CB02 - Study of Anode Compaction Using a Model-Fluid

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Abstract

Green anodes consist of dry aggregate (coke and recycled carbon material) surrounded by a binder matrix, which is composed of fine particles and coal-tar-pitch (CTP) with viscoelastic behavior. The CTP is mixed with dry aggregate, then compacted during the forming process. In the compaction, the coarse particles rearrange while the binder matrix plastically deforms and fills in the pores with the effect of reducing the overall porosity of the green anode. Then, the green anodes are baked in a furnace where the pitch is carbonized to improve the properties of the anode. Crack formation and uneven anode density distribution are the main problems that mainly occur during the anode formation. Experimental investigation on crack formation and the development of density gradient during the compaction process is quite complicated due to several factors such as relatively high temperatures (~ 180 °C), sensitivity of pitch to the temperature variations, temperature gradient inside, and the opacity of the anode paste. We proposed a novel method to replace the binder matrix with a transparent polymer at room temperature (model-fluid) having similar rheological properties to those of the binder matrix at high temperature to perform the compaction tests at room temperature. Different polymers have been tested to tune the model-fluid to mimic the rheological properties of the binder matrix at high temperature. The real anode pastes were compacted at high temperature, and the results were compared with the compaction of model-fluid at room temperature. The results show that the compaction behavior of the new mixture (model-fluid and dry aggregate) at room temperature is similar to that of the anode paste at high temperature. This approach may allow to design further experiments in future to follow the rearrangement of coke particles during compaction and to study the effect of rheological properties of binder matrix on the paste compaction process.

Keywords: Green anode, compaction, model-fluid.

1. Introduction

Carbon anodes have a crucial role in the Hall Héroult process, and their quality directly affects the efficiency of aluminium production process [1, 2, 3]. Density gradients and cracks in the anodes are the main anode problems that occur during the forming process in which binder matrix (the mixture of the coal-tar pitch and fine particles), at relatively high temperature, moves between the coarser particles. Detailed understanding of the forming process can convey valuable information to improve the quality of the anode [4, 5]. Pitch sensitivity to the temperature variations, temperature gradient during the forming process, and dealing with opaque materials are the serious challenges in this process.

Following our previous studies [6, 7], we have proposed a novel method to overcome these challenges. The rheological properties of the binder matrix, as part of the main parameters affecting the forming process, have been obtained at high temperature [7]. Then, we experimentally studied several transparent polymer solutions at room temperature to find a transparent model-fluid that has rheological properties similar to those of the binder matrix at high temperature. In this approach, the coarser particles mix with the model-fluid to make a new anode paste at room temperature, and then the effects of operational parameters during compaction on the quality of anodes could be studied at room temperature. In the current research, we focus on finding a promising model-fluid that has rheological properties similar to those of the binder matrix at high temperature. Then, the compaction behavior of the new paste is compared with the actual anode paste during a compaction in a press.

2. Experiments

Initially, the rheological properties of the binder matrix were determined at different temperatures [7]. The results show that the binder matrix is a viscoelastic material in which the elastic and viscous properties are increased by increasing the concentration of the fine particles and decreasing the temperature.

In the experimental work, the rheological properties of an actual binder matrix were compared with those of the potential model-fluids; then, the compaction behavior of the model-paste was compared with the behavior of the actual anode paste during compaction in a press.

2.1 Rheology Tests

A Discovery Hybrid Rheometer (DHR-3), equipped with two 20 mm Peltier parallel plates, was used to characterize the rheological properties of the pitch and different binder matrices. The gap thickness was 1000 µm. The rotation and oscillation tests were performed to determine the viscous and elastic properties of the samples. Note that, in this research, we considered a binder matrix with 30 %wt. of the fine particles as a reference. The experiments show that this binder matrix is a shear-thinning material at 178 °C ($\tau = 12.6\dot{\gamma}^{0.9}$). In addition, Fig. 1 demonstrates that the viscous properties (G'') of the binder matrix are higher than its elastic properties (G') at high temperature. Therefore, we should consider two main criteria in choosing the model-fluid, shear-thinning effects with elastic modules smaller than viscous modulus.

Carbopol solution was one of the potential viscoelastic model-fluids that failed in the first step due to its plastic behavior (the results are not presented due to brevity) [8].

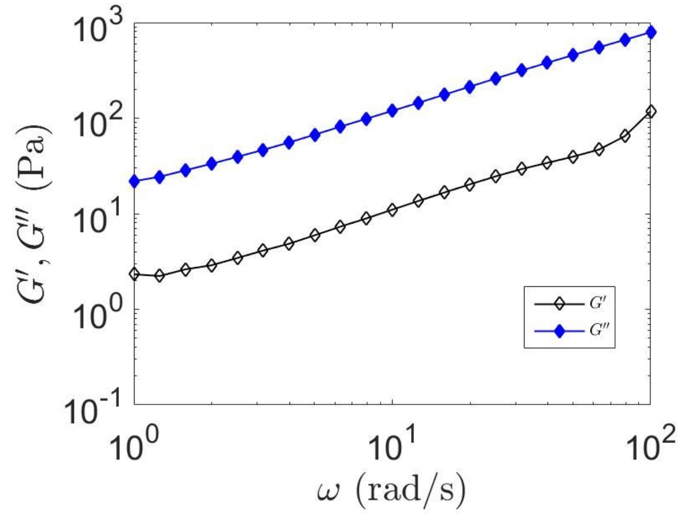

Figure 1. Elastic and viscous moduli of the binder matrix (30% of fine particles) vs angular frequency at 178 °C.

5. References

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