Retrofit opportunities in aluminum smelter using DIDION rotary thimble cleaning and carbon crushing equipment

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Abstract

All primary aluminum smelters are interested in improving their efficiency and energy saving. Two areas where DIDION rotary processing equipment can improve the efficiency of operation, energy use and significantly reduce existing maintenance cost is in the crushing of spent anodes and cleaning cast iron thimbles and pig iron. Aluminum smelters typically use a series of crushers, conveyors screens and magnetic separation for crushing spent anodes for recycling into the green carbon plant. Maintenance costs on this type of equipment in ageing smelters are quite high and the downtime significant. A DIDION RT Crusher can replace an entire crushing line, encompassing several primary, secondary and tertiary crushers with one unit capable of receiving full size baked scrap carbon blocks and spent anodes at production rates up to 30 tonnes per hour. The thimble cleaning operation in most smelters is typically done with a series of storage hoppers and conveyors into a batch processing shot blast unit that uses steel shot as a consumable product. After processing, the thimbles are often still carbon contaminated, which reduces the quality of the iron collars for cast iron sealing of carbon blocks to the anode rods and thus increases the stub-to-carbon voltage drop in the cells. With age these systems become expensive to maintain. The DIDION thimble cleaner simplifies this process, requires less production space and produces a cleaner thimble as well as pig iron for cathode assembling.

Keywords: Processing of spent anodes; DIDION crusher; DIDION thimble cleaner.

1. Introduction

DIDION has the most widely developed equipment and applications for rotary crushing and separation systems for the recycling and recovery of dissimilar materials that are often mechanically bonded together. The development of this technology was started in the foundry industry in the early 1970's. The first step was the separating of metal castings from the foundry sand mold pieces in which the castings were created. Handling these hot, heavy castings required the development of a very durable machine. The equipment was next used for sand reclamation applications to keep these foundry materials in use and out of landfills.

The continued improvement of the DIDION RT/RS TUMBLERS has made mechanical processing of mixed materials a very cost effective and low maintenance alternative to other processing systems [1]. These flexible systems can perform surface scrubbing, crushing, screening and sizing in one single piece of equipment. The DIDION systems take up far less space than conventional crushing and screening process facilities. While at the same time the system requires less maintenance and manpower to operate.

2. Basic system design features

There are four basic features of the DIDION RT/RS Rotary Processing Systems:

- First, the ability to process very large pieces of feed stock in the same processing step as finer materials. Depending on the model, up to 1800 mm (72") blocks can be processed at the same time as granulated fines.
- Second, the ability to "scrub" a surface removing materials that are foreign to the base structure allowing for valuable base structure materials to be recycled and reused.
- Third, the ability to crush with controlled fines generation and full dust control.
- Fourth, the ability to classify several sizes of material from bag house dust to 1800 mm (72") solid metallic pieces, within the same piece of equipment.

Figure 1. DIDION RT 108 DIDION Crusher / Metal Separator.

3. Spent carbon anode processing

The standard recycling process for spent anodes typically involves a primary jaw crusher, two or three horizontal shaft impactors and several cone crushers for the final carbon sizing. Magnetic separation units for the removal of tramp iron in the crushed carbon are located at multiple locations in the processing line. Multiple conveyors and screens keep the material flowing in the right size to the right crusher. If there are full size, either green or baked anode blocks that are scrap, they have to be handled separately and manually crushed. Thimbles and stubs must be removed from the process line as they could seriously damage the jaw and impact crushers.

Conversely, the RT systems will handle full size baked carbon anodes and crush them without any problems. Stubs/spiders can be charged into the unit without any fear of damage, as they will be restrained to the first crushing chamber and simply help in the autogenous crushing process.

Thimbles imbedded in the spent anodes too are no issue in the process and will ultimately be discharged clean from the carbon crushing RT unit. This is a very unique and money saving feature of this process. This one RT unit will also replace the primary jaw, secondary impact and fine cone crushing steps and perform this job in one RT unit. Screening the material to size and controlling the dust generated in the process all in the one processing step, saving significant floor space, energy and maintenance dollars that would have been spent on the standard type of crushing system along with its many conveyors and screening systems.

The RT Rotary crushing approach to spent anode and carbon recycling gives a lower cost recycled product to be reintroduced into the green carbon recycling process that is high quality and from a system that is more flexible with anomalies that may occur in the process. The crushed carbon product that is produced is angular in nature and with an acceptable fines level for green carbon recycling.

4. Crushing of large blocks of material

Handling large blocks of material can be particularly difficult for most processing systems. Most systems either use a primary jaw crusher or a mobile hydraulic hammer/crusher for this first breaking step.

The RT Systems process these blocks in the first section of the drum. The larger material is charged by end loader into a large hooded vibratory feed hopper that loads the drum. Hot materials can be charged with a vibratory cooling conveyor. Large cast steel teeth lift the blocks and then crash them down on hardened spikes for severe impact and size reduction. Stub/spiders or thimbles if mistakenly still attached to the carbon blocks cause no damage in this stag of the operation. The dam ring separating the main autogenous crushing chamber from the Concentric Crusher^{TM} (CC) chamber will not allow – 250 mm materials to pass thru to the next chamber.

Carbon pieces now less than 250 mm will pas thru the CC chamber and be impact crushed by this massive rotating fixture. This impact action produces the angular product with out generating large quantities of carbon dust and fines.

Figure 2. Spent anode, stub, thimble & bath.

Figure 3. Crushed carbon.

5. Crushing with controlled fines generation

The impact action of the material falling on the cast steel flights in the secondary autogenous chamber produces a violent crushing action. Uniquely this system also immediately removes the fines that are being generated in the process. The impact breaking action of the system continues to give sharp fracture angles on the particles, which are preferred for most bath and carbon recycling process. This step is critical to achieving process efficiency and success. The key technical challenge that the RT unit accomplishes is both removing these fines and preserving the preferred crushed material sizing, chosen by the liner slot openings.

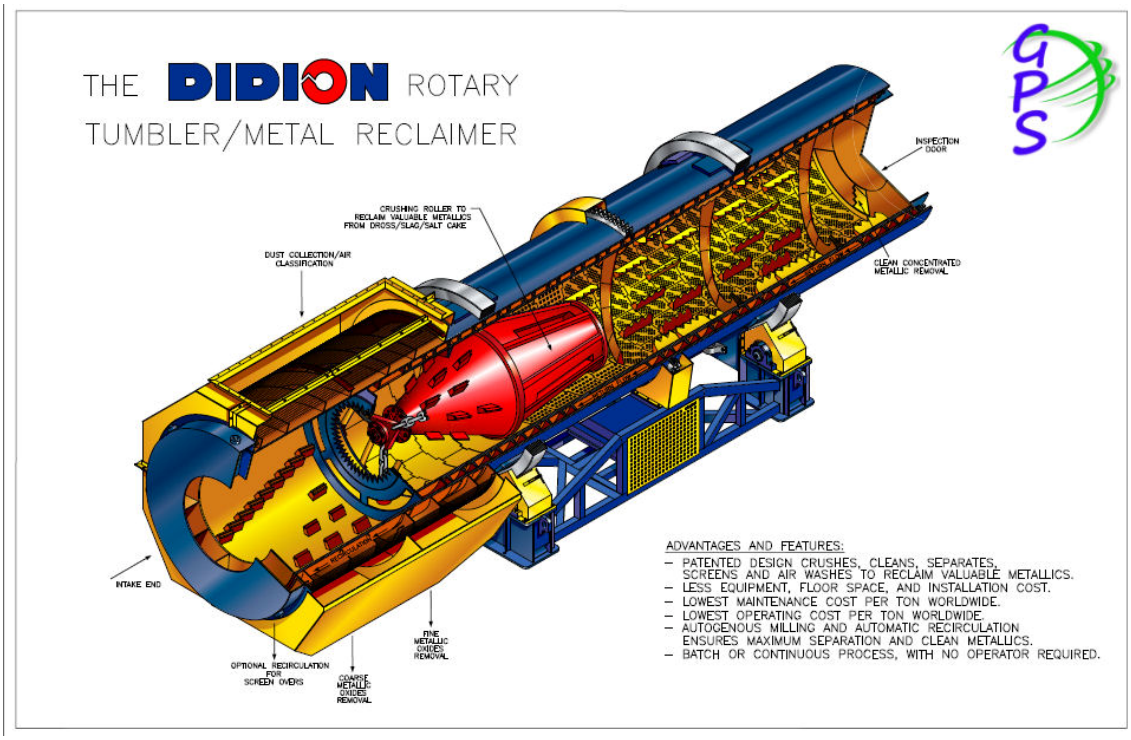

Figure 4. DIDION RT - Material flow diagram and fines separation .

Preselecting the correct liner opening and screen size determines the distinctiveness of materials, accomplishing the generation of the appropriate sized fines for further processing. This flexibility is a significant advantage of this process. Each smelter tends to have an upper size limit that can be closely set in the RT system.

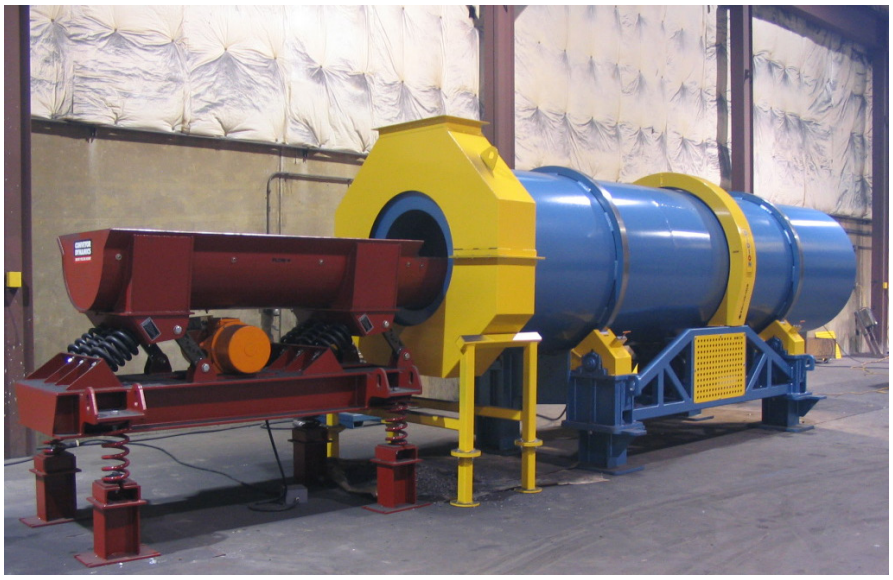

Figure 5. DIDION RS 200 SM thimble cleaner.

6. Rotary Thimble Cleaning

Dirt, rust and frozen alumina bath is left on the cast iron thimbles after they are removed from the stubs on anode rods. This contamination of the thimbles when melted in the induction furnaces reduce the quality of the cast iron thimbles and increases significantly the voltage drop between the stubs and carbon anodes and thus reduces the metal output from the cells.

Good smelter practices warrants cleaning these thimbles before remelting for their next campaign. This will provide better cast iron sealing of the stubs and carbon anodes and thus improved electric conductivity in the cells, reduce the anode voltage drop and increase metal output.

Today most aluminum smelters use conventional “shot blasting chambers” for cleaning the thimbles from the stubs on anode rods with some variation of a wheel shot blasting machines. These shot blasting machines are a quite big chamber with four/five blasting wheels.
The experience from most aluminum smelters is that these shot blasting machines work quite well the first year in operation but then the main problems are:

- High maintenance cost of the blasting wheels,
- High operation cost of steel shots,
- Steel shots on the floor, etc,
- Quite big machine and difficult to install in existing rodding shop,
- High investment cost in supply and installation.

Many smelters have stopped using these machines and are looking for better solutions. Some simple material tumblers have been used with mixed process results and maintenance characteristics.

The DIDION RS System has proven very good at replacing these shot blast units in several primary aluminum smelters. DIDION Rotary Carbon Separator / Thimble Cleaners utilize a highly efficient tumbling action for thorough cleaning of carbon and dirt from cast iron thimbles, including recesses for a cleaner melt.

The patented segmented alloyed wear-liner design, provides lower noise levels and much better wear resistance than other equipment possibilities. Cost savings include the elimination of shot blasting altogether, saving equipment, shot consumption, wear parts, maintenance time, floor space, and labor costs. The machine also serves as a horizontal storage silo with fully automatic feed of thimbles to reduce labor costs. The most common capacities of thimble cleaning in aluminum smelters are 2 tph or 4 tph.

7. "Scrubbing" surfaces removing materials that are foreign to the base structure

The principle of operation for the DIDION RS is low velocity impact and scrubbing action of the cast iron feed material. This feed material is lifted by the rotation of the drum and consequently drops from lifters cast in the wear liners within the drum itself. The system works by using the bits and pieces of the thimble materials to process itself, relying on the size differences of individual pieces of the material to clean even in the pockets where small amount of bath or carbon may be trapped. This tumbling action causes the products to impact and scrub upon each other and in doing so releases the trapped fluorinated waste and adhered carbon along with any other friable attachments. The released material is allowed to pass through holes within the wear liners as it is fed backwards inside a plenum chamber. The finer materials are then air transported by air to the bag house for collection. The remainder of the coarser materials are belt conveyed away from the process for recycling.

The interior design of the DIDION RT/RS systems can allow for multiple sections accomplishing a variety of processing goals. The scrubbing or removal of foreign material from the base material is a standard application for DIDION rotary equipment. In the original foundry applications for the units, it was the removal of sand from the base casting.

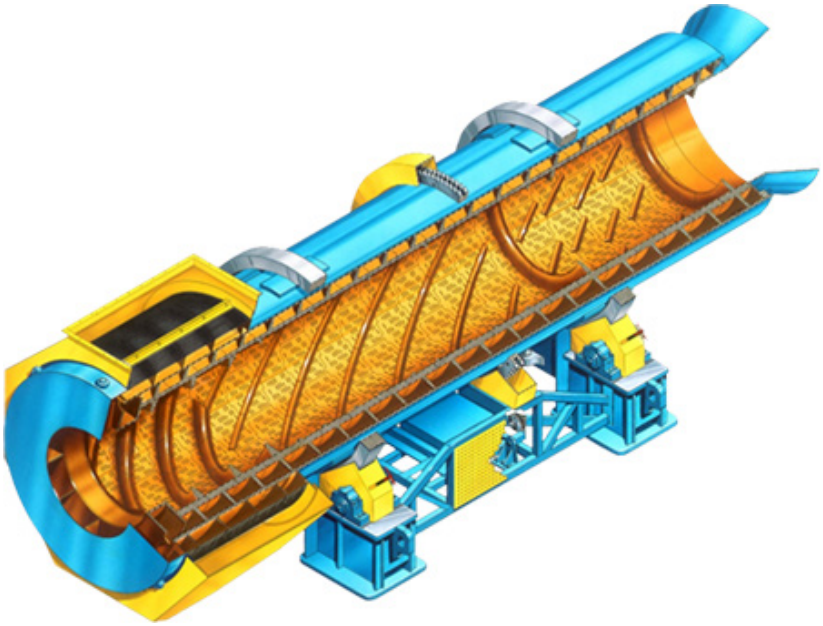

Figure 6. DIDION RS Heavy duty rotary separator / thimble cleaners.

In the case of removal of the bath and carbon from the thimbles, the RS Process leaves almost no carry over to the melting process. There is no shot contamination of the melt. The standard practice of shot blasting is inefficient and time consuming.

The steel shot is an expensive consumable that can be carried over into other aspects of the process. It is very important to remove essentially all of the sodium/bath contamination to the next phase of the process. These salt contaminants when cast into the thimble typically cause problems with the refractories in the carbon backing furnaces and in the thimble casting furnaces. The RS processing technique stops the majority of the bath and carbon carry over into the next part of the production process improving if not eliminating the furnace refractory issues.

Figure 7. Dirty thimbles.

Figure 8. Clean RS processed thimbles.

Further to cleaning the thimbles before melting. It is easy to add the pig iron to the thimble cleaning cycle. Pig iron is often stored outside and can be severely oxidized. This not only causes more slag build up in the melting furnaces shortening the refractory life but also can cause pops if the material is damp. Processing through the RS System can completely stop these safety and slag generation issues with the pig iron.

Figure 9. Pig iron and clean thimbles.

The purpose of cleaning the thimbles is to have more efficiently operated pots in the potline. The pay back of the system outside of the operating cost and maintenance is due to a reduction in anode voltage drop.

The average anode voltage drop between the stubs on the anode rods and the carbon anode is approximately 120 mV. MetalTech of Iceland, with some smelters has made *in situ* tests by comparing the mV drops in stubs not cleaned with proper stub cleaning technology. The result was that stubs properly cleaned showed in average 10 % reduction in this anode voltage drop or some 12 mV based on actual performance measurements at these smelters. MetalTech estimates that proper thimble cleaning with removal of carbon and electrolyte material from the cast iron before remelting in the induction furnaces will also reduce the anode voltage drop some 5 % or 6 mV.

It is estimated that proper thimble cleaning by the Rotary Carbon Separator will readily achieve an improvement of 6 mV, meaning power savings of 5 % of the anode voltage drop between the stubs on the anode rods and the carbon anode. This is a significant energy savings and helps with a rapid project payback period of only 1 – 2 years.

8. General comments

The installation space requirement for the largest RT unit in a carbon crushing application is an envelope of approximately 6 x 30 meters (20 x 100'). The envelope for a typical RS for thimble cleaning application is 5 x 10 meters (15 x 30'). This layout would assume that materials discharge into tubs. Conveyors can be added to the system for continuous input and removal of the products. These conveyors can be set up in many configurations for additional separation steps such as magnetic separation and/or product bulk bagging.

Operational costs are very low. The largest unit operates with a 200 kW (275 Hp) drive motor, the smallest with a 22 kW (30 Hp) drive motor. Processing cost per ton will vary with the size of the unit but are considered very low for crushing/separation/screening systems. Custom sizes, throughputs and processing configurations are part of the DIDION philosophy of equipment design and can always be evaluated and normally accomplished. Manpower requirements are also very low. Loading is typically automatically by the in feed vibratory conveyor.

9. Summary

The flexibility of the design configurations of the DIDION rotary processing equipment has many potential applications in the primary aluminum smelter environment. The RT and RS Systems are excellent candidates for retrofit as the process foot print is much smaller than the initial purchased systems with more product efficiency and a higher process quality. These dynamic systems can lower overall processing cost by reducing manpower, maintenance, energy consumption as well as reducing the plant area required for the anode crushing or thimble cleaning.

10. References

1. David Roth and Brian Best, Recycling materials through rotary crushing and materials separation in the aluminum smelter, Paper Al 19–T, ISCOBA 2012, 29 October – 2 November 2, 2012; Belem, Brazil.