

Listening for Cane Loss

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Abstract

A method is described for controlling sugar cane loss during harvesting. In a mechanical harvester, unwanted leaf material is separated from sugar-bearing cane in an air-stream, and waste material is thrown back onto the field. Up to ten percent of the cane harvested is also lost, and this can represent up to fifty million dollars per year. The primary extractor fan of a harvester generates the air-stream, and is the principal cleaning system during the harvesting process. The effectiveness of the fan varies with speed, and a compromise must be achieved between retaining trash and losing cane. An accurate and reliable measure of cane loss can be obtained by detecting the impacts of harvested cane on the blades of the fan. Field trials of this detection process have been successfully conducted on a cane harvester in Bundaberg.

Keywords:

Sugar cane harvester, billet, cane loss, acoustic, primary extractor fan

1 Introduction

All sugar cane in Australia is harvested with mechanical harvesters. A majority of the crops are cut green; the alternative being to set fire to the crops to remove unwanted dry leafy material. In consequence, the efficiency of the on-board cleaning system of the cane harvester has become a more prominent issue. The cane must now be efficiently cleaned while it is being harvested to minimise losses. Transport costs and milling penalties associated with unclean cane must also be minimised.

The mechanical sugar cane harvester's principal on-board cleaning system is the primary extractor fan. This fan cleans the cane by pneumatically separating harvested cane ('billets') from unwanted material ('trash') during the harvesting process. The trash is ejected from the extraction chamber and is thrown back onto the field, however many billets are also lost. Up to ten percent of the harvested cane is lost during the cleaning process, and this is estimated to cost the Australian sugar industry up to fifty million dollars per year. Figure 1 illustrates a cane harvester in operation cutting green cane and depositing billets into a 'haul-out' bin, which is taken to the mill for processing.



Fig 1. Cane harvester in operation cutting green cane and depositing billets into a 'haul-out' bin

The primary extractor fan is hydraulically driven, and 15-20m/s up-draughts are generated by it in the extraction chamber. To be most effective, the speed of the primary extractor fan must be adjusted by the operator to achieve a compromise between excessive trash in the harvest, and a substantial quantity of cane being lost. The operator has many responsibilities when operating the harvester, and as a result controlling the extractor fan speed often has low priority. Therefore, if cane loss could be accurately quantified in real time, this information could be used to control the fan speed, either automatically, or by assisting the operator by providing necessary information. This way the operator's responsibilities will be reduced, and when needed, the necessary attention can be given to this integral function of a cane harvester.

2 Method

Existing cane loss monitors [1] have relied on detecting the impact of ejected cane billets on the hood of the primary extractor fan. This method uses a piezoelectric device to sense the severe resonance caused by a billet striking the metal hood. This method suffers some inconsistency, because many lost billets fail to hit this hood. Furthermore, plastic hoods have largely superseded metal shrouds, so this method of impact detection has been made more difficult as the resonance that was relied on before is now damped. As a result of this design change, the technique of detecting billet impacts on the hood of the extractor fan does not have the same effect, and there is now a new need to obtain an accurate and reliable measure of cane loss in real time.

An alternate method involves detecting the impact of billets on the blades of the primary extractor fan. This method has the potential to be superior to any existing cane loss monitoring technique because almost all billets that are lost have struck the fan's blades and either been damaged or have disintegrated. Practically no billets appear to pass undamaged through the fan and strike the hood only. These assumptions can be confirmed with such traditional methods as "blue tarp" tests, which involve a visual assessment of the trash that has been ejected from the

extraction chamber and onto a tarpaulin. By detecting billets striking the fan blades, a qualitative measure of cane loss can be achieved.

Detecting events very near to the point of contact provides a more active approach to cane loss estimation than methods attempted before.

2.1 Derived technique

Related work [2] has concentrated on both basecutter height control as well as automatic steering of a mechanical sugar cane harvester. This research used 'moving magnet' microphones to detect vibrations on a cane harvester's basecutter blades. The magnet in these transducers vibrates within the sensor coil when the blade vibrates, generating a voltage with relatively low source impedance.

The primary extractor fan application also uses a novel acoustic transducer. This is a 'variable reluctance' microphone that detects the differential movement between the hub and the fan blades that occur upon an impact. The optimum position for the acoustic transducer is in the hub flange of the extractor fan. The microphone fits neatly in a custom sleeve in the flange, and is magnetically coupled to the fan blade. Vibrations are converted to current when the magnetic flux cutting the sensor's coil changes. The more severe vibrations, such as that of a billet impact, cause a higher rate of change of flux, and hence a larger current is generated.



Fig 2. Acoustic transducer located in a flange of the primary extractor fan

By positioning the transducer near the point of contact does present a major issue: bridging the signal from the rotating fan to a stationary member of the cane harvester. To overcome this, a passively-induced rotating transformer is implemented. This still involves having a primary and secondary, however there is no physical contact between the two. The primary is a coil of copper-insulated wire that has been wrapped around the external sleeve of the drive shaft. This coil sits on top of a 'money belt' arrangement of highly permeable mumetal, and has been impedance matched to the transducer coil. The secondary is an inductive pick-off with a 'c-shaped' cross-section that is mounted on the stationary frame of the harvester.

Signal that is generated by the microphone will supply current to the primary, which acts as a load. This current creates a magnetic field and induces a current in the pick-off, across the air gap. Therefore the primary and secondary of this transformer are not required to have any physical contact, because a continuous path for magnetic flux is provided at all times, even though there is a small air gap between. This technique provides a simple method to transfer any signal produced by the transducer from the rotating shaft of the fan to the stationary harvester frame.

The returned signals are recorded in wave file format (*.wav) on a laptop computer in the cabin of the harvester via the line-in of the soundcard. This allows the recovered signals to be accessed, viewed and/or played back immediately, which is beneficial when working in the field.

3 Results and discussion

Figure 3 illustrates a one second sample of data that was recorded on a Case-Austoft harvester at a recent field trial at Avondale, Bundaberg. The series of field trials were conducted under normal operating conditions for plantation cane, for which the fan rotates at its maximum speed, which is approximately 1500rpm. Plantation cane is harvested for planting new crops and is required to be extremely clean, so the extractor fan is set at a much higher speed than it would be when harvesting commercial cane.

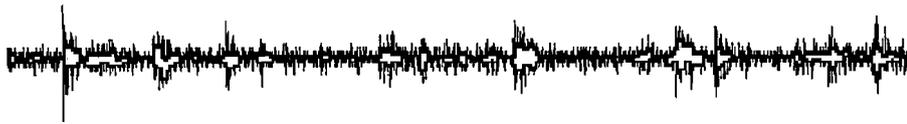


Fig 3. One-second sample of recorded data

As can be seen from the waveform illustrated in Figure 3, there is a considerable amount of activity in a relatively short period of time. The waveform consists of signals of varied magnitudes, and each peak is characteristically followed with a short period of damped oscillation. By correlating the magnitude of the signal with these intense portions, it is a simple task to visually discriminate the cane billet impacts from trash impacts and other ambient noises, such as the motor and other cyclic noises. Using these criteria, the sample in Figure 3 reveals up to nine impacts.

Analysis techniques such as an auto-correlation function confirm that the signal resonates at a characteristic frequency after the impulse event. This is confirmed aurally when the recorded signal is played-back at varied rates.

Subsequent Fourier Transforms of portions of the above sample demonstrates that the activity is in the lower end of the spectrum. Below 1kHz there are moderate amounts of noise, which are associated with ambient noise. In the 2kHz region there is a severe peak indicating an impact event. Some samples even give up to three peaks in the spectrum, which could be attributed to the characteristic frequency of each of the three blades.

An important point to note is that the output spectrum of the returned signals would be specific for the cane variety, moisture content and other conditions that were experienced at the time of any test that was conducted. As these conditions change, the output waveforms will vary slightly. In particular, as the blades wear, the natural frequency of the system will change.

These issues raise the point that any filtering technique that is devised in a signal processing module or algorithm as a 'real-time' solution will need to be either adaptive to the environmental conditions, or independent of them.

4 Signal Processing

In Figure 3 the nature of the signal returned from the audio transducer has been illustrated, and the complication due to the blades resonating is clearly identifiable. Deconvolving the signal to reduce an impact to a single impulse event still remains as the most crucial step in processing the information from the microphone.

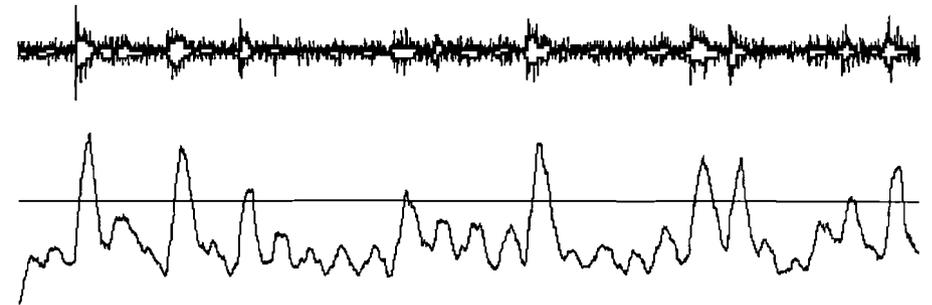


Fig 4. Sample from Figure 3 (above) and filtered output (below)

Many signal processing techniques and algorithms were attempted to eliminate the severe sinusoids that followed an impact. The main criteria used when assessing any filtering method was the level of discrimination achieved, and the ability for the algorithm to operate in 'real-time' or faster.

The filter that was deemed most effective is illustrated in the lower half of Figure 4. This shows the output from a running filter that uses the evenly weighted sum of the past n samples, where n is chosen for the efficiency and level of discrimination achieved. As can be seen from this waveform, by using the filter there is a high level of discrimination between billet and trash impacts. The horizontal line is an arbitrary threshold that has been chosen as the magnitude level that signifies a cane billet. The filter can be performed in less than 'real-time' and hence could be implemented as part of a continuous system. Additional to the arbitrary threshold that is illustrated in Figure 4, there would also have to be some form of time threshold after an impact to minimise counting the one billet as a multiple impact.

This signal processing technique gives an output that would be very simple to be implemented as a 'leading-edge' or some other counter in a micro-controller in 'real-time'. The cane loss that is quantified could be implemented to control the fan

speed, and this would remove some of the responsibility from the harvester operator.

5 Conclusions

A method of assessing cane loss has been described in which an audio transducer directly detects cane billet impacts on the blade of the primary extractor fan. The signals from this transducer bridge the gap between the moving fan to the stationary frame of the harvester via a passively coupled rotating transformer.

Field trials of these detecting and recording processes have successfully been conducted on a mechanical cane harvester in Bundaberg. A sample of the raw waveform has been presented here, and post-processing techniques that may be used to discriminate between billets and trash have been illustrated and discussed. The most successful of the signal processing techniques is described and the output waveform is illustrated. This method could be implemented digitally with a micro-controller in 'real-time', and the measure of cane loss that is quantified could be implemented to control the fan speed.

The methods described here show promise of providing an accurate real-time assessment of cane loss.

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