Light Metals 2012 *Edited by: Carlos E. Suarez*
TMS (The Minerals, Metals & Materials Society), 2012

A TECHNO-ECONOMIC OPTIMIZATION MODEL FOR ALUMINIUM ELECTROLYSIS PRODUCTION

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Keywords: Aluminum production, Techno-economic Analysis, Optimization, Model, Optimal current

Abstract

The major factors affecting the profit of an enterprise are the price of the product, the price of raw materials and energy consumed, depreciation of fixed assets, labor cost, output and process consumptions, etc. In this paper, based on a cost-volume-profit (CVP) analysis method and the process techniques of aluminium production, a series of techno-economic analysis and optimization models for the production of the aluminium smelter enterprises are built. The models can be used for the aluminium smelters in various market situations to get the optimum technical parameters of production, which are necessary for obtaining the greatest economic benefit. Thus, it will guide the aluminium smelters in different market environment, according to their own conditions, to adopt different technical parameters of production to maximize the gains and to minimize the losses. We also have studied the optimization of potline current of a 300 kA aluminium smelter by the models as an example.

Introduction

Under changing external market environment the product cost and sales income of a company are changing during different times, and with different price of raw materials in different regions, the cost and benefit of companies in different regions will vary. Also for an aluminum smelting enterprise the prices of primary aluminium and raw materials are going up and down, and the disparities of the electrical energy prices in different regions, for example in China, where the power price varies from 0.2 Yuan/kWh to 0.6 Yuan/kWh, and alumina prices can vary greatly in different regions and countries because of rich or poor mineral resources. In the areas with various electrical energy prices, or when the electrical energy price changes, or with the great fluctuation in prices of aluminum, alumina or carbon anodes, how can the aluminum smelter enterprises optimize their technology and process data, combined with self practical condition, to adjust the output for maximum benefits? High current density or low current density, is there a more economical technical solution? Based on the current conditions, is it better for benefits to intensify the current or decrease the current? The current density and ACD (anode-cathode distance), voltage, and current efficiency are related closely, and how to get the best economical balance between them?

In this paper, based on a cost-volume-profit (CVP) analysis method, a series of techno-economic analysis and optimization models on aluminum electrolysis production are built. Each smelter, under different market environment, can optimize its parameters of process and technology using the models according the market factors in order to obtain maximum benefit.

A techno-economic analysis model

The total cost and gross income of an aluminium smelter increase nonlinearly with its volume, so their typical model of cost-volume-profit (CVP) analysis[1] is shown in figure 1. The profits rise up firstly and then drop down with the increase of production. The area enclosed by the Income line and the cost line is the profitable zone. while a raw material costs decrease results in the cost line to shift down or the sale price increases lead to the income line to move up, the profit zone will be expanded, and vice versa. Enterprises are usually running in the profit zone, further, if the output achieves the optimal volume -- Q_{OPT}, the firm will get the maximum profits -- E_{max}. If the aluminium smelter enterprises were in different countries and regions or in different time, they would have different profit zones and optimal yield volumes. So we need to study the relationship between the market factors and aluminum production volume and parameters of the technology and process to acquire the optimal volume Q_{OPT} for the maximum profits. When the income line is all located below the cost line, this is, the profit zone does not exist, and the company has a loss at any production volume, we also need to study and adjust the aluminum technology and process parameters to get the optimal volume to minimize the loss, and even consider whether to stop cells or not, according to the losses and the forecast duration of the bad market and the restart costs of cell.

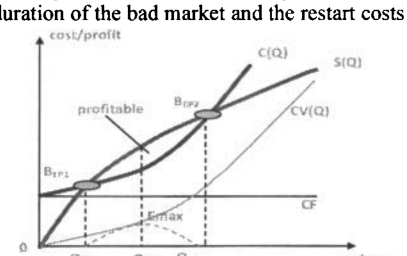

Figure 1. Cost-volume-profit analysis model

C: Costs, S: Sales income, CV: Variable costs, CF: Fixed costs, Q: production volume, B: Break-even point, E_{max}: Maximum profits , Q_{OPT}: Optimum production volume, E: Profits.

Now, we will analyse the cost, the volume and the profit of aluminium smelter enterprises.

Production volume and sales income

$S = Q \times P_{AL} = P_{AL} \times 24 \times 0.3356 \times I \times \eta \times 10^{-3} \times 365 \times N$

S: Sales income, P_{AL}: Aluminium price,

I: Current intensity, η: Current efficiency, N: number of pots

Fixed costs—CF

Fixed costs are those that remain unchanged, irrespectively of the level of output and they include:

-Depreciation on the fixed assets
-Overhead charges
-Maintenance costs
-Fixed salary

Adjusting the production to the optimum volume, it does not need to increase or decrease the number of workers. Furthermore, in China the state-owned enterprises still need to pay wages even if they have stopped production for a period, so we count the salary into the fixed cost.

Variable costs—CV
Variable costs are those that change related to the level of output. Usually, variable costs are counted by per ton of aluminium. In fact only the alumina and carbon anode and electrical energy consumption are related closely with the aluminium production, which depends on the current intensity and current efficiency. Auxiliary materials expense and energy cost are mostly related to the running time, so they should be counted by per day or per year.

-Auxiliary materials expense includes:
Electrolyte consumption---CV_{BATH}
Consumption of fluoride salts and additives---- CV_{ALF3}

-Other energy cost---$CV_{POWER\text{-}ELSE}$, includes:
Pot fume scrubbing system
Compressed air system

-Sales cost---CV_{SALE}
Sales cost is considered together with the sales price of the aluminium in the model, so it is no longer listed separately.

The part of variable costs counted by time is CV1.

$$CV_1 = 365\times(CV_{BATH} + CV_{ALF3} + CV_{POWER\text{-}ELSE})\times N$$

$$CV_1 = 365\times(Q_{BATH}\times P_{BATH} + Q_{ALF3}\times P_{ALF3} + Q_{POWER\text{-}ELSE}\times P_{POWER})\times N$$

P: purchase price, Q: daily consumption, N: number of pots

-Major raw materials cost includes:
Alumina cost--- CV_{AL2O3}
Carbon anode cost----CV_C
Alumina costs, CV_{AL2O3}, are counted by two ways, one is purchased at 17% of the sales price of aluminum:

$$CV_{AL2O3} = 1.935\times Q_{AL}\times 0.17\times P_{AL} = 0.32895\times Q_{AL}\times P_{AL}$$,

The other way is purchased at market price:

$$CV_{AL2O3} = 1.935\times Q_{AL}\times P_{Al2O3}$$.

The constant 1.935 is the average alumina consumption per ton of aluminium produced, and it can be changed by each enterprise according to itself. If we choose way number one, the effect of fluctuation of the alumina price is not considered, so we choose the market price of alumina in our model.

$$CV_C = Q_C\times Q_{AL}\times P_C$$

Qc: Carbon anode consumption per ton of aluminium,
Pc: anode price

-Energy consumption:

$$CV_{POWER} = U\times I\times 24\times P_{POWER}\times 365\times N$$

U: Pot voltage, I: Current intensity , N: Pot Number, P_{POWER}: Electrical energy price

Profits
E=S-CF-CV
CF is constant and unchanged with the production. The equation above will be the techno-economic analysis model on aluminum electrolysis production after detailed the non-constant term, as shown in equation-1 below:

$$E = P_{AL}\times Q_{AL} - CF - CV_1 - 1.935\times Q_{AL}\times P_{AL2O3} - Q_C\times Q_{AL}\times P_C - U\times I\times 24\times P_{POWER}\times 365\times N$$

....Eq-1

Here,

$$Q_{AL} = 24\times 0.3356\times I\times \eta\times 10^{-3}\times 365\times N$$,

E: Profits per year of an aluminium smelter

Once a smelter is built, the fixed costs are basically unchanged. What it can do to get the best returns in various markets is adjusting the technical parameter in the process to the economic optimal production volume. In the electrolytic production process, the production is mainly concerned with the current intensity and current efficiency, and energy consumption, mainly determined by the voltage, so we need to find a balance between these three parameters to enable enterprises to gain the maximum profit.

3 Techno-economic optimization models

Using the ***techno-economic analysis model on aluminum electrolysis production***, we analyse if a smelter should run at high or low current intensity, and if a smelter should rise the production or drop the cost to improve the efficiency when the market is changed, and which balance state of voltage and current efficiency gives the optimal production program for maximum revenue.

Economic evaluation of potline current
According to the Techno-economic analysis model we want to make economic evaluation on production and technical parameters to judge whether the potline current is running at the economic optimal value, and then how to adjust it. According to Eq-1, we can calculate the first-order partial derivative of profits E to potline current I, to get the partial derivatives. Then if:

$\frac{\partial E}{\partial I} = 0$: Potline current is running at the economic optimal value

$\frac{\partial E}{\partial I} > 0$: The smelter needs to increase current to raise the production to improve benefits

$\frac{\partial E}{\partial I} < 0$: The smelter needs to decrease current to reduce the production to improve benefits

Now, let us put the production of aluminium Q_{AL} and pot voltage U and the function f, which is mainly on the current and current efficiency and the pot voltage , into Eq-1 to solve and obtain $\frac{\partial E}{\partial I}$.

$$U = (\frac{(Uo-1.7)}{Io} I + 1.7)$$

1.7: Back electromotive force constant
To a design smelter:
Uo: Design pot voltage, Io: Design potline current
To a running smelter:
Uo: Running pot voltage, Io: Running potline current

If the relation function between current and efficiency and pot voltage is $U = f(I, \eta)$, then:

$$\frac{\partial U}{\partial I} = f_I' + f_\eta' \frac{\partial \eta}{\partial I} = (\frac{(Uo-1.7)}{Io} + \frac{\partial U'}{\partial \eta}\frac{\partial \eta}{\partial I}$$

Calculate the partial derivatives of E to I, $\frac{\partial E}{\partial I}$, to get:

$$\frac{\partial E}{\partial I} = (P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times (24 \times 0.3356 \times (\eta + I \times \frac{\partial \eta}{\partial I}) \times 10^{-3} \times 365 \times N)$$
$$-[(\frac{2 \times Uo - 3.4}{Io} + \frac{\partial U'}{\partial \eta} \times \frac{\partial \eta}{\partial I}) \times I + 1.7] \times 24 \times P_{POWER} \times 365 \times N \qquad \text{.........Eq-2}$$

If ACD is located at the position where the change of the current intensity has little effect on the current efficiency, Eq-2 can be simplified to Eq-3:

$$\frac{\partial E}{\partial I} = (P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times (24 \times 0.3356 \times \eta \times 10^{-3} \times 365 \times N)$$
$$-(\frac{2 \times Uo - 3.4}{Io} \times I + 1.7) \times 24 \times P_{POWER} \times 365 \times N \qquad \text{................Eq-3}$$

According to Eq-3, we can put the detailed data of a smelter in it, such as aluminium price, alumina price, price and consumption of carbon anode, electric power price, current efficiency, current intensity, cell voltage, etc., and we can then carry out an economic evaluation of its production. If the current runs at the best economic value $\frac{\partial E}{\partial I} = 0$, it should maintain the current operating status or further improve efficiency or reduce energy consumption without changing the other conditions for better benefits. $\frac{\partial E}{\partial I} > 0$ shows a tendency that the smelter's benefits will be improved along with the increase of the current, and the smelter needs to intensify the current to gain maximum benefit. $\frac{\partial E}{\partial I} < 0$ shows a tendency that the smelter's benefits will be improved along with the decrease of current, and the smelter then needs to reduce the current to gain maximum benefit.

The optimal potline current

While $\frac{\partial E}{\partial I} \neq 0$, and if the ACD is located at the position where the change of the current intensity has little effect on the current efficiency, set $\frac{\partial E}{\partial I} = 0$ and solve the equivalent and get the current I_{OPT}, which is the economic optimal running current intensity. Set:

$$0 = (P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times (24 \times 0.3356 \times \eta \times 10^{-3} \times 365 \times N)$$
$$-(\frac{2 \times Uo - 3.4}{Io} \times I + 1.7) \times 24 \times P_{POWER} \times 365 \times N$$

Solve and obtain I_{OPT}:

$$I_{OPT} = (\frac{(P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times 0.3356 \times \eta \times 10^{-3}}{P_{power}}$$
$$-1.7) \times \frac{Io}{2 \times (Uo - 1.7)} \qquad \text{..Eq-4}$$

Using Eq-4 we can get the optimal economic current intensity to run, so we can adjust the current to the optimum to change $\frac{\partial E}{\partial I} \neq 0$ to the conditions of $\frac{\partial E}{\partial I} = 0$. Then the smelter will obtain the optimal benefits.

Meanwhile, Eq-4 shows that I_{OPT} is inversely proportional to the power price P_{POWER} and cell voltage Uo, and it is proportional to current efficiency η and major *materials benefits* M_M, which is the gross income that is equal to the price per ton of aluminum minus the cost of alumina and anodes consumed per ton of aluminium produced:

$M_M = (P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C)$.

Thus, we can get the guide rules from Eq-4 for the smelter to obtain the optimal profits when the market changes. Assume that a smelter is running at its optimal current, and if the price of aluminum rises or the price of alumina and anode carbon drop down leading to material benefits up, enterprises should strengthen the current to increase production to gain more. If the power price rises or the cell voltage increases for some reasons leading to material benefits down, enterprises should decrease the current to decrease production to gain more, and vice versa.

Optimization of the cell voltage and current efficiency

If the ACD is located at the position where the change of the current intensity impacts the current efficiency significantly, we need to find the best economic balance point between the current efficiency and cell voltage. Setting a relationship between voltage and current to $U = f(\eta)$, and if we put it into the Eq-1, we get the formula of partial derivatives $\frac{\partial E}{\partial \eta}$. Then we put the market data in the formula to solve the value of $\frac{\partial E}{\partial \eta}$, which will tell a smelter whether it is more economic to increase or decrease or keep the ACD and the cell voltage and efficiency constant.

$\frac{\partial E}{\partial \eta} = 0$: Running at the economic optimal balance of voltage and efficiency.

$\frac{\partial E}{\partial \eta} > 0$: The ACD should be increased for higher current efficiency and more output to improve benefits.

$\frac{\partial E}{\partial \eta} < 0$: The ACD should be reduced for lower voltage and less costs to improve benefits.

$$\frac{\partial E}{\partial \eta} = (P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times (24 \times 0.3356 \times I \times 10^{-3} \times 365 \times N)$$
$$-\frac{\partial U}{\partial \eta} \times I \times 24 \times P_{POWER} \times 365 \times N \qquad \text{.....Eq-5}$$

When $\frac{\partial E}{\partial \eta} = 0$, it is running at the economic optimal balance point between voltage and current efficiency. Set $\frac{\partial E}{\partial \eta} = 0$, and put it in Eq-5, then solve it to get:

$$\frac{\partial U}{\partial \eta} = \frac{(P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times (0.3356 \times 10^{-3})}{P_{POWER}}$$

…….Eq-6

Eq-6 shows that the *material benefits* and the power price are the key market factors for the product routes choosing the route of higher current efficiency or the route of lower cell voltage. If the relation of market factors equals the relation between voltage and current efficiency, as shown as the red line in fig-2, it says that the smelter is running at the economical balance point of voltage and current efficiency under the current market environment. If the point ($\frac{\partial U}{\partial \eta}$, $\frac{(P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times (0.3356 \times 10^{-3})}{P_{POWER}}$) is above the red line, we should increase the voltage and efficiency . If it is under the red line, we should decrease the voltage and efficiency in order to get better benefits.

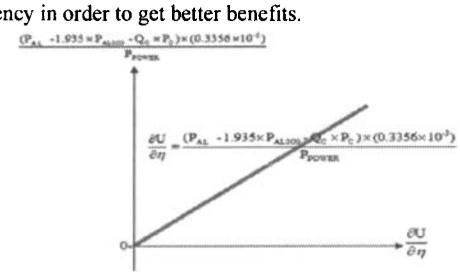

Figure 2. The optimal economical balance relationship between cell voltage and current efficiency.

We can get the economic optimal potline current and the optimal balance between cell voltage and current efficiency under a market by using the Techno-economic optimized model in theory. However, because of the limits of the energy adjustable capacity of the cell, the heat-preservation capacity and the heat-dissipating capacity, and limits of other devices or technology conditions, we can only adjust the production toward the optimal direction. Sometimes it is only running at a better status instead of the best status.

Optimization of outage and reduction in output

Under adverse market conditions, sometimes, even running at the optimal potline current, the smelter still suffers losses. At this point it should take some measures to reduce the losses or turn from deficits to profits. If the losses are inevitable after all measures are taken, the smelter should determine whether or not to stop part of or all the cells according to the relationship between aluminium price and the variable costs and the fixed costs, and the forecast duration of the bad market, and the restart costs of cell.

If running at the optimal potline current, the smelter still suffers losses, this means the cost line—C, in figure 1, is all above the sales line—S. Now, the first method is to try its best to improve current efficiency and reduce the consumption quantities to reduce the variable cost. Secondly, to try to reduce the part of depreciation of fixed assets in the fixed cost. So the cost line maybe moves down to cut the sale line and the benefit zone will reappear.

When should the cells be stopped? If the value of losses is less than the fixed cost, the smelter should run instead of stop. From Eq-1, we can get:

$$E = (P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times Q_{AL} - U \times I \times 24 \times P_{POWER} \times 365 \times N - CV_1 - CF,$$

CF is fixed cost, which must be paid whether the smelter runs or not, and:

$(P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times Q_{AL} - U \times I \times 24 \times P_{POWER} \times 365 \times N - CV_1$ is variable cost, which only is paid during the smelter running. It is to say, even it suffers losses, if:

$$(P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times Q_{AL} - U \times I \times 24 \times P_{POWER} \times 365 \times N - CV_1 > 0$$

The smelter will lose less than when it is stopped, if:

$$(P_{AL} - 1.935 \times P_{AL2O3} - Q_C \times P_C) \times Q_{AL} - U \times I \times 24 \times P_{POWER} \times 365 \times N - CV_1 < 0$$

It means that the aluminium price is lower than the variable cost per ton of aluminium, and that means produce more loss. Now, the cells should be stopped partly or all, which depends on:

$(P_{AL}-CV_{AL})$ *T and C_R

T: the forecasted time for loss

C_R: the cost of a cell to be restarted.

Calculate the loss, $(P_{AL}-CV_{AL})$ *T. If $(P_{AL}-CV_{AL})$ *T>C_R, stop all cells, or else consider the lifetime of each cell, and if its remaining life is less than T, it should be stopped.

Analysis and optimization cases

It will guide the production of each aluminium smelter enterprise in various markets to run at the optimal conditions to obtain the maximum profits or minimize losses by the techno-economic optimization models. Now, we will analysis the roles of each market factor in the production optimization. Due to the space limitation of the present paper, we will only analyse the optimization of the potline current of 300 kA cells in different markets, and given that the current efficiency is 0.93, and the cell voltage is 4.1 V.

Aluminium price and optimal potline current

For a given alumina price of 2900 yuan/t, and when the anode carbon block price is 2800 yuan/t, while the quantity of consumed anode is 520 kg/t Al, the relationship between optimal current and aluminium price is shown in figure 3. I/Io is the ratio of economic optimal current to design or running current, calculated by Eq-4. The ratios of the current should be adjusted under various aluminium prices and power prices and they are shown in figure 3. The light blue line is the corresponding conditions for designed or unadjusted current, which means economic current equal to the design current or running current under that market environment. From figure 3 we know that the higher current density is more suitable to the smelter in the region and country with lower power price or during the time with higher aluminium price.

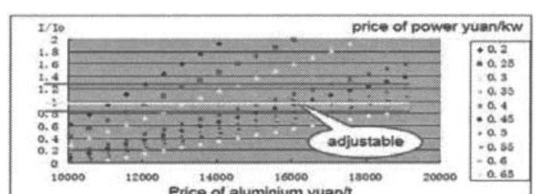

Figure 3. The economic optimal current for different prices of aluminium and power.

In figure 3, I/Io is the ratio of current that should be intensified to the design current or the running current under different market conditions in theory. However, due to the limits of the power balance and the energy balance, the real range of current adjustment depends on the heat-preservation capacity and the heat-dissipating capacity of the cells. The study suggests that different types of cells have different heat-preservation capacity and heat-dissipating capacity, which determines the adjustable range of current. The adjustable range of I/Io for 300 kA cells is from 0.825 to 1.308, as shown as the red lines in figure 3. The red lines are the same as those in the figures shown below.

Alumina price and optimal potline current

For a given aluminium price of 14000 Yuan/t, and an anode block price of 2800 Yuan/t, and when the anode consumption is 520 kg/t Al, the relationship between the economic optimal current and the alumina price is shown in figure 4.

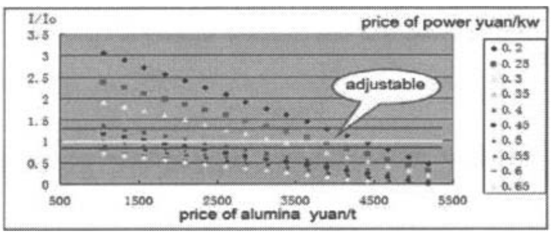

Figure 4. The economic optimal current for different prices of alumina and power.

Anode block price and optimal potline current

Again, for a given aluminium price of 14000 Yuan/t, and an alumina price of 2800 Yuan/t, and when the anode consumption is 520 kg/t Al, the relationship between economic optimal current and anode price is shown in figure 5.

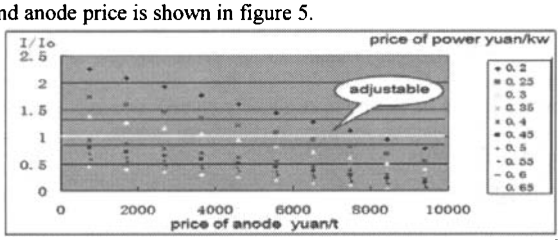

Figure 5. The economic optimal current for different prices of anode and electric power.

Comprehensive evaluation of the current up or down

According to the technology, it is ideal for cells running at the design current, and all the indexes of electrical balance and thermal balance and magnetic field and fluid field of the cells are all close to the design value. However, for the fluctuation of the market, the benefits would not always be the best when the cells run at their design status. Now, using Eq-4, let us analyse what are the necessary market conditions for the cells when the optimal current is the design current for maximum benefits, and analyse whether we need to increase or decrease the current or not.

According to Eq-4, if running at design status Io=I, we simplify it, and then we get:

$$2\times(Uo-1.7)=(\frac{(P_{AL}-1.935\times P_{Al2O3}-Q_C\times P_C)\times 0.3356\times\eta\times10^{-3}}{P_{power}}-1.7)$$

This study shows that if the design cell voltage is 4.1 V, and if we put it in the above equation, we can get the necessary market conditions:

$$P_{power}=\frac{(P_{AL}-1.935\times P_{AL2O3}-Q_C\times P_C)\times 0.3356\times\eta\times10^{-3}}{6.5}\ldots\text{Eq-7}$$

Set $M_M=P_{AL}-1.935\times P_{AL2O3}-Q_C\times P_C$, then:

The market conditions ensure the cells running at design current is:

$$P_{power}=\frac{M_M\times 0.3356\times\eta\times10^{-3}}{6.5}\qquad\text{Eq-8}$$

Eq-8 shows that the higher M_M and current efficiency, the cells will run at design current with the higher power price. Given the current efficiency of 0.93, the relationship between M_M and power price P_{POWER} is shown below:

$$P_{power}=M_M\times0.48\times10^{-4}\qquad(6)$$

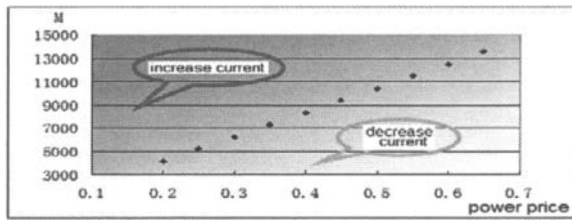

Figure 6.The relationship between M_M and power price.

For a given alumina price of 2900 Yuan/t, and anode block cost of 2800 Yuan/t, and when the quantity of consumed anode is still 520 kg/t Al, the necessary relationship of aluminium price and power price for the optimal current equals the design current is shown in figure 7.

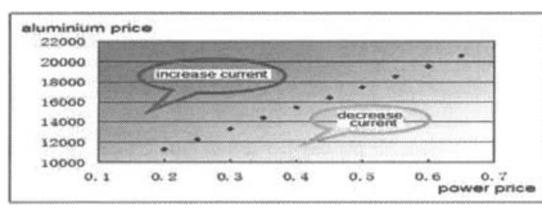

Figure 7. The necessary aluminium price and power price for cells run at design current.

In figure 6 and figure7 the points in the line are the market conditions for cells run at optimal current, which is the same as the design current. While the conditions are changed, if the point is located in the area of increasing current, the current should be intensified to its optimal value for more benefits, and if the point is located in the area of decreasing current, the current should be decreased to its optimal value for more benefits.

Analysis of optimal potline current and the benefits

Under different market environments, by economic evaluation we always have the optimal potline current. However, when the adjustable value of current is too large, due to limitations of the properties of cells or equipment, cells cannot run at the best current. They can then run at a value permitted.

While cells run at the optimal current permitted, the benefits depend on the difference between the price and variable cost of aluminium per ton. If we assume that the difference is larger than zero, the smelters will maximize the gains, and reversely, the smelters will minimize the losses. For a given alumina price of

2900 Yuan/t, and anode block price of 2800 Yuan/t, and when the anode consumption is 520 kg/t Al and the fixed cost is 8044 Yuan/cell.-day, which includes all costs independent of production. The benefits of the cells running at design current at different aluminium prices are shown in figure 8. The benefits of cells running at optimal current at different aluminium price are shown in figure 9. The comparisons of the benefits between the cells running at design current and optimal current are shown in figures 10,11, and 12. In these figures, the area inside the pair of blue lines is a range of difference of two currents less than 3%, and the area inside the pair of yellow lines is a range of difference of two benefits less than 100 Yuan per day per cell. The area inside the pair of red lines is the adjustable range permitted by the technical conditions and equipment capacity.

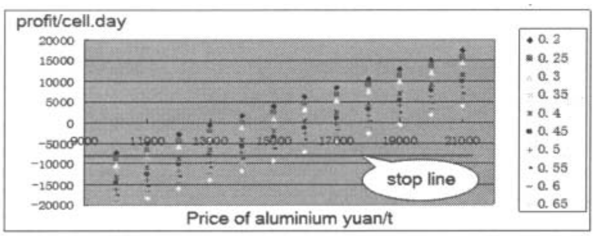

Figure 8. Benefits per day per cell of 300 kA cells at design current.

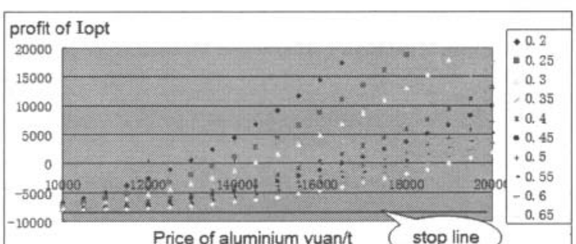

Figure 9. Benefits per day per cell of 300 kA cells at the best current in theory.

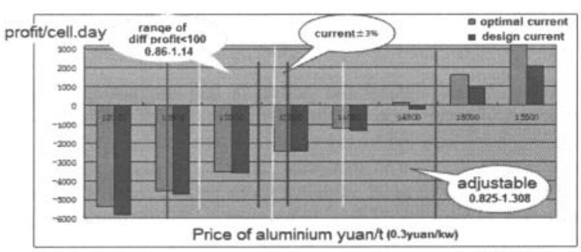

Figure 10. Benefits per day per cell of 300 kA cells run at two currents.

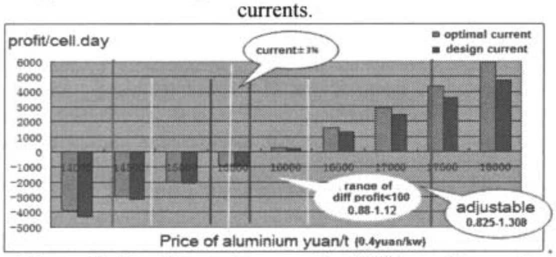

Figure 11. Benefits per day per cell of 300 kA cells run at two currents.

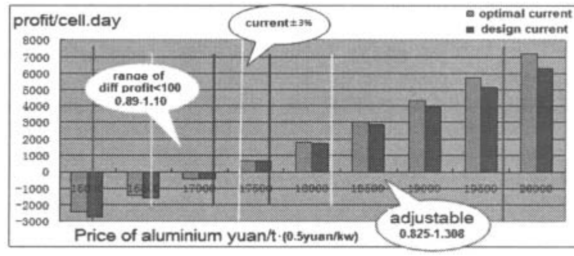

Figure 12. Benefits per day per cell of 300 kA cells run at two currents.

Although we can get the optimal current to guide the aluminium production for the maximum benefits in theory by the optimization model, we still need to comprehensively analyse the fluctuation range and time of the market and the additional cost for adjustment of the measures taken, and compare the additional benefits and additional cost to decide whether to adjust them or not.

Conclusion

In this paper we have studied and established the Techno-economic analysis and optimization models on aluminium electrolysis production. We have studied the optimization of potline current and optimization of cell voltage and current and optimization of outage and reduction in output, and many theoretical formulas were presented for this optimization. At the same time we have analyzed and optimized some examples of the potline current with the real market data, and compared the benefits difference between cell running at the design current and optimal current, and put forward a comprehensive analysis method to judge whether the current should be increased or decreased.

It is shown that when using the models and formulas and method presented in this paper, aluminium smelter enterprises, in different regions or countries or in different time, under various market conditions, can be guided to combine with self practical condition to adopt deferent technology and process parameters to gain maximum benefits.

Reference

[1] C.T.Horngren, S.M.Datar, George Foster, "Cost Accounting : A Managerial Emphasis", (13th Edition), Prentice Hall Press, London, 2008.