Development and Utilization of Detailed Process and Technology Models at RUSAL Alumina Refineries

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Abstract

RUSAL is completing the development of detailed steady-state mathematical models of the process technology in its alumina refineries in the current year. Models have been developed for refineries based on different technologies: Bayer process, parallel Bayer-Sinter and stand-alone Sinter processes. Each model includes equipment specifications for the production sites, mud disposal and Combined Heat and Power Plants (CHPP). The control logic of the models reproduces a refinery control system. Particular attention was paid to the creation of kinetic relationships for digestion processes, which help to predict recovery of alumina and soda, as well as the thermodynamic equilibrium of impurities in liquors. A large number of laboratory studies have been performed for the development of these thermodynamic and kinetic models. Several types of problems are solved using these mathematical process models, such as sensitivity investigations, "What-if" analyses, production optimization, business planning and estimation of capital investment efficiency. RUSAL has organized departments for mathematical modeling at their refineries and a central development team in its St. Petersburg office. Refinery specialists monitor the production process and perform routine daily calculations. They propose solutions for managing the production process to achieve maximum refinery efficiency based on their experience and modelling results.

Keywords: Mathematical modeling, alumina refinery optimization, process modelling.

1. Software for Process Simulation

RUSAL is developing a new unified approach to efficiency assessment, business planning and optimal process technology management at the enterprise level in the framework of its alumina refinery development program. This approach will allow the production of alumina of the required quality and at the minimum cost.

There are many conditions in solving for alumina production optimization. It is necessary to take into account the capability and the condition of equipment, resource portfolio, transport logistics, prices of energy carriers and auxiliary materials, climate change and weather. The optimum quality or cost of alumina is not an exceptional set of values for production parameters, but a sequence of dynamically changing states, since these factors are variable in time. The cost and quality of alumina ultimately depends on finding this dynamic optimum and maintaining it.

The unified approach to the assessment of process efficiency at all RUSAL's refineries is based on the use of SysCAD software, a product of the Australian company KWA Kenwalt Pty Ltd. SysCAD is a specialized software environment for the development of detailed Bayer process alumina refinery models. Although we were aware of the availability of alternative software environments (Table 1), and having similar software developed in-house, we nevertheless settled on SysCAD [1, 2]. The highly specialized orientation of this product, the competitive cost and the recommendations of other users influenced our choice.

Table 1. Software for process simulation.

Software*	External thermodynamic databases**	Solvers ***	Scripting language	Compatibility Interfaces	Technologies where software is more often applied
Aspen Plus	OLI	SS, D	Fortran, VBA Excel	OPC, Excel, Word	chemical technology, metallurgy, energetics
Hysys		SS, D	Fortran, VBA Excel	OPC, Excel, Word	oil and gas treatment
SysCAD	HSC	SS, D	SysCAD	DDE, OPC, Excel, DXF, DLL	production of alumina, potash, sugar
ProSimPlus	DIPPR, User defined DLL	SS	Excel, VBA, C++, Fortran	Excel, DLL	oil and gas treatment, biochemistry, food industry
IDEAS	OLI, Gibbs	SS, D		OPC, DDE, Excel	pulp-and-paper production, oil-sand mining and treatment, oil transportation, heap leaching
METSIM	FactSage	SS, D	APL	DDE, Excel, DXF	mining, crushing, separation and classification
HSC Chemistry	-	SS, D	Excel	Excel, OPC, COM	crushing, separation and classification
UniSim Design	Hysys, DIPPR	SS, D		OLE	oil and gas treatment, chemical technology
JKSimMet	-	SS	-	-	crushing, separation and classification
JKSimFloat	-	SS	-	-	flotation
PRO/II	OLI, HTRI, DIPPR, Koch-Glitsch Spiral CrudeSuite	SS	Excel		oil and gas treatment, chemical technology
USIM PAC	DIPPR	SS, D			crushing, separation and classification
Math Designer	-	SS	VB, C#	Excel, OPC, COM, DXF, DLL	alumina production, building materials production

* All names of software products and trademarks mentioned in the table belong to registered owners; ** Except of built-in expanded database; *** SS – Steady-State solver, D – Dynamic solver.

The first steady-state models of RUSAL alumina refineries were created with the involvement of outside specialists. Since 2012, a subsidiary company, RUSAL-Australia has joined the development of models for Bayer refineries for non-Russian locations. RUSAL-Australia independently created models for refineries in Jamaica and Ukraine. An important decision to develop models for Russian refineries was taken in 2014. It should be noted that Russian alumina is produced from bauxites by parallel Bayer-Sinter processes and from nephelines by the Sinter method. There were no examples of SysCAD models to describe such flowsheets, but it was decided not to change the software platform, but to combine the skills of RUSAL-Australia specialists with the experience of the RUSAL Engineering and Technology Center in St. Petersburg to jointly develop these models. The current year is important for the project, because development of basic steady-state mathematical models for RUSAL alumina refineries will be completed in 2017. In total, this work has taken 7 years.

2. Models of RUSAL Refineries

Each mathematical model is a complete description of the material and heat flows, equipment specifications and control algorithms of an individual refinery. Material flows are characterized by consumption, chemical and mineralogical composition, aggregate state, particle size distribution, pressure and temperature. The production equipment is described both with the use of typical software units, and with the help of specially developed models for some technology elements that are not a part of the SysCAD software library. The control system logic of a real refinery is accurately reproduced in the model.

- calculation of the best pressure profile for flash train of digestion lines;
- playing scenarios for saving soda;
- reduction in water consumption;
- study of options for recycling secondary steam.

Model calculations are often performed within the framework of business planning. This type of calculations is used to study the implementation efficiency for a group of changes simultaneously. As a rule, the total effect of several measures is not additive, and sometimes it turns out to be the opposite of that expected. In this way, technological specialists at RUSAL are now achieving the optimum efficiency of alumina refineries with the support of their experience and modeling activities.

5. Conclusions

At their Engineering and Technology Center, RUSAL creates detailed models using SysCAD and our own software solutions and applies them to a wide range of scientific and engineering problems, including solutions for alumina production by the hydrochloric acid process, solving environmental problems, and for example, the development of a method for utilization of spent refractory from aluminum electrolysis. Separate processes and equipment that require special attention are optimized by computational fluid dynamics.

Further efforts to develop detailed process and technology models will focus on improving their quality and ease of use. Creation of dynamic models for individual areas and units, optimization calculations and the use of mathematical models in refinery control systems loops are also areas of priority for further development.

The utilization of dynamic models for individual areas and units provide additional opportunities to alumina refineries. Dynamic models can be used for optimal control of both ultrafast and slow-flowing processes. For example, using a detailed dynamic model, it is possible to accurately predict the particle size of hydrate and productivity of the precipitation area with a horizon of up to 3 months, and approximately estimate the long-term consequences of the actions taken with the horizon up to 12 months [4, 5]. In a series of predictions, various scenarios for adjusting seed ratio, temperature regime, concentration of aluminate liquor, and holding time can be considered, and then the results used to define the operational actions to undertake regulation the process. Dynamic models can be used to train operators, configure control systems, including pre-tuning and real-time tuning of advanced process control systems [6-8].

Today, the possibilities of using detailed models at alumina refineries is quite wide and the scope of their application will expand. This is because mathematical modeling is a source of a deep understanding of process fundamentals, and a tool for objective analysis of their efficiency.

6. References

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