The analysis of disperse and elemental composition of dust from drobestry installations of foundry at the production of construction structures for altitude buildings

Irina Ivanova [1,*] *Elena* Golovina[1], *Kirill* Kulakov[2] and *Andrey* Sorokin[3]

[1]Voronezh State Technical University, Moscow Avenue, 14, Voronezh, 394026, Russia
[2]Moscow State University of Civil Engineering, Yaroslavskoe sh. 26, Moscow, 129337, Russia
[3]Moscow Aviation Institute (National Research University), Volokolamskoe highway, 4, Moscow, 125993, Russia

Abstract. In the production of building structures for high-rise buildings, the dangerous and harmful factors of foundry production include high concentrations of dust and harmful gases released at various stages of the process. Disperse and elemental compositions of dust determine the hygienic state of the working area of the foundry. According to experts, the presence of dust of less than 10 microns in size in the air increases the danger of getting occupational diseases, such as pneumoconiosis (silicosis), bronchitis, dermatitis, conjunctivitis. The determination of the granulometric composition of the powder sample provided was carried out by the laser diffraction method realized on a laser particle analyzer Fritsch NanoTec «ANALISETTE 22».

1 Introduction

In the air environment of foundries in the production of building structures for high-rise buildings, in addition to dust, there are large numbers of carbon oxides, carbon dioxide and sulphurous gases, nitrogen and its oxides, hydrogen, aerosols saturated with iron and manganese oxides, hydrocarbon vapors and other [1]. Melting aggregates, heat treatment furnaces, dried for molds, rods and buckets, etc. are sources of contaminants. The foundry shop of machine-building production is located in the urban development. The degree of environmental safety is determined by the microclimate in the zone of shot blasting and the intercore zone of the plant (with dispersion of emissions).

When melting cast iron, in addition to dust, a significant amount of carbon oxides is produced, as well as sulfurous anhydride, hydrocarbons, and nitrogen oxide In induction furnaces in addition to the above ingredients, chlorine and hydrogen fluoride are released, when smelting aluminum. Foundry production is characterized by gas evolution under the influence of the heat of liquid metal on the molding mixtures. Depending on the type of

---

* Corresponding author: ivanova-eco@mail.ru

components of the molding mixtures, benzene, phenol, formaldehyde, furan, cyanide, ammonia, and other toxic substances can be released from them [2].

Dust, the main constituent of which in foundries is silica, is formed during the preparation and regeneration of molding and core mixtures, smelting casting alloys in various melting units, the release of liquid metal from the furnace, out-of-furnace processing and pouring into molds, in the knockout section of the castings, in the process stump and cleaning of casting, in the preparation and transportation of raw bulk materials.

The air condition of the working area of the foundry, as a rule, does not meet the normative hygienic requirements. This is determined by the complexity of the technological processes of production as a whole [3].

The dispersed and elemental composition of the dust also determines the hygienic state of the working zone of the foundry. According to experts, the presence of dust in the air of less than 10 microns in size increases the danger of obtaining occupational diseases: pneumoconiosis (sialicosis), bronchitis due to the low settling rate of dust and its prolonged stay in the air of the working area. In addition, fine dust and dust of less than 10 μm creates additional difficulties in dust collection [4].

2 Materials and Methods

Large particles of dust linger on the mucosa of the upper respiratory tract, particles with sizes less than 10 microns can penetrate into the alveoli of the lungs, where the main part of them is retained (Table 1). Hazard class -3, MPC = 0.5 mg/m^3.

Suspended particles can cause a toxic effect by one or more of the following three pathways [5]:

1. A particle may be toxic due to its chemical or physical characteristics.

2. A particle may interfere with one or more mechanisms by which the respiratory tract is normally cleaned.

3. A particle may be a carrier of a toxic substance absorbed thereon.

Table 1. Observed impact of suspended particles on the environment and human

Concentration, mg/m^3	Time interval	Impact result
60-180	Average annual geometric mean, in the presence of SO2 and moisture	Increased corrosion of steel and zinc plates
150	A relative humidity of less than 70%	Reducing visibility to 8 km
80-100	Simultaneous level of sulphate precipitation in 30 mg/(cm^2 per month).	Increase in mortality by 50% can occur
100-130	Concentration of S02 120 μg/m^3	Possible increase in the number of respiratory diseases in children
200	Average daily at SO2> 250 μg/m^3	Diseases of industrial workers can lead to an increase in absenteeism
300	Maximum for 24 hours with simultaneous concentrations O2>630 μg/m^3	Patients with chronic bronchitis will experience a sharp exacerbation symptoms
750	Average daily SQ2> 715 μg/m^3	Can come significant increase in diseases and deaths

Provision of safe levels of maximum permissible concentrations of pollutants in the operator's work area shot blasting area and in the wind zone of the foundry is the purpose of this work.

Due to the fact that the existing dust collection system using cyclones is not effective and there is a multiple exceeding of the maximum permissible concentration (MPC) of dust. The actual efficiency of the dust collectors in the shop is inadequate. In order to further purge the ejection into the intercorpus zone and bring the contaminants in the working area to acceptable levels, the dust collection system can be supplemented with a second "wet" stage.
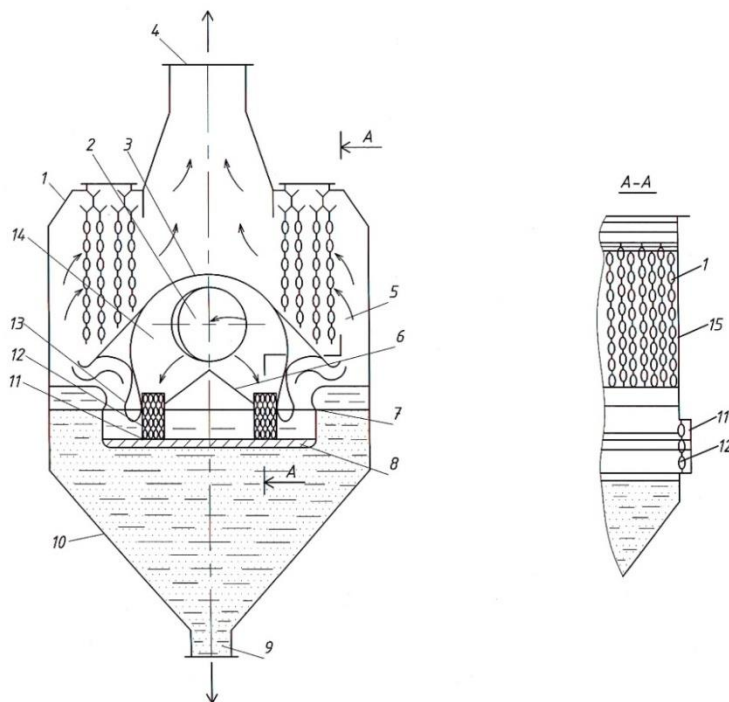

Fig. 1. Wet Dust Collector:

1 — shell; 2 — inlet branch pipe; 3 — baffle; 4 — outlet branch pipe; 5 — clean gas chamber; 6 — reflecting plates; 7 — bottom baffle; 8 — louvered grille; 9 — branch pipe for sludge removal; 10 — bunker for collection of caught dust; 11 — poket; 12 — blinded loose hanging chains; 13 — upper baffle; 14 — dusty gas chamber; 15 — drift catcher

Authors V.I. Semkin, A.V. Dumnov, N.I. Adzhiev, suggest a device for cleaning emissions, which is developed in the research and design institute for the protection of labor of building materials.

For the dust analysis, the dispersion (granulometric) analysis method was used.

Determination of the granulometric composition of the powder sample provided was carried out by the laser diffraction method implemented on the laser particle analyzer Fritsch NanoTec "ANALISETTE 22" (Fig.2, 3).

To study particles in the analyzer, the principle of comparing laser radiation from samples and the object of research is used. We used Fraungofer model. This model is used only for samples with particles larger than 0.1 μm (100 nm);

Fig. 2. General view of the laser analyzer Analysette-22 NanoTec (Fritsch, Germany)
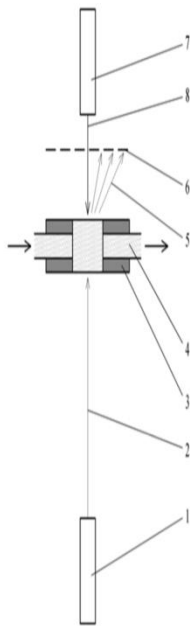

Fig. 3. Optical part of laser particle analyzer Analysette-22 NanoTec:

1 – front laser; 2 – front laser beam; 3 – measuring cell; 4 – dispersed medium containing a sample; 5 – laser-scattered sample; 6 – detector; 7 – back laser; 8 – back laser beam

3   Results

Based on the results of the analysis, the granulometric composition of the samples was determined. The results are summarized in Table 2 and are shown in Figure. 4.

Table 2. The granulometric composition of the sample, the % content of particles of a certain size.

Value,%	particle size, μm	Value,%	particle size, μm	Value,%	particle size, μm
5.0%	<= 19.285 mkm	10.0%	<=26.295mkm	15.0%	<=30.679mkm
20.0%	<=34.802mkm	25.0%	<=38.617mkm	30.0%	<=42.615mkm
35.0%	<=46.354mkm	40.0%	<=50.105mkm	45.0%	<=53.895mkm
50.0%	<=57.549mkm	55.0%	<=61.440mkm	60.0%	<=65.570mkm
65.0%	<=70.497mkm	70.0%	<=75.998mkm	75.0%	<=82.355mkm
80.0%	<=89.220mkm	85.0%	<=97.614mkm	90.0%	<=115.049mkm
95.0%	<=162.398mkm	99.0%	<=189.947mkm		

In table 1 the particle size is fixed. As a result, sample contains 90% of particles with size less or equal to 115.049μm and 10% of particles with large size. Particles of this size are dangerous for human health, as they cause pneumoconiosis.
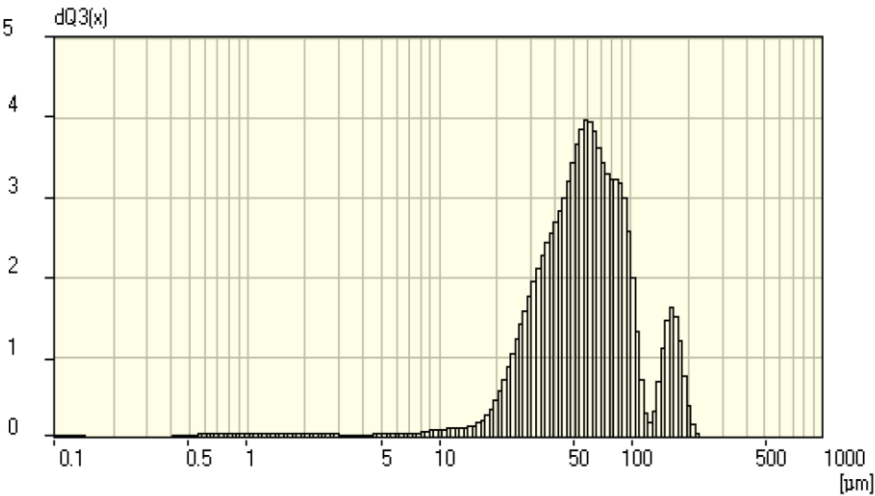

Fig. 4. Graphical results of dispersion analysis of distribution of dust particles.

The sedimentation method does not answer the question of how much particles of a certain size there are in a given system; it only shows the percentage of particles that have dimensions that are in the interval between one radius and another.

In order to estimate the dust parameters more accurately: dispersion and element composition, the X-ray phase analysis method was used, in which the following equipment was used:

1. X-ray diffractometer "DRON 04".
2. X-ray diffractometer "Radian DR-02".
3. Wave X-ray fluorescence spectrometer "Bruker S8 Tiger".

The study of the structure of dust,

The study of the structure of the dust formed during X-ray spectral analysis showed, that it, as a rule, has a form, which makes it possible to conditionally consider it spherical. When the dust particles fall, they always try to occupy the position corresponding to the greatest resistance in the air, this form contributes to their settling in the atmosphere and in inertial dust collectors. However, the presence of particles smaller than 10 μm indicates their considerable settling time and the need for highly effective post-treatment systems. As a result, 86.2% of the sample is less than 100 μm, 13.8% is heavy particles larger than 100 μm. Particles of this size are dangerous for human health, as they cause pneumoconiosis, and in the presence of a SiO_2 film of silicosis [6].

A scanning electron microscope is supplemented by spectrometers of both varieties. The quantitative analysis is based on a comparison of the intensity of the characteristic X-ray radiation from the sample under study and standards of samples of known composition. The results of calculation of concentrations and absolute random errors were displayed on the display and the printer.

In the course of the experiment, the operational error control of the measurement results for each of the chemical elements was carried out.

Control is carried out by estimating the concentrations of elements in existing standards. Initially, an analysis was performed to determine the phase composition of the substance using a DRON 04 diffractometer with CoKα radiation (1.789Å) in the range of angles 2Θ (10-110) ° at U = 29kV, I = 26mA. Table 2 and Figure 3 show an X-ray spectral analysis of the dust collected from the shot blasting section of the casting.

Table 2. X-ray spectral analysis data on the «Bruker S8 Tiger» equipment.

Sample Name	Na (%)	Al (%)	Si (%)	S (%)	Cl (%)	K (%)	Ca (%)	Ti (%)	Cr (%)	Mn (%)	Fe (%)	Ni (%)	Cu (%)	Zn (%)	Ga (%)	Zr (%)	Mo (%)	Ce (%)
Dust from shot blasting plants	0.141	21.295	27.94	0.04	0.056	0.183	0.143	0.095	0.511	0.712	48.535	0.139	0.05	0.014	0.022	0.014	0.072	0.038

The manifestation of a large number of reflexes indicates the presence of several phases in the sample. To determine the phases, a diffraction measurement database "PDF-2012" was usedDue to the large number of possible elements and phases, X-ray spectral analysis was used to reduce the possible phase variants of the sample. The survey was performed twice on the Radian DR-02 diffractometer with the function of X-ray fluorescence analysis.

X-ray spectral analysis indicated the presence of a phase of iron (Fe), titanium (Ti) and chromium (Cr). The iron (Fe) phase predominates (78%). Due to the lack of the possibility of determining the "light" elements on the "Radian DR-02" diffractometer, the X-ray spectral analysis was carried out on the "Bruker S8 Tiger" wave X-ray fluorescence spectrometer at the CCU of the NO VSU.
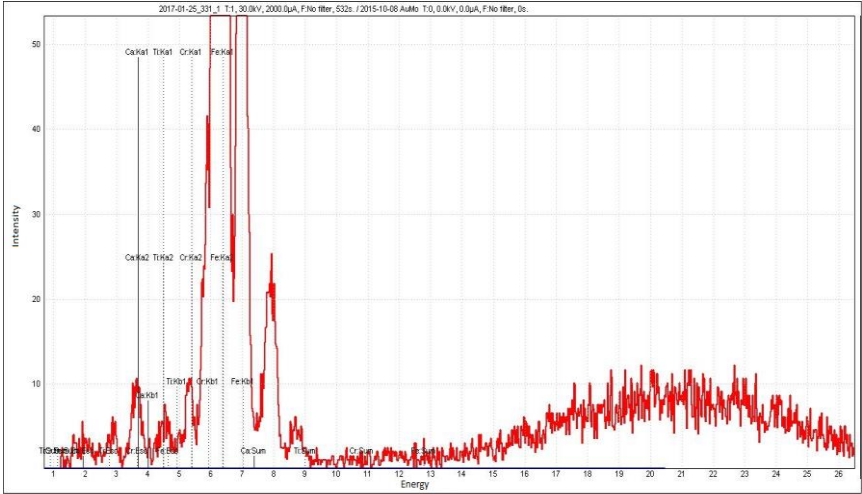

Fig. 5. X-ray spectral analysis of the sample on the diffractometer "Radian DR-02".

4 Discussions

X-ray spectral analysis showed a more accurate percentage of elements in the sample. The presence of Al, Si, Cr, Fe reduces the search time in the "PDF-2012" database for phase analysis. The phases of oxides can only be detected using the X-ray phase analysis method. The remaining elements have a small percentage value.

The results of the analysis show that in the foundries there is a presence of dispersed dust of less than 10 μm, while 78% of iron (Fe) is present in the shot blasting section in the dust. Also, the analysis of dust concentration in operator's work area revealed significant excess of the MAC of the working zone. The dispersion of the dust composition was evaluated, which showed a large amount of fine dust (less than 10 microns) of 86.2%.

In addition to dust in emissions of the foundry there are harmful gases: sulfur oxides (SO_2, SO_3), oxides of nitrogen (NO_2, NO), carbon oxides of CO and CO_2, phenol (C_6H_5OH), formaldehyde (HCHO), benz (a) pyrene ($C_{20}H_{12}$) [10,11]. Since the results of the parameter estimation are unstable, we had to use more accurate methods with the help of a diffractometer.

5 Conclusion

Dust structure research showed: when crushing, 86.2% of the dust produced has a fraction size of less than 100 μm, i.e. refers to medium and fine dust, having a settling rate of less than 7 cm/s.

It is established that the iron (Fe) content in the elemental composition of all dust is 78%, which happens due to the processing of castings with iron shot. The phase composition was refined in the second stage of the research with the help of the Radian DR-02 diffractometer and the diffraction measurement database "PDF-2012".

References

1. A.N. Boldin, Foundry, **3**, 33-34 (2005)
2. O. Kalinina, O. Valebnikova, Advances in Intelligent Systems and Computing, **692**, 1315-1322 (2018) DOi - 10.1007/978-3-319-70987-1_139
3. I.A. Ivanova, Bulletin of the DGTU, **2 (45)**, 200-204 (2010)
4. E.I. Golovina, I.A. Ivanova, S.A. Ivkov, Internet Journal of Science, **2 (39)**, 62 (2017)
5. V.L. Murzinov, V.Ya. Manokhin, E.I. Golovina, Polimatic network electronic scientific journal of the Kuban State Agrarian University, **130**, 155-172 (2017)
6. E.I. Golovina, I.A. Ivanova, M.V. Manokhin, Vestnik of the Don State Technical University, **2 (89)**, 141-148 (2017)