Industrial Trials Results of Scandium Oxide Recovery from Red Mud at UC RUSAL Alumina Refineries

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Abstract

UC RUSAL pioneered the development of technology to extract scandium oxide from red mud with a pilot plant arranged at one of the company alumina refineries. Pilot production comprises of a site of scandium concentrate production and a site of scandium oxide production. In the paper, the results of industrial trial of scandium oxide production process from red mud are given, in particular: processes of scandium concentrate production and its re-cleaning yielding a commercial product – scandium oxide. In the course of industrial trials, pilot batches of scandium oxide with scandium content 99.9 % were obtained. From the pilot batch of scandium oxide aluminium-scandium master alloy was produced corresponding to the requirements of GOST R 53777-2010 for master alloy of AlSc2 (A). The developed process, which was implemented at pilot scale is competitive and can be easily integrated into the alumina production. This process does not yield acidic or toxic effluents and provides competitive production cost of scandium oxide

Keywords: red mud, scandium oxide production.

1. Introduction

In recent years, there has been a trend of increasing the demand for scandium oxide and scandium-containing materials. According to [1], in 2017 the scandium oxide market was estimated at 16.3 t/year, and in 2018 it was estimated at 18.9 t/year. By 2028, the demand for scandium is forecast to increase up to 300 t/year in terms of scandium oxide due to its wider application in such industries as shipbuilding, aerospace, aircraft engineering, 3D printing and others [1].

Currently, scandium is mostly produced in China from solutions resulted from the processing of ilmenite concentrates at titanium dioxide production sites and from industrial solutions at zirconium production sites. At the same time, it is known that most of the world's scandium volume is contained in bauxite and its process waste, which is red mud (RM) [2]. It is only the RUSAL alumina refineries located in Russia that annually produce over 2 million tonnes of red mud containing about 240 tonnes of Sc. Unlike other ore and man-made sources of scandium, red mud has a number of advantages, namely, it has already prepared for processing and does not require any extraction and grinding costs.

For more than 50 years, researchers from different countries have been working on the problem to recover scandium from red mud. During this time, various technologies have been developed, including those that include both the scandium pre-concentrating stages through the use of enrichment processes or pyrometallurgical processes and technologies involving direct leaching of scandium with acid and salt solutions [3]. Unfortunately, almost all of these technologies have been tested on a laboratory and large laboratory scale where the amount of processed red mud is calculated in grams and kilograms. Such scale allows researchers neither to obtain an objective assessment of the technology being developed both in terms of the specific consumption of agents and energy costs nor to assess the influence of various factors on the quality of the end product (presence of impurities and their effect on each of the stages of the process, loss of agents and commercial product with effluents and waste, accumulation of impurities in solutions during their recycling process and their impact on subsequent process cycles, impact of the key equipment design and its operation modes on the process performance indicators). All these factors can be investigated only when creating a pilot plant to be operated in a continuous mode, which will make it possible to fine-tune and optimise each stage of the process.

UC RUSAL is the first company in the world to have designed and built a pilot plant (PP) to produce scandium oxide from red mud, which is capable of processing several thousand tonnes of red mud per year to produce up to 100 kg/year of scandium oxide. For several years of plant operation, such processes as leaching of scandium from red mud, concentrating of scandium by sorption from liquors and slurries, recovery of scandium concentrate and removing of impurities from it to produce scandium oxide were fine-tuned; pilot lots of scandium oxide with a purity of Sc2O3 = 99.0 - 99.9 wt.% in the calcined product were produced and tested at customers' sites, and fundamentally new equipment designs were created and tested.

This paper presents the results of the pilot field tests of the technology to produce scandium oxide from red mud that were carried out at an own pilot production site located at one of the UC RUSAL alumina refineries.

Unlike competitors' technologies, the RUSAL's technology has a number of advantages, namely:

- own stable source of raw materials (red mud from the process implemented at the alumina refineries and waste red mud stored in red mud disposal areas);
- the technology was developed using own R&D resources of the company;
- this is the world's only technology implemented to produce scandium oxide from the red mud delivered from alumina refineries;
- in contrast to other known technologies for the production of scandium, it does not provide for the use of acids at the stage of scandium recovery and concentrating; therefore, the technology does not have any acidic and salt effluents;
- the red mud, from which scandium was extracted, is prepared for further processing into other commercial products or for storage in an 'ultra-dry' way, which allows reducing the capital expenditure for the construction of red mud disposal areas by approximately 30%;
- exhaust kiln gases can be used as agents, which cuts operating costs and reduces carbon dioxide emissions;
- scandium oxide of a specified quality can be produced for the needs of own production of Al-Sc alloys and master alloys; and
- flexibility to increase production as the market for scandium develops.

2. Experiments

The basic process flow diagram of pilot production of scandium oxide from red mud is shown in Figure 1 and includes the following process areas:

- filtering the source red mud slurry;

Table 4. The chemical composition of a pilot lot of scandium oxide, produced by UC RUSAL, wt.%.

Sc_2O_3	Zr	Si	Al	Fe	Ti	Ca	Mg	K	Na	Th	∑Ln
99.9	0.038	0.001	0.0024	0.0075	0.0018	0.0016	0.001	0.001	0.022	0.015	0.002

Pilot lots of scandium oxide produced by the pilot plant were successfully tested at potential customers' sites. At the aluminium master alloy production area of RUSAL ETC in Krasnoyarsk, an aluminium scandium master alloy the quality of which meets the requirements of GOST R 53777-2010 for AlSc2 (A) master alloys was produced (Figure 7).

Figure 7. The photo of an Al-Sc master alloy produced by RUSAL as per GOST R 53777-2010.

3. Conclusion

The operation of the pilot plant for the production of scandium oxide from red mud made it possible to fully fine-tune the technology which was developed by the UC RUSAL own engineering centre. Pilot plant testing allow optimisation: reduce operating costs for the production of scandium oxide by several times by achieving the maximum degree of scandium recovery in each of the process areas, optimising the process parameters and also test the new equipment.

The pilot field tests were continuously carried out for 4 years. This made it possible to obtain reliable data on the consumption of agents and energy resources, commercial product yield, identify the features of individual process stages, which arise in a closed process cycle, develop pilot lots of scandium oxide and test them at potential customers' sites.

According to the results of the pilot field tests, the authors obtained data that formed the basis of a feasibility study for the construction of an industrial scale production facility to produce scandium oxide from red mud.

4. References

1. http://scale-project.eu/wp-content/uploads/2018/12/2-J.-Grandfield_Outlook-Scandium-Market.pdf
2. V.N. Lavrenchuk, A.V. Stryapkov, E.N. Kokovin, *Scandium in bauxites and clays*, Kamensk-Uralsky: GUP SO Kamensk-Uralsky, 2004, 291 P.

3. O. Petrakova et al., Application of modern methods for red mud processing to produce rare earth elements, *1st European Rare Earth Resources Conference*, 4-7 September, Milos, Greece, P. 221-229.
4. Production of scandium containing concentrate and subsequent extraction of high purity scandium oxide therefrom: RU 2647398: IPC C22B 59/00, C22B 3/12, C22B 3/20, C01F 17/00 / A.G. Suss, A.B. Kozyrev, A.V. Panov; Assignee: Limited liability company "United Company RUSAL Engineering Technology Center"– No. 2016132359; Filed: 04.08.2016; publ. 15.03.2018, Bulletin No. 8.
5. Способ получения оксида скандия из скандийсодержащих концентратов: пат. 2669737 Рос. Федерация: МПК C22B 59/00, C22B 3/38, C01F 17/00 / А.Б. Козырев, С.Е Вишняков, О.В. Петракова, А.Г. Сусс, С.Н. Горбачев, А.В. Панов; патентообладатель Общество с ограниченной ответственностью "Объединенная Компания РУСАЛ Инженерно-технологический центр" – № 2018102058; заявл. 18.01.2018; опубл. 15.10.2018 г., Бюл. № 23.
6. Способ извлечения скандия из красного шлама глиноземного производства: пат. 2692709 Рос. Федерация: МПК C22B 59/00, C22B 3/12, C01F 3/24 / А.Б. Козырев, О.В. Петракова, А.Г. Сусс, С.Н. Горбачев, А.В. Панов; патентообладатель Общество с ограниченной ответственностью "Объединенная Компания РУСАЛ Инженерно-технологический центр" – № 2017136945; заявл. 21.06.2017; опубл. 26.06.2019 г., Бюл. № 18.
7. Olga V. Petrakova et al., Improved efficiency of red mud processing through scandium oxide recovery". *TMS (The Minerals, Metals & Materials Society). Light Metals 2015*, 2015, c. 93-96
8. A.G. Suss et al., Specific features of scandium behavior during sodium bicarbonate digestion of red mud*, IX International Congress Non-ferrous metals and minerals, Krasnoyarsk, 2017, p. 51-61*
9. Л.Н. Комиссарова, *Неорганическая и аналитическая химия скандия*, М.: Эдиториал, 2001, с. 512 (с. 216).
10. Olga V. Petrakova et al. Sorption of scandium from solutions of red mud carbonation leaching *X International Congress Non-ferrous metals and minerals*, Krasnoyarsk, 2018, p. 269-273.
11. A.G. Suss et al. Specifics of scandium concentration and purification via double sulphates during production of commercial scandium oxide from red mud *X International Congress Non-ferrous metals and minerals,* Krasnoyarsk, 2018, p. 279-284.