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Automatic Control System of Steel-Teeming Ladle Heating-Up Regime

B.P. Krikunov, D.V. Kolesnikov, Yu.V. Petrov, A.V. Dorofeyev, Yu.A. Bogoslavskiy, Ye.V. Dmitriyev, A.T. Yakovenko

Branch "Metallurgical complex" of CJSC "Donetskstal Iron & Steel Works"
122 Ivan Tkachenko St., Donetsk, 83062, Ukraine

The automatic control system of steel-teeming ladle heating-up regime (APCS) is developed under conditions of steel melting shop. The implementation of automatic control system allowed high-temperature heating-up of ladles prior to steel tapping and pouring. As a result, it is possible to increase resistance of monolithic refractory lining and reduce the natural gas charge in average by 130 m^3/h or 40 m^3/h per ladle heating cycle.

Keywords: "LADLE-FURNACE", CONTINUOUS - CASTING MACHINE, STEEL-TEEMING LADLE, TUNDISH LADLE, REFRACTORY CONCRETE, FUEL SPECIFIC ENERGY, AIR-FLOW COEFFICIENT, THERMAL BALANCE, PROGRAM LOGIC CONTROLLER

Introduction

Ladle-furnace is constructed and put in operation, current slab caster and ladles are upgraded with mastering of new production methods in open-hearth plant of CJSC "Donetskstal Iron and Steel Works".

Introduction into service of ladle-furnace required changes in the steel teeming ladle construction, lining pattern with the application of new refractory materials. Step-by-step adoption of combined lining pattern with monolithic working layer of dense corundum-spinel refractory concrete and brick lining work row of slag-line area made of periclase-carbonacious brick. The change in ladle construction allowed more rational arrangement of slag pots – steel teeming ladle is located in line with two slag pots in the furnace cinder tunnel [1].

Furnace slag cutoff method using steel-tapping hole with skimmer brick and vertical sluiceway which allows draining slag to the slag pot positioned on the same line with the hole and steel-teeming ladle is changed [2].

Four high-temperature heating stands for steel-teeming ladles are placed on free areas near the furnaces in shop ingot-casting bay, and two of them have been already put on operation.

Heating stand is equipped with two low-pressure burners LPB–100 with two-stage air supply pumped up by blower. Temperature is measured by thermocouple set in the stand crown. The installation works up to 15 hours per day, hourly average natural gas rate is 200 m^3/h.

Previously the heating used to be carried out in manual mode by means of starting the burner and setting the nominal gas flow rate, herein the ratio "gas-air" was set at the rate of 1:10. Steel-teeming ladle heating was accomplished with comparatively high natural gas flow rate under such heat conditions.

Results and Discussion

For the purpose of natural gas economy the experts of our enterprise recommended to heat the ladles in automatic mode, which eliminates human factor effect and provides the optimal conditions for refractory lining service.

The substance of suggested method consists in the following: as soon as specified temperature of lining is achieved, the air and gas flow rates are corrected automatically with the consideration of the heat accumulated by refractory lining [3].

Continuous measuring of technological parameters in the ladle, control, comparison, signals forming of operating mechanisms control are carried out using program logic control. According to preset optimal ratios of gaseous fuel and air flow for burning, in the real time mode this logic control provides required fuel flow for its combustion with marginal fuel flow coefficient α = 1.05-1.10 and ensures acceptable heating temperature of refractory lining 900-1200°C.

Thermocouple is located in the lining at the height of ½ of the ladle height for determination of temperature of ladle monolithic refractory lining heated layer and temperature wave oscillation period in the experimental setup-researching works.

Thermo-physical and constructive parameters of ladle refractory lining such as thermal conductivity coefficient of ladle refractory lining (λ_c), its density (ρ), surface area (F_{lin}) and thickness (S) are given in **Table 1**.

When upgrading APCS of steel-teeming ladle heating stands, flow sensors and pressure-responsive elements for ventilator air and natural gas are installed in vertical position; subprograms of temperature control for program logic controller (ACS of melting furnace) of gas flow maintenance and ventilator air ratio are worked out.

The screen for displaying carrying charges, calibration screen and gas rate display screen (momentary, five-minute, hourly) are made on the computer of melting furnace ACS visualization. After ACS introduction into service, the heating mode is adjusted and optimum relationship of gas and air rates is determined.

Technological parameters and ladle heating tests results such as temperature of ladle lining internal surface (t_c), lining temperature after previous heating (t_{acc}), amount of heat accumulated by the lining (Q_m) and that after the previous heating (Q_{acc}), calculation heat-availability factors (η) and fuel rate coefficients (α), actual time of heating (τ_p), fuel rate (V_g), number of metal pourings (n) are given in **Table 2**.

As follows from **Table 2**, implementation of suggested method with the use of heat accumulated by refractory lining during previous heating and natural gas combustion with marginal fuel combustion coefficient α = 1.05 enabled to reduce ladle heating time, decrease fuel rate for required lining temperature maintenance.

Table 1. Thermo-physical and constructive parameters of ladle refractory lining

Ladle capacity, t	λ_c*, W/(mK)	ρ, kg/m^3	F_{lin}, m^2	S, m	Refractory material composition, %		
					Al_2O_3	SiO_2	MgO
155	2.0+190·10t_c	3100	91.3	0.18	92.0	0.4	8.0
15	t_c from 400 to 1200°C λ_c = 2.83-2.31	2800	25.0	0.12	83.0	12.0	-

* accepted $\lambda_c = \lambda_{acc}$

Table 2. Technological parameters and test results of ladle heating

Option	t_c	T_{acc}	$Q_m \cdot 10^3$	$Q_{acc} \cdot 10^3$	η	α	τ_p	V_r	ΔV_r	n
	°C		W		-	-	h	m^3/h		pourings
Steel-teeming ladle, capacity 155 t										
Before introduction	1100	500	2805.3	760.8	0.35	1.30	5.3	173.6	-	76
After introduction	1200	700	3199.1	1171.7	0.45	1.05	2.1	133.8	39.8	80
Intermediate ladle of CC machine, capacity 15 t										
Before introduction	1100	400	187.0	216.6	0.20	1.25	2.0	70.0	-	1000
After introduction	1200	600	695.1	325.0	0.30	1.05	1.4	30.0	40.0	1050

Conclusions

Heating mode automatic control system for steel-teeming ladles with capacity of 150 t and tundish ladles of slab caster is worked out. This system helps heat the ladles taking in account the usage of heat accumulated during previous lining heating. This system implementation provided the following:

- increase of steel-teeming and tundish ladle lining resistance by 5 %;
- reduction of lining heating time to the required temperature by 5 %;
- reduction of natural gas rate by 40 m^3/h.

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Система автоматического управления режимом разогрева сталеразливочных ковшей

Крикунов Б.П., Колесников Д.В., Петров Ю.В., Дорофеев А.В., Богославский Ю.А., Дмитриев Е.В., Яковенко А.Т.

В условиях сталеплавильного цеха разработана автоматическая система управления режимом разогрева сталеразливочных ковшей (АСУ ТП). Внедрение АСУ ТП позволило на стендах разогрева производить высокотемпературный нагрев ковшей перед выпуском и разливкой стали, позволяющая увеличить стойкость монолитной огнеупорной футеровки и снизить расход природного газа в среднем на 130 $м^3$/ч или на 40 $м^3$/ч за цикл нагрева ковша.