Elimination of Mould Level Oscillation Disturbance from Mould Level Measurement using Adaptive Noise Cancelling Techniques

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Technical Report EE9278

August 1992

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Abstract

This report addresses the issue of signal processing to remove an unwanted disturbance from mould level measurement obtained when the measuring instrument is mounted on the mould frame. Adaptive noise cancelling techniques are used to eliminate the disturbance without affecting the integrity of the underlying measurement. Preliminary results indicate that the method is feasible and it is suggested that a more detailed investigation be carried out leading to an algorithm suitable for implementation.

1 Introduction

This report describes techniques which are proposed to deal with the problem of mould oscillation disturbances on mould level measurement. This is part of a study to see if it would be feasible to mount the mould level measuring instrument on the frame of the mould in a continuous bloom caster at BHP Newcastle. Mounting the instrument in this way has many advantages but has the potential disadvantage that the frame of the mould is subject to a superimposed oscillation. This oscillation will appear as an unwanted disturbance on the mould level measurement.

An independent measurement of the mould frame oscillation is available via a measured feedback signal. This suggests that we should be able to apply *noise cancelling* techniques [1] to eliminate the disturbance signal from the measured mould level without compromising the measurement bandwidth.

This report investigates this possibility using real data collected from the bloom caster.

2 Low Pass Filtering

To provide a bench-mark against which the noise cancelling can be compared, a test was performed with an ordinary low-pass filter. The difficulty with this approach is that the phase lag through the filter also compromises the measurement of the mould level. Typical results are shown in Figure 1. We see that a substantial lag is necessary in the mould level measurement to eliminate the oscillation disturbance. This lag is very large compared with the mould-level control loop bandwidth and thus would significantly deteriorate the loop performance.

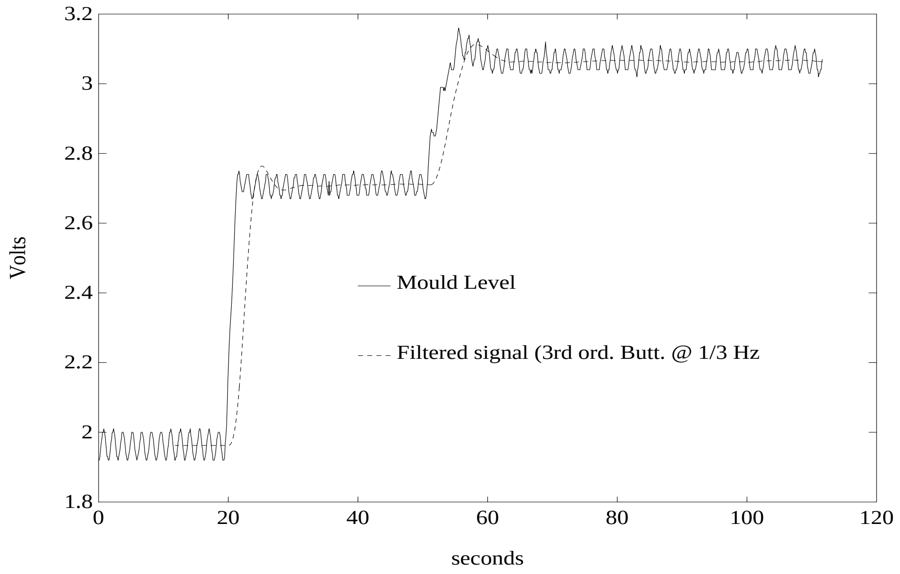

Figure 1: Low-pass filter test @ 40cpm oscillation frequency

3 Noise Cancelling Solution

The basic idea of the noise-cancelling solution is to build a narrow notch filter which eliminates the oscillation disturbance without compromising the mould level measurement.

Preliminary inspection of the data indicates that the mould oscillation is essentially sinusoidal in nature, This suggests that a 2-tap noise cancelling filter should suffice.

It is suggested that the time between zero-crossings in the oscillation measurement be used to determine the oscillation frequency. The basic structure of the proposed noise cancelling filter (ncf) is then as in Figure 2.

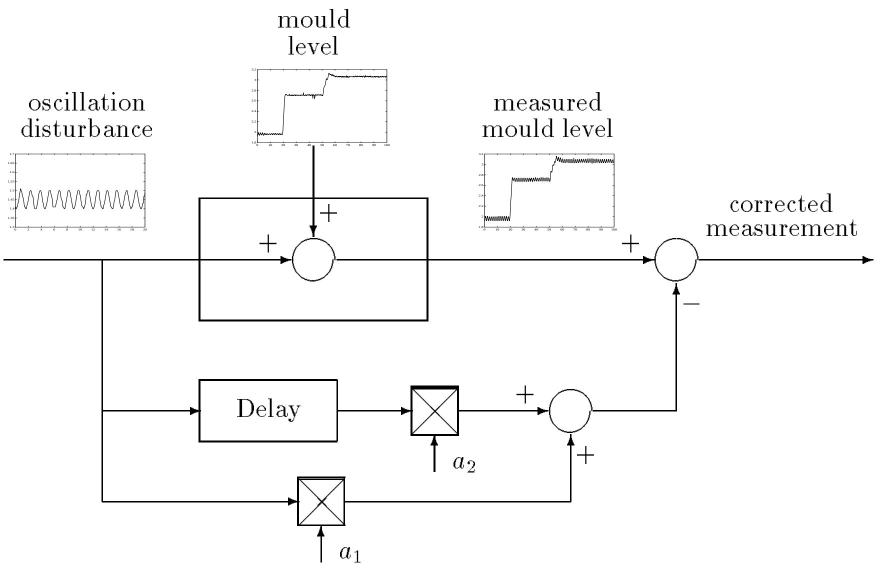

Figure 2: Noise Cancelling Filter

It is suggested that the delay in the ncf be set to approximately $\frac{1}{2}$ the zero crossing time of the oscillation; *i.e.* about 90° phase shift. Denote this time by τ.

Let the measured mould level be $y(t)$ and the measurement disturbance be $d(t)$. The disturbance $d(t)$ should be high pass filtered to eliminate any d.c. level.

The coefficients a_1, a_2 can then be adjusted on-line by parameter estimation. Let

$$\theta = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \tag{1}$$

$$\phi(t) = \begin{pmatrix} d(t) \\ d(t-\tau) \end{pmatrix} \tag{2}$$

the algorithm structure is then

$$\hat{\theta}(t) = \hat{\theta}(t-1) + P(t)\phi(t)[y(t) - \phi(t)^T\hat{\theta}(t-1)] \tag{3}$$

where

$$P(t) = \frac{1}{\lambda}[P(t-1) - \frac{P(t-1)\phi(t)\phi(t)^T P(t-1)}{1+\phi(t)^T P(t-1)\phi(t)}] \tag{4}$$

Finally the noise cancelling filter has the form:

$$y'(t) = y(t) - \phi(t)^T \hat{\theta}(t) \tag{5}$$

4 Preliminary Results

Results corresponding to the data in Figure 1 are shown in Figure 3. Other frequency results for the data collected from the bloom caster at BHP Newcastle are shown in Figures 5, 6, 7 and 8. Table 1 summarizes the values of the computed gains a_1 and a_2 for each set of data.

frequency (cpm)	40	73.8	90.7	102
a_1	0.7201	0.1671	0.1491	0.0974
a_2	0.0732	0.0495	0.0821	0.0433
delay τ (seconds)	0.4	0.2	0.2	0.1

Table 1: Computed values for the noise cancelling filter.

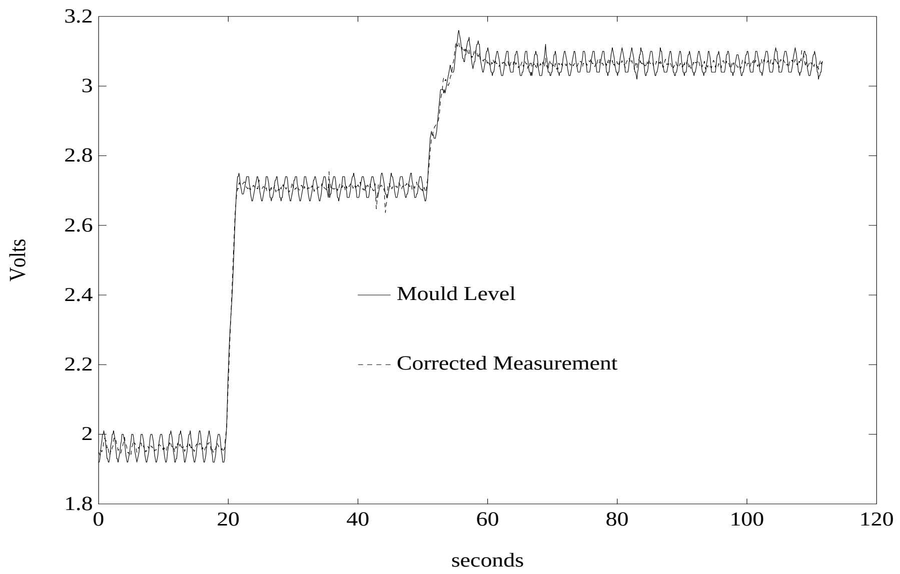

Figure 3: Noise cancelling filter test @ 40cpm oscillation frequency

Remark 1 *Comparing the results in Figure 3 with those in Figure 1 shows that substantially better results are obtained than resulted from the use of a simple low pass filter.*

Remark 2 *The simulation tests revealed that a reasonable good measurement of the oscillation disturbance $d(t)$ is required to obtain a corrected mould level measurement $y'(t)$ free of extra spurious disturbances. The measured data of the disturbance oscillation $d(t)$ contained some spurious peaks, which have been removed by means of preprocessing the signal with a* rate limiter. *As the* *expected maximum rate of $d(t)$ may be known, higher signal variations may be suppressed by setting appropriately the truncation levels of the rate limiter. This device has shown to be effective in simulations over the collected data (Figure 4).*

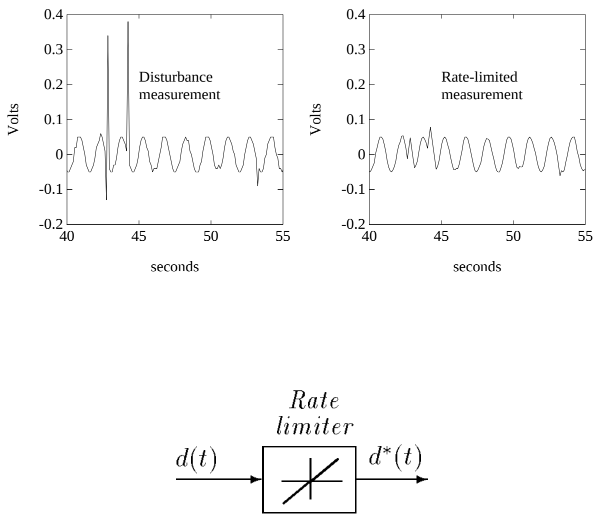

Figure 4: Spurious peak suppression on the oscillation disturbance measurement

Remark 3 *All the collected data have been sampled @ 0.1 seconds. This rate is too slow for the data corresponding to the frequencies 90.7 and 102 cpm. In consequence, the delay τ used for the oscillation disturbance in those cases was far from the suggested $90°$. It is suggested that a higher sampling rate is necessary to deal with those cases.*

5 Further Data

To finalize the specification of the algorithm it is necessary to know

1. how frequently the oscillation frequency changes
2. over what range the oscillation frequency changes
3. the dependence of $\hat{a}_1, \hat{a}_2$ on oscillation frequency.

One would hope that in the final solution, either fixed values of $\hat{a}_1, \hat{a}_2$ could be used or possibly gain scheduled values scheduled off the oscillation zero crossing time.

6 Conclusions

The noise cancelling technique described in this report has been shown to have the potential to eliminate the mould oscillation disturbance without serious deterioration in the fidelity of the underlying mould level signal.

The technique requires further fine tuning. However, the preliminary results indicate that when this is done it should provide an acceptable answer to the problem of rejecting the unwanted disturbance. Other related ideas including a digital notch filter should also be investigated in a more comprehensive study of this problem.

References

[1] Graham C. Goodwin and Kwai Sang Sin, *Adaptive Filtering Prediction and Control*, Prentice-Hall, Inc, Englewood Cliffs, New Jersey, 1984.

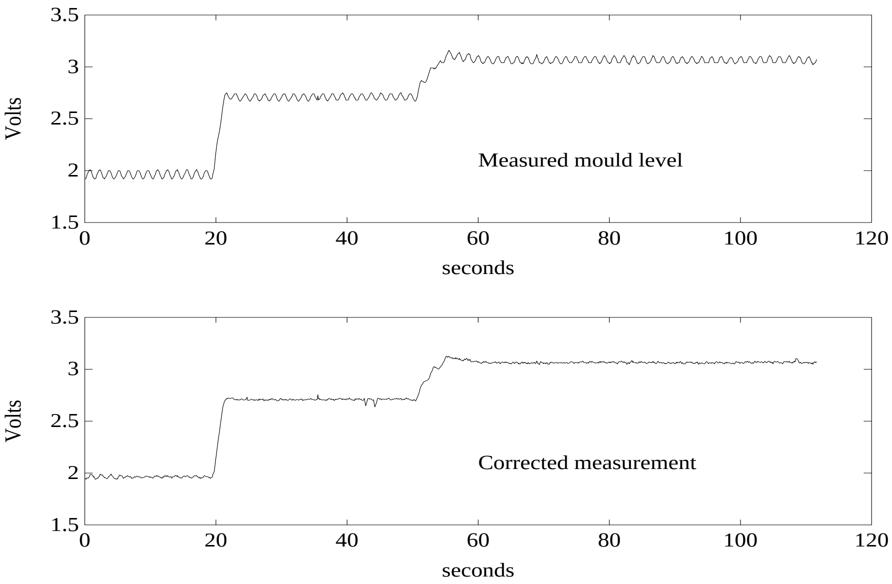

Figure 5: Noise cancelling filter test @ 40cpm oscillation frequency

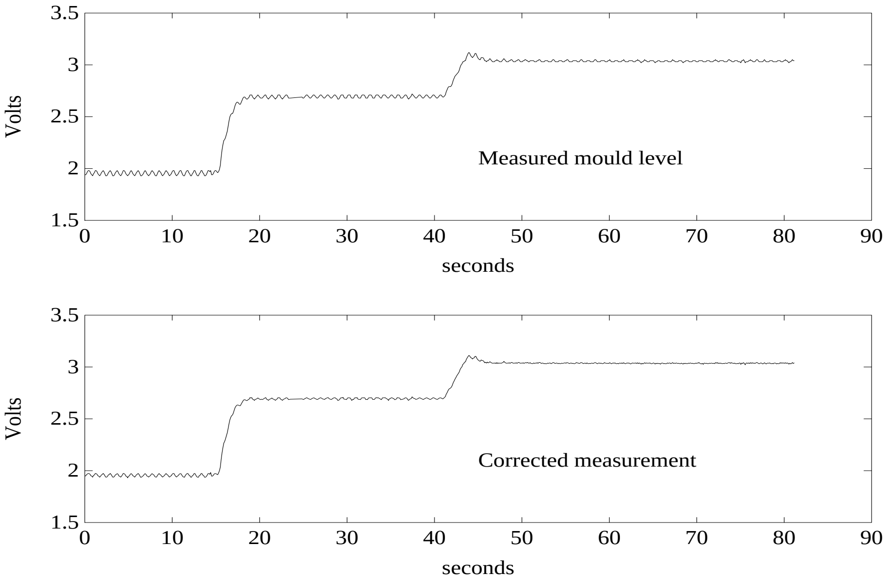

Figure 6: Noise cancelling filter test @ 73.8cpm oscillation frequency

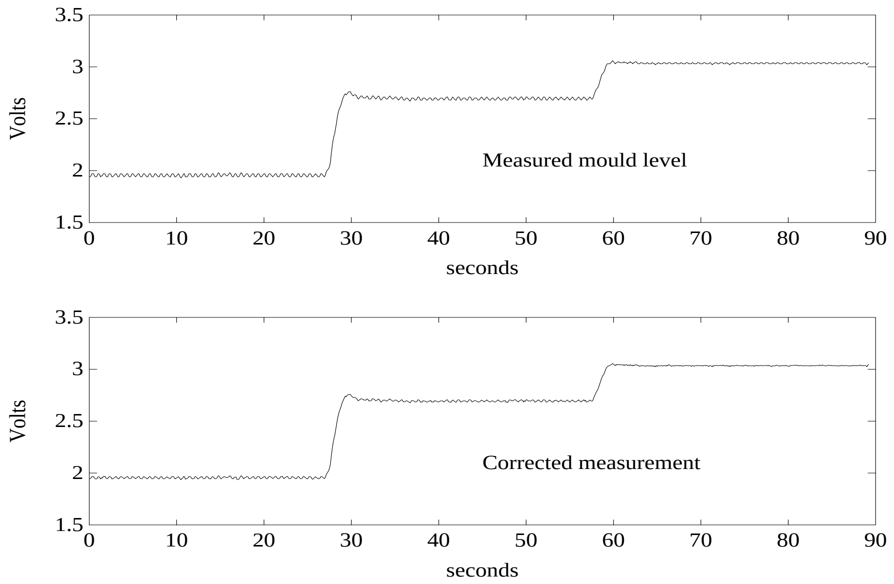

Figure 7: Noise cancelling filter test @ 90.7cpm oscillation frequency

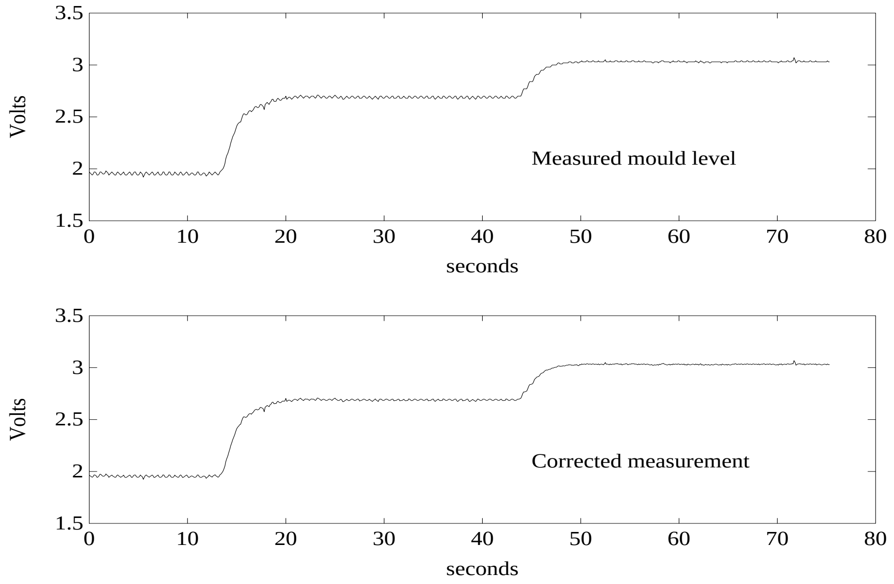

Figure 8: Noise cancelling filter test @ 102cpm oscillation frequency