

The STAS ASIS^{3D} – The automated anode stub inspection system

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Abstract

Currently, anode stub inspection is done manually by visually assessing the stub assembly as it travels on the conveyor. Stubs can be worn, leading to current imbalances and hot spots, and some stubs may even be missing. Worn, crooked or tapered stubs increase voltage-drop which, in today's ultra long potlines, can result in important energy losses. STAS has developed a new Anode Stub Inspection System, the ASIS^{3D}, which can handle both single-row or double-row distributed stub (hexapod) assemblies. The system precisely evaluates every anode assembly and can automatically issue work orders for the ones deemed to be in need of repair. This also allows users to get statistically significant data to allow for intelligent decision-making using Six Sigma and Lean Manufacturing techniques. And ultimately, it can result in lowered voltage-drop, which can potentially save the plant millions of dollars annually.

Keywords: Anode stub; Inspection; Anode rod tracking; Process monitoring.

1. Introduction

STAS has developed and designed a novel equipment to perform the inspection of anode stubs: the ASIS^{3D} (Anode Stub Inspection System). It has the capability of inspecting anode rods fitted with a single (bipods, tripods) or a double (tetrapods, hexapods) row of stubs. In this paper, we will use the term "hexapod" to refer to any kind of stub arrangement.

1.1. Anode rod inspection – current practice

Currently, anode rod inspection is done by operators using manual gauges. A visual check determines whether a rod has to be tested with the manual gauges or sent to be rodded with a new anode.

Manual inspection, performed using gauges and visual standards, is somewhat limited when more complex measurements have to be taken. And with manual inspection, records of the rod fleet condition are not kept. This practice relies on the operator's skills, for not every single anode is verified but only the ones that 'look' off, which makes the method very subjective. In addition, the data collected is seldom retained for further statistical analysis, depriving the plant of a huge opportunity for process optimization.

1.2. Impact of crooked, broken or worn stubs

In recent years, many studies related to performance penalties associated with the condition of the anode stubs have been published [1] [2] [3] [4] [5].

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. For mega smelters like the ones in the Middle-East where capacities are approaching and even surpassing a million tonnes per year, the cost

associated with increased voltages due to bad stub alignment is commensurately higher! In addition, costs related to rodding line stoppage, offline anode handling, greater probability of anode-related problems in the cells could also be associated to less-than-perfect inspection.

2. Automated inspection - statistical process control in the rod shop

Automatic inspection is not subjective. All measurements are taken in the same manner and 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 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.

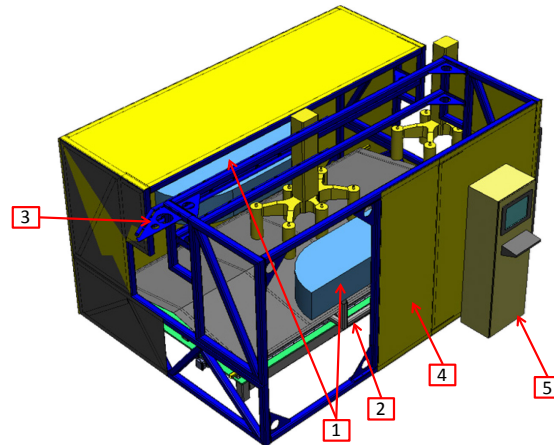
3. Presentation of ASIS^{3D}

Working with Alcoa and the Quebec Industrial Research Organization (CRIQ), STAS has developed the ASIS^{3D}. The ASIS^{3D} scanning unit is built around four 3D sensors. The 3D sensor assemblies are designed for a long stand-off and a deep field of view. The sensors allow to configure the digitizer so that they never get in the path of or between the stubs of the hexapods. There is no sensor placed under the path of the hexapod, either. This prevents damage to the system if some cast iron falls or if a clad gives up during the measurement. Figure 1 shows a typical hexapod scanned using the ASIS^{3D}.



Figure 1. Typical scanner output of ASIS^{3D}.

The system uses class 3 lasers installed in a fully opaque enclosure (Figure 2). 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.



- | | |
|---------------------|--------------------------------|
| 1. 3D laser sensors | 2. Shuttle assembly |
| 3. Anode rod guide | 4. Laser safety enclosure |
| 5. Computer panel | 6. Labelling station(optional) |

Figure 2. 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 3 shows a typical arrangement of the conveyor and sensors.

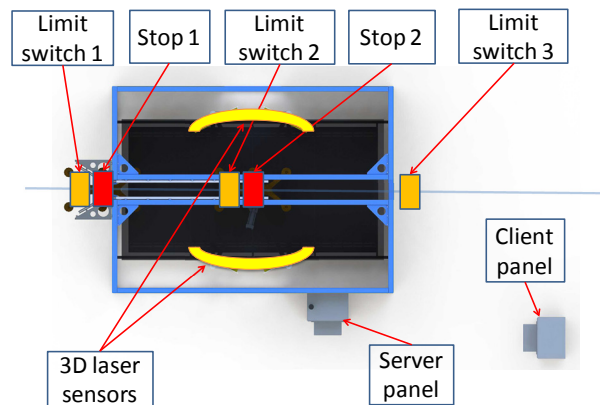


Figure 3. ASIS^{3D} typical arrangement.

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.

4. Results Phase 1

To verify the accuracy of the system, a modified hexapod was used that mimicked a new and straight sample that allowed to take precise manual measurements. We measured the distances from stub to stub and the stub diameters. Table 1 contains the results of the diameter measurements as shown in Figure 4.

Table 1. Stub diameters.

Diameters measured manually (mm)			Scanned value	Offset scanned-manual
1st axis	2nd axis	Average		
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

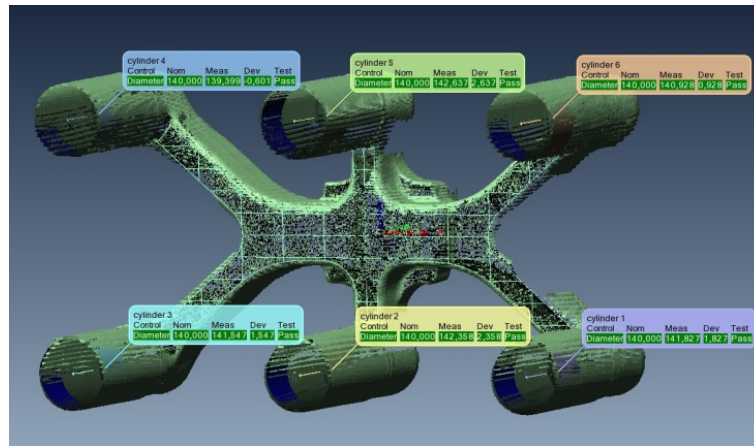


Figure 4. Stubs diameters.

Figure 5 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.

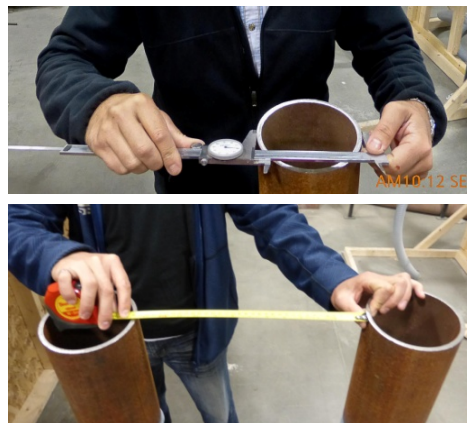


Figure 5. Manual measurement of stubs.

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

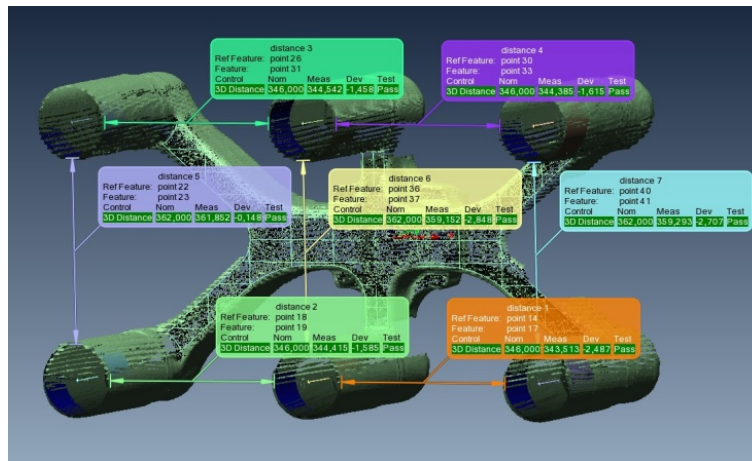


Figure 6. Stub to stub distances.

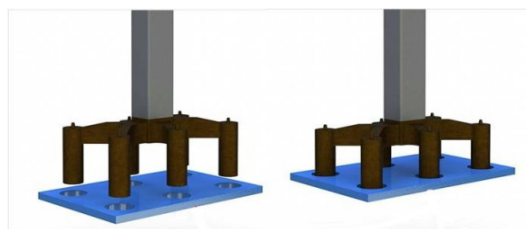


Figure 7. Virtual go gauge.

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 small 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.

4.1. Results Phase 2

Additional testing was done to assure that the ASIS^{3D} can inspect various types of stub issues with precision. A prototype based on the AP30 dimensions was built introducing typical stub defects easy to measure manually.

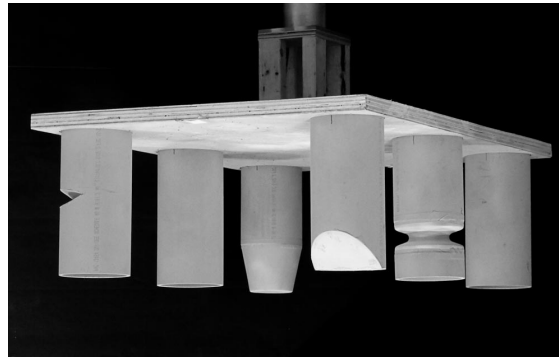


Figure 8. Prototype of typical defects.

Table 3. Comparison of stub defects measurements.

Typical Defect	Manual Measurement	Results of 10 scans using the ASIS ^{3D}	
		Average	Std Dev.
Worn tip	48.10%	48.90%	0.30%
Eroded tip	118.5 mm	117.7 mm	0.3 mm
Beaver effect min diameter	96.5 mm	95.5 mm	0.1 mm

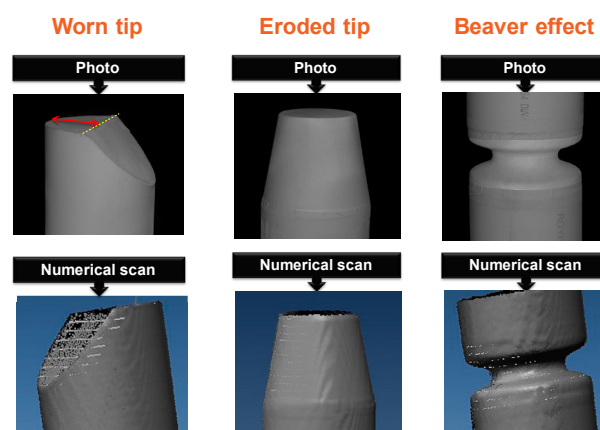


Figure 9. Stub defects inspected.

5. Conclusion

Automatic inspection of anode stubs is a sure way to remove the subjective aspect out from the equation. The ASIS^{3D} has demonstrated that it can identify and measure the stub defects in a time span that does not interfere with normal rodding shop processing. The footprint required is rather modest and the operation proved to be relatively easy.

In addition, and some may argue most importantly, the automatic measurement and data acquisition can yield great process analysis power that can significantly impact the cost if acted upon. The system can generate the necessary data to allow for process engineers to see how their process is robust. Unacceptable stubs can be identified automatically and rerouted from the conveyor, with a work order issued to repair the stub with the appropriate configuration.

Also, 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, the 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 does more than replace manual inspection. It is a very powerful tool for planning the operations and forecasting the needs of a rodding plant.

6. References

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