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Professional paper

THE ESTIMATION OF EFFICIENCY OF THE LADLES HEATING PROCESS

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The paper presents a system of drying and heating the metallurgical ladles. The ladle heating parameters significantly affect the metallurgical processes. The heating process target of the ceramic ladle lining can reduce the steel temperature in the furnace. It resulted in reduction of energy consumption what is an economic benefit. Adopted drying and heating rate of the ladle depends on the ladle refractory lining - an alkaline or an aluminosilicate. The temperature field uniformity of ceramic lining is a basic technological requirement. The presented industrial research shows the way of the ladle heating where the self-recuperative burner was used. The recuperative burner application gives the rapid increasing of the preheated air temperature what has resulted in the reduction of fuel consumption for the same thermal power. The examinations of the two ladles heating process were presented and the energy efficiency of that process was identified.
Key words: ladle, self-recuperative burner, heating, energy reduction.

Procjena učinkovitosti procesa zagrijavanja lonaca. U radu je prikazan sustav sušenja i zagrijavanja metalurških lonaca. Parametri zagrijavanja lonca značajno utječu na metalurške procese. Ciljani proces zagrijavanja obloženog keramičkog lonca može smanjiti temperaturu čelika u peći, a to rezultira smanjenjem potrošnje energije što pridonosi ekonomskoj učinkovitosti. Usvojena brzina sušenja i zagrijavanja lonca ovisi o njegovoj vatrostalnoj oblozi - alkalnoj ili aluminosilikatnoj. Uniformnost temperaturnog polja keramičke obloge je osnovni tehnološki uvjet. Predstavljena industrijska istraživanja pokazuju način zagrijavanja lonca pri kojem se koristi rekuperativni gorionik. Primjena rekuperativnog gorionika daje brzo povećanje temperature predgrijanog zraka što ima za posljedicu smanjenje potrošnje goriva za istu toplinsku snagu. Predstavljena su ispitivanja zagrijavanja dva lonca i identificirana je energetska učinkovitost tog procesa.
Ključne riječi: lonac, rekuperativni gorionik, zagrijavanje, redukcija energije.

INTRODUCTION

The issue of proper conducting the process of drying and heating the ladle lining has taken on a special importance with the development of ladle metallurgy methods and the dissemination of continuous casting of steel. This has resulted in an increase of casting temperature and the scope of the technological processes carried out [1-7].

Requirements of ladle drying and heating are different, but these processes have a major impact to its durability, reliability and the quality of the castings. The drying requires a very slow and uniform heating with controlled velocity and dependent on the lining and the capacity of the ladle. Usually a ladle lining is composed of two layers - insulation and operating. The appropriate temperature condition has to be

required depending on the type of lining. The alkaline lining must be held at high and uniform temperature (this is because of its very high sensitivity to the thermal shock). The heating process is characterized by very high speed. Basically, these speeds are above 100 K/h and it is about 10-30 times greater than in the drying process [2, 3, 10, 11].

It is possible to decrease the metal temperature in the converter for the required process parameters if the optimal ladle preheating methods are used. In this way it is possible to achieve the significant economic benefits [12-15]. There is reported in the literature that the ladle lining temperature increasing from 1100 to 1200 °C is about twenty times cheaper than the steel overheating in the furnace from 1500 to 1520 ºC. It also allows to avoid such a negative thermal shock in the lining when the steel is drained.

Many methods and ways of drying and heating the ladles have been elaborated till now. Many of these the most often used: waste gas enthalpy of another source, waste heat of hot ingots, heat recovery devices, serial connection system of two ladles, devices for drying and ladle heating with traditional self-recuperative burner.

THE MODERN SYSTEM FOR DRYING AND LADLE HEATING WITH AUTOMATIC SELF-RECUPERATIVE BURNER EPR-300

The relative effective solution is the device with the self-recuperative burner compared to the others. However, the condition is that the burner should be characterized by the high gas dynamics and the high combustion air preheating. In this way, while maintaining the same thermal power, the fuel flow is reduced. The consequences of it are the measurable economic effects [16-18]. This also significantly improves the temperature distribution in the ladle. This allows to keep the technological requirements of the thermal process, even at low and medium temperatures [3].

In order to eliminate the drawbacks of prior solutions the new and original stand for drying and ladle heating with self-recuperative burner EPR-300 has been developed
(0). The EPR-300 burner works in a programmable range of 5-120 % of nominal heat power output [19]. The lower heat output range is mainly used for drying and keeping the temperature at a certain level. The upper range is used for the intensive heating.

During the experimental tests carried out in the Laboratory of Industrial Gas Burners Silesian University of Technology it was found that the burner is characterized by very good flame stability over the entire range of thermal power burner with very high momentum outflowing substrates [19]. The self-recuperative burner outlet of high reactant flow rates (60-100 m/s) is situated in the wall vertical plane of the cover (lined by insulating fiber material) which closes the heating space (0). The high outflow speed of reactant makes the ladle lining distribution temperature uniform. Differences in the selected measuring points not exceed 10 °C. The thermocouples were used during the measurements. The ladle before the drying or heating is positioned at the horizontal level. In the case of heating the smaller ladle (below 5 Mg), the self-recuperative

burner with a lower heat output and with a significant simplification of the stand may be used. The burner is equipped with full automation and flame detection. This ensures a safe operation and precise control of the temperature distribution.

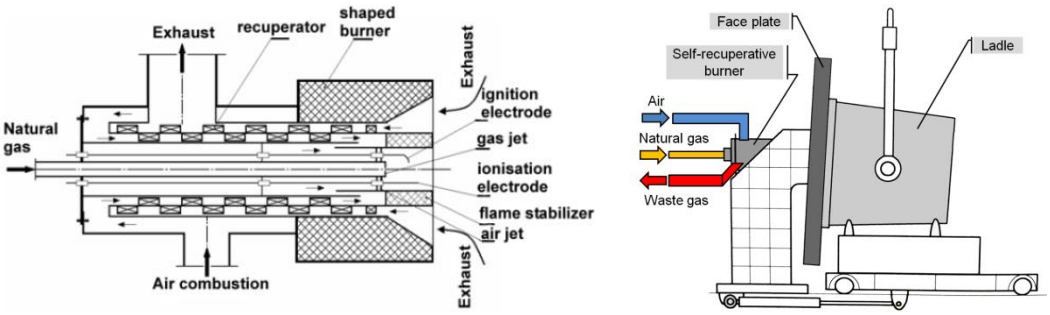

Figure 1. Scheme of the low power self-recuperative burner and the heating stand of the ladle
Slika 1. Shema rekuperativnog gorionika niske snage i eksperimentalni postav zagrijavanja lonca

The 0 presents the ladle heating diagram for different capacities 10 – 60 Mg to temperature 700 ºC. The 30-minutes withstand at this temperature was assumed.

The design of the self-recuperative burner EPR 300 allows heating the casting ladle up to 1200 °C [13, 16]. However, the ladle temperature heating of 700 °C is currently required in the smelters technologies. Additionally, increasing the ladle heating temperatures fosters the homogeneity of the casting metal composition [2, 3].

The industrial research results conducted in Ironworks Buczek are presented in 0. The ladle of 25 Mg capacity has been heated during that research and the self-recuperative burner has been also used. The aim of the ladle research consisted of four basic steps:

- intensive heating until 350 °C of lining temperature (full power burner),
- keeping the lining surface temperature at 350 °C to equalize the temperature in the cross section of lining,
- intensive heating until lining temperature of 700 °C,
- re-heating for a specified period of time (30 min was assumed).

In addition, the heating process is characterized by the low concentrations of NO_X in the exhaust gases, which for the ladle heating temperature of 700 °C were on average only 38 ppm (20.1 g/GJ) at the same time the low CO concentrations at the level of 28 ppm (9.08 g/GJ) has been noted [1-3].

0 shows a comparison of the two methods of ladle heating - the previous method and a new one of using the self-recuperative burner.

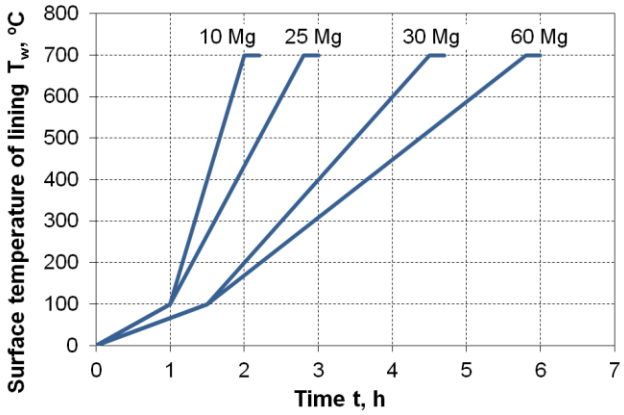

Figure 2. The ladle heating diagram for different capacities
Slika 2. Dijagram zagrijavanja lonaca različitih kapaciteta

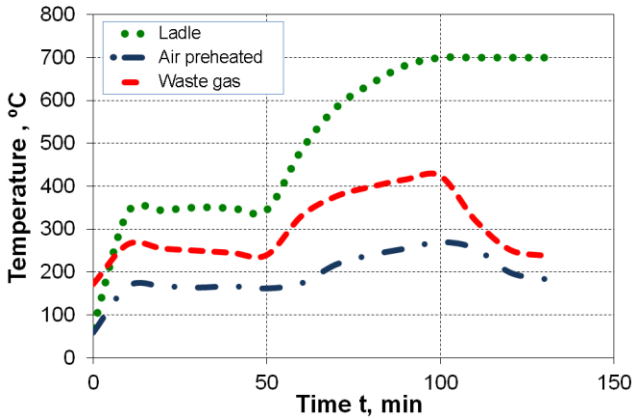

Figure 3. The results of industrial research of the ladle heating
Slika 3. Rezultati industrijskih istraživanja zagrijavanja lonaca

Table 1. Comparison of the old and new methods of ladle heating
Tablica 1. Usporedba stare i nove metode zagrijavanja lonca

Parameters	Previous ladle heating method		New ladle heating method	
	25 Mg ladle capacity	30 Mg ladle capacity	25 Mg ladle capacity	30 Mg ladle capacity
Average temp. surface linings (ºC)	439	274	700	700
Heating time (min)	210	180	165	240
Gas consumption (m^3)	239	213	63.3	73.4
Energy accumulation (useful) (MJ)	606.1	562.3	1144.7	1179.9
Efficiency (%)	7.1	7.4	46.3	43.9

CONCLUSION

In comparison with the previous ladle heating, it was found that the ladle heating by the self-recuperative burner EPR-300 provides:

- faster heating - depending only on the technology (0),
- reducing the natural gas consumption from 239 m^3 to 63.3 m^3,
- possibility of increasing the ladle heating temperature of around 260-430 °C,
- uniform surface temperature distribution,
- radical reduction in CO emissions (9.08 g/GJ) and in NO_X emission (20.1 g/GJ),
- increasing the durability of the ladle linings.

The automatic low-emission self-recuperative burners can be also used in the chamber furnaces to both the charge heating and heat treatment [3, 12, 14, 15, 19, 20].

The thermal power of the self-recuperative burner may be increased to 600 kW in the case of a faster ladle heating of the capacity over 100 Mg and to use for the large chamber furnaces. However, for the smaller ladle capacities and the small chamber furnaces the burners for power to 100 kW can be used.

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