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ELECTRODE TECHNOLOGY FOR ALUMINUM PRODUCTION

Anode Rodding and Inert Anodes

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ANODE STUB 3D INSPECTION SYSTEM

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Abstract

In the production of aluminum from conventional prebaked Hall-Héroult electrolysis cells, anodes have to be replaced on a regular basis. The anode rod assemblies, which are submitted to multiple heating/cooling cycles, tend to deform over time, and attacks from HF gas and liquid bath erode the stubs to a different extent at each cycle. Following the anode butt recycling stage, the stubs have to be inspected to determine if the anode rod assemblies are still suitable for another run in the pot or if they require repairs. STAS has recently completed the development of a 3D measuring system allowing the measurement of hexapods and the likes. The proposed system allows multiple measurements to be taken at once. Stub lengths, erosion profiles, diameters, straightness and others can all be monitored. In addition to anode rod fitness for sealing, the system allows to keep statistics on the rod population.

Introduction

This paper presents a novel equipment designed to perform the inspection of anode stubs. Called the ASIS^{3D} (Anode Stub Inspection System), this new equipment is fully capable of inspecting anode rods fitted with a single (bipods, tripods) or a double (tetrapods, hexapods) row of stubs. In the present article, we will use the term “hexapod” to refer to any kind of stub arrangement.

Importance of Anode Rod Inspection

Anode rod inspection, whether manual or automatic, is an essential activity to ensure the proper operation of the rodding shop and of the electrolysis cells. Traditionally, anode rod inspection was limited to a visual check by an operator as well as some manual gauging as shown on Figure 1. The visual check would allow to send to repair rods with eroded, missing or bent stubs, and gauging would ensure that the alignment of the stubs allows the sealing of the rod in a new anode.

Figure 1. Manual gauging

In recent years, many studies related to performance penalties associated with the condition of the anode stubs have been published.

A fleet of anode rods of poor quality can easily consume an additional 50-70 mV over its designed voltage drop, which could result in millions of dollars annually in additional direct energy costs for an average size smelter [1]. Also, other costs such as rodding line stoppage, offline anode handling, greater probability of anode-related problems in the cells, etc., are associated to less-than-perfect inspection.

Manual inspection, performed using gauges and visual standards, is somewhat limited when more complex measurements have to be taken. With manual inspection, records of the rod fleet condition are not kept. Moreover, such inspection can be highly subjective and influenced by external factors such as workload of repair shop, frequency of defects observed in a given period of time, budgets, etc.

Automatic inspection, on the other hand, is not subjective, for all measurements are taken in the same manner, using the same references, and the system never gets “tired” or “bored” of doing the same task year after year. Moreover, there is more of an advantage in the use of an automated measuring system:

- Repeatability, independent of human perception.
- Capacity of taking measurements not possible for an operator, such as the stub lengths relative to a reference plane.
- Possibility to create a precise work order for each anode rod that requires repair. Online stub repair equipment can be automatically fed with the precise information.
- Capacity of building a database that records the condition of the entire fleet of rods.
- When used in parallel with unique rod IDs, ability to follow each rod individually and monitor its evolution in time.
- After data has been recorded for a while, the database will allow the anode rod repair shop to forecast the work load weeks in advance.
- Using the database and knowledge from the many studies on the factors affecting the stub-carbon connection, one could probably choose the repairs that have the greatest positive impact from an economic point of view.
- Using the same database and knowledge base, one could possibly evaluate the average anode-rod-related mV penalty associated to the average condition of a fleet of anode rods.

Automated Inspection Systems – Market Overview

Today, automated stub inspection systems are rarely implemented in rodding plants worldwide, one reason being certainly the unavailability of proven equipment. In 2006, however, STAS, in collaboration with Alcoa, developed such a system for single plane stub assemblies. The STAS ASIS-2D system [6] (shown on Figure 2) is installed at Alcoa Deschambault's smelter and has been running since 2006, relentlessly measuring some 400 AP-30 tripods a day. Still, 3D systems were not available to the industry, although some attempts have been made by a few companies to measure hexapods.

Figure 2. Tripod transit in STAS' 2D system

Development of ASIS^{3D}

Back in 2008, STAS investigated a few avenues to perform fast and accurate measurements of hexapods and the likes. Many simulations were performed back then, and exploratory prototyping was achieved for a few alternate concepts. At the beginning of the decade, STAS focused its work on one concept in particular and went through conceptual proof with the support of the laboratories and scientists of the CRIQ[1] (Centre de recherche industrielle du Québec). The selected approach was then confirmed to be effective and viable. However, the trillions of mathematical operations that have to be performed on every point cloud and the power of commercially available computers were an obstacle. Thanks to the fast developments in the field of computer hardware and the price decrease for multi-core CPUs, the computing power required for point cloud organizing algorithms now brings both the cost and the processing time at acceptable levels. From there, the winning conditions for an affordable and reliable 3D measurement system were laid, and STAS initiated the final phase of development. In late 2013, a complete prototype unit was developed within STAS' facilities, and the software development work was completed. The system is now ready for industrial implementation.

Presentation of ASIS^{3D}

The ASIS^{3D} scanning unit is built around multiple cameras and laser planes. The camera/lens assemblies are designed for a long stand-off and a deep field of view. The sensors allow us to configure the digitizer so that the cameras never get in the path or between the legs of the hexapods. There is no sensor placed under the path of the hexapod either. This prevents damaging the system if some cast iron falls or if a clad gives up during the measurement. Figure 3 shows a typical hexapod scanned using the ASIS^{3D}.

[1] Quebec Industrial Research Center

The system uses class 3 lasers installed in a fully opaque enclosure (Figure 4). Access to the scanning area is restricted by interlocked doors that prevent the operators to enter the machine while it is in operation. With all the security systems in operation, the equipment becomes a class 1 laser product, which means it is safe under all conditions.

Figure 3. Typical scanner output of ASIS^{3D}

Figure 4. ASIS^{3D} system

The system is installed in line with the rod conveyor, usually in the area where measurements are taken manually. In order to ensure the proper positioning of the rods to be inspected, a set of sensors and stoppers, interfaced with the conveyor control system, are used. When the rod assembly is stopped, scanning takes place and measurements are taken within the actual cycle time of the line.

Figure 5 shows a typical arrangement of the conveyor and sensors.

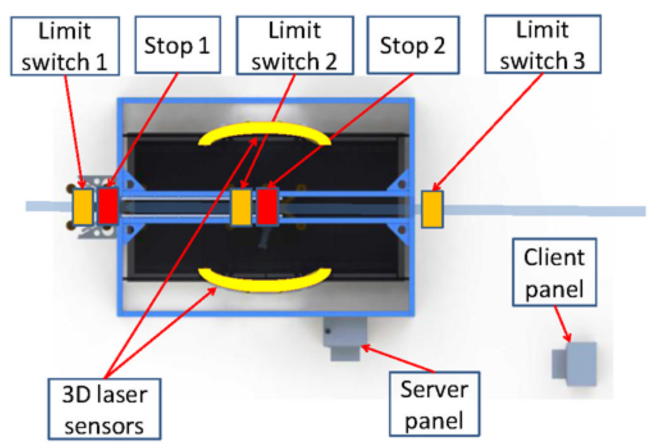

Figure 5. ASIS^{3D} typical arrangement

To perform the point cloud analysis, the system uses a world-class metrology software with algorithms developed by STAS. The ASIS^{3D} is designed to perform a thorough inspection of each of the hexapods. Inspection includes the following measurements:

- Length of each stub relative to a reference plane.
- Minimum stub diameter.
- Erosion of stub tip.
- Suitability for mating with a new anode block using a virtual go gauge (Figure 9).
- Etc.

To verify the accuracy of the system, we used a modified hexapod that mimicked a new and straight exemplary that allowed us to take precise manual measurements. The rather worn-out exemplary shown in Figure 3 was just not suitable for investigating the accuracy of the system. We measured the distances from stub to stub and the stub diameters. Table 1 contains the results of the diameter measurements as shown on Figure 6.

Table 1. Stub diameters

Diameters measured manually (mm)			Scanned	Offset
1st axis	2nd axis	Average	value	scanned-manual
141.3	141.5	141.4	141.8	0.4
141.0	141.5	141.3	142.4	1.1
141.5	141.3	141.4	141.5	0.1
140.5	140.2	140.4	140.9	0.5
140.3	140.2	140.3	142.6	2.3
140.5	140.1	140.3	139.4	-0.9
Average offset				**0.60**
Standard deviation				**1.08**

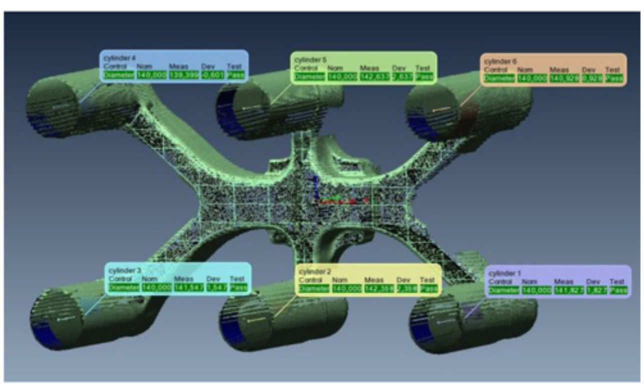

Figure 6. Stubs diameters

Figure 7 shows a skilled technician measuring stubs manually. All stub diameters were measured using a caliper. Each stub was measured in two perpendicular directions to ensure better precision as the stubs were slightly out of round.

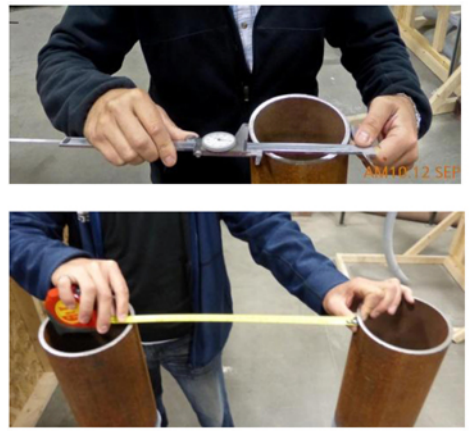

Figure 7. Manual measurement of stubs

The following table shows the results for the stub to stub distances. We measured the stubs from edge to edge to ensure we could compare the manual and automated measurements directly without any further mathematical operations.

Table 2. Stub to stub distances

Stub to stub distance (mm)		
Measured	Scanned	Offset
Longitudinal		scanned-manual
345	344.5	-0.5
346	345.4	-0.6
347	345.5	-1.5
345	345.4	0.4
Transverse		
361	360.3	-0.7
362	360.2	-1.6
362	362.9	0.9
Average		**-0.51**
Standard deviation		**0.91**

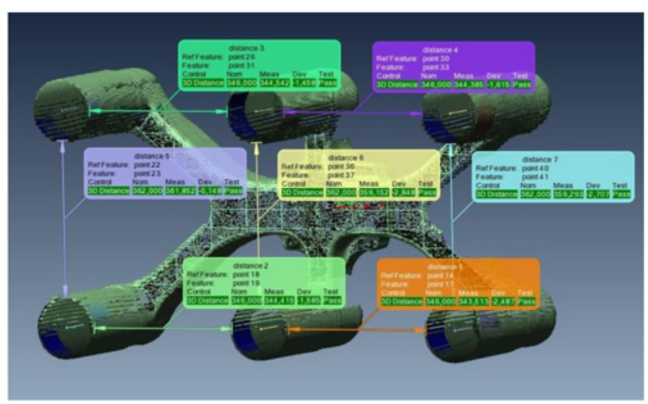

Figure 8. Stub to stub distances

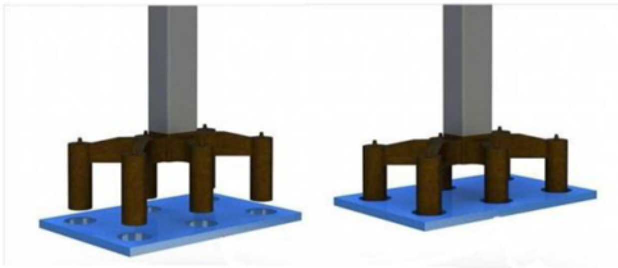

Figure 9. Virtual go gauge

The small offset in measurements is caused by the parameters used in the metrology software. In order to measure the reduced areas and subtle deformations in the stub profiles, we have to keep a maximum of points. Doing so makes the cloud a little thicker, which, in turn, slightly offsets the values. However, some refinements and tuning need to be performed on the algorithms to further reduce these offsets.

An automatic fine calibration algorithm included in the ASIS^{3D} program uses a movable target that can be permanently installed inside the enclosure of the scanner.

Conclusion

The fleet of anode rods is a very important asset for any smelter. The direct maintenance costs associated with such a fleet represent several million dollars a year [1]. An automated inspection system can supply all the necessary data to allow a rodding shop to pinpoint the most critical repairs on each rod and perform only the required maintenance. After a few months of operation, the information stored in the database will allow the planners to forecast the workload of the rod repair shop.

With ever increasing energy costs and the efforts of the industry to make the refining process more efficient, the need to lower the power loss from the rods, stubs and anodes has become a necessity. Thanks to an automated inspection system, data necessary for a plant to evaluate the mV penalty at plant level can be supplied to help determine the repairs that represent the best return on investment.

The STAS ASIS^{3D} / Automated Stub Inspection System is more than replacing manual inspection. It is a very powerful tool for planning the operations and forecasting the needs of a rodding plant.

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