Features of ventilation at the enterprises of metallurgy and mechanical engineering

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Abstract. The processes of foundry of machine-building enterprises are accompanied by the release of excess heat and a large number of hazards. Reducing the harmful impact of enterprises on the environment should be ensured by a complex of technological and construction measures, as well as the effective operation of ventilation systems. When designing ventilation systems, it is necessary to solve an optimization problem that takes into account their energy and environmental reliability, and economic efficiency. As a result of the analysis of the reliability of ventilation systems, their energy efficiency, heat consumption for the needs of heating and ventilation of a number of metallurgical industries, in order to reduce operational energy costs, it is recommended to solve a set of problems that include increasing the level of use of secondary energy resources. The authors propose a cyclone-heat exchanger, where cleaning of dust and gas flow and its heat recovery are combined in one apparatus. Design and construction of energy-efficient ventilation systems with high technological reliability will reduce operating power consumption from 30 to 75%.

1. Introduction

Foundry production is the basis of all machine engineering. The number of operating foundries and workshops only in engineering is about 1250 units [1-3]. The foundry employs about 300 thousand people, and the output of castings per worker is 20.8 tons per year.

Production of castings composes 34% for the automobile and tractor industry, 11% for construction and road engineering, 16% for heavy and power engineering, 8% for electrical engineering, chemical engineering and light industry, 6% for machine tool technology and tool engineering, 17%, for other industries 8% [4, 5].

Processes of foundry production are accompanied by the evolution of excess heat, dust, carbon monoxide, oxides of various metals (copper, zinc, iron), fuel combustion products and the decomposition of binders. In the production of 1 ton castings of steel or cast iron, the amount of harmful emissions is: dust - 50 kg, hydrocarbons - 1 kg, carbon monoxide (II) - 250 kg, sulfur oxide (II) - 1.5-2 kg, a number of other harmful gases, such as phenol, formaldehyde, acetone, benzene. In the foundry of the blast furnace, during the release of cast iron and slag, intense heating is generated from the liquid metal and slag mirrors in the gutters and also from the buckets. Simultaneously with heat, gases (CO and CO2) in the amount of 400-600 mg / m³ and dust containing mainly iron oxide are emitted into the atmosphere of the foundry and subdomain [6]. On the average, 20-60 mg / m³ is produced in the foundry of carbon monoxide, and about 20 mg / m³ of sulfurous anhydride (Table 1).
Table 1. Harmful discharges in blast-furnace workshops.

| Workshops’ department                        | Heat amount Q, [GJ/h] | CO₂, [kg/h] | Dust, [g/t] |
|---------------------------------------------|-----------------------|-------------|-------------|
| Casting yard (for 1000 m³ furnace volume):  |                       |             |             |
| single-shot casting                         | 23                    | 35          | -           |
| multi-shot casting                          | 37,6                  | 60          | -           |
| Castings                                    | -                     | 60          | 40          |

2. Relevance

The dustiness of the casting yards of blast furnaces with a volume of 2000 m³ is characterized by the following data:
- over the tap for release of: slag 300 – 600 mg/m³, cast iron 2000 – 3500 mg/m³;
- over the drain of: slag 400- 600 mg/m³, cast iron 3000 – 4000 mg/m³;
- in the average of casting yard 40 – 50 mg/m³.

The type and amount of harmful emissions from arc steel melting furnaces and converter plants are presented in Tables 2 and 3 [7-10].

With the known space-planning and design solutions of the building, the main factors affecting the performance of ventilation systems are the climatic parameters, technological characteristics and associated gross emissions of hazards that form heat, moisture, gas, dust accumulation in production facilities, reliability of ventilation systems [11]. Incorrect quantitative and qualitative assessment of the receipt of hazards can lead to a failure in work, or to an unjustified supply of ventilation equipment.

Table 2. Harmful discharges from arc steel melting furnaces.

| Name                                           | Oven capacity, [ton] |
|------------------------------------------------|----------------------|
| Heat evolution through a furnace construction, GJ/h: |                      |
| – without taking into account a heat of breakthrough gases | 8                    |
| – with taking into account a heat of breakthrough gases (to 30%) | 9,6                  |
| Amount of released combustion products, m³/h | 3500 5300            |
| Speed of gas flow, m/s                          | 3 – 4 4              |
| Amount of dust, %, with fraction: – <3 µm | 64 64                |
| – >3 µm                                       | 36 36                |

3. Problem statement

To achieve the necessary sanitary and hygienic effect, to ensure the required microclimate parameters and air purity, significant emissions of convection and radiant heat, release of gas and dust contaminating the work area, should be prevented primarily by technological and construction measures, as well as by the efficient operation of ventilation systems [12].

Ventilation systems of the foundry are characterized by the following efficiency indicators:
- reliability (guarantee) of maintaining in the served room the required parameters of the microclimate and air purity;
- energy efficiency;
- economic efficiency.

During the process of designing ventilation systems for such productions, it is necessary to solve the optimization problem that takes into account all the efficiency indicators of the ventilation system [13,14].
Table 3. Characteristics of harmful emissions in converter workshops (per 1 ton of steel).

| Section of a workshop                          | Heat amount, [GJ/(h ton)] | CO₂, [g/(h ton)] | SO₂, [g/(h ton)] |
|------------------------------------------------|---------------------------|------------------|-----------------|
| Converter bay                                  | 0,35                      | 280              | -               |
| Casting bay                                    | 0,34                      | 360              | -               |
| Bay of repair and drying of converters         | 0,11                      | 140              | 220             |
| Bay of repair and drying of ladles             | 0,22                      | 100              | 130             |
| Exhauster                                      | 0,004                     | 4                | -               |
| Transforming substation                        | 0,0046 – 0,0011           | -                | -               |
| Mixer room (for 1 mixer): 1300 ton             | 13,38                     | 0,3              | -               |
| 1000 ton                                       | 11,29                     | -                | -               |
| 600 ton                                        | 9,2                       | -                | -               |

4. Theoretical part

Reliability is an important indicator that determines the consumer properties of ventilation systems. The reliability of the ventilation system is its ability to provide and maintain the required values of microclimate parameters and air purity in a given period of time in a served room, and under failure - the state when the values of these indicators have exceeded the specified limits.

Reliability \((P)\) - probabilistic characteristic of the operation of ventilation systems and depends on the selected system performance and equipment reliability.

The ventilation systems of the foundry are characterized by the following efficiency indicators [15]:

- air heating system with a loaded reserve heating unit \((P= 0,91)\);
- air heating system with an unloaded reserve heating unit \((P= 0,95)\);
- air heating system with an unloaded reserve fan \((P = 0,52)\);
- exhaust mechanical ventilation system \((P= 0,51)\);
- exhaust mechanical ventilation system with a reserve fan \((P= 0,85)\).

Foundry production is the main consumer of heat for heating and ventilation needs among all metallurgical industries. According to the analysis of the total heat costs at a number of plants, it is established that the foundry at the plant has a capacity of about 1 million tons / year of steel, heat consumption is about 460-545 GJ / h, and electricity - about 10,000 kWh. The need for heat and electricity by Depending on the composition and characteristics of the main equipment, individual workshops are shown in Table 4.

In this regard, in order to save thermal and electrical energy is recommended:

- to increase the thermal protection of buildings by optimizing the architectural and construction solutions of industrial buildings;
- to improve technological processes, insulation and sealing equipment in order to reduce energy consumption and reduce the allocation of harmful substances directly affecting the capacity of ventilation systems;
- to use systems and devices that ensure the least heat and power consumption, operate them in the most economical mode;
- to increase the level of use of secondary energy resources (maximally recover heat in process units, and also utilize other types of low-potential heat with the help of heat pumps) [16,17].

Machine-engineering plants, which include foundries, have significant energy resources. The overwhelming majority of the secondary energy resources of this industry are thermal, in the temperature range from 400 to 14000 °C with the output of combustion products from 300 to 10 000 m³ / h from each process unit [18]. In this regard, in order to save energy and increase the efficiency of the use of energy resources, it is necessary to use secondary energy resources for the needs of heating...
and ventilation systems and develop multifunctional devices that allow to carry out various processes and functions in one apparatus [19].

Table 4. Heat and power consumption for heating and ventilation.

| Consumer | Building volume, $[10^3 \text{ m}^3]$ | Heat consumption, $[\text{kJ/h grad}]$ | Electro energy, $[\text{kWh}]$ |
|----------|-------------------------------------|--------------------------------------|-------------------------------|
| Blast furnace with a volume of 2000 m$^3$: Bunker overpass, casting yard, top lift, rooms of shields, central air supply stations with air treatment, machine room and substations, central station for air supply and cooling of a bedding plate | 326 | 167 200 | 1 571 680 | 8 500 |
| The same, 2700 m$^3$ | 259 | 121 220 | 1 818 300 | 8 370 |
| The same, 3200 m$^3$ | 261 | 186 010 | 1 692 900 | 15 400 |
| Steel melting workshop with productivity 100000 tons per year | 1 345 | 4 180 | 313 500 | 2 200 |
| Electric arc furnace shop consisting of three furnaces with a capacity of 100 tons and two SCCP: | 900 | 82 770 | 1 450 460 | 2 500 |
| The same, in the composition of two furnaces with a capacity of 45 tons and three furnaces with a capacity of 70 tons | 503 | 22 150 | 5 430 | 200 |
| Converter workshop consisting of three converters with a capacity of 130 tons | 450 | 28 010 | 794 200 | 1 290 |
| The same, in the composition of three converters with a capacity of 250 tons | 1 000 | 207 330 | 75 2400 | 2 500 |

5. Practical significance
As an example of such a device, a cyclone heat exchanger developed by the authors is proposed [20]. The equipment refers to devices for dust collection, gas cleaning, as well as associated heat recovery of cleaned gases and can be used in various industries, including metallurgy and machine building.

The cyclone-heat exchanger is a cyclone consisting of a cylindrical and conical part located on the top of a tangential inlet for air, an inner exhaust pipe with a spiral coil attached thereto, the cylindrical part of the cyclone having screw-like outer edges and being coaxially disposed at a distance cylindrical housing with a lower tangential inlet for water and an upper branch pipe for water outlet. The technical result of using the cyclone heat exchanger lies in the fact that the presence of an outer cylindrical body, mounted on the cylindrical part of the cyclone, with screw-like ribs fixed on it, allows to combine in one apparatus the functions of cleaning the heated gas-dust stream and utilizing its heat for heating water circulating in the volume between the wall of the cylindrical part of the cyclone and the wall of the outer cylindrical body of the apparatus. The presence of ribs and their location promotes directed movement of water from the bottom to the top, providing a counterflow of water and gas-dust flow and increases the heat exchange surface. The counterflow allows maintaining a constant temperature difference between water and gas, ensuring maximum efficiency. In this case, the wall of the cyclone is cooled, increasing the efficiency of gas purification due to the emerging phenomenon of thermophoresis. Non-contact heat removal by water ensures its quality and improves the hygienic and technological reliability of the apparatus.
6. Conclusion

The design and construction of energy-efficient, high-technology heating, ventilation and air-conditioning systems would reduce operational energy costs by 30 to 75% without reducing their comfort and functionality.

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