Study of Slab Quality and Tonnage Determination for Overlapping Heats in a Continuous Casting Tundish

Ayşe Oran¹,², Müberra Gürel³, Bora Derin¹
¹Istanbul Technical University, ²Çolakoğlu Metalurji A.Ş., ³Safir Company - Türkiye

Abstract

There is a common implementation called “Overlapping Heat Application” for many iron and steel making plants that uses “continues casting” in the world. In this application, different quality slab heats are planned and produced in the same tundish in case of the tonnage, quality, dimension (slab width) unsuitableness to optimize the steel plant’s production conditions. At the end of present application, two different qualities are mixed, overlapped in the same tundish and the borders of this overlapped slab mixing becomes unknown. Since there is a requirement to know the borders and the new chemical composition of mixing steel, a study on slab quality and tonnage determination for overlapping heats in a continuous casting tundish study was done. Accordingly, mass balance was taken as a base of this modelling programme. Also, Microsoft excel formulas were used in any step of the study. Furthermore, this study permits to decide the cast id name (quality name) according to Çolakoğlu Metalurji A.Ş. quality and chemical compositions standards and slab lengths according to Çolakoğlu Metalurji A.Ş. slab dimension standards. In practical case, people in Çolakoğlu Metalurji A.Ş. separate overlapped slabs from original heats with their experience without any measurement, calculation and chemical tests. In order to control the chemical results of present modelling study, some experimental studies were applied to the real overlapped slabs. The results were compared with each other in tables, graphs. Eventually, results of modelling study that was already compared with experimental results are found quite successful except negligible deviations.

1. Introduction

Steel is an alloy of iron and carbon that is widely used in construction and other applications because of its high tensile strength and low cost. In the present day, two common ways are followed to produce and refine the steel as mentioned “Blast furnace-converter method” and “Electric arc furnace method”.

After the electric arc furnace process, secondary metallurgy processes begin (ladle furnace, vacuum degasser etc.) for molten steel. The molten steel that was processed in secondary metallurgy is casted through the tundish to the molds with considering sales order requirements for shape, dimension and weight. In a process of continues casting, tundish is the last metallurgical channel to cover and accommodate the melted steel before pouring to the molds and permitting to begin the solidification. Hot metal level in tundish is set to the same level during casting in order to provide regular casting to the molds. Because, if tundish level fluctuations occurs and hot metal pouring becomes irregular, micro inclusion problems may be observed on the surface or inside of the slabs [1]. Çolakoğlu Metalurji owns a slab casting facility with two strands and tundish mechanism [2,3].

As a common application for many companies in the world and Çolakoğlu Metalurji A.Ş., slab or billet heats which has different quality names so different chemical compositions are produced in the same tundish during continues casting process in case of the tonnage, quality, dimensions (slab width) unsuitableness to optimize the steel plant’s production conditions. At the end of relevant application, two different qualities are mixed in the same tundish and the borders of this overlapped slab mixing are unknown. There is a requirement to know the borders and the new chemical composition of mixed steel. "Study of slab quality and tonnage determination for overlapping heats in a continuous casting tundish" work was done in this study. The main purpose of this study is to clarify the quality borders of overlapped slabs so that to calculate the overlapped slab’s tonnage and most suitable slab lengths according to the tonnage though. In addition, the study helps to name the overlapped slab quality.
2. Overlapping Heat Application in a Continuous Casting Tundish

As it shown in Figure 1, while X quality hot metal is pouring to the molds from tundish, another Y quality hot metal starts to pour into the tundish from ladle because of some mandatory reasons. As a result of this overlapping heat application, a mixed quality (X+Y) hot metal generates in the tundish. Mixed quality hot metal that was gained in tundish continues to be poured into the molds following to pure X quality hot metals. After mixed quality hot metal ends (the borders are unknown) pure Y quality hot metal starts to pour into the molds as well.

3. A Modelling Program for Overlapped Heats

Quality name and number of slab pieces decision for overlapped slabs is based on forecast and experiments in Çolakoğlu Metalurji A.Ş. Because start, finish borders and chemical composition between the borders cannot be known without any analysis. These forecasts may be sometimes right but sometimes may cause pure slabs to be named as overlapped, to wait in the stockyard, customer complains because of this inconvenient quality names. In order to eliminate these problems, "Study of slab quality and tonnage determination for overlapping heats in a continuous casting tundish" work was done. Details of the modelling programme are listed below:

- The modelling program was prepared in “Microsoft Excel” office program and some formulas based on Microsoft Excel are used in any step of it.
- There is a need to fill in the some information of “Input Table”. For instance, remaining and incoming cast ID names (X and Y quality names), requested slab width, thickness and casting speed. Furthermore, remaining hot metal amount in the tundish is accepted as 40 tonnes in order to stay the safety limit for tundish refractory. At last, steel density is always 7,85 g/cm³.
- Quality parameters table in the program is filled in automatically by excel formula according to input information. Remaining X quality and incoming Y quality chemical compositions, Y quality’s minimum and maximum values of chemical composition for each element are seen in this table which is taken from quality system source of Çolakoğlu Metalurji A.Ş.. Also, target chemical composition is decided according to incoming Y quality because the mixed hot metal in the tundish turns into Y quality from X systematically.
- Details of the calculations are explained below; The m symbols which are seen in Figure 2 are created by changing from casting speed (m/min) to mass flow rate (kg/min).

![Figure 2. Overlapping Heat Application.](image)

![Figure 2. Tundish simulation.](image)

$$m: \text{Remaining hot metal amount in the tundish (40 tonnes)}$$

$$m1: \text{Mass flow rate of hot metal, which is poured from ladle to (kg/min).}$$

$$m2,m3: \text{Mass flow rate of hot metal, which is poured from first and second holes (strands) to molds (kg/min).}$$

$$x1, x2: \text{Incoming quality chemical composition’s % values that is coming from ladle to tundish and outgoing quality chemical composition’s % values that is from tundish’s two strands to molds respectively.}$$

Mass Balance formula shown with a following equation (1):

$$m1-m2+m3=\frac{dm}{dt}$$

Addition of chemical compositions (x1, x2) to the formula (1) helps to create following mass balance equation;

$$m1x1-m2+m3x2=\frac{dmx2}{dt}=mdx2dt+x2\frac{dmx2}{dt}$$

(2)

It is accepted that level alteration in the tundish is not existing. So that, $\frac{dm}{dt}=0$ equation appears and formula (1) comes out.

$$m1x1-m2+m3x2= mdx2$$

(3)

Dividing both sides by $m$,

$$\frac{(m1x1)m-m2+m3x2}{m}=dx2$$

(4)

is obtained. By replacing $(m1x1)m$ by A and $m2+m3$ by B,

$$A-Bx2=dx2$$

(5)

is obtained. By integrating (5), that is,

$$dt=dx2(A-Bx2)$$

(6)

the following solution is obtained.

$$t=\ln(A-Bx2)(-B)+c$$

(7)

At the moment of $t=0$, $x2$ is equal to remaining X quality chemical composition. Through this, c integral constant could be found with formula (8).
\[ c = \ln(A-Bx2)B \quad (8) \]
x2 is outgoing quality chemical composition’s % value for each element and it has to be equal to last target value. The time period to reach the last target value should be found and it is possible with the combination of (1) and (2) formulas.

Formula (1) helps to find the time period (t) to reach the last target x2 chemical composition.

\[ t = \ln(A-Bx2)(-B)c \quad (7) \]

1. In order to find an amount of mixed quality steel that should be separated from pure X or Y quality steel, recently calculated m2 ve m3 should be used.
2. Two different chemical compositions are described with kg/min and t is described with minute so that, if they are multiplied with each other, the amount of mixed quality steel that should be separated can be found as kg. Afterwards kg is turned into tonnes.
3. Slab weight for one meter is found by the help of some input information (slab width, thickness, density). Afterwards, separated total slab length (m) can be calculated through separated amount of mixed steel.
4. Average chemical composition of separated overlapped slabs is calculated in the following steps:
   1. First of all, a time period to produce 1 slab (min) is found. It is calculated through decision of separated slab length to be divided by casting speed.
   2. The time period that is found previous step, is divided into 10 equal pieces. Afterwards, 10 different chemical compositions could be found for each slab by using formula (1) with integral limits.

\[ 0t1dt=\alpha \beta dx2(A-Bx2) \]
\[ t10t=\ln(A-Bx2)(-B)\alpha \beta \]  
where \( \beta \) denotes the analyses of the quality which is at the basis of tundish and \( \alpha \) denotes chemical composition of the element in a chosen t1 instant.

1. An average chemical composition is found for 10 different chemical compositions for each separated slabs.
2. In the last step of program, all casting qualities of Çolakoğlu Metalurji A.Ş. are listed and separated slab(s)’s average chemical composition for each element that is calculated in the previous step is checked to find weather it is between the requested minimum and maximum limits or not. Microsoft excel formulas are used again to apply calculation. If the element’s % value is between limits it is written “1”, but it is not between the limits this it is written “0” to the “Quality Control” table. Thus, if one casting quality’s all the important elements % value supplies the request and gets number “1” in quality control table separated slab’s cast ID name could be found. But, if any of important element % value gets number “0” in the table, separated slab cannot be take any ID from casting quality source. Because the numbers of important elements are multiplied with each other and the last decision becomes “0” means negative result.

4. Comparison of Experimental and Calculated Results

In order to compare the experimental and calculated results, 3 samples from head, middle, end of the overlapped slabs, which were separated from pure steel qualities by quality control department workers experiment and forecasts were taken and analyzed through mass spectrometer machine. 3 different chemical compositions were gained and called as “experimental results”. Thus, the chemical compositions alteration could be monitored and compared with the “calculated results”, which are acquired from modelling program.

5. Conclusion

As a result of “Overlapping Heat Application” in Çolakoğlu Metalurji A.Ş., two different qualities are mixed, overlapped in the same tundish and the borders of this overlapped slab mixing are unknown. It is aimed to end up confusing and unknown situation with modelling program. Accordingly, mass balance was taken as a base of this program. Also, Microsoft excel formulas were used in any step of the work. Experimental and calculated results are compared with each other. Eventually, the comparison results have been found quite successful except small and negligible deviations. "Study of slab quality and tonnage determination for overlapping heats in a continuous casting tundish" work gave a chance to know the borders and the new chemical composition of mixed quality steel. In addition, this study permits to decide the cast id name (quality name) according to Çolakoğlu Metalurji A.Ş. quality and chemical compositions standards and slab lengths according to Çolakoğlu Metalurji A.Ş. slab dimension standards. Basically, this study provides opportunity to work with more reliable result instead of the results based on forecast and experiments about overlapping heats in Çolakoğlu Metalurji A.Ş. plant.

Acknowledgement

The authors are gratefully acknowledged for the financial support of ITU-BAP and Colakoğlu A.S.

References