Aluminium Times

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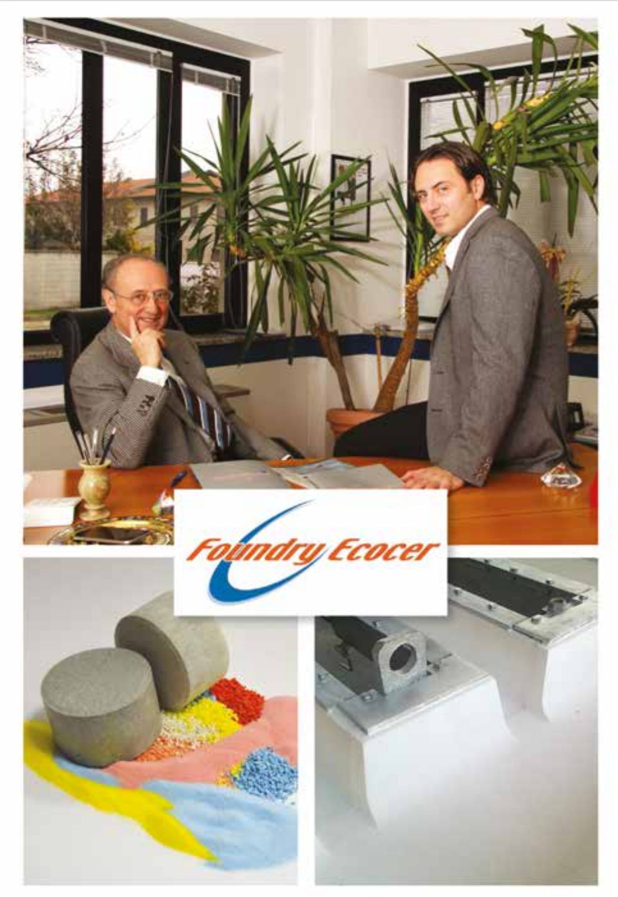
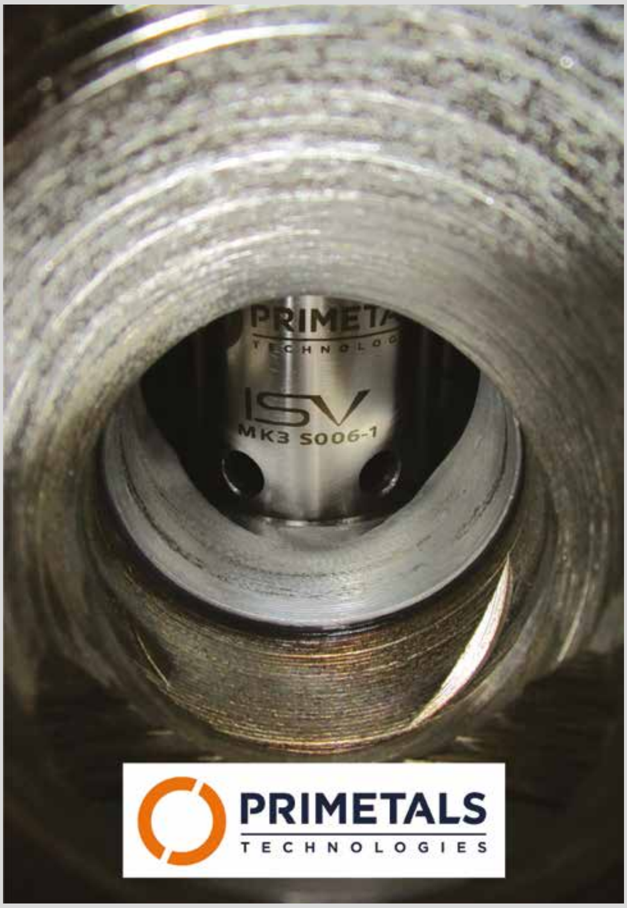




modern media communications ltd
ISSN 1465-8240

Progressing aluminium radiation thermometry

Eleanor Chalkley, Design Physicist for AMETEK Land, works at the frontiers in aluminium radiation thermometry, aiming to produce reliable, accurate measurements in all conditions at all points in the aluminium manufacturing process.

The most sensitive variable in the processing of aluminium is temperature. At critical stages, it is vital to obtain accurate measurements of billet and product temperature. The difficulty in producing this measurement has led to many technological advances in the field of thermometry - from contact measurements to single wavelength pyrometry, to ratio pyrometry to counteract the low and unknown emissivity value, to algorithm pyrometry to counteract the non-greyness of the aluminium, to advanced algorithm thermometers which can account for non-greyness and low emissivity across multiple aluminium alloys.

The aluminium surface

The central difficulty in performing radiation thermometry on aluminium is its surface is much more efficient at reflecting incoming radiation than radiating thermal radiation. Emissivity (1-Reflectivity) is the property which describes how efficient a surface is at radiating thermal energy. For aluminium, this efficiency is extremely low, with values below 0.05 for freshly extruded smooth surfaces. Emissivity increases with surface roughness, and also varies with wavelength, temperature and alloy. Extra complication is added by the propensity of aluminium alloys to develop surface oxides and oxides of minor alloy compounds.

The low emissivity and relatively low working temperatures of aluminium mean that the radiation thermometer receives less energy from the target, and a less favourable signal to noise ratio. High reflectivity means that any thermal radiation from the environment, such as a furnace or sunlight through a window aligned so that light is reflected from the target surface into the measurement instrument, may form a significant proportion of the radiation received by the instrument. To the measurement instrument, this background contribution is indistinguishable from the thermal radiation from the target surface. It is possible to correct for background radiation mathematically, but only if the temperature of the background and the emissivity of the target surface are known. The instrument must be shielded from direct and reflected sunlight.

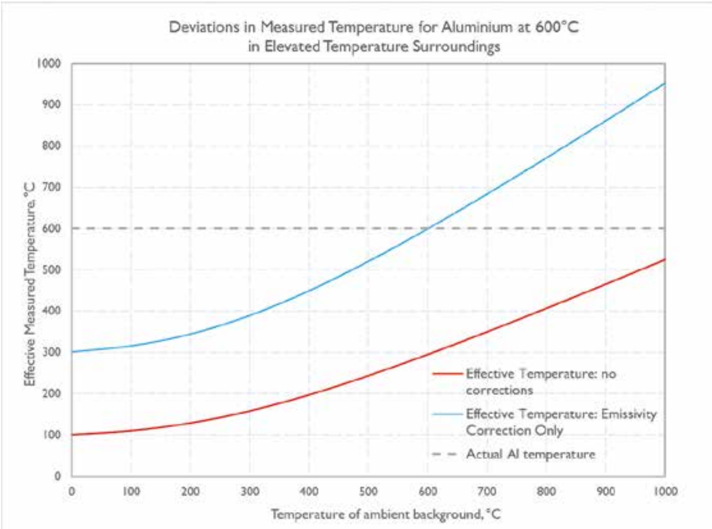
Changing emissivity

Like all metals, aluminium is highly reflective in the visible and infrared wavebands because of the cloud of free electrons. This property of metals allows them to react to incoming radiation swiftly and with the minimum of energy absorption. The same mechanism that allows incoming radiation to be reflected also reflects thermal infrared radiation back into the bulk of the material when it tries to escape the surface. This leads to the fact that for opaque materials $\varepsilon + R = 1$ - the sum of the coefficients of emissivity and reflectivity is equal to 1.

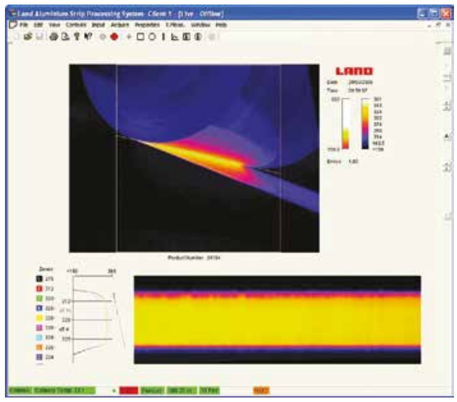
Pure aluminium which has no oxide layer fits the description of a simple ideal metal with a free electron cloud surrounding a solid formation of ions. However, the highly reactive surface of aluminium readily grows oxide layers during heat treatment and with exposure to air. This means that soon the pure metal emissivity and reflectivity behaviour of free electrons is supplemented by an additional component of dielectric reflection.

At an extrusion press exit, the surface is freshly formed aluminium with an oxide layer only a few angstrom (Å) thick. During the quenching process, a thicker layer of oxide forms, with thickness and chemical composition dependent on quench rate and alloy type. In contrast, aluminium slabs enter the rolling process with oxide layers hundreds of Å thick. During the rolling stages, the initial thick oxide layer is destroyed, and the new layer formed during the final stages is only around 15Å thick. Aluminium reversing mills for hot rolling present a specific challenge for infrared thermometry - a single instrument must be able to perform accurate temperature measurements on a surface at every stage of rolling, and that includes varying and hard to predict levels of oxides and other alloy components.

For thin dielectric layers, reflectivity is a complex function of film thickness as well as composition and surface quality. The thickness and type of oxide layer on the surface modifies the emissivity of the material. By understanding the evolution of the oxide layer and how this modifies the emissivity, it is possible to create an algorithm that allows an accurate pyrometer reading at any point during the processing of the alloy. If the thermal history of the part is known and the relationship between the oxide layer and emissivity is understood for the alloy in question, then it will be possible to create a pyrometer which can apply oxide emissivity tuning to live thermometry data. This technique requires a thorough systematic understanding of the formation of oxide layers for different categories of aluminium alloys and how these oxide layers modify the surface emissivity. Work on systematising the emissivity of aluminium oxide layers is underway.



Graph shows deviations in measured temperature for aluminium at 600°C in elevated temperature surroundings.



Thermal image from AMETEK Land Aluminium Strip Coil Thermometer.

Beyond ratio thermometry

The traditional solution to radiation thermometry of surfaces with unknown emissivity is to use ratio thermometry. The radiation at two closely separated wavelengths is measured. If the emissivity of the substance is the same at the two wavelengths, the surface is described as 'grey', and it is possible to back-calculate the temperature that the substance must have. Ratio thermometry gives poor results on aluminium, as the emissivity of aluminium varies with wavelength. For a non-grey surface at the temperatures at which aluminium is processed, these deviations in measured temperature can be significant.

Developed in 1993, the first generation of AMETEK Land specialist aluminium pyrometers, the Aluminium Strip

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APPLICATION

SPOT AL EQS and Actuator scanning a profile along the billet as it arrives at the press

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Actual SPOT image view

Thermometer System, introduced a new logarithm-based method of compensating for oxide non-greyness. A family of pyrometers were produced, each of which was tuned to excel in measurements of a different part of the aluminium manufacturing process - extrusion, quench and strip rolling. These pyrometers implemented the logarithm-based non-greyness correction algorithm in a way that allows temperature measurement of an arbitrary aluminium alloy to be performed. AMETEK Land developed other highly specialist instruments such as the fibre optic Aluminium Die Thermometer, the emissivity enhanced Aluminium Billet Thermometer and the innovative image-based Aluminium Strip Coil Thermometer, which uses the serendipitous emissivity enhancement at the base of a coil to produce live temperature correction for an aluminium strip scanner.

Current solution

The newest specialist radiation thermometer for use in aluminium processing is the AMETEK Land SPOT AL EQS, an instrument which provides thermometry for the extrusion, quenching and strip processes on aluminium. The development brings together AMETEK Land's 70 years of expertise in radiation thermometry on metals and the latest developments in fundamental research on aluminium processing. The SPOT AL EQS uses an algorithm generated from a comprehensive and thermometry dataset

AMETEK Land SPOT Aluminium Extrusion, Quench and Strip (AL EQS) Pyrometer.

gathered in a live aluminium processing setting, with well understood data traceable back to the ITS90 thermometry standard, and the full implementation of Planck's Law to remove the inaccuracies caused by using Wien's approximation. The SPOT AL EQS digitises, updates and improves upon the earlier instruments - the three separate algorithm thermometers are now available as options within a single instrument, with extended temperature ranges, precision Cassegrain optics and multiple readout options.

The ultimate aim for temperature measurement during aluminium processing is to be able to produce reliable, accurate measurements in all conditions at all points in the manufacturing process. To do this, AMETEK Land leverages fundamental materials science research, leading edge instrument design and factory floor aluminium

SPOT AL EQS on a manually adjusted mounting at the press exit.

processing experience. The company designs and manufactures a wide range of instruments for industrial non-contact temperature measurement, combustion efficiency and environmental monitoring. AMETEK Land is a business unit of AMETEK, Inc., a leading global manufacturer of electronic instruments and electromechanical devices.

www.landinst.com

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