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Improved design of water-cooled dust precipitation chamber for high-capacity electric steelmaking furnaces

Peculiarities of removal of dusted technological gases at electric arc furnace during intensification of steel smelting were considered. Purpose, device, operation concept, technical and economical characteristics of operation of water-cooled dust precipitation chamber is described. Analysis of achieved characteristics is done. State enterprise "Ukrainian research and technology center of metallurgical industry "Energostal" (SE "UkrRTC "Energostal") has realized reconstruction of cooled gas outlet of arc furnace with real charge of 120 t under intensity of oxygen blowing up to 9000 Nm³/h in electric steelmaking shop No. 2 at JSC "Chelyabinsk Iron & Steel Works". New design of inlet nozzle allowed to avoid slag and dust depositions in it (these depositions earlier were removed manually), to improve environmental conditions in the shop due to almost complete elimination of exhausting of waste gases out of the furnace in the shop under increase of through capacity of gas-escape track. Efficiency of cooled chamber with this design was verified during commissioning test and further operation — chamber operation parameters exceeded design ones. Works for further upgrading of dust precipitation chamber design were carried out based on obtained experience. Development of these type coolers for furnaces of electrical steelmaking shops at certain metallurgical and machine-building enterprises is in sight.

Key words: *electric steelmaking furnace, water-cooled gas outlet, CO afterburning, dust precipitation chamber, cooling, nozzles, gas cleaning.*

Arc furnaces are widely used in large metallurgy and at metallurgical mini-mills for smelting of high-quality carbon and alloyed steel production. At the end of XX and at the beginning of XXI century great attention was devoted to increase arc furnace capacity and it was reached by:

— use of transformer with enlarged specific capacity (up to 0.8 MW/t of charge);

— heating of burden materials out or in furnace (with installation of gas-oxygen burners);

— use of oxygen for furnace bath blowing;

— combining of electric furnace smelting and out-of-furnace steel treatment.

Growing of electric steel production using new technologies entails oversized formation of dust process gases with high content of CO that stimulates developing of effective systems for outlet, cooling and cleaning of dust waste gases at electric steelmaking furnaces.

During intensification of steel smelting process in arc furnace with charge of 120 t, the melt quantity will be able to increase up to 23 and more per day. Quantity of gases, escaped from furnace during oxygen blowing, attains 50 thousand Nm^3/h. Gas temperature in smelting process is 900–1650 °C, dust content — up to 100 g/Nm^3, CO content — 12–13 % [1, 2].

State enterprise "Ukrainian research and technology center of metallurgical industry "Energostal" (SE "UkrRTC "Energostal") has realized reconstruction of cooled gas outlet of arc furnace with real charge of 120 t under intensity of oxygen blowing up to 9000 Nm^3/h in electric steelmaking shop No. 2 at JSC "Chelyabinsk Iron & Steel Works". Possibility for creation of upgraded gas outlet in the form of water-cooled dust precipitation chamber for heavy-operative electric steelmaking furnaces is based on more than 30-year experience of SE "UkrRTC "Energostal" as well as foreign experience in the field of investigation, development and implementation of equipment for outlet and cleaning of waste gases of electric steelmaking furnaces, converter gas coolers, cooled gas outlets in ferroalloy metallurgy.

Before reconstruction the cooled gas outlet was a round horizontal gas duct shielded by water-cooled tubes. It did not provided necessary cooling of furnace gases for further transportation along non-cooled gas duct to gas cleaning and CO afterburning. In horizontal gas duct the crusts formed; it required frequent stop of furnace for manual cleaning. High temperature of gases after passing the cooled gas duct requires dilution with air for transportation through non-cooled gas duct, beside it the receiving part of non-cooled duct, manufactured from heat-resistant steel often burn-out with formation of holes. Cause that existing gas cleaning equipment dosen't provide evacuation of all combustion products of furnace gases. It is resulted in increase of gas emission in the shop up to 50% of to gas formed in furnace during oxygen blowing, so CO explosions took place in horizontal gas duct.

Dust precipitation chamber developed by the authors is intended for CO afterburning, preliminary cleaning of waste gases, its cooling up to temperature provided transportation along non-cooled gas duct in main gas cleaning system. Advantages of proposed chamber are the following: simple design, operation and repair. Gas is cooling to temperature for transportation in non-cooled duct. Scheme of furnace gases outlet is shown in **figure**.

Waste gases enter in inlet nozzle 3 where they are mixed with atmosphere air and particularly afterburning occurred. CO final burning is realized in afterburning chamber 4 which cover 7 functions as fire safety valve. During speed-down and gas flow bend in dust precipitation chamber 5, the large particles of dust and slag-metal losses are deposited. Final cooling of gases down to temperature, required according to transportation conditions before gas cleaning, occurs in cooling chamber 6. At least 50% of dust and losses from the furnace are deposited in dust precipitation chamber; CO afterburns in inlet nozzle and afterburning chamber due to leak-in of atmosphere air.

New design of inlet nozzle 3 allowed to avoid slag and dust depositions in it (these depositions earlier were removed manually), to improve environmental conditions in the shop due to almost complete elimination of exhausting of waste gases out of the furnace in the shop under increase of through capacity of gas-escape track.

Swinging water-cooled gate has flexible connections in end walls for providing mechanized removal of main slag and dust from the lower part of cooling chamber 6, for supply of water to its cooled surfaces and for discharge of heated water.

Dust precipitation chamber was made from separate detachable water-cooled panels fixed on frame that gives possibility to mount and to repair it in short time. Repair works are eased by removable cover of afterburning chamber, demountable design of the most heat-stressed inlet nozzle, fixing of convective blinds on cover of the cooling chamber 8 that allows its repair out of the chamber.

Dust precipitation chamber was designed on the basis of existing shop conditions.

Main technical and economic parameters of the chamber operation are shown in **table**.

Water-cooled chamber with above-described design has been developed and implemented during overhaul in October, 2011 and operated successfully at present days.

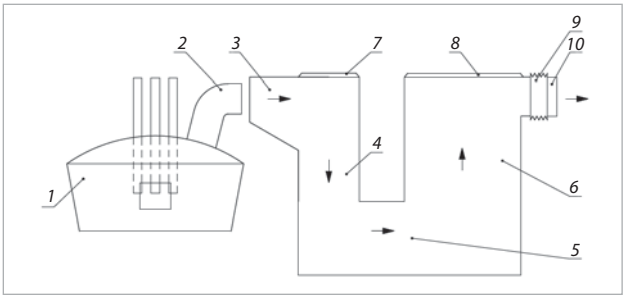
SE "UkrRTC "Energostal" has realized the work for creation of water-cooled dust precipitation chamber in complex:

— process development;
— equipment designing;
— installation project documentation;
— manufacture and supply of equipment;
— mounting and field supervision, commissioning.

Efficiency of cooled chamber with this design was verified during commissioning test and further operation — chamber operation parameters exceeded design ones [3]. Patents applied for chamber design in Ukraine (No. u201214020 dated 10.12.2012) and Russian Federation (No. 2012156043 dated 24.12.2012).

Works for further upgrading of dust precipitation chamber design were carried out based on obtained experience.

Development of these type coolers for furnaces of electrical steelmaking shops at certain metallurgical and machine-building enterprises is in sight.



Scheme for furnace gas outlet:
1 — electric arc furnace; *2* — dome nozzle; *3* — inlet nozzle; *4* — afterburning chamber; *5* — dust precipitation chamber (chamber lower part is lined, walls and ceiling are water-cooled); *6* — cooling chamber; *7* — cover of afterburning chamber (fire safety valve); *8* — cover of cooling chamber with blinds; *9* — compensator; *10* — non-cooled gas duct to gas cleaning

Main technical and economic parameters of water-cooled dust precipitation chamber operation

Description	Units	Value
Waste gas consumption (max.)	thousand Nm^3/h	50
Chamber inlet gas temperature (max.)	°C	1650
CO content (max.)	%	12–13
Gas consumption through chamber	thousand Nm^3/h	200
Outlet CO content	mg/Nm^3	250
Chamber outlet gas temperature (no more)	°C	400
Inlet water temperature	°C	30
Outlet water temperature (no more)	°C	45
Water consumption	m^3/h	1300
Inlet water pressure	MPa	0.45
Total mass of metal structures	t	130

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