OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY
FACT SHEET

Non-Contact Temperature Measurement

Inductive Johnson Noise Measures Hot Metal

Existing Technology Falls Short of Industrial Needs

Precise control of thermo-mechanical metal processing is needed to accomplish production of high volume metal products with consistent and often pedigreed mechanical and chemical properties at competitive prices. Manufacturing methods used to produce aluminum and steel, for example, are highly energy intensive and generally lack the real-time diagnostic equipment to adequately characterize performance and adapt manufacturing lines quickly to changing requirements. Processing for most steel and aluminum products is an open-loop, recipe-based approach without sufficient diagnostic measurements. The desire is to develop on-line diagnostic methods to better characterize materials during processing so that the necessary adjustments can be made. For this reason, non-contact temperature measurements without the uncertainty issues of infrared pyrometry need development.

Thermal Noise Measured at a Distance

Johnson noise is caused by the random thermal motions of electrons in a conductor. This motion causes an open-circuit voltage across any resistance, which is random with zero mean. The relationship between temperature, resistance, and voltage generated is given by the Nyquist relation:

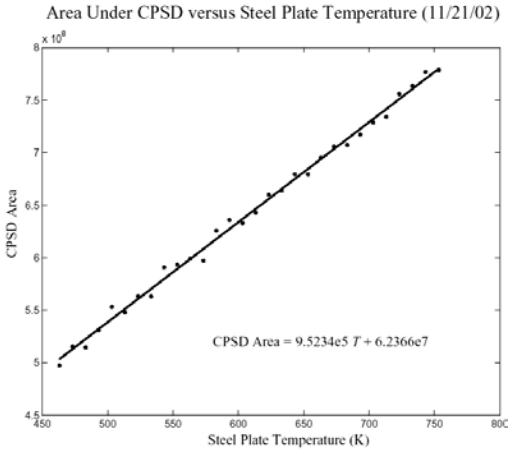
$$\langle V^2 \rangle = 4k_B TR\Delta f$$

Inductive Johnson Noise Temperature measurement Apparatus

We have adapted the Nyquist relation to resonant antenna circuits and therefore made it possible to measure thermal noise emission from a metal plate without contacting it. Earlier attempts used complicated preamplifiers and inadequate hardware-based signal processing. We developed a dual channel preamplifier coupled with software processing algorithms to perform real-time cross-power spectral density (CPSD) calculations. Integration of CPSD data directly yields the surface temperature. The CPSD rejects noise contributions from each of the preamplifiers making the preamplification appear noiseless. We have also developed several antenna configurations for different metal types. The method shows excellent temperature tracking.

Features

- Non-contact temperature measurement without emissivity issues associated with pyrometry
- Extended temperature range
- Inherently self calibrating since Nyquist noise is a fundamental property of matter
- Feasibility has been demonstrated
- Next steps are to develop system for field demonstration



Measurement Results Show Excellent Tracking with Thermocouple

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