Prebaked Anodes Cracking at Forming - Reasons and Solutions

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Abstract

Avoiding prebaked anodes cracking during forming depends on two principles: avoid trapping pressurized air in anodes during forming and adjusting anode cohesion forces to retain anode internal stresses. Consequences of misinterpretation of these two principles explain most cracking problems related to forming of prebaked anodes. A good understanding of these two principles facilitates the diagnostics of anode cracking problems and finding ways to improve anode properties by adjusting parameters of processes before forming and those of forming process itself.

Keywords: Prebaked anode cracking, optimal binder, capillary bridge, binder viscosity.

1. Introduction

Prebaked anode forming is an important step in obtaining a good baked anode quality for use in electrolysis pots. Part of this step looks like black magic, because it is often difficult to find explanations to observed behaviours like appearance of cracks. It is common to stay in comfort zones, far from limits where unexplainable behaviours happen.

Prebaked anode quality improvement imperatives, tied to potline current increase or tied to raw material quality degradation, sometimes oblige one to navigate in areas where quality problems start afflicting anodes. A better understanding of physical changes that happens during anode compaction is then required to modify forming process parameters themselves or to modify previous processes parameters to correct cracking problems as they appear.

2. Cracks Formation Principles

Understanding two principles is needed to understand crack formation mechanisms during anode forming:

- Avoid trapping pressurized air in anode during forming;
- Adjusting cohesion forces which hold the anode together to retain internal anode stresses.

2.1. Avoid Trapping Pressurized Air in Anode During Forming

Why is air trapped in the anode during forming? Air is trapped when open pores transit to closed pores.

Optimal binder level is binder level that saturates aggregate after unmolding from the vibrocompactor mould or press mould [1, 2] and it is usually the target to reach. This corresponds to maximum binder quantity the anode structure can retain. If anode is under saturated, it lacks binder and there are pockets of space filled with air instead of binder. This gives a baked anode density lower than the one obtained if the anode was saturated. If anode is oversaturated, this means that aggregates float in the binder and the excess binder will be exuded at baking when temperature will be high enough to make binder flow freely above 200 °C and before binding the cokefaction.

Binder, that anode structure cannot hold, will come out of the anode which leads to the packing coke sticking to the surface of baked anode. When the binder comes out, the volume formerly occupied by binder will be filled by air, reducing baked anode density below what would be achieved at anode binder saturation. (Figures 1 a, b and c, adapted from Reference [3].)

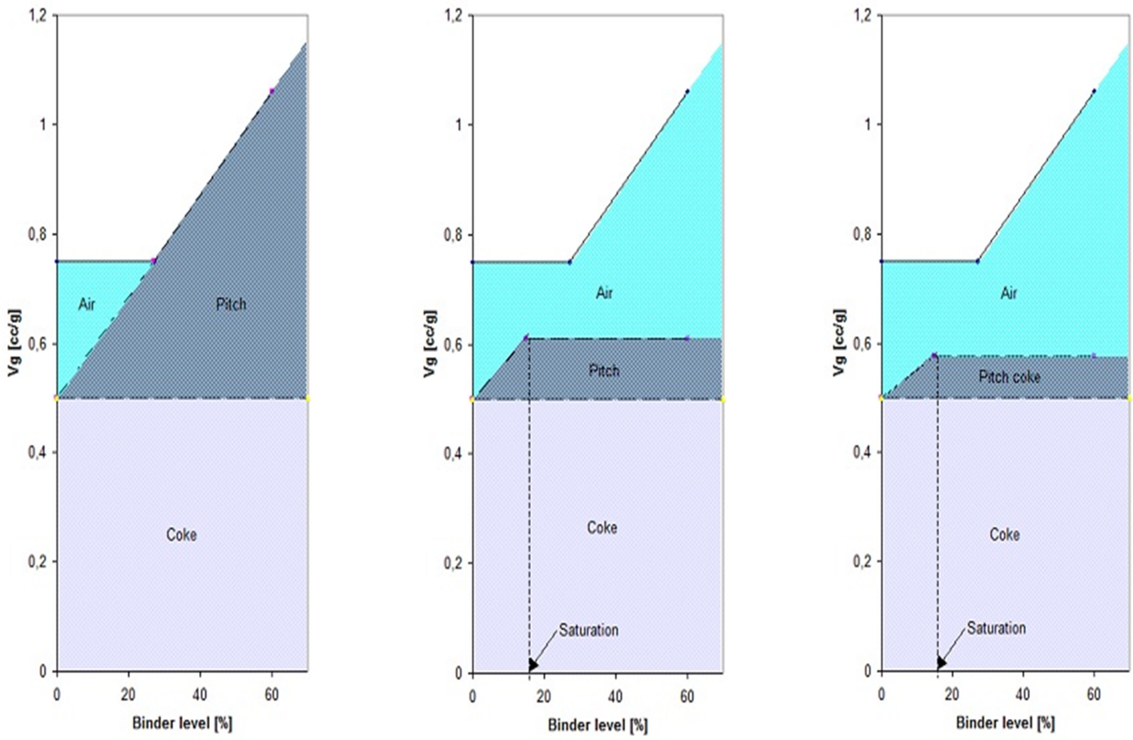

Figure 1a, Volume of green anode, simplified from figure 10b, Reference [3]

Figure 1b, Volume of green anode at 200 C in baking furnace

Figure 1c, Volume of baked anode, simplified from figure 13b, Reference [3]. Shrinkage neglected for clarity.

Figure 1. Creation of anode porosity and low anode density.

During forming stage, the paste goes from an undersaturated state to a saturated state, to end in an oversaturated state. To be saturated after unmolding, the paste has to be oversaturated in mould during forming. This has important implications.

While forming, when the paste starts in an undersaturated state, pores containing air giving low green anode density are open. This means that, during undersaturated stage, air has paths to come out of paste, permitting anode densification. When anode comes to an oversaturated state, this means aggregate floats in binder. This implies that pores containing air, transit from an open state to a close state and the air remains trapped in the pores. Green anode densification then results from compression of air contained in pores, an elastic reversible compression of aggregates themselves [1], which does not contribute to anode densification.

Compaction advances by paste plastic deformations. The aggregate becomes more compact by reduction of pores volume by increasing air pressure in closed pores (and reversible elastic deformation of aggregate matrix) when in oversaturation state. Each time forming pressure lowers, between press forming pressure, and between each vibrocompactor counterweight hit, pore pressure lowers, because pores regain their volume partly. If internal pressure of the pores generates stresses higher than anode cohesion forces, cohesion forces fail, causing microcracks.

- Deformation caused by level differences during anode transfers between equipment to cooling trays;
- Squeezing anode between anode pusher and an obstacle when ejecting anode from vibrocompactor table or transferring anode using pneumatic or hydraulic cylinders, with either ejector cylinder lengthens too much or an obstacle usually not there appears; or
- Deformation of the anode caused by deformed cooling trays. They are cambered or warped, a problem caused by repetitive thermal stresses.

4. Conclusion

Manufacturing a dense and crack free anode is not easy. The number of variables that can affect anode cohesion at forming is important and mastering them all requires a good understanding of principles used during anode paste and blocks manufacturing. Even with rigorous control, it is still possible that a variable escapes operation or process personnel attention.

Need for dimensions or property changes of anodes supplied to electrolysis, or important changes in anode raw materials, may also deviate from usual process parameters, obliging to venture outside comfort zones where behaviour of paste, equipment or green anodes is known.

Among ways to avoid or to solve these problematic situations, there are several options:

- Formal technical training,
- Technical self-training, through reading technical articles in anode manufacturing,
- Through plant structured testing, to test process limits, when possible,
- Peer meetings, through other plant visits, inside or outside the company, or during conferences,
- Attendance to technical conferences, and
- Call to people who already encountered problems happening in your plant.

Problem solving use may sometimes be pertinent, but without adequate knowledge among team members of principles driving the processes, problem solving may be of little use. As Louis Pasteur said:

"*Dans les champs de l'observation, le hasard ne favorise que les esprits préparés.*"

"In the fields of observation, chance favours only the prepared mind".

5. References

1. Michel Jarry, Élaboration des anodes précuites en carbone aggloméré pour l'industrie de l'aluminium, PhD Thesis, Université de Grenoble, 1977.
2. Kenton B. Wright and R. W Peterson, Pitch content optimization model for anode mixes, *Light Metals* 1989, 479-488.
3. J. Okada and Y. Takeuchi, Dependence of the density and other properties of bonded carbons on the binder proportion in the green mix, *Proceedings of the Fourth Conference on Carbon*, 1960, 657-669.
4. E.S. Lee, K.E. Yoon, D.H. Kim and K.J. Lee, Storage stability of liquid coal tar pitch, *Light Metals* 1994, 535-539;
5. Marie-Josée Dion , Cyrille Gaudreault, and Yvon Ménard, Calcined petroleum coke density separation process: Solution to maintain anode quality with degrading coke density, *Light Metals* 2015, 1039-1044.

6. P. Stokka, Green paste porosity as an indicator of mixing efficiency, *Light Metals* 1997, 565-568;
7. A. Gagnon, Y. Menard et al., Determining dosing of binding agent for combining with particulate material to produce an electrode, *Word Property Organization Patent Application* WO 2016029306 A1, 2016.