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Hot Charge of Continuously Cast Slabs in Reheating Furnaces

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Abstract

The hot charging of continuously cast slabs steel is usually considered an effective method to reduce the energy consumption in the hot rolling mills. In this work the application and optimizing of hot charging of continuously cast slab in Mobareke Steel Company has been investigated. Mathematical relationship between the cooling time of the stack of slabs and its mass average temperature is described. The results show that the application of the hot charging of slabs could reduce the energy consumption by 40%.

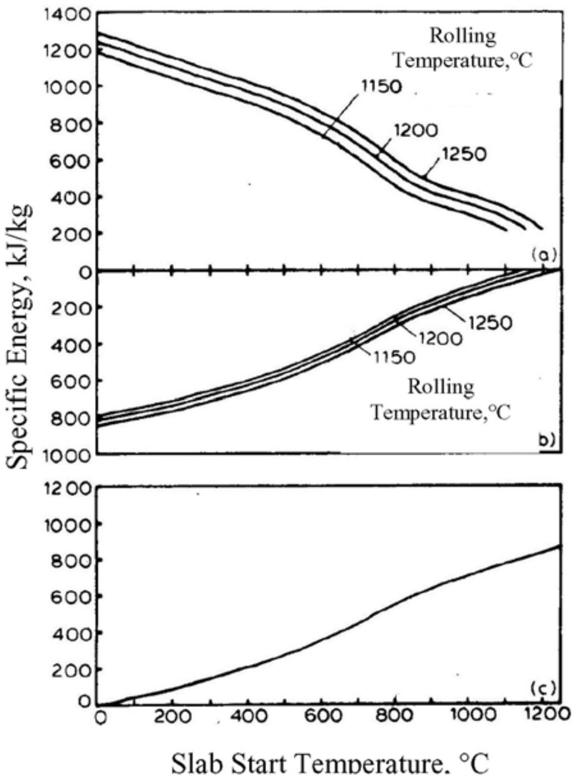
Keyword: Hot charging, Slab, Continnous casting, Mathematical relationship

Introduction

Today, a whole range of technological operations can be applied to steel processing which are individually beneficial but in combination have an increased significance in facilitating the connection between continuous casting and hot rolling. The primary aim of this connection is reduction in energy costs, which are major engineering and processing priorities [1]. The continuously cast slabs can take different process routes depending on condition and temperature. The most economic route is hot direct rolling (HDR) where, minimum extra heat is applied to the slab before rolling. For cooler slabs, a cold charge route (CCR), or warm charge route (WCR), or hot charge route (HCR) may be required [1-3].

In order to hot charge slabs into reheating furnaces, without any conditioning processes, it is necessary to decrease surface defect such as entrapped scum, pinholes, transverse crack and longitudinal cracks as well as internal defect. Among them, longitudinal cracks are the worst defects for hot charging. So, it is necessary for hot charge system to establish the quality guarantee system in addition to the high standard of operation, namely, the quality of slabs should be checked and only those which meet the standard requirement should be hot charged into the reheating furnace. For this purpose, optical inspection system for hot slabs, which mainly detects longitudinal cracks defects, has been used in the line [1,4-5].

Direct rolling and hot charging methods promote the production of continuously cast slabs with high internal and surface quality, with a maximum possible heat content, which closely corresponds to the entry temperature into the rolling mills. The amount of heat required in typical strip mill feedstock before rolling is shown in Figure 1.



a) Energy consumption for heating , b)Heat to be added to slab, c) Heat content in slab

Fig. 1. Added heat energy for rolling versus slab start temperature [1].

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Efficient hot charging requires interrelated planning and control of operations, beginning with steel making and ending with rolling, to ensure a high quality of the cast metal, which eliminates the need for surface conditioning in the cold state[6]. The benefit of increasing the temperature of the cast feedstock can be seen in Figure 1[1].

The relationship between the cooling time of the stack of slabs and its average temperature was studied by F.E. Beiglzimer and et al. [4].

The aim of this work is to present an equation modified for mathematical relationship between the cooling time of the stack of slabs and its average temperature.

Experimental Procedure

In the Mobareke Steel Company, the slabs leave the continuous casting plant at an approximate temperature of 900 °C and are stored in the open area of the rolling plant. The variations of surface temperature during cooling of one slab and a stack of 8 slabs were measured by pyrometer of FMPI series with temperature range 300-2000 °C. All slabs have a dimension of 20*135*1000 cm.

The chemical composition of slabs is presented in Table 1. The hot slabs with a mean temperature of 660°C were charged in one of the reheating furnaces and cold slabs with an ambient temperature were charged in to another one for comparison of energy consumption.

*Table 1. **C**hemical composition (wt.%) of the slabs used in this work.*

C	Si	Mn	P	S
0.12 - 0.15	0.1 – 0.3	0.4 – 0.5	<0.02	<0.014

Results and Discussion

The slabs leave the steel plant casting at an approximate temperature of 900°C and are then transported to the rolling plant and stored in the open area. The variation of surface temperature during cooling of one slab and a stack of 8 slabs is measured and presented in Figure 2.

As can be seen in this figure, after one hour the temperature of 1 slab decreased about 180 °C, where as, a stack of 8 slabs in this period of time had only a reduction of temperature of about 60 °C.

The relationship between the cooling time of the stack of slabs and its average temperature was obtained by F.E. Beiglzimer and et al.[4] as a result of approximation of calculated data in the following form during cooling in the open area of store:

$$T = (T_o - T_{os})\exp[-0.0642(\frac{1}{B} + \frac{1}{nH})\tau^{0.785}] + T_{os} \quad (1)$$

Where:

T_o: and T are the initial and final values of the mass average temperature of the slab stack, °C

T_{os} : the temperature of the ambient atmosphere in the shop, (°C)

τ : the cooling time of the stack, (h)

H and B the thickness and width of the slab, (m)

n : the number of slabs in the stack.

For example, during cooling of one slab and a stack of 8 slabs with an initial temperature of 680 °C in open air (T_{os} = 30 °C) variation of surface temperature for experimental and theoretical (Equation 1) data was shown in Figure 2. As can be seen in this figure the average temperature of slabs in the store before hot charging into the reheating furnace is influenced by the average number of slabs in the store.

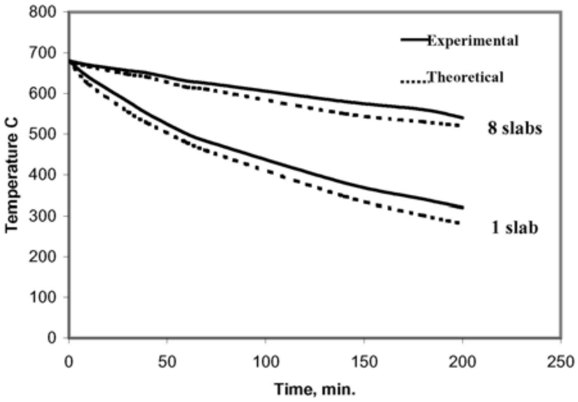

Fig. 2. The Variation of Temperature during cooling of slabs.
(Experimental data and theoretical data from equation 1)

This figure also shows, the theoretical data from equation 1 isn't consistent with experimental data. Thus, this equation with these constants could not be used to predicate the slabs average temperature during cooling time. To calculate the value of constants of equation 1 the following method was used.

Equation 1 could be written in the following form:

$$(T - T_{os}) = (T_o - T_{os})\exp[-\alpha(\frac{1}{B} + \frac{1}{nH})\tau^{\beta}] \quad (2)$$

and hence

$$\frac{T - T_{os}}{T_0 - T_{os}} = \exp[-\alpha(\frac{1}{B} + \frac{1}{nH})\tau^{\beta}] \quad (3)$$

$$\ln\frac{T - T_{os}}{T_0 - T_{os}} = -\alpha(\frac{1}{B} + \frac{1}{nH})\tau^{\beta} \quad (4)$$

$$\ln(-\ln\frac{T - T_{os}}{T_0 - T_{os}}) = \ln\alpha + \ln(\frac{1}{B} + \frac{1}{nH}) + \beta\ln\tau \quad (5)$$

The value of α and β is estimated from a plot of $[\ln(-\ln\frac{T - T_{os}}{T_0 - T_{os}}) - \ln(\frac{1}{B} + \frac{1}{nH})]$ against ($\ln\alpha + \beta\ln\tau$) using the experimental data. The results show that, these constant values are α=0.0530 and β =0.848. Thus, the Beiglzimer equation (Equation 1) changed to the following form:

$$T = (T_o - T_{os})\exp[-0.0530(\frac{1}{B} + \frac{1}{nH})\tau^{0.848}] + T_{os} \qquad (6)$$

Figure 3 shows the variation of temperature during cooling of one slab and 8 slabs with an initial temperature of 680 °C in the open air (T_{os} = 30 °C) for experimental and theoretical (Equation 6) data. This figure shows that, the theoretical data from equation 6 is consistent with all experimental data obtained in this research.

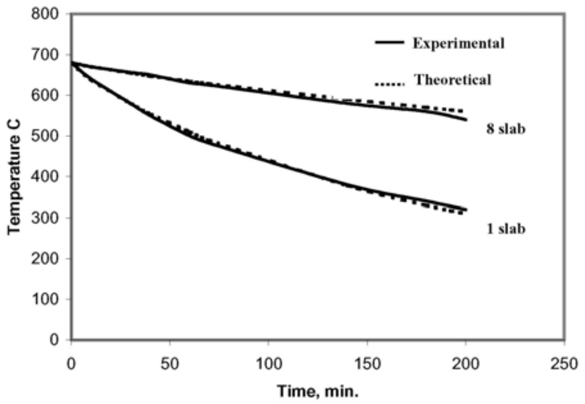

Fig. 3. The Variation of slab temperature during cooling of slabs.
(Solid line presents the experimental data and dashed line showed the theoretical calculation (equation 6))

When slabs transfer from caster to rolling mill, some temperature adjustment is required before hot rolling [7]. This may be in the form of a reheating furnace for hot charge or a specific edge heating arrangement for temperature equalization for direct rolling [1]. The efficiency of reheat furnace in the case of hot charging, increased as the charge temperature raises and this is reflected in the energy consumption for heating to rolling temperature in Figure 1.

The amount of energy consumed for heating to slab rolling temperature (1150 °C) before rolling for the present slabs in the shop was determined and the result is shown in Figure 4.

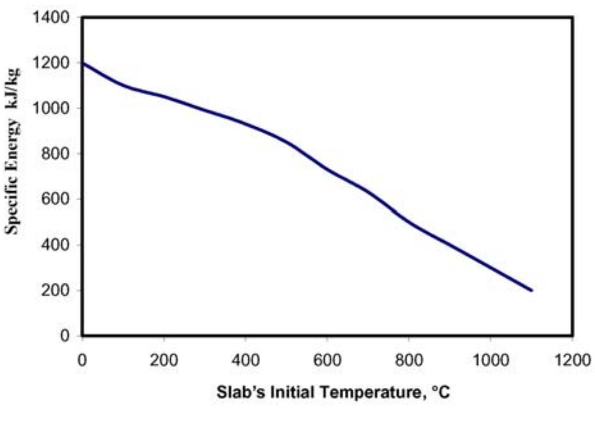

Fig. 4. The energy consumption versus slab's initial temperature.

This figure indicates that the specific energy required when charging at ambient temperature was 1170 kJ/kg, whereas only 680 kJ/kg energy used when, hot charged slabs with a temperature of 660°C, i.e. about 40% reduction of energy consumption. The calculation showed that each 100 °K increase in the slab temperature charged into the furnaces, resulted is a reduction of the energy consumption by ~ 90 kJ/kg, i.e. about 7.5% reduction of energy consumption.

Conclusion

1- Hot charging of continuously cast slabs is an effective method in energy saving, every 100° K increase in the slab temperature charged into furnaces resulted is a reduction of the energy consumption by ~ 80-120 kJ/kg.

2- The formula used in this work could clarify the relationship between the cooling time and its average temperature in the case of 1 slab or stack of slabs.

3- The constant values of Beiglzimer equation depends on the various parameters which means that, in each case these values should be obtained before using this equation. In this research after obtaining these constant values, the theoretical curve was very close to the experimental data.

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