Developments in Cathode Stripping Machines - An Integrated Approach for Improved Efficiency

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Abstract

Copper cathode stripping machines and stainless steel cathode plates are critical elements determining the longevity, productivity and efficiency of modern tank houses. In the last decade notable innovations have been the ISA2000 and Kidd robotic cathode stripping machines, and enhanced integration with the overall electrode handling system. The acquisition of Falconbridge by Xstrata in 2005 provided a unique industry opportunity to bring two competing technologies together and has led to the development of a new stripping system which accesses the successful IP, experience and know-how of both ISA and KIDD systems of the past.

This paper presents a new copper cathode stripping system, developed and prototyped by Xstrata Technology in 2009, for the electro refining and electro winning industries. It features the use of robots for both the handling and stripping functions, providing a highly reliable, low-maintenance handling system. The flexibility that comes with robotic operation also offers shorter delivery time, simplified installation and high operational capacity.

The performance, safety and efficiency features of the new Xstrata Technology Robotic Cathode Stripping system are presented, along with an introduction to flow on impacts for other areas of tankhouse design and operation.

Introduction

The adoption of permanent stainless steel cathode electrodes in the electro-refining of copper was the most significant process development since the first commercial electro-refineries were built in the late 19th century. Invented and commercialised by Mount Isa Mines, the ISA PROCESS^{TM} was first implemented into Copper Refineries Limited (CRL), Townsville, in the 1970's. The KIDD PROCESS by Falconbridge evolved in the 1980's and was first implemented into the Kidd Creek Tankhouse, both operations converting from traditional copper starter sheets.

Due to the permanent re-usable nature of the stainless steel cathodes, it has been a critical design requirement of electro-refineries to have an efficient and reliable integrated electrode handling and cathode stripping system. The acquisition of Falconbridge by Xstrata in 2005 has led to the development of a new cathode stripping system which accesses the successful IP, experience and know-how of both the ISA and KIDD systems.

Background

Permanent Cathode plate Technology

Numerous benchmarking studies [1,2] clearly demonstrate the widespread use and operational record of the ISAPROCESS™ and KIDD PROCESS for copper electrorefining and electrowinning. Today more than 11 million tonnes/annum of copper cathode is produced worldwide using ISAPROCESS™ and KIDD PROCESS. The significant features are summarised in terms of;

- Improved copper cathode quality
- Higher operating intensity and current efficiency, giving increased production rate per cell
- Longevity and Reliability
- Improved labour productivity
- Operational flexibility

Although stainless steel permanent cathode plates are critical components in maintaining a productive and efficient tankhouse, just as important are the stripping machines that process the Cathode plates on a daily basis.

Permanent Cathode Stripping Machines

The ISA and KIDD cathode stripping systems have both constantly improved and evolved as a result of the ongoing research and development carried out by MIM and Falconbridge respectively, resulting in several generations of CSM design over the past 30 years. The historical developments of the ISA and KIDD technologies have been well documented [3,4,5], and today there more than 100 installations worldwide.

The method of stripping copper from stainless steel and associated handling of the permanent cathode plates and the copper cathode product all have several options in their design and commercial application. Commercial applications can be grouped by the stripping mechanism, and material handling methods, as shown below in Table 1, summarizing the various stripping systems developed by Xstrata Technology.

Table 1 - Comparison of Layout, Materials Handling and Stripping Mechanism

	Low Capacity (<150 plates / hour)	**Medium-High Capacity (150–600 plates/ hour)**
ISA	➢ Flexor Stripper with Pivot Arm. ➢ ISA 2000 Flexor stripper	➢ Original ISA Machine, traverse conveyor, using wax bottom masking. ➢ ISA 2000
KIDD	➢ Standard Linear KIDD machine.	➢ Original KIDD carousel machine. ➢ KIDD multi-function stripping station using Robotic loading / unloading.

The key difference between the ISA and KIDD stripping mechanism is related to the physical form of the copper product. The ISAPROCESS™ stripping produces a split sheet product, 2 separate sheets of cathode from each Cathode plate, while the KIDD PROCESS stripping produces a V-sheet or “taco” style cathode copper which remains joined along the bottom edge.

Both types of copper product are widely accepted, and user preference often dictates design. For example, the ability to automatically reject only one side of the cathode plate using the ISA stripping system is preferred by many electrowinning operations, whereas the new KIDD stripping system is preferred by some refining operators.

Electrode Handling Systems

Efficient integrated electrode handling is paramount to a productively operating efficient tankhouse. The prime objective of the cathode stripping machine is to safely process the copper as quickly as possible, in order to minimise the downtime associated with cathode stripping operations. In business terms, asset utilisation and productivity comes through continuous plating of copper and this cannot occur unless blank SS Cathode plates are routinely returned to the electrolytic cells. Lost time efficiency from stripping operations generally accounts for around 4-6% in electrorefining operations.

The electrode handling system productivity depends on both mechanical and process factors. This section considers the main process related factors that affect overall cathode stripping machine throughput. Common causes of reject copper in the CSM are briefly given below;

- **Thin copper deposits** are caused by short circuits, limited plating time, poor alignment or poor electrical contacts. Thin copper is difficult to separate from the stainless steel plate due to its lack of rigidity, and generally requires rejecting and manual stripping
- **Sticky copper deposits** are generally related to poor surface condition on the cathode plate, such as corroded surface or improper mechanical treatment. These are also problematic to separate in the flexing station.

- **Heavily nodulated cathode** can often cause stoppages in the cathode stripping machine as the protruding nodules interfere with guides and other parts of the machine. It is generally more efficient to reject these plates than to attempt to strip them through the machine and risk long interruptions to the stripping.

- **Laminated Copper** is a particular issue that occurs with ISA 2000 cathode stripping machines. This results when DC power supply to the electrodes is stopped during the growth cycle, then resumed again, causing a lamination in the cathode deposit. While these events are rare, they can have a significant impact on cathode stripping rate for the affected cathodes.

  ISA 2000 stripping relies on the separation of the 'frangible' portion of copper inside the bottom edge v-groove, see Figure 1. This portion has a natural line of weakness starting from the void inside the v-notch and travelling downwards vertically through the deposit. Laminated cathode has a secondary line of weakness along the lamination which often affects the ease with which the two sheets can be separated. The ISA2000 cathode stripping machine successfully deals with this cathode by detecting splitting failure and automatically carrying out one or several repeat down-ending cycles (referred to as 'flapping'), however does lead to slower overall stripping rates as reported at the Hitachi refinery [6].

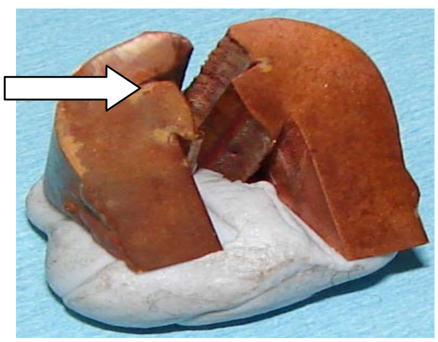


Figure 1 – Laminated Copper

Figure 2 – Magnified view of lamination

- **Strong Envelope c**aused by thick copper deposits or exceptionally hard copper. Causes curving above bottom of the cathode, difficult to separate, difficult to bundle neatly, aesthetics of final product lowered.

In summary, various operating factors can result in longer CSM cycle times, thereby lowering productivity and efficiency. Furthermore, manual handling by operators and other staff is generally required (increasing chances of injury) if separation can not be achieved. Therefore, it is apparent that a stripping machine needs to be designed to handle all types of copper deposit conditions as ideal conditions can not always be achieved in the real world.

Objectives and Methodology

The objective for Xstrata Technology in this development was to create a more accommodating and universal stripping machine, initially focussing on the production of spilt sheet cathode copper product. This new process was created with the goal of bringing the designed stripping rate, effective stripping rate and actual shift rate closer together. In order to achieve this, rather than designing to a specific and strict set of copper conditions, the new process and machine were designed to flex and strip copper regardless of how variable the deposit. Therefore, improving the reliability of the machine and meeting scheduled production rates independent of process variables.

The Xstrata Technology core designs principles were maintained, namely:

Safety - specifically the controlled handling of the copper cathode sheets during stripping operation, Reliability, Ease of Operation, Noise Reduction, Minimise potential for damage to the SS Cathode plates, Flexibility to handle all types of copper deposit and cathode plates, Maintainability and Sustainability across initial capital costs and investments to product and materials life cycle.

The design for the latest concept came as a result of a methodical and fresh approach adopted from the following:

1. Research and development conducted on several other successful Xstrata Technology designed, implemented and operating cathode stripping machines / processes.
2. Experience from numerous ISA/KIDD licensed refineries around the world.

Strengths and weakness from all machines were drawn upon when formulating the new Xstrata stripping concept. Standard design process and stages were then implemented.

Current CSM Technology

A number of machines were examined and tested in the creation of the latest robotic cathode stripping machine. A summary of operational backgrounds and key features from the existing designs that were critical to the development of the latest Xstrata Technology stripping system are presented below:

ISA 2000 CSM

The ISA 2000 Waxless machine uses hydraulics to drive a set of stripping knives downwards in between the copper cathode and stainless steel blade. This machine opens the copper envelope approximately 30 degrees each side (60 degrees total). The grippers then engage onto the copper sheets and the down enders rotate downwards about the bottom edge of the cathode until the copper sheets are taken just past horizontal position (approximately open to 195 degree angle). If separation does not occur, the downenders go up and down repeatedly (flapping) until the copper fatigues, cracks and separation occurs. The copper is then dropped onto a transfer conveyor where it is taken to be sampled, weighed, labelled, bundled and strapped.

The ISA 2000 CSM's have been operating successfully in refineries and electrowinning operations since 2001. They provide full control of copper sheets, produce a split sheet copper cathode product bundle and require minimal operator intervention during stripping.

Figure 3 – ISA 2000 Waxless machine stripping station

The need for improvement on this machine comes as a result of being originally designed to a strict set of "normal operating condition" copper deposits. Where there are variations in the operating conditions, the affects may result in increased cycle times. In addition, the force application position of the down ender grippers affects the separation reliability, especially when the copper is laminated or has a strong envelope.

ISA 2000 Flexor Stripper

This stripping system is a development based on the proven low capacity flexor stripper system patented by Xstrata Technology for use in electrowinning operations to allow operation without bottom edge strips or wax. The ISA 2000 Flexor Stripper uses a similar stripping function to that of the high capacity ISA 2000 Waxless machine.

The hydraulically driven knives on this machine extended the full width of the plate. This allowed the support and application of the stripping force across the full width of the stainless steel blade

and copper respectively. It also worked well in helping maintain a straight copper cathode in addition to aiding the separation of the cathode in the corners where it is generally more difficult to separate as shown in Figure 4and Figure 5 below.

Figure 4 – Thin Wedge, Curved copper due to separation issues on edges due to faulty edge strips

Figure 5 – Full Width Wedge, uniform copper separation

The first set of knives typically opened and split the copper. The secondary set of knives was used only when the bottom bond was strong or separation didn't initially occur (by opening the copper to the horizontal position). If separation still did not occur, flapping arms raised the copper back up to approximately 45 degree opening (90 degree open envelope) and then the knives were used again to bring it back down. Both sets of knives were attached to a "cassette" allowing the first set of knives to get closer to the bottom edge of the cathode (pivot axis of the copper envelope). The cassette moved up and down vertically and also had the flexing station attached.

This design allowed a full function machine to be compressed into the size of a single station making it ideal for space or capital limited operations, although cycle time is extended.

Critical learning's during testwork included the difficulty in flapping using the two separate mechanical devices (knives and flapping arms) as they had to be well co-ordinated. It was also observed that very large forces were required to strip the copper due to the linear movements and no mechanical advantage or leverage in the mechanical devices. However, this was easily overcome through the use of hydraulics.

Successful implementation and operation of this stripping system has been applied at the Tenke Fungurume electro-winning operation, with several more systems due for commissioning in developing projects. It is best suited for low production applications.

Figure 6 – ISA 2000 Flexor Stripper

Roller Stripper

The Roller Stripper CSM was developed and commissioned on site at Townsville copper refineries in 2008. This machine was primarily designed for research and test purposes with some potential for retrofitting to existing ISA 2000 machines and greenfield installations.

The prototype machine employed a new concept in copper cathode stripping (patented by Xstrata Technology). The objectives of this design and development were to:

1. Reduce friction
2. Eliminate Plate damage
3. Maintain a flatter copper cathode

A three roller combination was formulated and uses similar motions to that of a normal wedge. The rollers extend the full length of the plate providing maximum support to the plate and stripping force to the copper. As shown in Figure 7 below, the top roller supports the plate and provides a reaction force to help separate the copper from the stainless steel blade. The middle roller supports and applies the stripping force to the copper cathode (this is normal to the roller and perpendicular to the face of the copper cathode). As the copper rotates towards horizontal, the force applied by roller 2 becomes vertical. The bottom roller is used when separation does not occur first time and provides support to the copper when bringing the rollers back up to the start position. The cycle is then repeated.

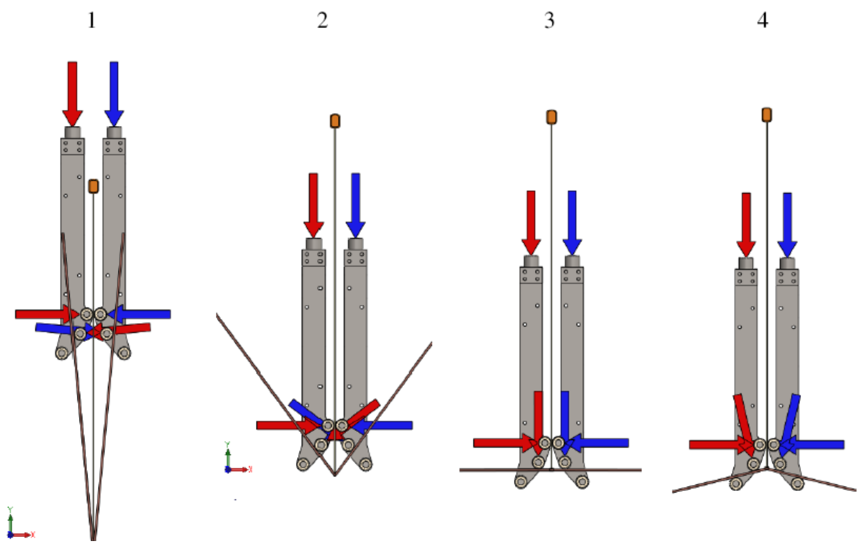


Figure 7 – ISA 2000 Roller Stripper

During testing it was observed that this machine was far superior in separating the copper sheets when compared to the previous two ISA 2000 machines. Test work demonstrated that in addition to supporting the copper across the full width, the rollers applied the force very close to the envelope pivot axis and concentrated all the fatiguing of the copper into the correct separation area.

This study gave an understanding of the critical force values which allowed the continuation and development of the new concept and confirming the possible use of robotics [7].

Other observations included:

- The ability to open the copper cathode past horizontal also aided in the fatiguing and crack propagation when trying to separate the copper. When the rollers moved upwards again, the force was still applied in the same position where as in other machines it can be dissipated and translates into bending of the copper cathode.
- The rollers were extremely quiet and left no plate damage.
- Maintains a very flat copper cathode sheet

The New Concept

It was apparent from the previous research and test work that the point of force application on the copper cathode had a substantial impact of the separation reliability. This was the main driving factor in the design and development of the new CSM process concept.

The following design parameters for the new concept were set based on the test work and operational experience from both the ISA and KIDD stripping systems:

- Small opening angle - Initially open the copper envelope as minimal as possible to prevent any bending of the copper in the sometimes weaker section just above the bottom edge of the envelope.
- Full width mechanism - Support the full width of plate (eliminate risk of plate damage) and copper (maintain straight flat copper cathode)
- Maintain or Increase Speed – Maximum speed to ensure fast cycle times
- Reliability – be able to strip the complete range of deposited copper from normal operating conditions to laminated
- Reduce Friction – to provide an efficient and lower maintenance machine

The following prototype was designed and constructed for initial testing on site at CRL. It comprised of four vertical members profiled in the shape of a wedge, it was designed to support the entire face of the copper cathode when rotating or stripping (Figure 8). The sharp angle allowed the wedge to reach the bottom whilst maintaining a minimal opening angle on the way down to prevent the copper bending as mentioned previously. The arms on either end locked in to a horizontal shaft to help keep the wedge in position during rotation, ensuring that the wedge made it to the bottom and guarantee that all forces were applied into the correct position on the copper cathode during separation.

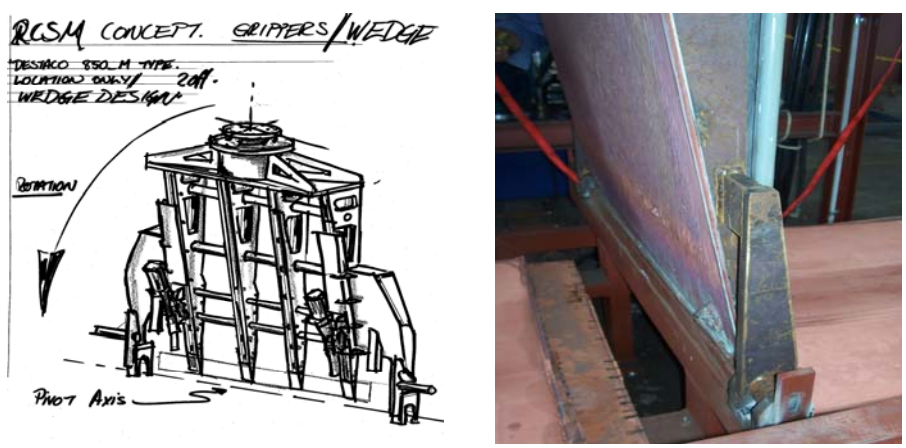


Figure 8 –Concept and prototype design

Some of the challenges in the design and development stages included:

- Forces involved with reaching the bottom

  - Initial test results from the roller stripper and prototype wedge suggested that the forces required to get to the bottom of the cathode plate might have been above the capabilities of the available robots. After further testing and an investigation by John Hart, it was found that with the recent improvements and advancements in robots, they would be able to handle to task with slight modifications being made to the process and program of the robots to aid and ensure they would reach the desired point.

- Process difficulties (the range of movements required)
  - The new concept could be applied to either hydraulically driven mechanical components or robotics. However, due to the complex range of movements required by the concept process, it was thought that it was not practical, economical or desirable to construct using hydraulics.

The New Xstrata Technology Robotic CSM

Xstrata Technology has now taken the new concept through a complete design process and obtained a patent on the new cathode stripping process and design. Mechanical components driven by electrical devices, pneumatics or hydraulics could be used, however XT's determined that robotics was a far superior choice due to the many inherent advantages, namely:

- 80,000 hrs mean time between failure (MTBF) ~ 18 years at 12 hours per day
- High accuracy and precise movements - protect the SS cathode plate
- Proven capacities 900 kg and greater –capable of performing stripping function
- Flexibility – can be programmed and or easily changed to suit a wide variety of plates, copper conditions and equipment layouts
- Installation and commissioning time – very easy program modification and installation
- Excellent safety standards – program incorporated safety features + complete operator control with reduced or eliminated manual handling.
- Low noise and clean - no hydraulic fluids

The choice of robotics itself was innovative as this was the first time robotics were used in a copper tankhouse to perform a process or task other than simple pick and place materials handling.

Tooling Design

The design of the new robotic tooling (Stripping wedge) was the next critical stage and consisted of the following features:

1: Guides – implemented to support the copper during the downwards vertical motion, ensuring the copper does not pre-strip. In turn making the new process safer as there is complete control over the copper cathode at all times.

2: Grippers – used to clamp the copper before the rotational down ending starts, again, giving the robot and the tool complete control over the copper cathode at all times. In addition, this prevents slippage and concentrates all the forces on the void or weak spot in the bottom edge of the copper envelope.

3: Rollers – designed to reduce the friction between the copper, stainless and the wedge during the downwards vertical motion. This lowers the force required to get the wedge to the bottom whilst minimising or eliminating damage to the plate, wedge and copper. Finally, with the reduction of friction there is a reduction in noise and wear on respective components.

4: Wedge – the current prototype wedge was constructed from 350 grade mild steel and 316 grade stainless steel. Optimisation of materials of construction is ongoing.

A. Wedge Frame – consisted of three vertical members for strength and rigidity whilst also providing attachment points for the guides, grippers and other equipment.

B. Wedge Blade – featured a bevelled tip to ensure scratching or damage is kept to a minimum. This also allowed for maximum support of the copper cathode.

5: Pneumatic components – pneumatic components were used to maintain the goal of eliminating hydraulics. In order to reduce maintenance and maintain a cleaner work environment. Further testing is currently being performed to determine if the pneumatics can produce the required strength and forces needed to carry out the stripping process across all ranges of copper deposit and production hours.

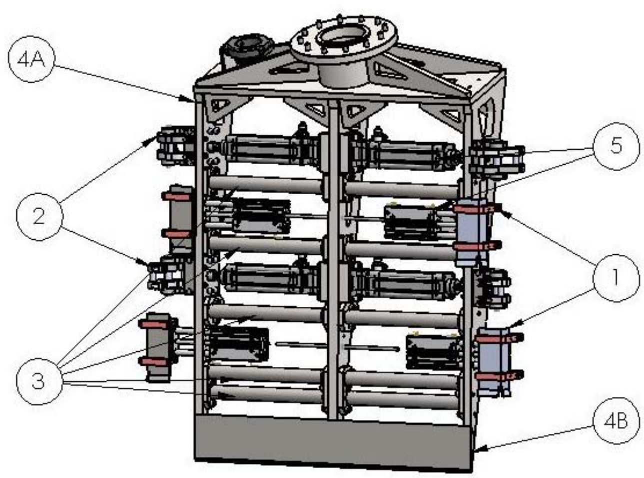


Figure 9 – ISA 2000 Stripping Wedge

Prototype Installation

On site at the Xstrata Townsville copper refinery a prototype robot cathode stripping machine was retrofitted into the original ISA 2000 waxless test stripping machine. As shown in Figure 10 and Figure 11 below, the robots greatly open up the stripping area allowing easy access for operators, maintenance, forklifts and other equipment.

Figure 10 – Before

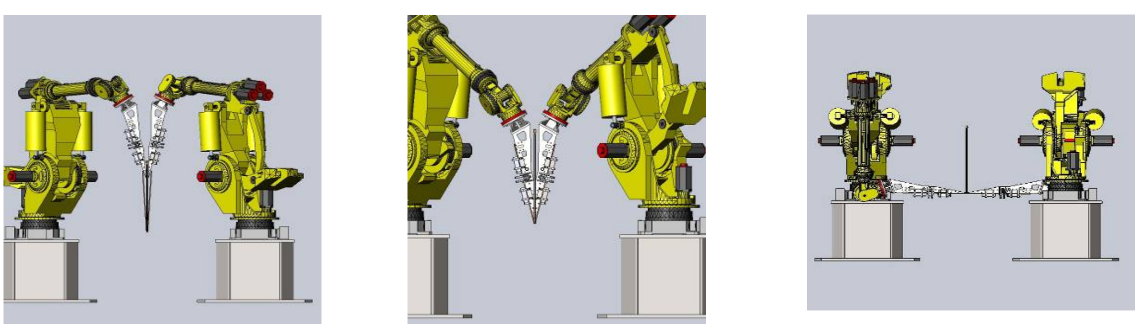
Figure 11 – After

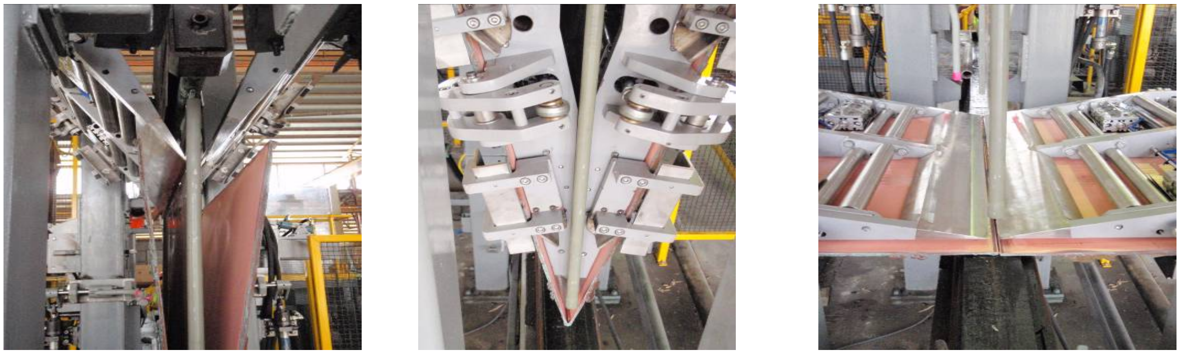
Stripping Process

The process in which the wedge works is similar to the original ISA 2000 waxless stripping machines. However, in this case the knife, grippers and transport conveyor are all in the one apparatus. Figure 12 A to C provides a snapshot view of the movements of the new Robotic stripping wedge and its flexibility.

The permanent stainless steel cathode is presented in the stripping station already flexed and pre-opened, the robots then bring the knives in tip first until the blade is approximately 50mm past the top of the copper. At this point, the wedges start rolling to a vertical position whilst they are travelling in a downwards motion (the tips of the knives only mm away from the blade on each side). Once the wedge is down far enough to clear the hanger bar (shown by recess in wedge profile) the wedge is completely vertical and the rollers are touching the stainless steel blade keeping the knife edge away and unable to cause damage.

Figure 12B shows each of the wedges in the bottom position just before down ending. At this point the grippers are activated and the copper becomes clamped. Both wedges roll to horizontal about an imaginary axis which is perfectly aligned with the void in the copper envelope cause by the v-groove. Once horizontal, the wedges rise slightly and then pull away from each other separating the copper and transporting it away to a bundle, transfer conveyor, weighing device, reject bundle, sampling device or any other station the customer desires.





A B C

Figure 12 – Robotic Cathode Stripping sequence

Performance and Results

Testwork of separation efficiency to date has been outstanding. No flapping has been observed in the Robotic Stripping system when processing standard V- grooved stainless cathode plates, with laminated copper cathode. When processing stainless cathode plates prepared with significantly reduced V-groove condition and laminated copper deposit, a maximum 3 flapping motions were required.

If the copper did not separate on the first attempt, the robots "flap" the copper in a specific program sequence. Importantly, there is no bending in the copper and all the forces are concentrated in the same location leading to the vastly reduced flapping frequency.

With increased separation reliability, the average cycle times gets closer to the designed cycle times providing operators with satisfaction and guarantee that they will meet throughput and production requirements irrespective of copper deposit conditions.

Testwork on the Robotic Stripping prototype is ongoing, and in parallel it is used by the Xstrata Copper operating refining to process stainless cathode plates rejected from the commercial stripping machines.

Flexibility and Safety

The robots can be programmed to handle a variety of different situations minimizing manual input. They have the ability to perform a number of different processes (initiated by the push of a button) throughout the stripping cycle dependent on the copper condition and operator's desires.

The robots also have the automatically or by operator controls to safely remove the copper with out any manual handling of the copper or entry into the stripping area. This feature greatly improves operator safety. Furthermore, if the copper sheet is to be rejected for quality reasons, whether it be one side or both, the robots have the ability to transfer the single sheets to a separate reject bundle or any other customer desired location with in the robots reach. This feature, in combination with online cathode quality scanning devices, would provide significant materials handling benefits to the operation.

Applications / Implementation

The new Xstrata Technology Cathode Robotic Stripping system is extremely flexible and is suitable for both green field and retrofit applications. It would be very well suited to implementation in:

- Plants with variable copper deposits which may be difficult to strip
- Plants where manual sorting of reject cathode copper occurs.
- Refineries with un-reliable power supply or regular power outages during plating)
- Smaller scale production operations
- Tankhouses where time efficiency is extremely important and critical to project continuation
- Conversion of older plants from wax to waxless

Ongoing Development

Xstrata Technology understands the features of the new stripping process and robotic control provide potential for advantages in other areas of the tankhouse design and operation to gain better productivity and efficiency. Scope will include optimising the permanent cathode plate design due to more precise and flexible control when using robotics to achieve reduction in operating and capital cost. In conjunction, there is potential for further improvements to automation of crane lifting and handling systems.

Xstrata Technology continues to develop these concepts as part of its' ongoing research and development programs

Summary

The Xstrata Technology research and development program achieved the objective to create a more accommodating and universal stripping machine, for the production of spilt sheet cathode copper product. Implementation and installation of the next generation Xstrata Technology Robotic Cathode Stripping system has the following advantages:

- Reduced capital costs (reduction in conveyors and transfer equipment)
- Small foot print especially for stand alone units
- Can retrofit into existing machines with small modifications
- Easy to install and commission
- Provides operations currently producing split sheet ISA product bundles increased flexibility in the sequencing of normal harvesting operations and during smelter shutdown periods.
- Reduced noise (elimination of hydraulics, reduced impact noise from copper sheets)
- Increased time efficiency

- Flexibility with copper transport and rejection

Acknowledgments

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