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Development of On-line Control Model for CSC No.2 Annealing and Coating Line

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The heating and cooling parameters for the Annealing & Coating Line (ACL) are important factors that affect the magnetic properties and the shape of the electrical steel strip. The set-point values from the existing model are not proper in the annealing process. Therefore, a set-point calculation model for CSC #2ACL was developed. The strip temperature model for the heating and cooling processes is based on the energy balance. It includes the radiation and convection heat transfer scheme. And the reverse method for the calculation of the furnace temperature and gas pressure was then created. The new model is flexible enough to adapt to other continuous annealing lines. The main features include the heating and cooling patterns for different steel grades, the self-consistent cooling of the strip for different line speeds, the adaptive computing intervals for on-line control. Moreover, it had the automatic calculation function for emissivity and heat transfer coefficient of the strip, to decrease the difficulty for the maintenance of the model.

Keywords: Continuous annealing line, Set-point, Annealing & Coating Line (ACL)

1. INTRODUCTION

The heating and cooling parameters for the Annealing & Coating Line (ACL) are important factors that affect the magnetic properties and the shape of the electrical steel strip. The set-point values from the existing model are not proper in the annealing process. For example, all sub-zones in the #1ACL maintain the same gas pressure to achieve the specified strip temperature at the exit of the slow jet cooling section. This leads to the phenomenon where the cooling rate would vary to a wide range that might affect the product quality. The model of the #2ACL uses the inlet strip temperature, outlet strip temperature and line speed to calculate the gas pressure. It ignores the interaction of the furnace temperature, gas temperature and gas pressure. The gas pressure pattern is too inadequate to be applied to the high grade product. The model of the #3ACL can control the strip cooling rate according to production requirements. But, the same gas temperature is used for different line speeds to simplify the Level 1 control. That induces the numerical divergence problem. Moreover, all these models cannot show the temperature histories of strips during the heating and cooling processes. The models also cannot support the flexible control for the production of new steel grades.

The on-line control method of the reheating furnace and annealing furnace generally falls into two categories:

(1) The set-points of furnace temperature are calculated in real time and used for the setting parameters on the production line.
(2) The relationships of furnace temperatures, line speeds, strip thicknesses, inlet strip temperatures and outlet strip temperatures are calculated in advance. Then the tables of the furnace temperature are created for lookup with interpolation and used for the setting parameters on the production line, such as the models of CSC #2ACL and #3ACL.

There is a dependent relationship between the gas temperature, the gas pressure, the strip temperature and the furnace temperature of the slow jet cooling section in the #2ACL. The cooling rate of strips might be different even at the same gas pressure and uncontrollable gas temperatures. In order to solve the problem, the gas temperatures were controlled independently in the #3ACL.

In this study, the real time on-line control model was developed and built for the #2ACL to resolve the problem of dependence of parameter settings. The procedure of research is described as follows:

(1) Developing the strip temperature model for the heating and cooling processes.
(2) Developing the furnace temperature model and the gas pressure model.
(3) Developing the calculation model to modify heat

transfer coefficient and the thermal emissivity.

(4) Programming the set-point calculation model and designing the human-machine interface.

2. RESEARCH METHOD

2.1 The calculation model for strip temperature

The strip temperature during the heating and cooling processes in the furnace could be attributed to the energy change in the strip. The modes of heat transfer on the strip surface were shown in Fig.1. Where HS is the Heating Section; SS is the Soaking Section; CTZ is the Cooling Tube Zone; SJC is the Slow Jet Cooling Zone; FJC is the Fast Jet Cooling Zone; W_r, W_c and W_j denote the heating power or cooling power of the strip by the radiation of the furnace atmosphere, the convection of the furnace atmosphere and the convection of the impingement flow, respectively. The energy of the strip can be converted to the strip temperature using the enthalpy table that depends on the steel grade. The length of the sub-zone was divided into N segments, and the energy difference of the strip in the k th segments of the sub-zone was:

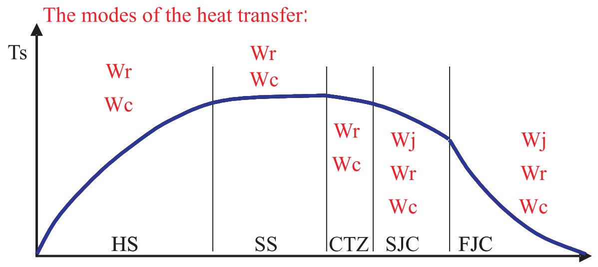


Fig.1. The heat transfer of the heating and cooling process in the different sections of the furnace.

Where, $h_{in,k}$ and $h_{out,k}$ are the strip enthalpy values (kCal/kg) at the entrance and the exit of the k th segments of the sub-zone, respectively; ρ, W, V, δ and dt denote density (kg/m^3), width (m), line speed (m/s), thickness (m) and residence time (s) of strip, respectively. While the strip temperature is known, the enthalpy value ($h_{in,k}$) of the strip can be determined by looking it up in the enthalpy table. Therefore, the enthalpy values ($h_{out,k}$) of the strip at the exit can be calculated when the $Q_{m,k}$ is known, then the strip temperature can also be determined by looking it up in the enthalpy table.

2.1.1 The heating and cooling processes based on radiation heat transfer (HS, SS and CTZ)

The strip is heated or cooled mainly by the radiation heat transfer in the furnace. The heating power $Q_{f,k}$ in the k th segment of the sub-zone makes a change in the enthalpy of the strip. That means the heating power $Q_{f,k}$ is equal to the energy difference $Q_{m,k}$ (Eq.1) of the strip in the k th segment of the sub-zone. The $Q_{f,k}$ can be obtained by solving the radiation and convection heat transfer equation given by:

$$Q_{m,k} = (h_{out,k} - h_{in,k}) \times \rho \times W \times V \times \delta \times dt \cdots\cdots (1)$$

$$Q_{f,k} = (W_{r,k} + W_{c,k}) \times dt \cdots\cdots (2)$$

Where, $W_{r,k}$ and $W_{c,k}$ are the input power by the radiation and convection heat transfer (kCal/s), respectively. The equations can be written as:

$$W_{r,k} = 4.88 \times 10^{-8} \times \left[\, T_{f,k} + 273)^4 - (T_{s,k} + 273)^4 \,\right] \times \varepsilon \times 2 \times (W \cdot L)$$

$$W_{c,k} = HC \times (T_{f,k} - T_{s,k}) \times 2 \times (W \cdot L)$$

$$\varepsilon = 1 / (1/\varepsilon_m + 1/\varepsilon_f - 1)$$

Where, $T_{f,k}$ is the furnace temperature (℃) in the k th segment of the sub-zone; $T_{s,k}$ is the average strip temperature (℃) in the k th segment of the sub-zone; L is the length (m) of the k th segment of the sub-zone; ε_f, ε_m denote the emissivity of the furnace and the strip, respectively; HC is the heat transfer coefficient (W/m^2 ℃) between the furnace atmosphere and the strip.

2.1.2 The heating and cooling processes based on convection heat transfer of the impingement flow (SCS, FCS)

The strip is heated or cooled mainly by the convection heat transfer from the impingement flow. The power $Q_{g,k}$ is equal to the energy difference $Q_{m,k}$ (Eq.1) of the strip in the k th segment of the sub-zone. The $Q_{g,k}$ is obtained by solving the radiation and convection heat transfer equation given by:

$$Q_{g,k} = (W_{j,k} + W_{r,k} + W_{c,k}) \times dt$$

$$W_{j,k} = HC \times LMT \times 2 \times (W \cdot L) \cdots\cdots (3)$$

Where, HC is the heat transfer coefficient (W/m^2 ℃) between the furnace atmosphere and the strip; LMT

is the log mean temperature difference (℃). The equations can be written as:

$$HC = HcInc \times CHC \times 2 \times (W_F \cdot L_F) \times 0.01 \times V_g^{\alpha} \times \left(\frac{15+273}{T_g+273}\right)^{\beta}$$

$$LMT = \frac{T_{sout,k} - T_{sin,k}}{ln\left(\frac{T_g - T_{sin,k}}{T_g - T_{sout,,k}}\right)}$$

Where, W_F and L_F are the width and length of the sub-zone (m), respectively; $T_{sin,k}$ and $T_{sout,k}$ are the strip temperatures (℃) at the entrance and the exit of the k th segment of the sub-zone, respectively; *HcInc* is the coefficient of the H_2; *CHC*, V_g and T_g are the specific shape factor, gas velocity (m/s) and the gas temperature (℃), respectively; α and β are the constant coefficients.

While the furnace temperature, gas temperature and the gas pressure are known, the power ($Q_{f,k}$, $Q_{g,k}$) depends on what the main heat transfer is on the strip and is equal to the energy difference $Q_{m,k}$ (Eq.1) of the strip in the k th segment of the sub-zone. Therefore, the difference of the enthalpy $(h_{out,k} - h_{in,k})$ can be determined, and then $dT_{s,k}$ would also be obtained by looking it up in the enthalpy tables. The strip temperature at the exit of the k th segment of the sub-zone can be obtained by solving the equation: $T_{sout,k} = T_{sout,k-1} + dT_{s,k}$. This is because the calculations of the $Q_{f,k}$ (Eq.2) and $Q_{g,k}$ (Eq.3) require the strip temperature ($T_{sout,k}$), the $Q_{f,k}$ and $Q_{g,k}$ should be recalculated after the strip temperature is obtained. Then the strip temperature is recalculated again. The iterative procedure is repeated until convergence (by comparing results of 2 consecutive iterations). The strip temperature in the $k+1$ th segment of the sub-zone is also calculated in the same way until the calculation of the strip temperature history in the sub-zone is finished ($k = N$). The strip temperatures in all sub-zones (1 to Z) of the furnace are calculated sequentially in the same way. That is the strip temperature history in the heating and cooling processes.

2.2 The calculation model for furnace temperature and gas pressure

2.2.1 Furnace temperature

There is an infinite number of furnace temperature patterns (heating curves) that could achieve the same annealing temperature for the strip. Therefore, constraints on the conditions are required to attain a single solution. In other words, there is one furnace temperature pattern for the annealing temperature. It is a prerequisite for control stability. The constraining conditions could fall into two categories:

(1) Restriction of the furnace temperature pattern: the differences in furnace temperatures between two adjacent sub-zones are the constant value (Fig.2). Due to the differences in all adjacent sub-zones being known, there is only one unknown variable (the furnace temperature of #1 zone) for the annealing temperature. The other furnace temperatures are the result of the #1 zone furnace temperature. Therefore, the furnace temperature pattern can be calculated easily by the iterative method. The furnace temperature patterns by this method with less computation time are compatible with the current pattern on the production line.

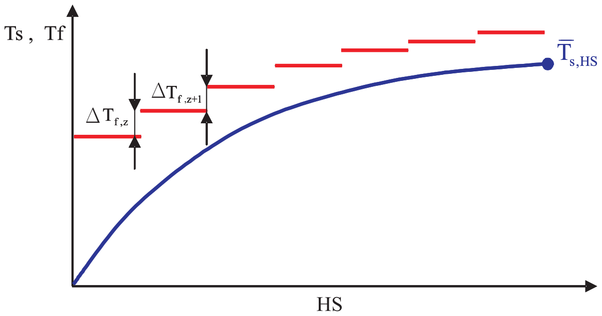


Fig.2. The temperature difference of the sub-zones in the heating section.

(2) Restriction of the heating curve of the strip:

a. The heating curve is expressed as a polynomial equation. The aim is to calculate the strip temperature at the exit of the sub-zones. Thus the furnace temperatures can be determined sequentially, as shown in Fig.3. The method would take more computation time for the iterative processes in all sub-zones. The polynomial equations of the heating curves are difficult to decide due to the actual heating powers in the sub-zones may not meet its needs.

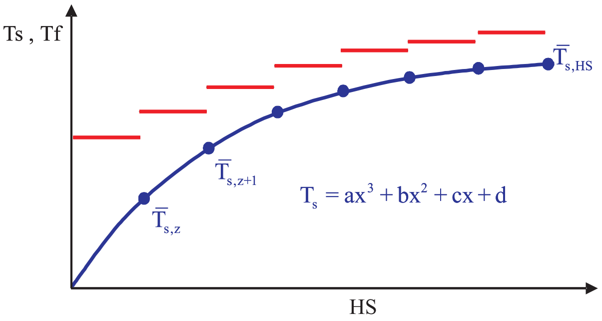


Fig.3. The target temperature of each of the sub-zones.

b. The area under the heating curve is minimized, as shown in Fig.4. If the area is smaller, the energy consumption will be less. Therefore, the heating curve of the slab in many studies for reheating furnaces(1,2) are determined using this method. In practice, the furnace temperatures between two adjacent sub-zones could not have too large a difference. But the heating curve that is determined by this method might require a large difference in furnace temperature between two adjacent sub-zones. Thus, the furnace temperature limits in all sub-zones should be specified to avoid furnace temperatures being determined by the set-points on the production line.

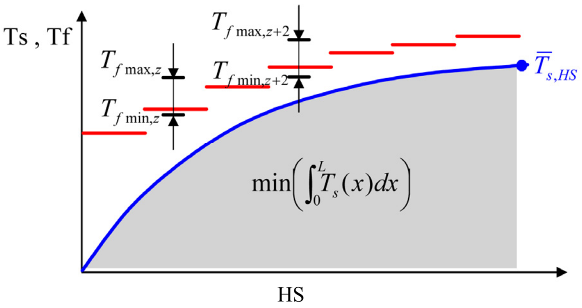


Fig.4. The minimum area under the heating curve in the heating section.

In this study, the advantages mentioned above are included into the objective function J (Eq.4)

$$J = min[\frac{1}{2}\cdot w_1 \cdot (T_{s,HZ} - T_{s,hz})^2 + \frac{1}{2}\cdot w_2 \cdot \sum_{z=1}^{Z-1}(T_{f,z+1} - T_{f,z} - \Delta T_{f,z+1})^2 + w_3 \cdot \int_0^L T_s(x)dx] \quad \cdots\cdots (4)$$

The objective function J (Eq.4) includes the difference between the target strip temperature and the strip temperature at the exit of the heating or soaking section, the difference between two adjacent sub-zones and the area under the heating curve. The weighting factors (w_1, w_2, w_3) are adjusted for the actual demands. In order to minimize the objective function *J*, the Hooke and Jeeves pattern search method(3-5) which is a simple and fast local minimization algorithm was used in the model. Among the search methods in non-linear numerical optimization, Hooke and Jeeves pattern search method stands out to be a simple yet very effective optimization technique. This technique consists of two major routines: the exploratory searches routine and the pattern move routine. The exploratory routine search the local proximity in the directions parallel to the coordinate axes for an improved objective function value, and the pattern routine accelerate the search by moving to a new improved position in the direction of the previous optimal point obtained by the exploratory routine. Optimal furnace temperatures in each sub-zone ($T_{f,1}$, $T_{f,2}$, …) are searched to minimize the objective function *J*.

2.2.2 Gas pressure

The cooling parameters of the strip in the cooling process include gas temperatures, gas pressures and furnace temperatures. The main factors are the gas temperatures and gas pressures. There are an infinite number of gas temperatures and gas pressure patterns that could achieve the same exit temperature for the strip. Therefore, constraints on the conditions are required to attain a single solution. If the relevant parameters (dimensions, properties and annealing temperatures) of the strip are the same, the calculated gas pressure or gas temperature should have remained static.

Because the strip cooling rates in the sub-zones of the slow jet cooling section are previously known and defined, the target temperature of the strip in all sub-zones can be determined directly. Using the cooling rates of the strip for the calculation of the cooling parameters, the cooling patterns of the strip would be more flexible and controllable. The gas pressures in all sub-zones can be calculated more quickly, as shown in Fig.5.

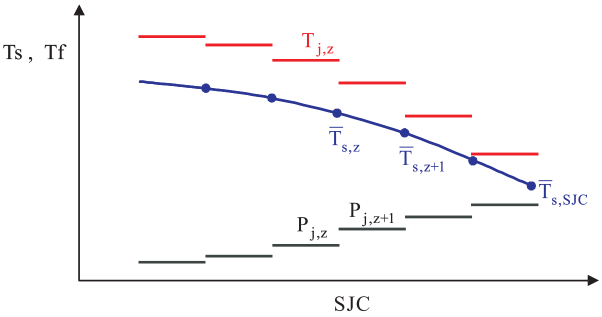


Fig.5. The calculation of the gas pressure based on the known gas temperature and strip cooling rate in the slow jet cooling section.

If the cooling rates of the strip at the entrance and the exit of the fast jet cooling section are known, the target temperature $\overline{T}_{s,z}$ of the strip in all sub-zones can also be determined by using a polynomial equation, as shown in Fig.6. After the gas temperatures are measured, the gas pressures in all sub-zones can be calculated quickly.

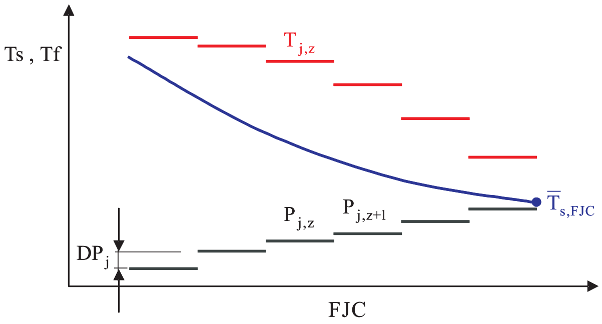


Fig.6. The calculation of gas pressure based on known polynomial equations in the fast jet cooling section.

3. RESULTS AND DISCUSSION

3.1 The developed on-line control system

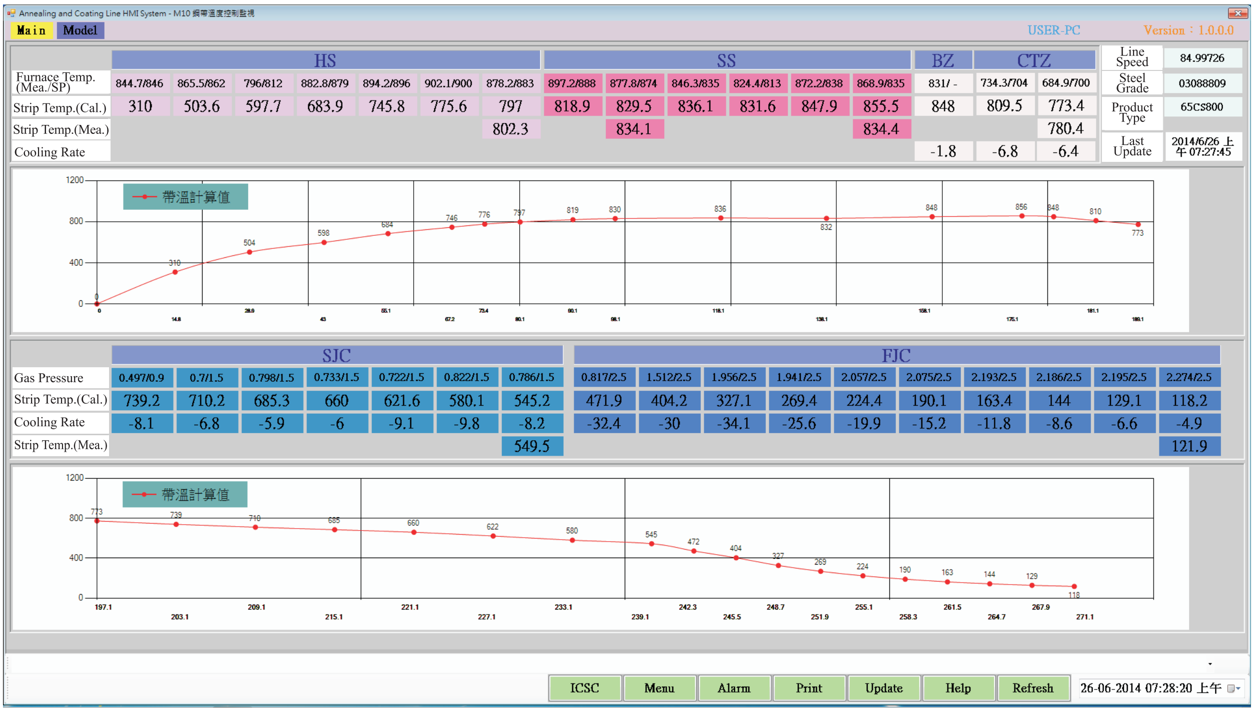
In the above models, a monitor for the on-line strip temperature has been developed, as shown in Fig.7. The actual furnace temperatures, gas pressures and the set-points for the furnace temperatures and the gas pressures are also displayed on the monitor. Thus, the gradual transformation between the set-points and the actual values can be observed to ensure stable control. Furthermore, due to the measurements of the strip temperature only at the exit of the each section, the strip cooling rate in all sub-zones of cooling sections are calculated and shown on the screen to help the temperature regulation.

Figure 8 Illustrates the pilot calculation model for the strip temperature, furnace temperature, gas pressures and emissivity. The strip temperature history can be calculated by furnace temperature and gas pressure measured values from Level 1 automatically or manually. While the cooling rates are inputted, the strip temperature and gas pressures can also be calculated. Therefore, the heating curve and cooling curve of the new grade of steel can be determined by the model. To improve the control performance, the heating and cooling patterns that induce good calculated set-points must be tried and defined ahead with prudence using this model.

3.2 The determination of heat transfer coefficient and emissivity

The heating and cooling efficiencies of the strip by the radiation heat are strongly affected by the furnace emissivity and strip emissivity. The furnace emissivity is related to the dimensions and the material of the furnace. Therefore, the emissivity is difficult to be determined in advance. The strip cooling efficiency in the slow and fast jet cooling sections is related with the heat transfer coefficient between the impingement flow and the strip.

The above model could compute the emissivity and the heat transfer coefficient reversely by the strip measured temperature. As shown in Fig.9, where the



	HS							SS						BZ	CTZ	
Furnace Temp. (Mea./SP)	844.7/846	865.5/862	796/812	882.8/879	894.2/896	902.1/900	878.2/883	897.2/888	877.8/874	846.3/835	824.4/813	872.2/838	868.9/835	831/ -	734.3/704	684.9/700
Strip Temp.(Cal.)	310	503.6	597.7	683.9	745.8	775.6	797	818.9	829.5	836.1	831.6	847.9	855.5	848	809.5	773.4
Strip Temp.(Mea.)							802.3		834.1				834.4			780.4
Cooling Rate														-1.8	-6.8	-6.4

Line Speed	84.99726
Steel Grade	03088809
Product Type	65CS800
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	SJC							FJC									
Gas Pressure	0.497/0.9	0.7/1.5	0.798/1.5	0.733/1.5	0.722/1.5	0.822/1.5	0.786/1.5	0.817/2.5	1.512/2.5	1.956/2.5	1.941/2.5	2.057/2.5	2.075/2.5	2.193/2.5	2.186/2.5	2.195/2.5	2.274/2.5
Strip Temp.(Cal.)	739.2	710.2	685.3	660	621.6	580.1	545.2	471.9	404.2	327.1	269.4	224.4	190.1	163.4	144	129.1	118.2
Cooling Rate	-8.1	-6.8	-5.9	-6	-9.1	-9.8	-8.2	-32.4	-30	-34.1	-25.6	-19.9	-15.2	-11.8	-8.6	-6.6	-4.9
Strip Temp.(Mea.)							549.5										121.9

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Fig.7. The monitor display of the strip temperatures, furnace temperatures and gas pressures.

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厚度 0.5

	HS						
Furnace Temp.	842.3	900.6	788.6	940.3	939.4	949.7	948.8
Strip Temp.	315.0	530.9	613.6	718.1	795.7	832.3	863.8
Strip Target Temp.							890
Emissivity							0.7
Strip Temp.(Mea.)							863.0
Cooling Rate							

	SS					
Furnace Temp.	948.8	939.75	935.7	931	926.05	921.4
Strip Temp.	888.76	901.24	919.33	925.49	925.78	923.73
Strip Target Temp.						920
Emissivity						0.3
Strip Temp.(Mea.)		906.70				885.00
Cooling Rate						

	BZ	CTZ	
Furnace Temp.	889.3	791.9	774.0
Strip Temp.	914.4	877.5	848.2
Strip Target Temp.			
Emissivity			0.8
Strip Temp.(Mea.)			831.9
Cooling Rate	-2.9	-5.8	-5.8

	SJC						
Furnace Temp.	717.7	682.7	655.3	612.3	559.5	532.2	498.6
Gas Pressure	0.299	0.498	0.6	0.598	0.694	0.774	0.749
Gas Temp.	581.3	581.3	584	551.8	471.8	448.9	439.6
Strip Temp.	785.9	743.5	712.2	679.2	631.5	584.6	545.6
Cooling Rate	-16.6	-11.3	-8.4	-8.8	-12.7	-12.5	-10.4
Heat transfer coef.							0.654
Strip Temp.(Mea.)							546.3

	FJC									
Furnace Temp.	261.7	252.1	186.4	165.1	147.8	115.4	119.3	101.9	97.4	92.9
Gas Pressure	0.817	1.503	1.976	1.973	2.092	2.105	2.231	2.244	2.245	2.315
Gas Temp.	196.2	216.3	158.7	147.8	133.9	121.5	110.3	103	95.7	90.6
Strip Temp.	419.5	324.8	234.4	185.4	155.2	134.9	119.7	109.3	100.9	94.55
Cooling Rate	-86.55									-4.808
Heat transfer coef.										2.922
Strip Temp.(Mea.)										93.92

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Fig.8. The pilot calculation for strip temperatures, furnace temperatures, gas pressures and emissivity.

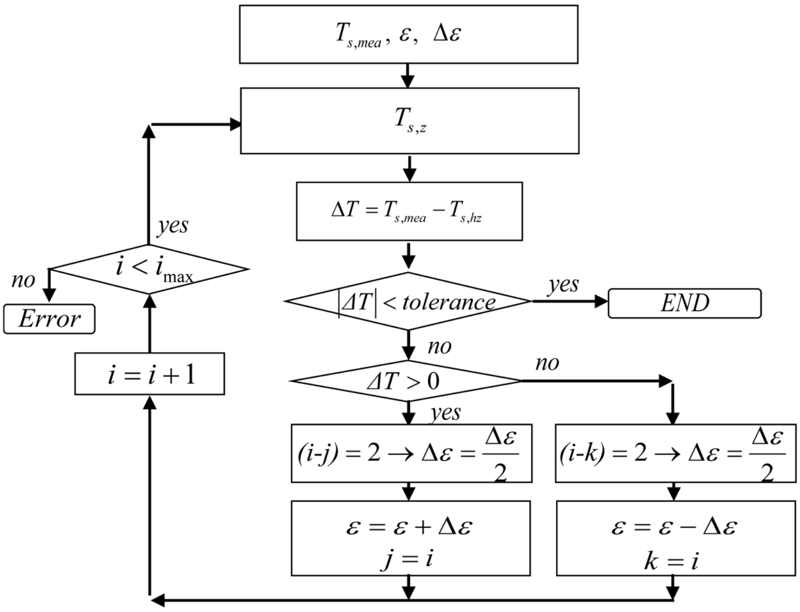
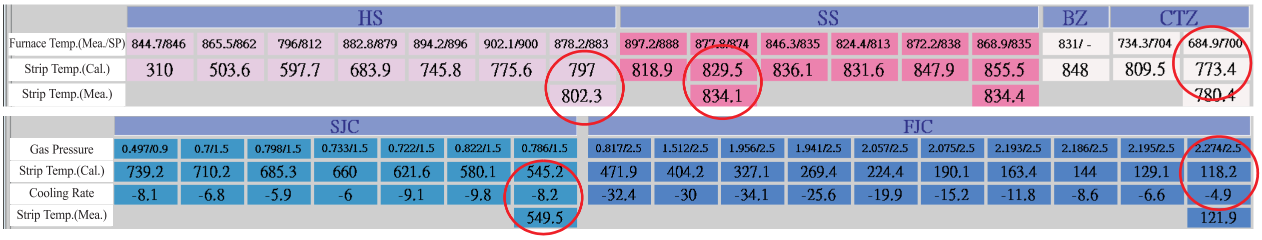


Fig.9. The calculation flow chart of strip emissivity and heat transfer coefficient in different sections.

ε denotes the emissivity or heat transfer coefficient. The iterative method is used to compute the emissivity and heat transfer coefficient. As shown in Fig.10, the errors between the calculated strip temperatures and the measured strip temperatures are less than ±10℃.

3.3 Limitation of heating power

In this study, a fact that some sub-zones might not have enough heating power have been found. It might lead to the phenomenon that the actual furnace temperature in some sub-zones could not rise to the set-points but the furnace temperature of the other sub-zones fall to the set-points, as shown in Fig.11. In other words, the furnace temperatures are calculated independently according to the design heating pattern, there might be a significant difference between the



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	SJC							FJC									
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Cooling Rate	-8.1	-6.8	-5.9	-6	-9.1	-9.8	-8.2	-32.4	-30	-34.1	-25.6	-19.9	-15.2	-11.8	-8.6	-6.6	-4.9
Strip Temp.(Mea.)							549.5										121.9

Fig.10. The measured strip temperature and calculated strip temperature in each section.

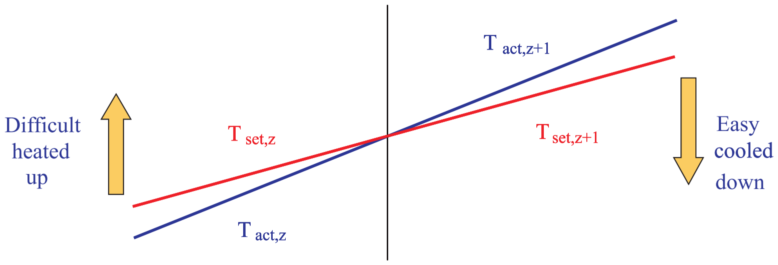


Fig.11. The different pattern of the furnace temperature for the same strip target temperature.

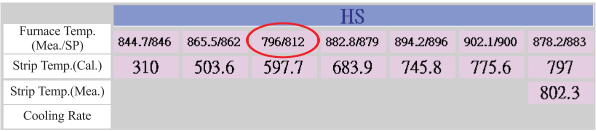
calculated furnace temperatures and the current furnace temperatures due to the limited heat power. The strip temperature would not reach a target temperature (annealing temperature). Therefore, besides the preceding methods that have the advantages for stable set-points, the differences between the set-points and the current furnace temperatures have been incorporated in the new objective function (*J*). According to the current furnace temperatures, the temperature-risings would be minimized to satisfy the annealing temperature:

$$J=\min\left\{\frac{1}{2}\cdot w_4\cdot\sum_{z=1}^{Z}[\max(T_{f,z}-T_{mea,z},0)]^2\right\}$$

Where, $T_{mea,z}$ is the current furnace temperatures in the sub-zones (z). The method with the minimum of temperature-increments could ensure that the deviation between the calculated furnace temperatures (set-points) and the current furnace temperatures are not too large. Considering the limitation of furnace heating power, the objective function (*J*) can be rewritten as:

$$\begin{aligned}J=\min[&\frac{1}{2}\cdot w_1\cdot(T_{s,HZ}-T_{s,hz})^2+\frac{1}{2}\cdot w_2\cdot\\&\sum_{z=1}^{Z-1}(T_{f,z+1}-T_{f,z}-\Delta T_{f,z+1})^2\\&+w_3\cdot\int_0^L T_s(x)dx]+\frac{1}{2}\cdot w_4\cdot\\&\sum_{z=1}^{Z}[\max(T_{f,z}-T_{mea,z},0)]^2\end{aligned}$$

As shown in Fig.12, the actual furnace temperature in zone #3 of HS is 796℃, but the manual input value was 880℃. Obviously, the heating power in this zone is not enough. If the calculated furnace temperature by the old objective function (870℃) is used as the set-point, the calculated furnace temperatures in other zones would be lower and the strip temperature at the exit of HS could not reach the target temperature. In the study, the new objective function is applied to avoid this phenomenon, and the new calculated furnace temperature in zone #3 of HS is 812℃. Besides solving the problem of the limited heating powers in some sub-zones, the switching time of the different annealing temperature depending on the steel grade could be reduced. The defective rate of products and the waste capacity for dummy coils during the transition period would be decreased.



	HS						
Furnace Temp. (Mea./SP)	844.7/846	865.5/862	796/812	882.8/879	894.2/896	902.1/900	878.2/883
Strip Temp.(Cal.)	310	503.6	597.7	683.9	745.8	775.6	797
Strip Temp.(Mea.)							802.3
Cooling Rate							

Fig.12. The actual furnace temperature and the calculated furnace temperature in the heating section.

3.4 Limitation of cooling power

Due to the limited cooling power of the fast jet cooling section, the cooling rates of the strip could not be highly varied. Therefore, the cooling rates of the different steel grades could only just be determined. While the strip temperature at the entrance or the exit of the section would have changed, the cooling rates should be modified again. Furthermore, the cooling power often cannot fulfill the requirements of the defined cooling rates. It is obvious that cooling rates that were defined in advance are not a good control strategy in this section. Therefore, the cooling rates are supplanted by the gas pressure differences between the adjacent sub-zones (ΔP_j) as the constraint conditions in the study, as shown in Fig.13. Due to the differences of all adjacent sub-zones being known, there is only one unknown variable (the gas pressure of zone #1) for the exit strip temperature. The gas pressure pattern can be calculated easily by the iterative method. Besides fully utilizing the cooling capacity of the equipment, the calculated gas pressures would be more stable.

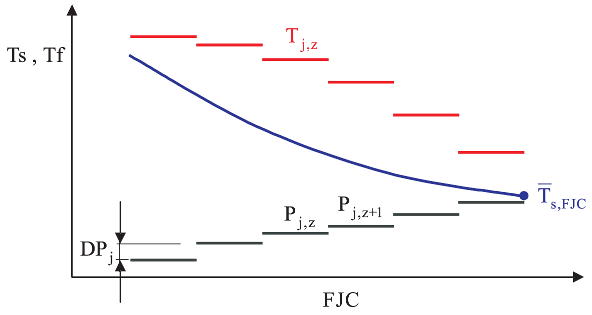


Fig.13. The calculation of gas pressure based on the defined differences between two adjacent sub-zones in the fast jet cooling section.

4. CONCLUSION

An on-line control model for a continuous annealing line was developed in this study including strip temperature, furnace temperature, gas pressure calculations and HMI. Input data include annealing temperatures, heating and cooling patterns for all steel grades. This on-line model has three outstanding functions: 1. The different sections of the furnace have different furnace emissivity. Also different steel grades have different strip emissivity in different sections. Therefore, This model can calculate the emissivity in each section. 2. Limitation of furnace heating power is considered in this model to solve the furnace temperatures. 3. The cooling rates are calculated in real-time in this model for the observation of the control status.

In conclusion, the set-point calculation model for the ACL was developed. To adapt to other continuous annealing lines, the model is very flexible. Besides the control of the heating and cooling patterns for different grades of steel, the cooling rate of the strip would change with different line speeds and the computing intervals could be adapted to the requirements of the production line. Because the emissivity and heat transfer coefficient are difficult to determine before, the automatic calculation function was developed to decrease the difficulty for the maintenance of the model.

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