Testing the operation of the developed swirling scrubber

Sabokhat Ganieva*, *Nazora* Khudoyberdiyeva, and *Razzoq* Jalilov

Navoi State University of Mining and Technology, Department of Chemical Technology, Navoi, Uzbekistan

Abstract. The article presents a study on the intensification of gas purification from solid particles using the hydrodynamic effect of centrifugal forces. An effective vortex dust collector design has been developed and is being implemented in production for cleaning from harmful impurities. The results of tests conducted at the facility to determine the efficiency of dust collection in a vortex apparatus with a tangential inlet of gas and liquid flow at various operating parameters are presented. The study found that the efficiency of the device increases with an increase in dust concentration. In the vortex apparatus, the efficiency of dust collection increases significantly with an increase in the axial flow velocity, which is characterized by an increase in centrifugal force and separation factor. The optimal operating modes of the developed vortex apparatus have been established in terms of the efficiency of dust collection.

1 Introduction

Today, all over the world, including in our republic, there is a rapid development of industry, bringing prosperity to our people, has its negative consequences. Among these problems, atmospheric air pollution is the most dangerous and harmful. Currently, in Navoi region alone, in addition to large industrial enterprises, there are more than 200 small enterprises of various industries that discharge harmful gases into the atmosphere. In turn, all this causes environmental damage to the atmosphere, exhaust gases containing dust, toxic and carcinogenic substances are emitted [1, 2, 3, 4].

The installation of sewage treatment plants at all large and small industrial enterprises has become a contemporary requirement. Otherwise, it will lead to environmental disruption and, as a result, will have a very bad effect on the health of the population. It is extremely important that each enterprise, analyzing its economic development from an environmental point of view, make the necessary changes to neutralize waste gases in accordance with environmental acceptable indicators.

It is known that much attention is paid to conducting research and introducing into production results that support the hydrodynamic effect of centrifugal forces of gas purification, contact heat transfer, absorption, rectification, drying and other processes occurring during the contact of gas and liquid phases.

* Corresponding author: saboxatganiyeva981@gmail.com

In such equipment, one phase or both phases move in a vortex, and are called centrifugal or vortex equipment. First of all, due to the circular motion of the medium, while maintaining the residence time inside the equipment, it is possible to increase the gas velocity. This, in turn, will make it possible to increase the performance of the equipment. Increasing turbulence due to an increase in the working media of the flow and the appearance of relative motion (velocity) of the phases in the vortex equipment, the contacting surface of the media and the driving force of the processes increase, and, as a result, the processes are accelerated.

For many years, under the leadership of the team, professor of technical sciences at the department of chemical technology of the Navoi state university of mining and technology, Hoshim Bakhronov conducted scientific research on the purification of exhaust gases coming from industrial plants. In the years since professor Hoshim Bakhronov has achieved significant success, is the author of numerous scientific papers on the design of vortex devices for cleaning gases from dust. The purification of gases from solid particles, as well as to accelerate the cooling processes of atmospheric air and circulating waters of industrial enterprises and increase their efficiency by improving vortex devices, has found its application in several large enterprises of the city of Navoi.

As a result of these studies, the design of vortex equipment designed to perform processes in which gas waste is recorded was developed. Compared with the currently used traditional equipment, this device differs with higher productivity and efficiency, theoretical and experimental studies have been conducted, studied and tested in industrial tests.

It should be noted that based on theoretical and practical analyses conducted in 2022-2023, the vortex devices under study were further improved, a simplified design of the device was developed with high efficiency and has an expanded scope of application. Everything is covered in detail in the articles [5, 6, 7].

Preliminary studies have confirmed the high efficiency of this equipment in carrying out the processes of dust removal of gases and other chemical processes. For this reason, a comprehensive program of in-depth studies of a vortex apparatus designed to perform various processes is being developed.

2 Research methods

In order to study the hydrodynamics of the apparatus, their intensity in the processes of cleaning gases from dust and toxic gaseous substances, an experimental device was assembled (Figure 1). This device mainly consists of the 1-high–pressure smoke pump; 2-vortex scrubbers; 3-hopper separator; 4-spray trap; 5, 6-absorbent pumps and control and measuring devices.

Studies have been conducted to study the hydrodynamics of the vortex apparatus (hydraulic resistance, spray wear, vortex flow structure and vortex damping), to determine the effectiveness of vortex equipment in heat exchange processes such as dust removal, gas and liquid, evaporative cooling, direct air cooling of liquids, purification of gases from toxic substances by the absorption method and their drying, increasing air humidity. Centrifugal machines have also been tested in industrial conditions. The influence of the velocity of the gas phase and the flow rate of the liquid, as well as the geometric dimensions of the vortex-forming nozzle of the apparatus, which is the main element of the equipment, on the efficiency of the equipment in the implementation of hydrodynamic, thermal and metabolic processes, has been studied.

The ratio of the surface of the cross-section of the apparatus F to the surface of the cross-section of the channel of the device forming the vortex $F_{ch.d}$ is the main geometric characteristic of the device and is denoted in the literature by the letter A, and is also called the rotation coefficient [4, 5, 6, 7, 8, 9]:

$$A=F/F_{ch.d} \quad (1)$$

With an increase in this ratio, the intensity of the process performed in the vortex equipment increases, and with it the hydraulic resistance of the equipment. It was also studied that in equipment with a tangential input, an increase in the length of the apparatus, or rather the ratio of the height of the vertical equipment H to the diameter H/D, leads to the disappearance of rotational motion and a decrease in the intensity of the process.

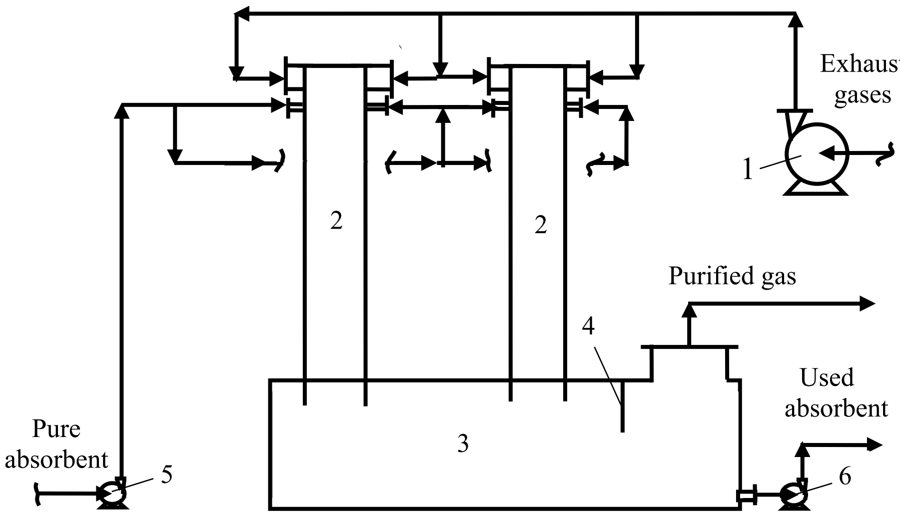

Fig. 1. Installation diagram application of vortex devices for exhaust gas purification:1 – high–pressure smoke pump; 2 – vortex scrubbers; 3 - hopper separator; 4 – spray trap; 5, 6 – absorbent pumps.

The energy efficiency of the equipment is determined by their hydraulic resistance. This value accounts for the bulk of the operating costs when performing a certain process. Any process can be accelerated by increasing the speed of the working environment. But at the same time, the hydraulic resistance of the equipment increases sharply. Therefore, the hydraulic resistances of various designs of the gas pumping device of the vortex apparatus were measured (in this part of the vortex apparatus, also called a rotary device, the gas pressure is greatly lost) at their various sizes, as well as vortex apparatuses in which liquid is not introduced and different amounts of liquid are introduced into them, with a wide range of gas velocities [10-15]. It has been found that as the velocity of the gas phase and the flow rate of the liquid phase increase, the hydraulic resistance increases rapidly. Increasing the value of the rotation coefficient also increased the gas pressure loss.

3 Results and discussion

At the maximum value of the investigated rotation coefficient A = 3, the ratio of the mass flow rate of the liquid and gas phases L_m/G_m = 3.0 and the average gas flow rate in the apparatus of 30 m/s, the hydraulic resistance of the vortex equipment increased to 3000 Pa. But this indicator, with the same performance as traditional devices designed to perform the above-mentioned processes, is much lower.

In experiments, the average flow rate in the cross section of the apparatus, determined by the volume flow rate of the gas phase, varied within 10-30 m /s, the ratio of the mass flow rate of the liquid and gas phases-within Lm / Gm = 0,5-3,0. Special attention was paid to the dispersion analysis of dust.

The following value was used as the main criterion for evaluating the operation of the vortex apparatus, determined by the ratio of the amount of dust captured to the total amount of dust entering the apparatus, and called the dust removal efficiency (in %) [9, 10]:

$$\eta = \left[\frac{M_{entr} - M_{exit}}{M_{entr}}\right] \cdot 100 = (G_{V_{entr} \cdot C_{entr}} - G_{V_{exit} \cdot C_{exit}})/(G_{V_{entr} \cdot C_{entr}}) \cdot 100 = ((C_{entr} - C_{exit})/C_{entr}) \cdot 100 \quad (2)$$

in this equation, M_{entr}, M_{exit} are, respectively, the mass flow rate of dust particles at the entrance to the apparatus and at the exit from it, kg/s; $G_{V_{entr} \cdot C_{entr}}$, $G_{V_{exit} \cdot C_{exit}}$ are the volume flow rate of the gas phase at the entrance to the apparatus and at the exit from it, m3/s; C_{entr}, C_{exit} are, respectively, the volume concentrations of dust particles at the entrance to the device and its outlet, kg/m3.

Table 1. The results of the experience.

Description	**Temperature °C**	**Pipe diameter, mm**	**The intersection area**	**Air flow rate m/sec**	**Volume of gas-air mixtures m³/sec**	**Dust m³/sec**
Vortex scrubber before cleaning	280	1600	2.009	20.4	40.98	9430.97
Vortex scrubber after cleaning	100	1600	2.009	2.36	4.75	101.4

$$\eta = ((C_{entr} - C_{exit})/C_{entr}) \cdot 100 = ((9430{,}97 - 101{,}4)/9430{,}97) * 100 = (9329{,}57/9430{,}97) * 100 = 98{,}9\%$$

4 Conclusion

The analysis of the results in the form of a dependence of the efficiency of dust removal in an apparatus with two different sizes of dust particles (8-9 and 3-3.5 microns) in the case when the ratio of the mass flow rate of water to the mass flow rate of gas is $L_m / G_m = 2$, on the average gas flow rate inside the apparatus showed the following. With an increase in the gas velocity from 12 m/s to 18 m/s, the efficiency of gas purification from dust increased for cases of purification from particles of both sizes. The rate of increase of η remained almost unchanged even for particles of two different sizes when the gas velocity exceeded 19 m/s. At the same time, the purification value for a particle with a diameter of 8-9 microns increased to 99.6-100%, and for a particle with a size of 3-3.5 microns-to 98-99%.

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