

RECENT EXPERIENCES WITH IMPROVING STEEL-TO-HOT-METAL RATIO IN BOF STEELMAKING

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Abstract

After the American company U.S. Steel pulled out of Serbia, the Serbian government decided to continue the steel production in Železara Smederevo. Given the unfavorable market conditions, this decision requires taking all necessary steps to reduce production costs in the time to come. Since most of the production losses occur during Basic Oxygen Furnace (BOF) process, this paper focuses on this stage of steel production. We provide an overview of related experiences in other steel plants as well as earlier production experiences in Železara Smederevo, and propose cost saving measures that will improve the overall business position of the Serbia's only one steel producer. These measures do not require new investments.

Key words: BOF process, scrap / hot metal ratio, yield, KPIs, cost production, Železara Smederevo.

Introduction

It is well known that the financial crisis of 2007-08 has pushed the world steel industry into deep recession. Demand for steel has contracted sharply, forcing steelmakers to introduce major production cuts. Further difficult market conditions contributed to very large drops in steel prices on the European as well as the world market, particularly in the period 2012-2015 [1].

Železara Smederevo was not immune to difficult economic environment. After working with both blast furnaces for approximately five years (2006-2011), it transitioned to have only one blast furnace in operation in 2012, which resulted in

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limited quantities of hot metal and new challenges. In normal conditions, the primary production of Železara Smederevo consists of two blast furnaces (about 1250m³ and 1650m³, respectively) and three 100t BOF converters, which brings the production to around 2 million tons of steel per year.

In 2015, the new Železara's management focused on selling finished products and finding more favorable terms to purchase raw materials. The later step allowed for the increase in production from 583000t in 2014 to 955000t in 2015 [2]. To continue this trend of reducing production losses, it is also important to improve the production efficiency. The path to accomplish this goal lies in further reducing hot metal ratio in the overall metallic BOF charging and increasing steel yield.

We provide an overview of applied practices, results achieved, and lessons learned in working with limited quantity of hot metals in some foreign steel plants and Železara Smederevo.

Some experiences from practices working with reduced quantity of hot metal

In several of its BOF steel plants, *Mittal Steel USA* has applied and analyzed a large number of measures designed for conditions with reduced hot metal to scrap ratio. Over the years they have tried a wide spectrum of techniques to melt more scrap with less liquid hot metal. They concluded that there are about twenty methods to reduce the hot metal/scrap ratio in BOF charging. Six or seven of these methods involve little or no investments and are relatively easy to start using. The measures without investments include the use of various types of solid fuels, the use of solid iron as a substitute for part of the steel scrap, the reduction of the tap temperature, the reduction of the amount of coolant materials in the converter, the reduction in the number of transport ladles between the blast furnace and the BOF, and the application of granular insulation. According to their findings, these measures present best options given the local availability of materials. They also concluded that hot metal percent in total metallic charge can be reduced from 77% to 66% [3].

Corus Strip Products IJmuiden in the Netherlands concluded that, in economic terms, the best practice for a steel plant with a balanced hot metal supply is not necessarily the best practice for a steel plant with a hot metal shortage [4]. Using the special mathematical methodology, they analyzed 33 measures and chose eight for implementation. Although they implemented only 40% of the planned measures, they achieved 60% of the planned effects. In addition to conventional measures, in order to prevent unnecessary increase in heat losses, the number of the converters, ladles and torpedo cars were also reduced. Planned cooling of steel before tap with steel scrap instead of iron ore or magnesite was not successfully implemented. During the period of reduced production of hot metal, which lasted for two months, they achieved 23.0kg/t of steel reduction in consumption of hot metal.

The Canadian company *Stelco Hamilton*, after the shutdown of one of its blast furnaces and having to work with a limited quantity of hot metal for

steelmaking, decided to improve its productivity with a series of measures [5]. The company formed a multidisciplinary team of experts (operations, metallurgy, systems, purchasing and accounting) with the task to minimize the hot metal charge and maximize the metal yield. They examined many operating measures with the aim to increase the metal yield (six well-known and common measures were selected) and to increase the scrap ratio. For increasing the scrap ratio they applied the following three measures: consumption reduction of dolomite lime based on daily monitoring of the lining wear and turndown performances, lower aimed carbon content at the end of blowing for all grades of steel, and increased silicon content in hot metal. The results showed that the most economical and feasible FeSi addition technique was injection into the hot metal stream during reladling. They achieved 36.0kg/t of steel reduction in consumption of hot metal.

During a 96 days long period of working with only one blast furnace, *Sideral Ternium Steelplant* in Argentina has increased steel production by 80000t thanks to increasing the scrap ratio [6]. They used a combination of preheating steel scrap with coke and oxygen, and using FeSi, CSi and pig iron as a part of charging materials. After testing the scrap ratio in wide range, they chose 27.5% as the preferred target level. To prevent large ejection of slag from vessel, the amount of FeSi / CSi was limited to 1t.

Žinecké Zelezarny in Czech Republic has used solid fuel both in the reduced production of hot metal, and in the normal level production [7]. Depending on the steel and steel scrap market conditions, scrap ratio was being raised up to 45%. The usual daily movements were in the range 25-34%. Solid fuels were used not only during blowing oxygen and for preheating steel scrap, but also for conditioning the slag to maintain the refractory lining.

Železara Smederevo had a very unique experience in applying solid fuels to increase steel production in periods of very small amounts of hot metal [8]. To increase the scrap ratio, as a heat source was used coke, FeSi and aluminum's scrap (one-stage process). An attempt was also made to use coal, but due to the higher slag foaming and the slopping problems, it was abandoned. In the cases when the scrap ratio was over 40%, it was necessary to extend the process time to about 90 minutes (two-stage process). The analysis of results after 681 heats has shown the significant reduction in consumption of hot metal in comparison to conventional technology - 113.9kg/t steel for the one-stage process, and 341.6kg/t steel for the two-stage process.

In addition, some unconventional measures were applied and achieved significant improvements in steel yield in the period 1985-1987 [9]. It was observed that the metal yield results vary among the shifts working in approximately same production conditions. That led to the idea of introducing the salary-incentive coefficients. The coefficients were used to determine monthly salaries for each shift, proportional to reported cost reduction effects. In the second year after the implementation of this measure, the metal yield

increased by about 1.5% . Comparative study of the work efficiency among all shifts can indicate the need for further training of some of the key operators or groups of workers.

Table 1 presents results of the implemented measures in the above mentioned steel plants.

Table 1: Achieved effects in BOF operations

Steel mill	Achieved effects in BOF operations		
	Hot metal ratio change, %	Yield change, %	Decrease of hot metal, kg/t steel
Corus Strip Products IJmuiden	NA*	NA	23.0
Stelco Hamilton	- 2.1	+ 0.8	36.0
Mittal Steel USA	- 11	NA	NA
Sideral Ternium	- 15.2	- 1.5	NA
Třinecké Zelezarny	(ratio decrease to as low as 55%)	NA	NA
Železara Smederevo	- 11.26	- 1.9	113.9

*NA - data not available

The impact of current production practices on the "steel-to-hot-metal ratio" parameter in Železara Smederevo

Irrespective of how Železara Smederevo works, with both or only one blast furnace in operation, the "steel-to-hot-metal ratio" parameter significantly affects the cost of steel production. The key question is, is there, given the current production practices, a room to improve this parameter? The answer can be obtained by comparing the converter process performance using the so-called Key Performance Indicators (KPIs) with other steel producers. This is common practice in steel production, and the Association for Iron & Steel Technology (AIST) has developed a tool for comparing KPIs [10].

It is clear, even without detailed comparison of plant conditions, that using only static charge calculation model for the BOF process [11] and relying on the so-called "slag foaming" technology [12], negatively impacts the "steel-to-hot-metal ratio" parameter.

On the other hand, it is well known that the use of Static Dynamic Models (SDMs), regardless of accompanying technical solutions such as sub lances, drop-in sensors and two turndown practice, can provide a number of advantages in comparison to using only static models: better turndown performances, reduction of the "end blow to start tap" time, better removal of phosphorus from metal, longer lining life of the BOF converter etc. In addition, Železara Smederevo has ten years of experience in using its own SDM based on the two-turndown practice [13]. The same method is used in the Mexican steel plant *Altos Hornos de Mexico, S.A.* [14].

Since Železara Smederevo does not have device for heating steel in a ladle (Ladle Furnace), the use of the two-turn-down practice in combination with the existing static model is most likely justified, given the financial state of the company. It is desirable to develop an algorithm for assessing the chemical composition of the steel at the end of blowing. That would ensure better utilization of the "quick tap" practice, which is the main purpose of this method.

The steel plant currently uses the "slag foaming" technology with the main aim to extend the BOF refractory life. This technology involves reaching about 10% MgO in a slag and adding a mixture consisting of 90% raw magnesite and 10% coke or coal (about 8 kg/t steel) into the converter near the end of the oxygen blowing.

In comparison to the "slag foaming" technology, the widely used "slag coating" practice or working without dolomitic lime, are relatively simple ways, given the current plant conditions, to reach additional reductions in the overall production costs.

Conclusions

Based on the above mentioned data and results presented in listed references, it is evident that many proven measures to reduce overall production costs can be applied. As they are deciding what path to take, it is important to keep in mind that some of the above described measures require little or no new investments. These measures can be classified into two groups: (a) measures that require no prior economic and/or technological analysis to justify implementation and (b) measures that require economic analysis before implementation

The first group includes measures for more efficient use of the available temperature of hot metal (measures that reduce heat losses from blast furnace to the steel plant), and measures for improving Key Performance Indicators of the BOF process. Available measures for improving KPIs are: replacing the "slag foaming" practice with "slag coating" technology or working without dolomite lime, applying the two-turn-down method, and improvement of the charge calculation model (SDM that was successfully used in the past in Železara is one candidate model).

The main aim of the second group of measures is reducing the hot metal ratio. These measures include the use of different kinds of solid fuels, and the increase of temperature and chemical heat of hot metal (with higher levels of Si and Mn). They have to be carefully studied before implementation to assure that the overall production cost will be reduced, despite the costs incurred by using solid fuels and/or changing the burden on blast furnace.

While choosing auxiliary fuel source which contains sulfur and setting its maximal amount, one could rely (with some modifications) on the mathematical model for balancing sulfur distribution among the slag, metal and gases described in [15]. In addition, when testing a converter process with a significant reduction in the hot metal ratio, it is preferable to select grades of steel that don't have rigorous requirements in terms of residual elements and nonmetallic inclusions.

Since all measures mentioned above are directed primarily at improving the steel-to-hot-metal ratio, it is desirable that they are coordinated by the Continuous Improvement (CI) teams.

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