THE DEVELOPMENT OF AN AUTOMATIC BIN UNCOUPLING DEVICE AT MARIAN MILL

By

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KEYWORDS: Automatic, Bin Uncoupling, Safety.

Abstract

THE UNCOUPLING and re-coupling of cane bin couplings at Marian mill is a labour-intensive task which introduces a range of safety issues as humans interact with cane bins. This paper describes a project aimed specifically at automating the uncoupling process to address these issues. Various bin sizes and coupling types demanded that the uncoupler have two operational modes. A robot was ruled out in the selection process due to the cost, development time and limited space. A conventional rotary uncoupler device for six tonne bins with Willison couplings and a pin popper for four tonne pin and link style couplings was introduced. The rotary uncoupler worked almost immediately offering reliable service while the four tonne pin popper had numerous introduction issues. The pin popper, however, did operate at the end of the 2006 season with reasonable results. This system has not yet eliminated the need for an operator, but with a higher level of coupling maintenance, an accurate bin positioning device, and additional detection of uncoupler failures, it will operate successfully with a person on standby.

Introduction

As the safety standard of the sugar industry increases, areas of high human interaction with hazards and therefore high operational risk have been controlled by reducing the exposure to the hazard. It is also becoming more difficult to employ competent operators for the long term, in what are sometimes very mundane jobs.

Marian mill has made this duty as comfortable as possible for the operators. However, the activity must be conducted in all weather conditions on a continuous basis. It is sometimes difficult to ensure that manual uncoupling is performed safely, reliably and at a frequency allowing the mill to crush at 750 tonnes of cane per hour with dual milling trains being fed by one only 12 tonne (2 x six tonne or 3 x four tonne) tippler.

The issues associated with uncoupling are magnified by the varied nature of the Marian mill bin fleet—three styles of four tonne bins with pin and link couplings, and six tonne bins with Willison couplings. The operators spend most of their time unsupervised due to the fact that the weighbridge where the bins are uncoupled and the factory are on opposite sides of a major road. The control strategy in the weighbridge area is one of the most complicated in the industry already. It attempts to make it as easy as possible for personnel to operate, based on the multitude of variations accommodated.

Continually ensuring that the operators do not breach interlocks and disregard procedures is difficult. Selection of the equipment for automating the uncoupling operation had to take into account coupling condition, overall service life, space constraints, and its incorporation within the whole control strategy of the weighbridge area. This project was part of an overall risk and operating cost reduction program of Mackay Sugar. This paper describes the methodology and implementation process.

Information review for the six tonne uncoupler device to suit Willison couplings

Three years prior to the Marian mill project, a rotary device used for uncoupling six tonne bins was installed at Farleigh mill. The principle of the rotary uncoupler is well proven. It is based on the use of a hydraulic rotary actuator with a circular plate on top, manufactured with lugs suitably positioned to capture the handles of a coupled pair of Willison couplings. The rotation of the plate moves the handles far enough for the internal latches to operate and hold the couplings disengaged.

Even though only one handle operation is necessary for the uncoupling procedure, both are activated to improve reliability. In other factories, including Farleigh mill, completing the uncoupling operation while the cane bins are being pushed from behind has proven to be an advantage, because at this point the couplings are loosely engaged. However, at Marian mill this benefit had to be sacrificed due to the limited space (approximately 700 mm) between the spotter drive head and the weighbridge. There was simply no room for a long travel carriage, taking into account that a device to remove the four tonne bin pins was also required.

The weighbridge spotter is a hydraulically driven, chain drawn carriage which pushes on the last axle of the last bin moving onto the weighbridge. The spotter has to travel over the top of the uncoupler position. It was evident that the uncoupler device had to be made telescopic in design to allow it to travel vertically in a confined space, and it also had to be interlocked with the spotter to ensure that they did not collide.

Information review for the four tonne uncoupler device to suit pin and link couplings

Manual removal of the four tonne bin pins, although simple in nature, requires that the cane bins be adequately buffered together. The pin is normally loosened by hitting it with a bar prior to its removal. The impact is normally made on the side of the head as it is easy to access from above.

This small impact can reduce the force required to lift the pin from thousands of newtons to 20 or 30 N. As the couplings at Marian mill vary extensively in age, the pins also vary in the amount of wear present. This wear plays a critical role in the reliability of the uncoupler device. It became evident that the device needed to allow for quite a high variation in coupling conditions. Although it was well known that replacement of all pins in the fleet would assist the project, it was considered that the uncoupler should be able to contend with a high degree of variation for the device to be reliable in the long term.

At the time as this project was being undertaken, a robot was being considered for use at Proserpine mill (Childs, 2006). The robot option was considered briefly but was ruled out due to overall cost, implementation time, space limitations and the difficulty for operator intervention if a failure occurs. Doubt also existed about the capacity of a robot to uncouple jammed pins.

Previous experience of Mackay Sugar personnel with the use of a pin popper at Cattle Creek mill indicated that the pin popper principle may have merit due to its ability to work from under the bins, as space was such a key factor. The pin popper at Cattle Creek mill

performed with quite a high level of reliability and operated on some of the same bins currently in use at Marian mill. One of the benefits of the bins in the Marian mill fleet is that they only travel in one direction, which allows the bins to be designed to have the pin on one end of the bin and the link on the other.

This removed the need for the device to make a decision about the position of the pin, therefore not needing a complex vision system as proposed with robotics. The pin popper system was also considered more easily maintained by mill staff, particularly as Marian is quite remote from on-call personnel.

The pin popper system is essentially a spring loaded hammer which is energised and latched in position. When uncoupling is required, the device is positioned under the pin and then fired. The hammer impacts the pin and shoots it out of the coupling. Once the pin is released from the coupling it continues to be attached to the cane bin via a small chain.

The operation of the pin release does not impose any major risks as the force applied by the device is controlled during manufacture. For similar reasons to the six tonne rotary uncoupler device, it was evident that the pin popper device needed to be telescopic in nature and had to be interlocked with the spotter to ensure that they did not collide.

Prototyping

During the 2005 season, discussions started on the uncoupler project. The operation of the six tonne rotary uncoupler was previously quite well understood so a prototype of this unit was deemed not necessary.

However, in relation to the four tonne pin popper, it was decided using past experience, that it needed to be a little more maintenance friendly as mechanical wear was an issue with the previous design at Cattle Creek mill. In order to fully understand the dynamics of the process, and incorporating the telescopic action so that only one actuator is required, a prototype unit was built.

This unit was operated pneumatically to raise the head and to energise the spring. The spring was held latched by a mechanical lock. The quality of the sharp working edge on the lock became very difficult to maintain.

The prototype did, however, provide much information confirming some expectations including:

- Raising and lowering operations could be combined with the actuator performing the spring compression.
- The space constraint criteria could be achieved.
- The maintainability could be improved by designing the device to be removed from above.
- A spring with a spring constant of 52 kn/mm would be adequate to remove the pins If compressed 80 mm before release.
- The hammer head needed to be positioned 50 mm below the base of the bin pin prior to firing but not so high as to hit the cane bin buffer on full extension
- The pin needed to protrude below the buffer approximately 25 to 35 mm.
- The cane bins needed to be positioned precisely over the device and fully buffered together.
- The device could not easily be integrated with the six tonne rotary uncoupler operation.

- The latch mechanism would play a large role in the reliability of the device.
- There was a preference for the latch not to be mechanical.

Implementation

The space constraints and interaction between both uncoupler devices and the weighbridge spotter head led to the understanding that conceptually this device would be difficult to design working in two dimensions. It was therefore decided to use a 3D graphic modeling package to perform the design.

All existing equipment was first modeled including the cane bins and couplings to a degree that allowed the design to be realised. Keeping costs in mind, the designer chose not to excessively model the system.

The key items were then designed so that the principle operations and all interferences with adjacent equipment could be analysed. The 3D package allowed details to be adjusted and then construction drawings became a small component of the process. The 3D images also improved communications throughout the project with all parties.

At all times, everybody had a good understanding of progress in the design development. This understanding also made positioning of sensing equipment and cabling easier, which allowed this detail to be defined early in the project and not just left to the end to discover.

The exact location of the six tonne rotary uncoupler position was within 100 mm of the four tonne pin popper position. This proximity meant that the two devices had to be either incorporated into one device or be able to slide between the two locations. Space limitations were investigated and it was found that the head shaft of the spotter could be moved backwards without effecting its operation.

With this in mind the option of incorporating the two devices was abandoned based on the inability to maintain one unit while the other unit was in-service. The amount of movement and the size of each device was such that both units would now fit within the space constraints and in a common slide carriage.

Figure 1 displays how accurate positioning of the slide carriage was made using a hydraulic cylinder complete with digital linear position sensor. The parking position for each device could then be adjusted online during commissioning.

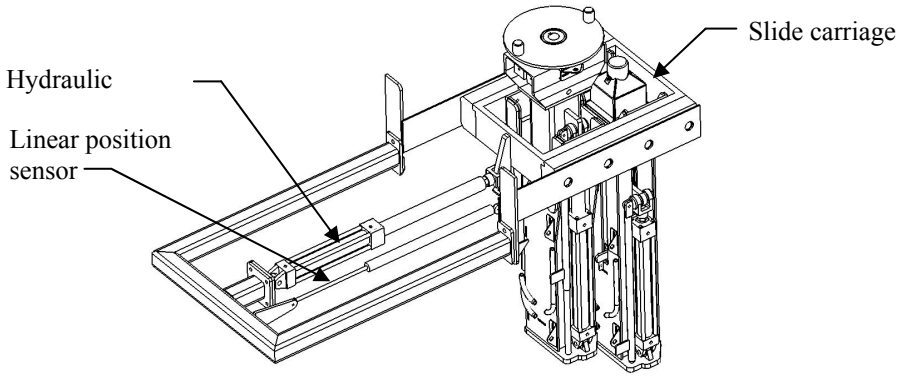

Fig. 1—Both devices housed within the slide carriage.

The six tonne rotary uncoupler device is quite simply a telescopic square tube utilising nylon sliding bearings with a hydraulically operated rotary valve mounted at the top to unlatch the Willison couplings.

Figure 2 shows the device independently removed from the slide carriage to allow maintenance. This does not affect the operation of the four tonne device. The rotary actuator selected was modified internally to match the unit at Farleigh mill for interchangeability of spares.

It was discovered previously that the life of the actuator could be improved by removing the fixed limit stops and replacing them with cushioned impact rings inside the actuator cylinders. The telescopic tube was made using square hollow section to allow for torsional restraint of the rotary motion.

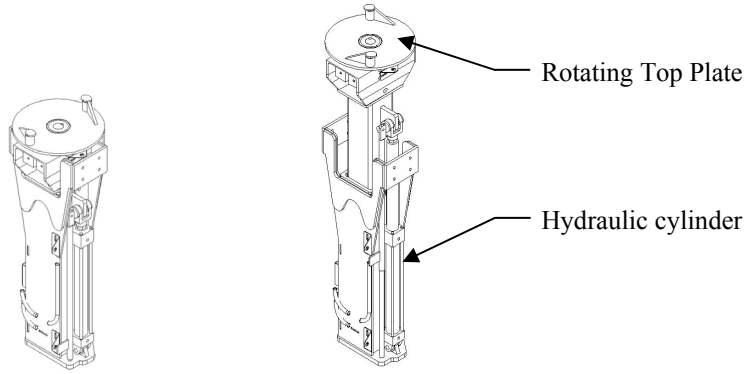

Fig. 2—Six tonne rotary uncoupler device in retracted and extended positions.

The four tonne pin popper device was manufactured using the same square hollow section with the same maintenance philosophy in mind, to permit removal of the device independently from the slide carriage, allowing the six tonne device to continue to operate.

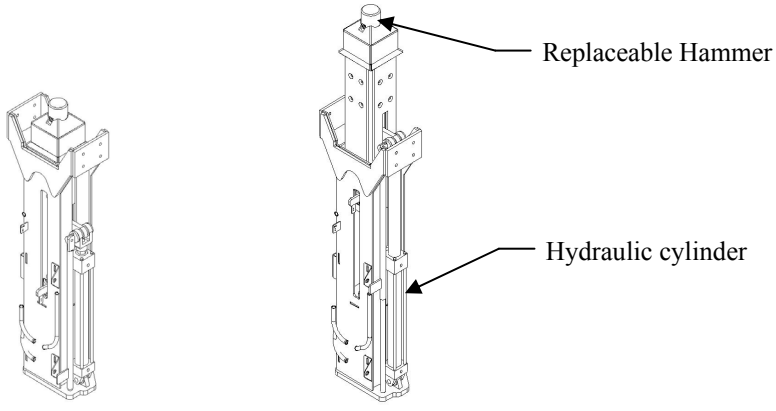

Fig. 3—Four tonne pin popper device in retracted and extended positions.

Figure 3 shows the four tonne pin popper removed from the slide carriage. The key elements of the pin popper are the stored energy system, and the quick-release latch mechanism. The stored energy system could have been one of many things, for example, hydraulic accumulator, gas accumulator, steel spring, rubber spring or even electro-

mechanical. However, it was decided to utilise an off-the-shelf compression spring primarily because a spring can operate for many millions of cycles, and is quite cheap to replace. It is expected that the spring will only operate approximately 60 000 cycles in one season, based on the relatively small number of four tonne bins in the fleet. With the guidance of a spring manufacturer, a size and style was chosen.

The latch mechanism, being the most critical component of the device, needed to be very reliable and preferably non-mechanical to eliminate the element of wear. The options were wide and varied, from stored gas, to sophisticated mechanical latches and electro-magnets. A choice was made to investigate the use of an electro-magnet to hold the spring energised and to release on demand after removal of the power to the coil. This system became the latch of choice due to the compact nature of the magnet and, most importantly, the absence of any wear components.

Many hundreds of thousands of cycles are achievable with electro-magnets providing duty cycle rating is taken into account during design and the load is placed firmly in contact on the face before it is energised. In this system, the magnetic coil was chosen to be energised just prior to needing it and then deactivated a few seconds later. The magnet is not energised again until required. This strategy reduced the duty cycle to not more than a few percent of the design capacity. The head of the hammer is high tensile steel and easily replaceable as mushrooming occurs. Quite a lot of switching and safeguarding in relation to human interaction was included to avoid injury and equipment damage; however, that detail is not included in this paper.

Initial results

The six tonne rotary uncoupler operated effectively for the 2006 season with a minimum of issues. The major interruptions were related to bent handles causing the device to fail to uncouple. A higher system pressure was required for the rotary uncoupler than used in the Farleigh mill unit, which was related to the bins being uncoupled in a stationary position rather than moving.

The reliability was also improved by manufacturing a new top plate which had better gripping power on loose handles and allowed bent handles to easily pass behind the uncoupler drive lug without causing further damage. An alteration was made to the PLC logic to allow the uncoupler a second attempt in the event of an uncoupler failure. Reliability was improved to a level where the operator could comfortably perform other duties (cleaning etc.) while the six tonne rotary uncoupler was in service.

The four tonne pin popper operated only for the later part of the 2006 season. Initial problems were associated with ensuring the magnet would hold the spring energised. The latch plate failed to achieve firm contact with the electromagnet, a problem which was overcome by mounting the magnet on a spherical surface to allow perfect bedding. Once this change was completed, the major issues were reduced to accurately positioning bins and having pins without excessive wear. A trial adjustable bin stop was manufactured to improve the positioning of bins. It was found that there was enough similarity between the bins (from front axle centre to the centre of buffer) to position the bins using a single, correctly placed anti-roll-back stop.

The reliability of the uncoupler improved, however more work needs to be completed during the 2007 season to further refine the operation. An operator is still required to monitor the four tonne uncoupler as its does not yet have an acceptable level of reliability. Further work will also be completed in 2007 to improve the standard of bin pins within the fleet of four tonne bins.

Conclusion

Uncoupler devices for six tonne and four tonne bins were installed at Marian mill prior to the 2006 season and operated with varied levels of success. The rotary uncoupler device is well proven and performs with a high degree of reliability. The four tonne pin popper device will work reliably with the introduction of an adjustable four tonne bin stop and with further maintenance on the condition of the four tonne bin pins.

A suitably sized electro magnet can be used effectively for reliable latching of an energised spring.

Extra sensing equipment and safeguarding will be installed to detect the failure of the device to uncouple. These additions will also offer easier intervention, allowing the operators' duties to be reduced to uncouple on an as-needed basis only, freeing their time to perform other duties, and reducing exposure to operating hazards.

Although not yet complete, the design offered a cost effective solution that has already made major gains at improving the flow of bins through the Marian mill weighbridge.

Acknowledgements

The authors would like to express thanks to management and board of Mackay Sugar for funding the project.

The authors would also like to thank Mr Royce Bishop for his technical interest and project leadership, the maintenance and operational personnel of Marian mill who ensured that the devices continued to perform well after commissioning. Tony Lloyd, Peter Mitchell and Peter Simpson are recognised for their concerted effort to ensure that the project presented a long-term solution and not just a quick fix.

Mr Ian Patterson and Jason Sheridan of Ian Patterson and Partners used their 3D capabilities to quantify the authors' conceptual ideas while Mr Clyde Muirden of Atrax Control applied his PLC programming skills and prior knowledge of the Marian mill weighbridge logic.

REFERENCE

Childs, E. (2006). Can robots with vision systems be used to uncouple cane bins? Proc. Aust. Soc. Sugar Cane Technol., 28: 415–419.