Study on the Model of Assessing the Output of the Ferrous Metal Factory

Won Kwang Sik

One of the important problems in the management and operation of the ferrous metal factories is the scientific assessment of the production capacity.

The great leader Comrade **Kim Jong Il** said as follows.

"Through a mass movement to tap into our reserves we can ensure higher levels of production with the existing equipment and materials." ("**KIM JONG IL** SELECTED WORKS" Vol. 13 P. 314)

What is important in managing and operating the ferrous metal factory in a planned way is to use the potentiality to the maximum in keeping with the requirements of Songun era and of industrial revolution in the new century.

The utility ratio of the various kinds of machines and equipments is an important criterion showing the management and operation levels of the ferrous metal factories. In particular, as the ferrous metal factories are making the industrial revolution of the new century to build the powerful nation with the knowledge based economy by pushing back the frontier of science and technology, the more they make use of modern production equipment, the better they can serve the people and contribute to the construction of the powerful nation. So they should scientifically assess the production capacity and use it effectively.

One of the important methods to do so is to use the optimization method.

The production capacity is the possibility to produce the main products to the maximum in a certain period.

The assessment of the production capacity is done on the basis of the main production processes and the main equipment used in those processes. The main equipment, however, sometimes is used to process various kinds of main products. In such cases, there is a difference between the standard process time by kind or their inverse numbers－outputs per hour by kind.

As a result, given that the planned working hour of the main equipment is set, the outputs of the main products are bound to be calculated differently. In other word, it gives the possibility of choosing the methods to define production capacity of the main products. Herein lies the just objective reason for appling the optimization method in the assessment of the production capacity in the ferrous metal factories.

Following are details.

The main production processes generally consist of iron-making, steelmaking and rolling processes. That produces the main products－pig iron, steel and rolled still are produced.

First of all, several kinds of rollers are used in the rolling process, one of the main production processes and they are classified into three categories on the basis of their production and technical relations.

First, some rollers, which make the finished products, do not hand over their products to the other. In case of making the semi-finished products, they are transferred to the auxiliary equipment for the production of the main products. The cold roller can be taken as an example. As such these rollers are called final ones for the sake of convenience in the model building.

Second, there are rollers which receive the semi-finished products from other ones to produce their own products and hand them over to other rollers as semi-finished products. The hot roller is the case in point. Some of the semi-finished products from these rollers are marketed outside or transferred to the auxiliary equipment for the production of the main products. These rollers can be called intermediate rollers for the sake of convenience.

Third, some rollers give their products to others without receiving their semi-finished ones. The blooming roller is one of such examples. We call them starting rollers. Therefore, the production capacity of the rollers should be assessed according to their characteristics.

First of all, let us see the final rollers. They are expressed with the suffix j ($j=1,\dots,n$). They make various kinds of rolled steel (finished or semi-finished products).

Let us express those from j th final rollers as i ($i=1,\dots,m_j$) and main kinds from the auxiliary equipment as b ($b=1,\dots,B$). In that case, we express the externally marketed output of the i th kind in the j th final roller as x_{ji}, output to be used for the production of b th main product in the auxiliary equipment as x'_{jib}, processing time per unit as f_{ji} and the planned working time as F_j.

Then the expression of assessing the output of rolled steel in the j th final roller is as follows.

$$\sum_{i=1}^{m_j} f_{ji}\left(x_{ji}+\sum_{b=1}^{B} x'_{jib}\right) \leqq F_j, \quad j=1,\dots,n \tag{1}$$

Next, let us see the intermediate rollers. Such kind is expressed as r ($r=1,\dots,R$).

Let us express the semi-finished kind from r th intermediate roller as g ($g=1,\dots,G_r$) and the main product kind from the auxiliary equipment as a ($a=1,\dots,A$). Here, we express the output of g th semi-finished kind marketed outside and consumed internally in the r th intermediate roller as x''_{rg} and x'''_{rg}, output to be used for the production of a th main product in the auxiliary equipment as $\tilde{x}_{rga}$, processing time per unit as f'_{rg} and the planned working time as M_r.

Then the expression of assessing the output of the semi-finished products in the r th intermediate roller is as follows.

$$\sum_{g=1}^{G_r} f'_{rg}\left(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A} \tilde{x}_{rga}\right) \le M_r, \quad r=1,\dots,R \tag{2}$$

The output of the internally consumed semi-finished products from the r th intermediate roller should meet the demand of the final rollers that can be calculated as follows.

Let us express the number of the final rollers which use the products from the intermediate rollers for the production as n_0 ($j=1,\dots,n_0$).

Let us assume that the semi-finished products of the g th kind from the r th intermediate roller is consumed by the quantity of b_{jirg} to produce a unit of the rolled billets of the i th kind by the j th final roller.

As a result, the expression for striking the balance between the main equipment is as follows:

$$\sum_{j=1}^{n_0}\sum_{i=1}^{m_j} b_{jirg}(x_{ji}+\sum_{b=1}^{B} x'_{jib}) = x'''_{rg}, \quad r=1,\ldots,R,\ g=1,\ldots,G_r \qquad (3)$$

Finally, let us see the expression to assess the output of the starting roller, that is, the blooming one.

Let us express the billets which are produced by the blooming rollers as d ($d=1,\ldots,D$) be kind and size. In this case, the quantity of billets which is consumed in the production by the final and intermediate rollers can be calculated as follows.

Let us express the number of the final rollers which consume the products from the blooming roller for the production as n_1 ($j=n_0+1,\ \ldots, n_1$) and assume that the j th final roller consumes the d th kind of billet by the size of b_{jid} to produce a unit of the rolled steel of the i th kind. Then the quantity of the billet of the d th kind which the proper final roller consumes for the production of the rolled steel of all kinds is as follows: $\sum_{j=n_0+1}^{n_1}\sum_{i=1}^{m_j} b_{jid}(x_{ji}+\sum_{b=1}^{B} x'_{jib})$

Let us express the number of the intermediate rollers which consume the product of the blooming roller for the production as r_1 ($r=1,\ldots,r_1$) and assume that the r th intermediate roller consume the d th kind of billets by the size of b'_{rgd} to produce a unit of the semi-finishted products of g th kind. Then the quantity of the billet of the d th kind which the proper intermediate rollers consume for the production of the semi-finished products of all kinds is as follows: $\sum_{r=1}^{r_1}\sum_{g=1}^{G_r} b'_{rgd}(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A}\tilde{x}_{rga})$

The processing time of the blooming roller needed for the production of billets by kind is ensured in a planned way.

Let us assume that the time needed to produce a unit of the billet of the d th kind in the blooming roller is s_d and the planned processing time is A. Then the expression to assess the output of billet by kind in the blooming roller is as follows:

$$\sum_{d=1}^{D} S_d(\sum_{j=n_0+1}^{n_1}\sum_{i=1}^{m_j} b_{jid}(x_{ji}+\sum_{b=1}^{B} x'_{jib}) + \sum_{r=1}^{r_1}\sum_{g=1}^{G_r} b'_{rgd}(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A}\tilde{x}_{rga})) \le A \qquad (4)$$

The steel making is the leading process in the rolling and one of the main production processes. The steel making process makes the steel for the rolling process. In this process the main equipment is steel making furnace that produces various kinds of steel. So let us make the expression for the production of steel by kind depending on the production capacity of these furnaces.

The type of furnaces for the production of steel is expressed as h ($h=1,\ldots,H$). This suffix is set as the ferrous metal factories have the steel making furnaces with the different production capacity and the different technical and economical indices.

Let us express the kind of steel as e ($e=1,\ldots,E$). In this case the quantity of steel by kind which the final roller($j=n_1+1,\ldots,n$), the intermediate roller($r=r_1+1,\ldots,R$) and the blooming roller consume for the production can be calculated as follows:

Let us assume that the j th final roller consumes the e th kind of steel by the size of b''_{jie} to produce a unit of the rolled steel of the i th kind. Such consumption criterion is calculated as the product of the steel consumption one per unit of the continuously casted billet and of the consumption one of the continuously casted billet per unit of the rolled steel. Then the proper final rollers consume the eth kind of steel by the size of $\sum_{j=n_1+1}^{n}\sum_{i=1}^{m_j} b''_{jie}(x_{ji}+\sum_{b=1}^{B} x'_{jib})$ for the production of the rolled billets of all kinds.

Let us express the quantity of the steel of the eth kind which the rth intermediate roller consumes to produce a unit of the semi-finished products of the gth kind is b'''_{rge}. Then the proper intermediate rollers consume the eth kind of steel by the following size for the production of the semi-finished products of all kinds. $\sum_{r=r_1+1}^{R}\sum_{g=1}^{G_r} b'''_{rge}(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A}\tilde{x}_{rga})$

Let us assume that the quantity(P_{de}) of the steel of the eth kind consumed by the blowing roller to produce a unit of the billets of the dth kind. Then the blowing roller consumes the eth steel by the following size for the production of the billets of all kinds.

$$\sum_{d=1}^{D} P_{de}(\sum_{j=n_0+1}^{n_1}\sum_{i=1}^{m_j} b_{jid}(x_{ji}+\sum_{b=1}^{B} x'_{jib})+\sum_{r=1}^{r_1}\sum_{g=1}^{G_r} b'_{rga}(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A}\tilde{x}_{rga})$$

The steel making process should produce the above quantity of steel by kind.

Lets us assume the production potentiality of the internally consumed steel of the eth kind in the hth steel making furnace as U_{he}. Then the expression for the provision of balance between the rolling process and steel making one is as follows.

$$\sum_{j=n_1+1}^{n}\sum_{i=1}^{m_j} b''_{jie}(x''_{ji}+\sum_{b=1}^{B} x'_{jib})+\sum_{r=r_1+1}^{R}\sum_{g=1}^{G_r} b'''_{rge}(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A}\tilde{x}_{rga})+$$
$$\sum_{d=1}^{D} P_{de}(\sum_{j=n_0+1}^{n_1}\sum_{i=1}^{m_j} b_{jid}(x_{ji}+\sum_{b=1}^{B} x'_{jib})+\sum_{r=1}^{r_1}\sum_{g=1}^{G_r} b'_{rga}(x''_{rg}+x'''_{rg}+\sum_{a=1}^{A}\tilde{x}_{rga})=\sum_{h=1}^{H} U_{he}$$
$$e=1,\ldots,E \qquad (5)$$

The steel(billet) made in the steel making furnace is also marketed outside the ferrous metal factories.

Let us assume the production potentiality of the externally marketed steel of the eth kind in the hth furnace as Y_{he}. Then the total quantity of the steel of the eth kind made in the hth furnace is $(U_{he}+Y_{he})$. The operation time if furnace needed for the production of steel by kind, is ensured by the planned operation time.

Let us assume that the time span of a_{he} is needed to produce a unit of the steel of the eth kind in the hth furnace.

Let us assume the planned operation time span as A_h. This is defined as the sum of the individual planned ones in case there are the several furnaces of the same kind.

As a result, the expression to assess the output of steel by the furnaces is as follows.

$$\sum_{e=1}^{E} a_{he}(U_{he} + r_{he}) \leq A_h, \quad h = 1,\ldots, H \tag{6}$$

In such case, the output of the externally marketed steel by kind produced in the steel making process is $\sum_{h=1}^{H} Y_{he}, \quad e = 1,\ldots, E$

The iron making is the leading process of the steel making and the first main production process. The iron making process produces the iron for the steel making process and for the production of the main products by the other auxiliary equipment and the iron is also marketed outside the ferrous metal factories.

The main equipment for the iron making process is the iron making furnaces. Let us see the expression to assess the output of iron by the furnaces in the iron making process.

Let us express the type of furnace as l ($l = 1,\ldots, L$), the degree of iron ore for the production of iron as p ($p = 1,\ldots, P$) and the kind of main product made from proper auxiliary equipment as c ($c = 1,\ldots, C$). In this case, let us express the outputs of the internally consumed and externally marketed iron from the p th degree of iron ore in the l th furnace as U'_{lp} and Y'_{lp} and the output of iron to be consumed for the production of the c th main product by the auxiliary equipment as U_{lpc}. Let us assume that the time span needed to produce a unit of iron from the p th degree of iron ore in the l th furnace is s_{lp} and the planned operation time span is N_l. Then expression to assess the output of iron in the iron making furnaces is as follows.

$$\sum_{p=1}^{P} s_{lp}(U'_{lp} + \sum_{c=1}^{C} U_{lpc} + Y'_{lp}) \leq N_l, \quad l = 1,\ldots, L \tag{7}$$

Then the output of the externally marketed iron on the iron making furnaces is $\sum_{l=1}^{L}\sum_{p=1}^{P} Y'_{lp}$.

The output of the internally consumed iron in the iron making process should meet iron in need for the production of steel in the steel making process.

Let us assume that the output of iron to produce a unit of the steel of the e th kind in the h th steel making furnace is b_{he}. As a result, the expression for the provision of balance between the steel making and iron making processes is as follows.

$$\sum_{l=1}^{L}\sum_{p=1}^{P} U'_{lp} = \sum_{h=1}^{H}\sum_{e=1}^{E} b_{he}(U_{he} + Y_{he}) \tag{8}$$

Finally the variables to assess in the relative expression (1)-(8) should not be negative. That is:

$$x_{ji}, x'_{jib}, x''_{rg}, x'''_{rg}, \tilde{x}_{rga}, U_{he}, Y_{he}, U'_{lp}, U_{lpc} \geq 0 \tag{9}$$

$j = 1,\ldots, n$, $i = 1,\ldots, m_j$, $b = 1,\ldots, B$, $r = 1,\ldots, R$, $g = 1,\ldots, G_r$, $a = 1,\ldots, A$, $h = 1,\ldots, H$, $e = 1,\ldots, E$, $l = 1,\ldots, L$, $p = 1,\ldots, P$, $c = 1,\ldots, C$

Let us make up the objective function.

Criterion of optimization is the output index of the main product in the ferrous metal factories. The output of the main product is the possibility to produce to the maximum the externally marketed rolled billet, steel, iron and other main products during the given planned period.

The output of the externally marketed rolled billet, steel and iron by kind was already defined.

The problem is how to define by kind the quantity of the main products in the auxiliary equipment.

To define this, let us assume that the kinds of semi-finished products made by the main equipment are consumed to produce a unit of the main products by the auxiliary equipment by the quantities of α_{jib}, β_{rga} and γ_c.

The output of the proper kinds of main products can be calculated to be $\alpha_{jib}^{-1}x'_{jib}$, $\beta_{rga}^{-1}\tilde{x}_{rga}$, $\gamma_c^{-1}(\sum_{l=1}^{L}\sum_{p=1}^{P}U_{lpc})$. Here α_{jib}^{-1}, β_{rga}^{-1}, γ_c^{-1} are the inverse numbers of α_{jib}, β_{rga}, γ_c because the only one kind of semi-finished products is consumed for the production of the proper kind of main product.

As a result, the objective function, is as follows

$$
\begin{aligned}
&x_{ji},\ \alpha_{jib}^{-1}x'_{jib} \Rightarrow \max, \quad j=1,\dots,n,\ i=1,\dots,m_j, b=1,\dots,B \\
&x''_{rg},\ \beta_{rga}^{-1}\tilde{x}_{rga} \Rightarrow \max, \quad r=1,\dots,R, g=1,\dots,G_r, a=1,\dots,A \qquad (10)\\
&\sum_{h=1}^{H}Y_{he}, \sum_{l=1}^{L}\sum_{P=1}^{P}Y'_{lp},\ r_c^{-1}(\sum_{l=1}^{L}\sum_{P=1}^{P}U_{lpc}) \Rightarrow \max,\ e=1,\dots,E,\ c=1,\dots,C
\end{aligned}
$$

Let us apply the lower limitation values into the objective expression (10). And let us add the following expressions to the objective expression (10).

$$
\begin{aligned}
&x_{ji} \geq \bar{x}_{ji},\ \alpha_{jib}^{-1}x'_{jib} \geq \bar{x}'_{jib}, \quad j=1,\dots,n,\ i=1,\dots,m_j, b=1,\dots,B \\
&x^n_{rg} \geq \bar{x}''_{rg},\ \beta_{rga}^{-1}\tilde{x}_{rga} \geq \bar{\tilde{x}}_{rga}, \quad r=1,\dots,R, g=1,\dots,G_r, a=1,\dots,A \qquad (11)\\
&\sum_{h=1}^{H}Y_{he} \geq \bar{Y}_e,\ e=1,\dots,E,\ \sum_{l=1}^{L}\sum_{p=1}^{P}Y^1_{lp} \geq \bar{Y}, \gamma_c^{-1}(\sum_{l=1}^{L}\sum_{p=1}^{P}U_{lpc}) \geq \bar{U}_c, \quad c=1,\dots,C
\end{aligned}
$$

Where, $\bar{x}_{ji}$, $\bar{x}'_{jib}$, $\bar{x}''_{rg}$, $\bar{\tilde{x}}_{rga}$, $\bar{Y}_e$, $\bar{Y}$, $\bar{U}_c$ are the lower limitation values for the assessment of the output of the externally marketed rolled billets, steel, iron and other main products. These values are set in order to obtain the efficient points suited to the requirements of the assessment of the output to meet the demand as the efficient points of the objective expression (10) give the different values of the individual objectives. Therefore these quantities can be set on the basis of the real output of the last period, the expected demand of the planned period and so on.

Like this, by applying the optimization method to the assessment of output in the ferrous metal factories, we can solve the problem of using rationally the main equipment in order to produce the externally marketed rolled billets, steel, iron and other main products to the maximum in a planned period while putting the production and technical relations and balance between the main production processes on a scientific basis.

As the ferrous metal factories give full play to their production capacity by making the best use of the optimization method in the assessment of output, they should perform its mission as the leading sector of the national economy in the construction of the thriving socialist country.