure to demonstrate sensor performance. Additional trials were performed with fiber-optic sensors embedded in an industrial tundish used in production. The results demonstrate that fiber-optic sensors using Rayleigh technology can provide accurate distributed temperature measurements in refractory-lined vessels and provide useful information about the process.

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Experimental Methodology and Implementation

Rayleigh Optical Frequency Domain Reflectometry (OFDR) Sensing Principles

The Rayleigh OFDR system's operation is based on the collection and analysis of Rayleigh backscattering signals from single-mode optical fibers. Microscopic changes in the refractive index (RI) profile are caused by inherent inhomogeneities in the material of optical fibers. A single-mode optical fiber's core inhomogeneities cause light to be scattered, which gives the fiber its own distinctive Rayleigh signature. Rayleigh OFDR sensing is based on the distinct and consistent Rayleigh signature in a single-mode optical fiber under steady-state conditions. Along the length of the optical fiber, the variations in the RI profile of the core can be viewed as a string of weak FBGs with arbitrary periods. Temperature variations alter an optical fiber's length and refractive index, which causes shifts in the Rayleigh spectra. Shifts in Rayleigh spectra can be used to gauge temperature changes. After placing the fiber in the test setup at room temperature, the reference signals from the fiber being tested are recorded using the OFDR interrogation technique. Cross-correlation between Rayleigh signals at high temperatures and the reference signal yields spectrum shift data, which is subsequently transformed into temperature measurements using temperature coefficients. The following formula describes how a change in temperature (ΔT) causes a shift in the Rayleigh backscattering spectra (Δλ):

$$\Delta\lambda = \lambda(\alpha + \zeta)\Delta T$$

(Eq. 1)

where

λ = OFDR system's operating wavelength,

α = thermal expansion coefficient (0.55×10^{-6}/°C) and

ζ = thermo-optic coefficient (8.5×10^{-6}/°C) of the optical fiber.

In the present work, single-mode optical fibers (SMF28) were interrogated using a commercially available eight-channel OFDR interrogator