Application of METSIM in Process Design of the Cleaner Chromate Production Using Sub-molten Salt

Ye-qing LV[1,2,3], Shi-li ZHENG [2], Shao-na WANG[2], Hao DU [2], Yi ZHANG [2]

[1]School of Chemical Engineering, Tianjing University, Tianjing 300072, China; [2]National Eng. Lab. Hydrometallurgical Cleaner Production Technology, Inst. Process Eng., CAS, Beijing 100190, China; [3]National Engineering Research Center of Distillation Technology, Tianjing 300072, China)

Abstract. The cleaner chromate production process using sub-molten salt has been successfully simulated using METSIM in order to evaluate the mass balance, energy consumption, and other conditions necessitate for the process scaling up. Based on the simulation results, the mass and heat balance of every operation unit are obtained, providing valuable reference for the process design. Further, the heat exchange network optimization using pinch technology is performed, enabling the reduction of the heat and cool energy consumption by 31.5% and 31.7%, respectively.

Keywords. sub-molten; process of chromate; METSIM; process simulation; pinch technology; optimization

1 Introduction

Chromium compounds are essential to many industries. Currently, the main manufacturing process is non-calcium roasting. In this process, however, the resource and energy utilization efficiency are quite low(<80%), and 2.5~3 tonnage chromium-containing residues are produced for manufacturing 1 tonnage of chromate, creating serious pollution problems [1].

In order to realize green production of chromate, a cleaner manufacturing process using sub-molten salt (SMS) technology has been developed by the Institute of Process Engineering, CAS. The recovery of chromate can reach 95%, and the residues produced can be reduced to one fifth in comparison with the traditional process. The technology has exhibited promising perspective for further industrialization.

Accurate mass and energy balances are critical for the process development, and are essential for the designing and scaling the process equipments. In this article, METSIM [2,3] has been believed to be one of the top choices for mineral treatment process designing. In this regard, the application of METSIM in calculating mass and energy balances for a typical hydrometallurgy process has been demonstrated, and based on the results, the heat network is optimized simultaneously in this paper.

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2 Process Simulation Using METSIM

2.1 Mass Balance

In this article, the simulation based on the reference of an annual capacity of 15,000 tons Cr_2O_3, and the process is designed to operate 24 hours a day and 300 days a year,. The main components of chromite ore are shown in Table 1.

Table 1. The composition of chromite

Component (%, ω)	Cr_2O_3	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	H_2O	Total
Chromite	42.6	2.7	0	10.0	27.6	12.1	5.0	100

The model developed using METSIM is shown in Fig.1, and the mass and energy balances results obtained are shown in Table 2 and Table 3, respectively. From Table 2, it can be seen that the maximum deviation is 5.99%, and the average deviation is only has 0.8%, confirming that the model is appropriate for simulation such a process.

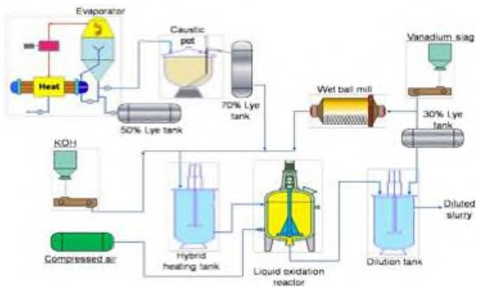


Fig. 1. The model of evaporation and liquid phase oxidation units using METSIM

Table 2. The result of mass balance

Diluted slurry		Simulation (kg/h)	Experiment (kg/h)	Deviation (%)
Liquid phase	H_2O	18955.9	20163.5	5.99
	KOH	23356.0	22653.3	3.0
	K_2CrO_4	90.3	90.6	0.3
	K_2CO_3	3171.5	3171.5	0
	K_2SiO_3	232.4	232.4	0
	K_2AlO_2	5225.9	5223.8	0.04
Solid phase	K_2CrO_4	5735.4	5729.6	0.1
	K_2CO_3	275.4	275.2	0.07
	K_2SiO_3	311.8	311.6	0.06
	K_2AlO_2	423.7	424.4	0.2
	Cr_2O_3	63.8	63.8	0
	MgO	499.1	499.1	0
	Fe_2O_3	1377.6	1377.6	0

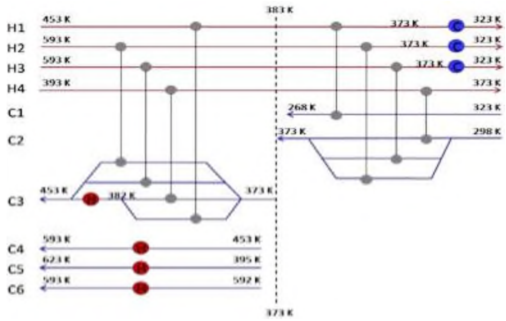
Table 3. The result of energy balance

Operation unit	Preheating	Evaporation	Alkali boiling	Hybrid heating	Leaching
Value (x10^7 kJ/h)	0.37	2.26	0.54	0.36	1.00

From Table 3, it is seen that the liquid oxidation and evaporation units have large energy consumption. At the same time, much high grade steam is produced in this process. By proper process design, energy consumption can be reduced, improving the economics of the new process.

2.2 Energy Optimization

The pinch technology is chosen to optimize the process. The matching rules are: (1) $N_{in} \geq N_{out}$; (2)$C_{p,in} \geq C_{p,out}$, N stands for the total stream numbers, and C_p is the heat capacity flow rate. the heat exchanger network is matched, shown in Fig.2



H1. Evaporation vapor H2. Alkali boiling vapor H3. Leaching vapor H4. Dilution vapor
C1. Compressed air C2. Lye preheating C3. Lye evaporation C4. Lye boiling
C5. Hybrid heating C6. Leaching

Fig. 2. The match result of the heat exchanger network

After optimization, the cool and hot utilities are reduced: $1-3.14\text{x}10^7/4.60\text{x}10^7=31.7\%$, $1-3.18\text{x}10^7/4.64\text{x}10^7= 31.5\%$.

3 Conclusion

The accurate mass and energy balances are critical for hydrometallurgical process development, and are essential for the designing and scaling the process equipments. In this article, METSIM has been proved to be appropriate to the cleaner process with sub-molten salt technology.

With the aid of processing simulation software-METSIM, the major components in streams and their mass flow can be clearly presented from the flowsheet. Based on the model, the processing conditions including the amount of wash water, the split ratio, and evaporation ratio can be changed with great flexibility, providing information for the practical process design.

The optimization of the heat exchanger network improves its economic benefits. Based on the match result, the cool and hot utilities are reduced by 31.7% and 31.5%, respectively, without changing the original devices.

In summary, the simulation using METSIM allows process designers to evaluate a hydrometallurgy process based upon experimental data and reasonable assumptions, providing important information for potential industrial applications.

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