

ANNOTATION

Dissertations for the Doctor of Philosophy (PhD) in the educational program
8D07201 – Metallurgy

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DEVELOPMENT OF REFINING TECHNOLOGY FOR PRIMARY ALUMINUM FROM VANADIUM IMPURITIES

Relevance of the dissertation topic. In the Pavlodar region of the Republic of Kazakhstan, on the basis of AK JSC and KEZ JSC, an aluminum cluster is being developed, the further development of which is associated with local enterprises Kazenergokabel LLP, GiessenHaus LLP, Vector-Pavlodar LLP, SNN LLP, producing aluminum rod and wire, alloyed aluminum, cast wheel rims, cast batteries, as well as enterprises supplying raw materials for the needs of electrolysis production (UPNK-PV LLP, production of calcined petroleum coke).

All aluminum alloys have certain impurities that affect their physical and chemical properties. The main ones are hydrogen, sodium, lithium, calcium, oxides Al_2O_3 MgO, spinel Al_2O_3 MgO, nitride AlN, silicate CaSiO_3 , aluminate CaAl_2O_4 , carbides SiC, TiC, Al_4C , intermetallic compounds Al_3Ti , Al_3Zr , AlTiZr, for the removal of which have been successfully introduced into production various refining methods.

In recent years, there has been a tendency to involve in the electrolysis production of aluminum lower-quality sources of raw materials for the production of anodes, which lead to contamination of raw aluminum with impurities such as V, Ni and heavy non-ferrous metals.

A number of works have proposed methods for refining primary aluminum from vanadium impurities, which have not found wide industrial application due to the high time and resource consumption of the purification process and economic unprofitability [15 – 18, 34 – 36]. Based on the above, the development of a comprehensive technology for refining primary aluminum from vanadium impurities and other metal impurities is very relevant.

Purpose of the dissertation work: research and development of a comprehensive technology for refining primary aluminum from vanadium impurities outside the electrolysis bath, through treatment with boric acid and induction mixing, followed by filtering through granular filters from the ash of Ekibastuz coal with further processing of used filters.

Scientific novelty of the results obtained:

1) For the first time, a comprehensive technology has been developed for refining primary aluminum from vanadium impurities through treatment with boric acid with induction stirring, filtering through granular filters from the ash of Ekibastuz coal and further processing of used filters.

2) Thermodynamic analysis in HSC Chemistry 9.0. and as a result of large-scale laboratory tests, it was established that the reduction in vanadium content

during refining with boric acid (H_3BO_3) in a volume of 1.2 - 2 kg/t and an induction stirring intensity index of up to 76 averages 55 - 59% with a processing time of up to 15 minutes over the entire operating temperature range of the electrolysis and casting process of primary aluminum due to the formation of VB_2 .

3) A decrease in the vanadium content in the aluminum melt (y , ppm) and its uniform distribution in the volume of the ladle was revealed due to an increase in boron consumption (x_1 , kg/t) and the stirring intensity index (x_2) according to the following dependence:

$$y = 76,83 - 4,58x_1 - 0,16x_2$$

4) The method of scanning electron microscopy revealed the grinding of vanadium and boron inclusions in aluminum samples under intense induction stirring due to the crushing of large sections of the resulting vanadium diboride.

5) Optical emission spectrometry has established a decrease in the content of metal impurities in raw aluminum during treatment with boron, and the degree of removal of all impurities during induction stirring is higher than during processing without stirring and is in the range: Si 43 – 97%; Cu 5 – 17%; Mn 4 – 50%; Mg 22 – 47%.

6) Large-scale laboratory tests have established that filtration refining of liquid raw aluminum after fluxing treatment with boric acid (H_3BO_3) with induction mixing from VB_2 intermetallic compounds formed during refining in solid form in a bulk volumetric filter with a thickness of at least 70 - 90 mm with granules of size 15 – 25 mm from the ash of Ekibastuz coal ensures the removal of vanadium to values of 0.0003 – 0.0012%.

7) Thermodynamic and X-ray fluorescence spectral analysis established the implementation of the reaction-crystallization mechanism of filtering liquid aluminum from vanadium diboride impurities due to the deposition of V_2O_5 in an amount of up to 0.1% on the surface of the iron oxides of a bulk filter from the ash of Ekibastuz coal.

8) The possibility of implementing a closed cycle for the production of primary aluminum using bulk filters from the ash of Ekibastuz coal has been experimentally established by involving waste filters in the processing in several stages: metallurgical processing of aluminum scrap and the use of waste filters separated from the grains as filler in a volume of up to 40% at production of concrete for building products ensuring the strength of concrete samples in the range of 20.89 - 37.75 MPa depending on the content of Portland cement (from 20 to 40%), which corresponds to the class of heavy concrete.

Novelty of the research results is confirmed by the invention patent of the Republic of Kazakhstan No. 36241 dated 06/02/2023 “Method for purifying aluminum and its alloys from heavy metal impurities”.

Main provisions submitted for defense:

- results of thermodynamic modeling in HSC Chemistry 9.0 of the occurrence of chemical reactions between H_3BO_3 and metal impurities in an aluminum melt based on the Al-V-B system;

- results of experimental studies on flux processing with boron-containing materials with additional induction mixing of primary aluminum to remove vanadium and other metal impurities;

- results of experimental studies of filtration refining through granular filters based on ash and slag waste from Ekibastuz coal of molten aluminum from the products of interaction of vanadium impurities with boron and other metal impurities after flux refining with induction mixing;

- results of experimental studies on the processing of used filters to produce construction products and recycled metal.

Practical significance of the work

A patent for an invention of the Republic of Kazakhstan, test reports, and a positive expert assessment of Kazakhstan Electrolysis Plant JSC have been received for the proposed technology.

It has been established that the transfer of anode production at KEZ JSC entirely to UPNK-PV LLP coke will increase the supply of local calcined coke from 51.875 thousand tons to 103.750 thousand tons, which will increase the local content of raw materials.

Publications and testing of work. The results of the dissertation work were published in five articles, including:

- one article in a journal included in the Scopus database (Q3, 35th percentile):

- Bykov P.O., Kuandykov A.B., Zhunusov A.K., Tolymbekova L.B., Suyundikov M.M. Complex processing of primary aluminum to remove impurities of non-ferrous metals // *Metalurgija* 62 (2023) 2, P. 293-295.

- four publications in journals from the list of publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan for the publication of the main results of scientific activity:

- Bykov P.O., Kuandykov A.B., Zhunusov A.K. Refining of Primary Aluminum from Vanadium // *Defect and Diffusion Forum*, 2021, 410DDF. – P. 405 – 410.

- Bykov P., Kuandykov A., Chaikin V., Zhunusov A., Suyundikov M. Scanning Electron Microscopy of Primary Aluminum Refined With Boric Acid // *Proceedings of the University*, 2022, No. 4. – P. 91 – 96.

- Kuandykov A.B., Bykov P.O. Study of refining primary aluminum from impurities of non-ferrous metals using “active” granular filters based on boric acid // *Science and Technology of Kazakhstan*, 2023, No. 3. – P. 203 – 210.

- Bykov P.O., Kuandykov A.B., Aryngazin K.Sh., Kaliyeva A.B., Larichkin V.V. Environmental aspects of processing granular filters for primary aluminum refining // *Science and technology of Kazakhstan*, 2024, No. 1. – P. 152 – 161.

A patent was received for the invention of the Republic of Kazakhstan:

- Patent for invention of the Republic of Kazakhstan No. 36241 “Method for purifying aluminum and its alloys from heavy metal impurities” / Bykov P.O., Kuandykov A.B., Zhunusov A.K., Kulumbaev N.K., Suyundikov M.M. – statement 2022/0038.1; publ. 06/02/2023.

The main provisions and results of the work were tested and reported at three international conferences in the form of oral reports:

- Bykov P.O., Kuandykov A.B., Smailov B.Sh. Prospects for the development of technology for refining primary aluminum from vanadium. // Materials of the international scientific and practical conference "XI Toraigyrov Readings". T. 5. - Pavlodar: PSU named after S. Toraigyrov, 2019. - P. 63 - 71.

- Kuandykov A.B., Bykov P.O., Chaikin V.A. Integrated technology for refining primary aluminum from impurities of non-ferrous metals // Proceedings of the international scientific and practical conference "Ulytau - Kazakhstan metallurgy and besigi". – Almaty: KazNITU named after. K. I. Satpayeva, 2023. - P. 110 - 115.

- Kuandykov A.B., Bykov P.O. The use of active granular filters in the processing of primary aluminum // Materials of the international scientific and practical conference dedicated to the 40th anniversary of the formation of the Department of Metallurgy "Problems and prospects of the metallurgical industry: theory and practice". – Pavlodar: Toraigyrov University, 2023. – P. 140 – 145.

Structure and scope of the dissertation. The dissertation is presented on 121 pages of printed text and consists of an introduction, five sections, a conclusion, a list of sources used and appendices. The work contains 42 figures, 41 tables, a list of used sources of 124 titles and 6 appendices.