Energy-efficient technologies for gas cleaning systems of aluminum smelters

V A Ershov, T I Zimina, I V Komogortsev, V O Gorovoy and A S Govorkov
Irkutsk National Research Technical University, 83 Lermontov street, Irkutsk, 664074, Russia
E-mail: ziminati@istu.edu

Abstract. The article presents the relevancy of creating a shell-and-tube heat exchanger for utilizing the heat of process gases from an aluminum electrolyser. On the basis of the results of virtual modeling, a heat exchange unit was created, which is currently being tested in industrial conditions under various operating conditions. In the future, recovered heat will be used to increase the energy efficiency of production, by using heat energy to generate electrical energy, preheat anodes and alumina.

1. Introduction
According to [1], up to 3% of heat is carried away from electrolyzers with a self-baking anode with anode gases that are removed into the system of gas cleaning units (GCU), and from electrolyzers with burned anodes - 12.5%. At the same time, the volume of the dust-gas-air mixture, withdrawn from the electrolyzer with a self-baking anode, is, on average, 600 ÷ 1000 m³/h, and with the burned anodes – 7000 ÷ 14000 m³/h [2]. For example, more than 2 million m³/h are withdrawn from two buildings of V-series of electrolysis of the Irkutsk Aluminum Smelter.

In connection with the requirements of the Russian legislation in the field of ecology [3] and energy [4], studies on increasing the degree of catching of pollutants and increasing energy efficiency by utilizing the heat of waste process gases are relevant.

The authors of [5, 6, 7] noted that when the temperature of the gases, that are being cleaned, decreases, efficiency of gas cleaning units increases (Figure 1), due to the intensive desorption of the trapped hydrogen fluoride (HF) by alumina.

2. Modelling of the process
Therewith, a decrease in the temperature of process gases has a beneficial effect on the operability and longevity of gas cleaning equipment. In accordance with figure 2, when electrolytic gases are cooled, their physical volumes decrease, which, in turn, reduces the operating costs of gas cleaning units.

According to [2], capital expenditures are from 15 to 40 US $ per m³ of capacity of gas that are being cleaned.

The need for cooling is due to the fact that in the warm season the temperature of gases at the entrance to the gas cleaning units can reach 190 °C, and the bag filters made of polyester, used in gas cleaning technology in recent years, have service limit values of 140 ÷ 145 °C. The use of filters made of heat-resistant fabrics, that withstand temperatures above 200 °C, will result in their 3 ÷ 4-fold increase in cost [8].

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At present time, various approaches to solve the problem of cooling technological gases are proposed. The simplest solution to the problem of high process gas temperatures is the addition of air to the gas ducts through adjustable dampers. [9] However, this entails an increase in the energy consumption of the fans, need for additional filter cloth areas will increase, and the maintenance costs of the gas cleaning units will be significantly increased [10].

Another way of cooling is to spray water in the gas stream before entering the gas cleaning facilities [1]. But it additionally requires the consumption of compressed air and purified water and, as a result, constant monitoring and maintenance. There is also a risk of appearance of corrosion on the equipment, increased hydrogen fluoride emissions due to the hydrolysis of solid fluorides, as well as an increased water content in enriched alumina [2].
It is possible to achieve gas cooling as far as they move along the gas duct due to the core type cooler, developed and patented by Solios [3]. The cooler has vertical metal rods, installed inside the U-shaped section of the gas duct that connects the electrolysers to the collecting gas duct. The pressure losses in such a cooler are compensated by a reduction in the physical volume of evacuated gases due to their cooling by, on the average, 10 °C.

Additional cooling can be achieved by equipping the gas duct grid with heat-sinking fins, located spirally on the outer surfaces of the gas ducts, which allows partial winding of the air flushes, which are surrounding the gas duct, increasing the heat transfer to the environment. [2]. The installed fins are able to increase the area of the heat-transfer surface of the gas-duct grid by 10 ÷ 25% and cool the anode gases by 20-25 °C, but at the same time they increase the dimensions of the gas ducts grids.

According to some authors, one of the most effective solutions for heat utilization is the use of heat exchangers [1]. This method has its drawbacks, because it requires maintenance due to the tendency of the pipe still to clog, and the use of additional equipment (water pipe, heat exchange circuit, measuring equipment, etc.). The advantage of this technology is the recovery of heat energy, which allows to achieve greater energy efficiency of production by: heating water for production needs; for heating, or cooling; obtaining distilled water; power generation; [5, 9, 10] preheating of alumina [1; 5] or baked anodes. Ultimately, efficiency of the use of heat exchangers should be evaluated from the standpoint of capital and operating expenditures.

In the course of work, it was determined that the most optimal, in terms of weight, overall dimensions, strength and performance characteristics. The body of the experimental heat exchanger is made in the form of a “pipe” of rectangular cross-section. 13 (thirteen) cooling blocks, consisting of heat-exchange elements, are inserted inside the body. The blocks are fixed to the supporting structure by means of a bolted connection on the gaskets at the top and bottom of the body by the process windows made in the outer walls. The windows are closed with lids on the gaskets. Cold water is supplied through the bottom cover via the piping system, pressure and rate of water supply to each heat exchange unit is regulated by means of a ball valve mounted on the water supply pipes.

On the bottom cover, there are branch pipes through which one coolant passes through the space between the parts of the supporting structure. To increase the heat transfer, fining of the heat exchange tubes is used, which represents a tape soldered along the entire length of the tube.

The heat exchange part, through which the coolant passes, consists of 169 pipes. Pipe still of heat exchangers and fins were made of copper sheet, there are holes in the fins to increase heat transfer and gas flow.

3. Conclusion
The article presents the relevancy of creating a shell-and-tube heat exchanger for utilizing the heat of process gases from an aluminum electrolyser. On the basis of the results of virtual modeling and optimization of the design, an experimental heat exchanger was created, which is planned to be tested in industrial conditions under various operating conditions.

Subsequently, recovered heat will be used to increase the energy efficiency of production by using heat energy to transform energy into the electric one, preheat the anodes and alumina.

The use of accumulated heat energy will allow to increase the technical and economic performance of aluminum smelters, reduce capital expenditures in operation and designing of gas cleaning systems and rationally solve the problem of utilization of process gases.

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