



DOI: <http://dx.doi.org/10.15688/jvolsu10.2014.3.8>

УДК 662.613

ББК 31.31

CLEARING AND COOLING OF SMOKE FUMES IN THE PRODUCTION OF POTTERY

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Abstract. Smoke emissions from re-fire kilns are the source of air pollution in the process of ceramic materials manufacture. In this connection, the modernized systems for purifying polluted air were designed. The authors suggest experimental research of the efficiency of clearing the gas emissions. The program of computing the hydrodynamics - Ansys CFX - allows modeling the process of gas and liquid stream. The ecological result of implementation of this system consists highly in utilization of waste-heat and betterment of ecological conditions in industrial zones.

Key words: pottery work, Dynamic Separator, smoke fumes, emissions, dust, Ansys CFX.

1. Introduction

Ceramics are the foundation of many microelectronic circuits, acting as the substrate to deposit conductive, resistive, and dielectric films to form interconnections and passive components. They are formed by the bonding of a metal and a nonmetal and may exist as oxides, nitrides, carbides, or silicides. Ceramics are ideal as substrates for thick-film and thin-film circuits because they have a high electrical resistivity, are very stable chemically and thermally, and have a high melting point.

Refractory materials are the pottery work, capable to stand temperature from above 1500 °C.

Refractory products of a various size and form are applied in many industries at exhaustion of a steel, pig-iron, cement, to exhaust, glasses, ceramics, aluminium, copper, on petrochemical manufactures, in furnaces for incineration of rubbish, on power stations, in systems of household heating, including boiler-houses. These products are necessary at high-temperature processes and are capable to resist to any kinds of voltage (mechanical, thermal, chemical), for example, to erosive deterioration, a creep strain.

The basic source of air pollution in manufacture of ceramics and refractories are smoke emissions from furnaces in the course of roasting. Contaminants are formed because of the maintenance of impurity in raw materials. Their

composition can vary depending on raw materials source, and also depends on type of used fuel. The problem is created by emissions of fluorides (containing in mineral ore), and also sulphur oxides (containing in minerals and sulphates). If glaze is used it is put in the course of roasting. Glaze is possible to a vaporous state and is put on a surface of a finished product for formation of a glossy surface.

The bulk of steams of glaze is taken out in the aerosphere. If the fuel oil furnace or the emissions of dust and coal increases, the sulfur oxides are used.

2. Substrate Manufacturing

Ceramics are made of various raw materials and burnt in furnaces of different types. Finished articles have various form, sizes and colour. The general process of manufacturing of ceramics is equal to all its aspects though by manufacture of a facing and low-ground tile, ware and ornamental products (economic-household ceramics), engeneering ceramics roasting often spend to some stages. Roasting of refractory materials conduct at temperatures 2050-2850 °C (Table 1).

Table 1

Melting Points of Selected Ceramics

Material	Melting Point (°C)
SiC	2700
BN	2732
AlN	2232
BeO	2570
Al ₂ O ₃	2000

The stand-up temperature depends on composition of a product and can attain the beginning of a temperature interval of deformation. At factory the gas-cleaning installation - the cyclone separator is installed. Separation efficiency of a waste-heat under the theoretical data should make 94 %. However, in reality, the separation efficiency does not exceed 70 %.

The smoke fumes which are released from the furnace at a high temperature, contain a lot of dust, resinous substances, chloride of metals and are unsuitable for swapping by gas compressors as the presence of impurity in it and high

temperature lead to rapid corrosion, to abrasive wear of expensive equipment (gas compressors) and to formation of the adjournment consisting of resinous and other substances.

For raise of efficiency of clearing of gas refire kiln redesign has been made. It has allowed to increase efficiency of process of clearing of gas emissions by 15-20 %.

3. Laboratory Facility and Technique of Conduction of Experiment

Dynamic gas washer, according to Fig. 1, contains the vertical cylindrical case with the bunker gathering slime, branch pipes of input and an output gas streams. Inside of the case it is installed conic vortex generator.



Fig. 1. The laboratory facility

Dynamic gas washer works as follows. The gas stream containing mechanical or gaseous impurity, acts on a tangential branch pipe in the ring space formed by the case and rotor. The liquid acts in the device by means of an axial branch pipe. When the dispersion liquid phase contact area increases and therefore the efficient use of the working volume of the device is more effective. The invention is aimed at increase of efficiency of clearing of gas from mechanical and gaseous impurity due to more effective utilization of action of centrifugal forces and increase in a surface of contact of phases. The centrifugal forces arising at rotation of a rotor provide crushing a liquid on fine drops that causes intensive contact of gases and caught particles to a liquid.

Owing to action of centrifugal forces, intensive hashing of gas and liquid and presence of the big interphase surface of contact, there is an effective clearing of gas in a foamy layer. The water resistance of the irrigated apparatus at change of loadings on phases has been designed. Calculated the angular velocity of rotation of the rotor and rotating guide vanes air swirler.

In Fig. 2 results of an experimental research of efficiency of clearing of dust are shown. For different diameter of the dust particles an increase in overall separation efficiency with decreasing concentration.

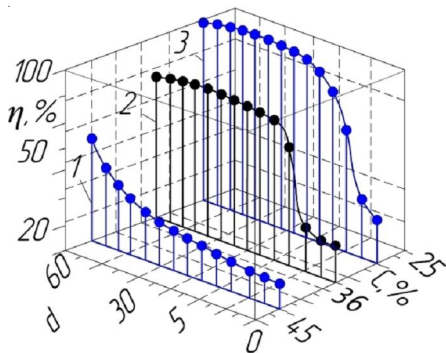


Fig. 2. Dependence of efficiency of separation on diameter and concentration of corpuscles

4. Numerical Simulation and Calculation of Clearing of Dust in the Apparatus

The algorithm of modelling the process of separation of a dispersoid in a gas stream with irrigation by a liquid has been developed. The carried out calculations allow to define potential possibilities of a dynamic scrubber at its use in the capacity of the apparatus for clearing of gas emissions. Verification of the data gained by calculation, and also an estimation of the parametres defining possibility of separation of a dispersoid on drips of an irrigating liquid, is modelled as the process of water gas stream in a packet of computing hydrodynamics Ansys CFX (Fig. 3). Numerical research of work of a scrubber will allow to analyse its work for the purpose to decrease power inputs at conservation of quality of gas cleaning. The developed model helps to simulate traffic of a dusty gas stream sweepingly and visually. The model can consider modification of geometry of the apparatus. Thus, the model can be applied in optimisation of dynamic scrubber design.

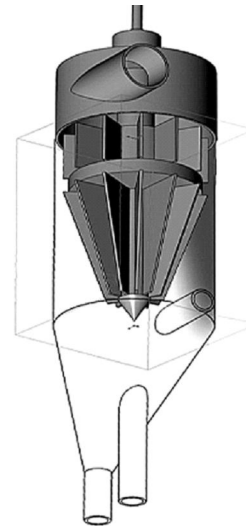


Fig. 3. Geometrical model of a scrubber

Quality gained on the basis of conducting of computing experiment results directly depends on quality of the builtd desing grid. Preprocessor GAMBIT allows to create and process sweepingly geometry of investigated processes. Ansys Mesh possesses the powerful oscillator of the grids, allowing to create various types of grids: the structured hexahedral grid, automatic (not structured) hexahedral and a grid tetrahedron (Fig. 4). Besides, there is a possibility of creation of boundary layers with the combined grids. After construction of a grid the user has possibility to muster its quality on various parametres (displacement of elements, a relationship of sides).

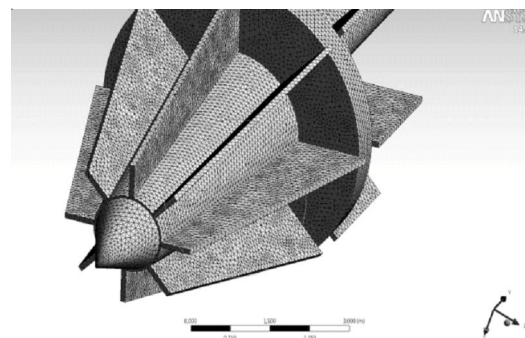


Fig. 4. Typical desing area, a desing grid and a surface of the interface of a twirled vortex generator

In Ansys CFX possibility of reception of integrated parametres of calculation, including typical for dedusters is realised also: the hydraulic resistance, a pressure, an input, efficiency of

clearing, swirling flow, and possibility to edit the formula on which these parameters are computed.

5. Clearing of Gases of a Dust in the Industry

The had results have been almost implemented in manufacture of roasting of refractory materials at conducting of redesign of system of an aspiration of smoke fumes of kilns. The devised scrubber is applied to clearing of smoke fumes of kilns of limestone in the capacity of the another echelon of clearing.

Temperature of gases of baking ovens in main flue gas breeching before the exhaust-heat boiler 500-600 °C, after exhaust-heat boiler 250 °C. An average chemical compound of smoke gases (by volume): 17 % CO₂; 16 % N₂; 67 % CO. Besides, gas contains 70 mg/m³ SO₂; 30 mg/m³ H₂S; 200 mg/m³ F and 20 mg/m³ Cl. The dustiness of the gas at the outlet of the converter is 200 mg/m³ and a dust composed of the same components but has a different content

of iron oxides. In one micron gas dust generated during the afterburning of carbon monoxide contained more iron oxide particles. This can be explained by the fact that the post-combustion of CO gas and the temperature rises there is an additional pair of excess oxides. Carbon monoxide is cleared before in a special chamber. The dustiness of the cleared blast-furnace gas should be no more than 4 mg/m³. The following circuit design (Fig. 5) is applied to clearing of the blast-furnace gas of a dust.

Gas from a furnace mouth of a baking oven 1 on gas pipes 3 and 4 is taken away in the gas-cleaning plant. In raiser and downtaking duct gas is chilled, and the largest corpuscles of a dust which in the form of sludge are trapped in the inertia sludge remover are inferred from it. In a centrifugal scrubber 5 blast-furnace gas is cleared of a coarse dust to final dust content 5-10/m³ the Dust drained from the deduster loading pocket periodically from a feeding system of water or steam for dust moistening. The final cleaning of the blast-furnace gas is carried out in a dynamic

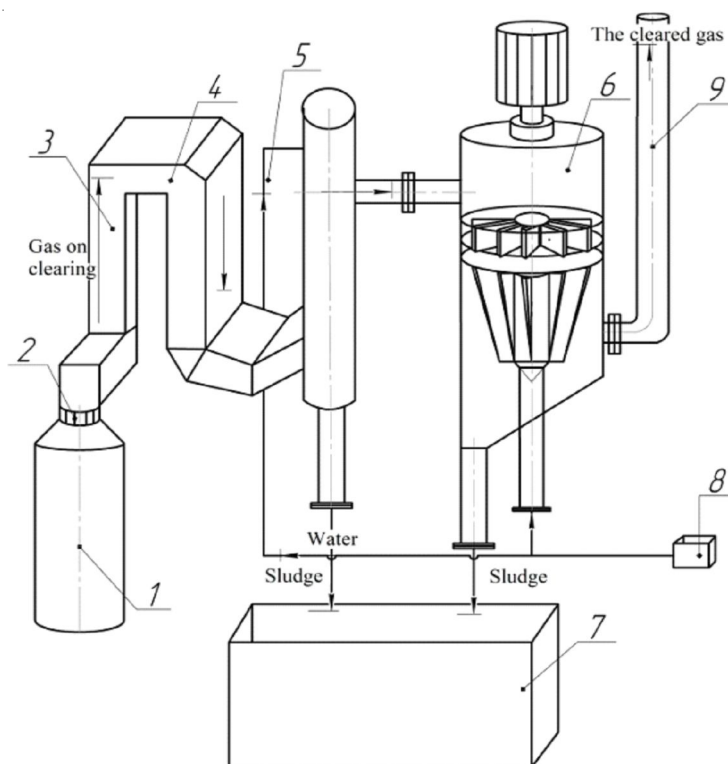


Fig. 5. Process flowsheet of clearing of gas emissions:

- 1 - bake roasting; a 2 - water block; a 3 - raiser; 4 - downtaking duct; a 5 - centrifugal scrubber; a 6 - scrubber dynamic;
- a 7 - forecastle of gathering of sludge; a 8 - hydraulic hitch; a 9 - chimney

spray scrubber where there is an integration of a finely divided dust. Most the coarse dust and drops of liquid are inferred from gas in the inertia mist eliminator. The cleared gas is taken away in a collecting channel of pure gas, whence is fed in an aerosphere. The clarified sludge from a gravitation filter is fed again on irrigation of apparatuses. The closed cycle of supply of irrigation water, and irrigation is used as milk of lime close to the physical and chemical properties of dusty gas. As a result of implementation of trial installation clearings of gas emissions the maximum dustiness of the gases which are thrown out in aerosphere, has decreased 3950 mg/m³ to 840 mg/m³, and from total emissions of dust from sources of limy manufacture were scaled down about 4800 to/a to 1300 to/a.

Such method gives the chance to make gas clearing in much smaller quantity, demands smaller capital and operational expenses, reduces atmospheric pollution and allows to use water recycling system.

6. Conclusion

1. The basic source of air pollution in manufacture of ceramics and refractories are emissions of smoke from furnaces in the course of roasting. Contaminants are formed because of the maintenance of impurity in raw materials. Their composition can vary depending on raw materials source. The special problem is called by emissions of fluorides.

2. For the first time research of hydrodynamics and dynamic spray scrubber separation in bundled software Ansys, on the laboratory and trial installation, allowed to study character of interconnection of the basic aerohydrodynamic parameters from design features of the apparatus is conducted.

3. On the devised trial installations the results which have been obtained during mathematical modelling of process of motion and separation of dispersion particles from a gas stream are experimentally confirmed.

4. The ecological result of implementation of systems and recommendations consists highly of clearings of waste-heat and betterment of ecological circumstances in industrial zone.

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**ОЧИЩЕНИЕ И ОХЛАЖДЕНИЕ КОПТИЛЬНОГО ДЫМА
ПРИ ПРОИЗВОДСТВЕ ГОНЧАРНЫХ ИЗДЕЛИЙ**

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Аннотация. При производстве керамических изделий выбросы дыма, образующие в процессе работы печей повторного обжига, являются источником загрязнения воздуха. В связи с этим создаются модернизированные системы очистки загрязненного воздуха. Программа вычисления гидродинамики Ansys CFX позволяет смоделировать процесс образования потоков газа и жидкости. Экологический результат эксплуатации данной системы состоит преимущественно в утилизации теплоотходов и улучшении экологических условий в промышленных зонах.

Ключевые слова: керамическое изделие, динамический разделитель, коптильный дым, пыль, Ansys CFX.