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# Innovative Burners with Wide Limits of Adjustment for Heating and Thermal Furnaces

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The results of the research and development of partial premix burners are given, their design and operation are described, and the results of tests of operation of thermal and heating chamber furnaces equipped with burners of this type are shown.

Keywords: BURNER, ADJUSTMENT LIMITS, FURNACE, HEATING SYSTEM, IMPULSE MEANS OF HEATING, UNIFORMITY OF HEATING, ECONOMY OF FUEL

## Introduction

In metallurgy the basis of burner park include burners of outdated designs that have limited range of variation in performance. The most common types of burning devices are direct-flow burners, 20% of which are burners of GNP type (a burner for low pressure natural gas) and the burners of "pipe-in-pipe" type.

GNP burners are designed to burn natural gas of low pressure in the range of variation of the heat capacity of 1:8, at the insignificant change in air flow rate. At the same time, the regulation of the air flow should be performed in a smooth operation mode. Otherwise, the violation of the fuel burning mode is observed. At low heat load conditions for the stabilization of the combustion process it is necessary to apply special igniters. The burners of "pipe-in-pipe" type, creating a diffusion flame, are characterized by narrow ranges of thermal power and air flow rate changes. The increase of air flow rate to 1.35-1.5 leads to a separation of the flame. Narrow limits of adjustment of GNP and "pipe in pipe" burners exclude step change in cost of gas and air, which makes it impossible to use them in the implementation of the impulse mode of furnaces heating widely used for heating of chamber furnaces.

Thus, the existing park of burning devices does not allow to implement modern technologies of management of furnace temperature field and to provide the required quality of the products thermal treatment and increase the efficiency of fuel usage.

## Problem Statement

The aim of the study is research and development of burner devices with wide limits of adjustment of heat capacity and air flow rate that can ensure reliable operation of heating and thermal furnaces with impulse heating and flame length control.

## Research Results

To solve the stated problems design of partial premix burner with a wide limits of adjustment is developed [1, 2]. The basis of design is GNP type burner, a new element is a tip of the gas nozzle, which has a cylindrical cup shape, the fuel supply port is located at its bottom input part. The primary air enters the nozzle tip through the side openings. Its amount depends on the ratio of fuel and air flow through the burner. The indraft of the part of the air inside the nozzle is effected by an exhaustion created by the gas jets. This increases the reliability of the burner and expands the limits of its adjustment.

In the study of the burner at the firing stand and existing furnaces it was found that the burning device is working steadily on the blast furnace, coke and natural gas as well as their mixtures, regardless of the initial furnace temperature condition. The range of adjustment of thermal power reaches 1:25, and the air flow rate is 1:5 [3].

Two sizes of burners underwent the acceptance tests at the National Centre for Testing and implementation of fuel-using equipment and are allowed for usage. The low level of nitrogen oxides in the flue gas should be noted, which is a necessary condition for operation of fuel-driven devices in the furnaces of modern designs.

Currently, the designed partial pre-mixing burners are successfully operating at several engineering and metallurgical enterprises of Ukraine and Russia.

As an example, the experience of the reconstruction of the heating system of thermal recirculating bogie furnace for the annealing of large ingots of high-alloy steels can be considered. The area of furnace hearth area is 47 m2, the fuel is natural gas. The furnaces operate on the vortex principle with uniflow rotational movement of the combustion products, which is provided by the location of burners in the side walls of the working chamber. On one side of the burner are installed in the lower part of the chamber, on the opposite side they are installed in the top part. The heating system consists of 16 two-wire GNP-3-type burners installed in the side walls. To stabilize their work the furnace design provides the additional GNP-1 burners, located in closed combustion chambers under the main GNP-3 burners. The main burners are combined with a closed firepots into recycling units which are connected to the furnace working chamber of the furnace through a system of channels. The adjustment of the furnace heat loads is performed by changing of natural gas flow to the main burner in the range of 80-380 $m^3$/h. The fuel supply to the additional GNP-1 burners is performed independently from GNP-3 burners, and the flow rate is 80 $m^3$/h.

In order to reduce fuel consumption in furnaces of this type the heating system is developed and tested, which provides the replacement of existing GNP-3 burners by the burners of partial pre-mixing, which have wide limits of adjustment of both thermal capacity and air flow ratio. The usage of these burners allowed to exclude closed combustion chambers equipped with GNP-1 burners from the heating circuit, which provided specific fuel savings of 20 kg of coal equivalent/tonne of annealed metal [4].

Along with the GNP burners the pipe-in-pipe burners are widely used at metallurgical enterprises. The narrow range of burner adjustment complicates their maintenance excludes a step change in cost of gas and air, which makes the automation of furnaces harder and makes it impossible to use impulse heating without changing the burners. To eliminate these disadvantages the burner of partial premixing type on the basis of "pipe-in-pipe" burners for coke-oven and blast-furnace mixture [3, 8] is suggested. It has a nozzle tip of cup shape with a perforated bottom and lateral surface. The principle of its operation is described above. The burners are working steadily on fuel with different calorific value and provide a large range of adjustment of thermal capacity and air flow ratio. This allowed to use them to implement the automatic control of zonal heating mode in the heat-treatment furnaces. However, at the long-term operation the holes are clogged by the deposition of paraffins in the burners using coke-oven and blast-furnace mixture. Therefore it is necessary to stop the oven periodically to clean the burners.

We managed to eliminate this drawback in the new partial premixing burner [9, 10]. A distinctive feature of the design is that the cup-shaped tip has smooth deflector on the air side and a sudden expansion area from the side of the gas channel, and the primary air inlets are arranged on the area of sudden expansion. The arrangement of air ducts in the area of sustainable exhaustion provides the indraft of required primary air for good mixing with the fuel. This provides a significant extension of the limits of adjustment.

The tests of the burners under Dneprospetsstal' thermal plant factory fixed stable performance of the burners at a ratio of "gas-to-air" of 1:25. The studies of fuel stoichiometric combustion showed that the adjustment limit of thermal capacity was 1:40 (from 7.45 to 300 kW) [11]. The existing designs of burners can not provide such limits of adjustment. Later the burner with a thermal output of 800 kW was developed based on the burner which was mentioned above. The certification of designed burners with the capacity of 300 and 800 kW was carried out by the National Centre of testing and implementation of fuel-driven equipment. The acceptance tests confirmed the results of the performed research and allow the use of burners for combustion of low calorific gas in thermal and heating furnaces.

One of the most effective ways to improve the quality of metal heating in the chamber furnaces is to control the flame length and therefore to control the size of the heat flow from the combustion products to the metal in the entire volume of the furnace working area.

In order to adjust the length of the flame and increase the operational reliability of the burner we developed partial premixing burning device, where the effect is achieved by changing the proportion of primary air and the degree of its mixing with fuel. The burner design involves the formation of two axisymmetric fuel streams differing in the content of the primary air. The combustion is carried out in the furnace working area, and the adjustment of the flame length is achieved by changing the ratio of gas consumption in the external and internal fuel stream [5]. The researches of the burner were carried out at the combustion stand and operating heating chamber furnace. It was found that the stable operation of the burner in the case of usage of natural and blast furnace mixtures is possible in the range of 1-7 at increasing of the air flow rate, or in the range 1-4 in the case of natural gas usage. Thus the limits of adjustment of heating capacity are 1:25. The burners operate stably at low flow rates of fuel and step change of heat load, which allows them to operate stably without ignition devices under automatic control, and the use of impulse heating methods.

The usage of the burners of designed structure in the heating chamber furnace with unilateral side heating allows to implement impulse method of its heating.

The existing system of furnace heating comprises eight burners arranged in two rows in height on the side wall of the working chamber. In the upper row four GNP-5 burners are installed, in the bottom row there are four GNP-3 burners. The presence of the upper and lower heating zones provides double-sided heating of billets, located on the skids. Meanwhile, the heating circuit with one-way side arrangement of the burners does not enable uniform heating of the metal in the direction of movement of burning gases. The assessment of the quality of metal heating at the existing method of heating was performed by the results of measuring of temperature in the forgings load. The results of these studies showed that the final temperature drop in the volume of heated load was 35 °C. The temperature of the workpiece surface situated near the burners was 10 °C higher, and the temperature of the workpiece surface situated on the wall opposite to the burner was 25 °C lower relating to the below the predetermined temperature of furnace equalizing.

The results of numerical simulation and study of the heating chamber furnace with unilateral side heating [6, 7] allowed to offer impulse system of heating in order to enhance the uniformity of temperature distribution in the furnace working area. A more uniform temperature distribution in the metal load compared to the conventional control method is achieved by periodic intensification of heat transfer processes throughout the volume of the workspace. The presence of pulsating flame with constant maximum possible length helps to reduce unevenness of the temperature distribution of the gas environment and, accordingly, increase the uniformity of the distribution of heat flows on the surface of the heated metal. This eliminates the possibility of the formation of local zones of overheating. The heat content and the temperature level of the metal surface located in the second half of the furnace (according to the flow of burning gases) increase.

Relating to the considered furnace the impulse heating method provided a step change of heat capacity during furnace equalizing from maximum value to the idle power. The assessment of the quality of metal heating at the existing method of heating was performed by the results of measuring of temperature in the forgings load. During the rise of temperature the variation of fuel consumption was performed in accordance with the required rate of furnace temperature increase. At the stage of equalizing the fuel supply was performed automatically: the duration of the fuel supply at the time of the impulse in the initial period of equalizing was about 3 minutes, and at the end of equalizing it was 1 min. In this case, the acceptable deviation of furnace temperature in relation to the desired temperature comprised ± 10 °C. At the end of the equalizing period, the temperature state of the test load was characterized by the following values: temperature difference by the load volume was 15 °C.

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## Conclusions

The new types of burners of partial pre-mixing are developed with wide limits of adjustment based on the GNP and pipe-in-pipe burners for natural gas and natural coke and blast-furnace mixtures. The burners provide the implementation of impulse systems of heating of chamber heating and thermal furnaces by upgrading the existing burners. The efficiency and the reliability of operation of new types of burners are confirmed in the industrial environment.

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## Инновационные горелки с широкими пределами регулирования для нагревательных и термических печей

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Представлены результаты разработки и исследования горелок частичного предварительного смешения, описана их конструкция и принцип работы, приведены результаты испытаний тепловой работы термических и нагревательных камерных печей, оборудованных горелками данного типа.