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EXPERIMENTS ON WIRELESS MEASUREMENT OF ANODE CURRENTS IN HALL CELLS

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Abstract

The currents of individual anodes provide information on Hall cells, e.g. the occurrence of “metal roll”. These currents are usually measured by voltage drops along anode rods but this is inconvenient for routine monitoring of pots because of the need to change anodes, plus the hazards of draping signal wires around. Experiments have been carried out on wireless measurement of anode currents. Hall effect probes measured magnetic fields, reflecting mostly the current in the nearby rod. Signals were relayed wirelessly to a laptop some distance from the pot. measurements have been carried out on both pots with pair-controlled anodes and pots with anodes on a fixed bridge. For the former, comparison with independent measurement is easily possible (from voltage drop along the anode flex). Although at the experimental stage, this investigation has served to show that wireless measurements agree roughly with other measurements; wireless measurements reveal metal roll and incipient anode effects.

Introduction

The reasons for interest in currents in individual anodes are two.

1. Pot performance is better (e.g. less deformation or roll of the electrolyte-metal interface) if the current is uniformly distributed over all the anodes, and
2. There is expectation that the alumina content will not be uniform in the electrolyte. Consequently an anode effect should start locally and this could be detectable as a drop in anode current at that location.

Individual anode currents can be determined by measuring the milliVolt drops along anode rods but this requires that contacts be attached to anode rods and is therefore cumbersome for routine measurement. Determining the current (AC or DC) in a conductor by measuring the magnetic field generated by the current is a well known technique and there is a previous report[1] of measurement of anode currents in this way. However such measurement is greatly facilitated if the magnetic field value can be reported wirelessly, rather than along instrument wires, and the objective of the present investigation was such wireless measurements. The investigation was a collaboration between Wireless Industrial Technologies (WIT) and Alcoa.

Wireless Devices Used

The WIT devices used in this investigation employed Moteiv Tmote Sky® “mote” coupled to two Hall effect probes. These were integrated into a polycarbonate box 89mm by 25mm by 17mm, along with a battery. In any permanent plant deployment operation off thermoelectrically generated power[2,3] or pot voltage, would be more likely; consequently a few motes were powered, successfully, by a Melcor thermo electric generator coupled with a custom fabricated DC-DC converter. The devices were placed behind the end of an anode flex at plant A, where pair control anodes were used, and behind anode rods at plant B, where the pots have anodes attached to a fixed bridge. Both locations minimized the danger of accidental damage to the motes during normal pot working such as an anode change. The non-contacting nature of the measurement meant that no modifications of anode changing procedures would be needed. Fig. 1 shows a mote at plant A with the box (white) containing the electronics attached to the flex tab by means of fiber reinforced plastic straps. Other devices were developed at WIT to report pot voltages over the same wireless network.

Hall effect sensors provide a safe method for obtaining relative current measurement and fluctuations. The sensors used in this study were effective up to 50 mm. away from the anode. The benefits measuring current fluctuations in a non-contacting manner are manifold:
1) The current measurement device can be placed completely off the anode rods. This allows the rods to be placed and removed without concern for damage to the sensor
2) The sensor can be further insulated from the operating temperatures of the pot. Internal measurements showed that an insulated device attached to the superstructure of the pot never reached a temperature above 70^0C.
3) The sensors can be installed without interfering with pot operations. Only three minutes were required to place a sensor at each anode
The two potential liabilities of Hall effect sensors are calibration and temperature drift. The strength of the magnetic field is a strong function of not only the distance from the anode, but the orientation of the sensor as well. This makes absolute calibrations difficult without proper magnetic modeling or a placement chuck.
The sensitivity of the Hall effect sensor also changes with temperature, and exposure to excessive temperature can permanently offset the sensor. Care must be taken to properly insulate the measurement devices and take temperature measurements at or near the sensing element. In our experiment our Moteiv Tmote Skies were equipped with internal thermistors placed less than 10 mm. from the sensing elements. The devices

were placed in polycarbonate boxes with 10 mm. of alumina fiber cladding.

Finally, as with any measurement, proper optimization of the sensing element to the magnitude of the sensed quantity must be considered. Hall effect sensots are typically rated by mV/Gauss sensitivity. In this study sensors with a sensitivity of one to ten mV/Gauss were tested.

There was no difficulty in establishing communication between motes and the laptop used to record data, placed approximately 150 ft. away from the pot under study. That pot was at the end of a potline. Preliminary tests indicated that a reliable network of motes could be established with approximately one repeater (relay) mote every five cells indicating that there would be no difficulty in monitoring cells further along the potline. As has been our previous experience, the motes were unaffected by the strong magnetic field of the cells.

Results

The tests at plant A were of less than two days; some results were those of Fig. 2. The horizontal axis is time in seconds while the vertical axis is the uncalibrated magnetic field at two anode rods, reflecting the current in the anode rods. This pot was in a “noisy” condition and the fluctuations of the currents due to metal roll, with a period of a few tens of seconds, are clearly discernible in the magnetic field. There were four anodes between the ones where these measurements were made so they are physically well separated. Note that the fluctuations in current (field) match in frequency and approximately in magnitude, but are out of phase; as the interfacial wave passes along the pot length there is a corresponding progression in the anodes closest to the metal which thereby carry more current.

Figure 1. WIT mote attached to the tab at the end of an anode flex in plant A.

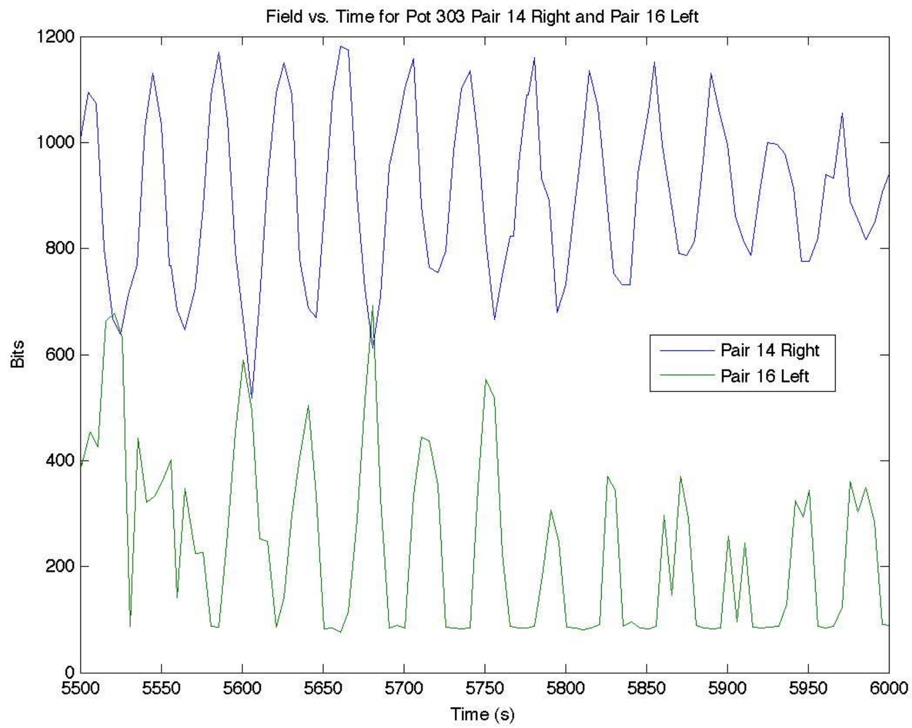

Figure 2. Magnetic fields (reflecting anode current) at two well separated anodes during first test of prototype for current measurement device at plant A.

Another indication of the success of the current measuring mote can be seen in Fig. 3. Here an anode, for which the current was being monitored, was raised twice then lowered. The effect of raising an anode is evident in Fig. 3 (for the same noisy pot as Fig. 2); in the uncalibrated field measurements increasing signal from the Hall effect sensor ("bits") corresponds to diminished current and we see the drop in current as the anode is raised (twice) and the current increase as the anode is lowered. ["On flex" or "on anode" and "one inch off" in Figs. 3 & 4 refer to Hall probes that were immediately adjacent to the flex (or anode rod) or one inch off.]

Finally in Fig. 4 we have a comparison between the current reported by the WIT mote and that reported by the plant A computer (as mV drop along the anode flex). These results are for a different pot that is not in a noisy condition. Recognizing that increased current means diminished signal ("bits") from the mote and increased mV seen by the plant computer, there is good agreement between the WIT sensor and plant measurements, although the WIT measurements are yet uncalibrated.

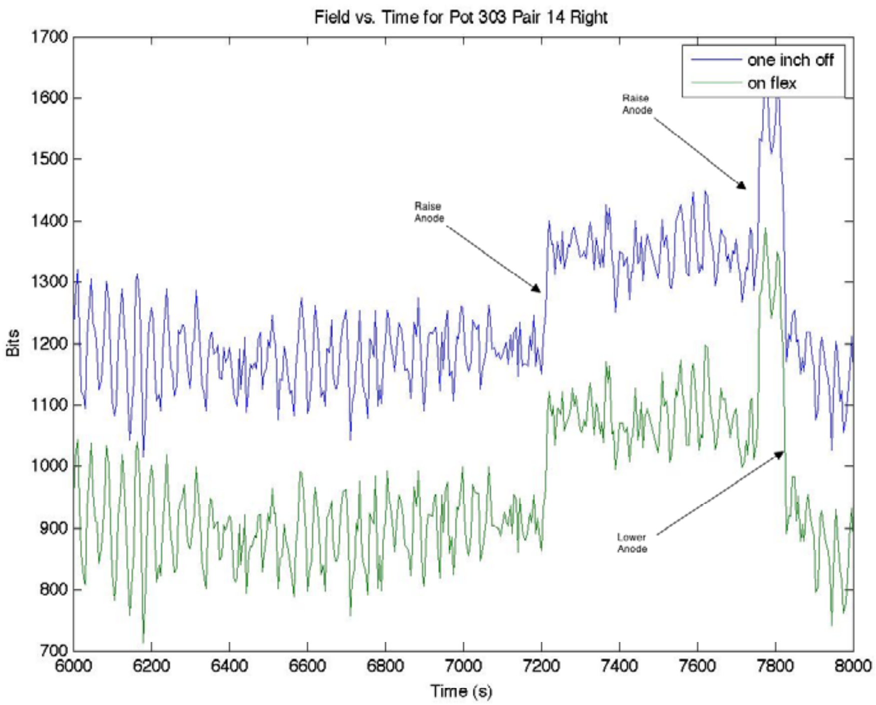

Figure 3. Current (magnetic field with "bits" diminishing as field increases) in an anode rod as the anode is raised or lowered.

Following this first test was a more extended test (five days) at plant B, this one with the common pot design where anodes are connected directly to the anode bus and therefore individual anode currents are presently inaccessible only by laborious "hand measurement" of voltage drops along anode rods.

An objective in the second test was to examine this second concept to see if an "early warning" of an anode effect appears in the trace of the anode currents before it is discernible in the pot voltage. Fig. 5 shows the pot voltage and currents for three anodes, all determined using WIT's wireless devices, during a ten minute period during which an anode effect occurred. Note that the current in one of the anodes (the one where the anode effect begins) starts to drop at about 410 seconds into the ten minute period, while the pot voltage does not show significant change until about 480 seconds. Measurement of anode current therefore gives about a minute of advance notice of an anode effect, ample time for a supervisory computer to take action to prevent the anode effect with its significant contribution to greenhouse gasses.

Fig. 6 shows results from a pot where the currents were measured using WIT wireless sensors for a period of 50 minutes during which pot current was cut and then restored. Clearly the sensors show the current interruption (the values during the current off period are zero offset). The pot is also seen to be "noisy" with the long period fluctuations of current in the anodes being due to the "roll" of the aluminum underneath the anodes.

Simultaneously with these measurements the WIT current sensors were calibrated by measuring the voltage drop along known lengths of each anode rod; the drop bears a known relation to the current in the rod, dependent on rod material and cross section. The voltages drops are measured manually in this method. The calibrations cannot be reproduced here as the rod currents are proprietary to the smelter. However it was clear that the large variation in current, from anode to anode, implied by Fig. 6 was borne out by the voltage drop measurements. Consequently measurements of the kind carried out to produce Fig. 6 readily reveal a pot where there is need for operator intervention.

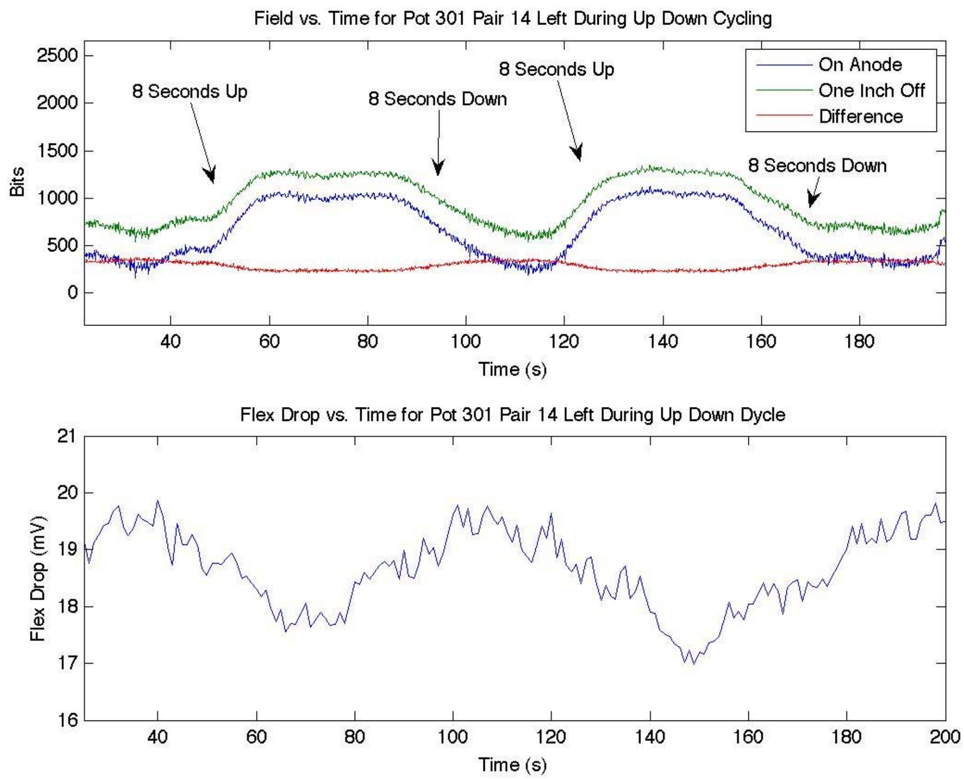

Figure 4. Comparison of anode current changes ascertained from WIT's mote measurement of field (decreased "bits" = more current) and those reported by the plant A computer (increased mV = more current). "Up" and "Down" refer to anode movements lasting the indicated time.

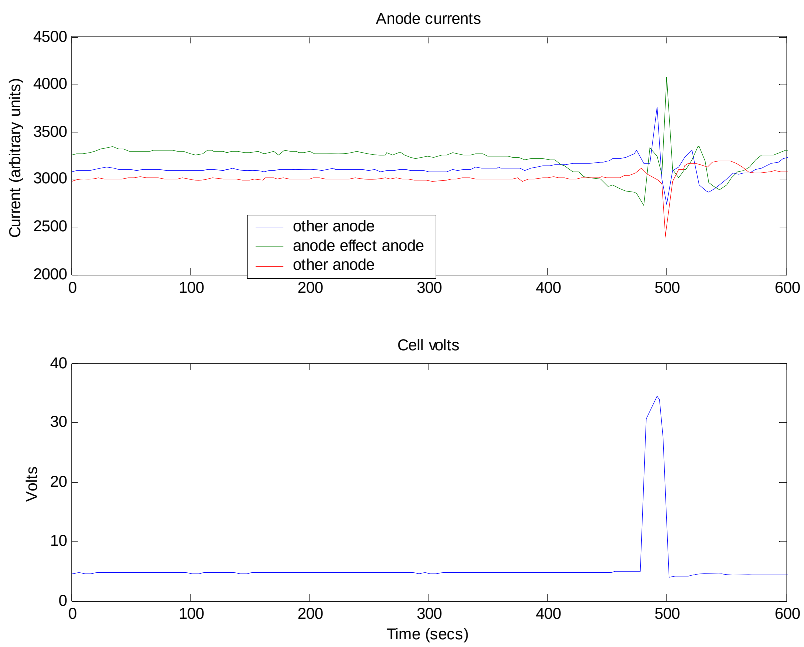

Figure 5. Cell voltage and anode currents measured wirelessly during a period when a cell underwent an anode effect.

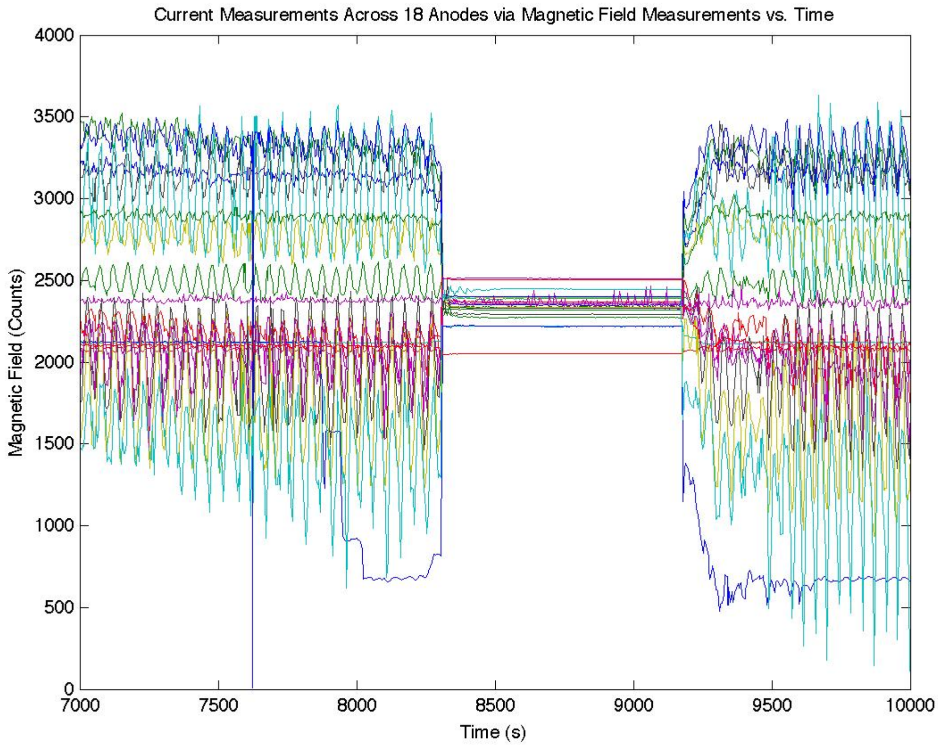

Figure 6. Currents (measured as magnetic fields) for 18 anodes on one pot measured during a 50 minute period where power to the pot was interrupted for about 15 minutes.

Concluding Remarks

Wireless measurement of pot parameters can be a way of improving pot performance without the hazards/costs of stringing instrument wires around the potroom. The investigation described here, although short, suggests that the applications of wireless technology to individual anode current measurement might be practical.

Acknowledgements

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