Current Trends in Natural Sciences Vol. 8, Issue 15, pp. 17-22, 2019

Current Trends in Natural Sciences (on-line)
ISSN: 2284-953X
ISSN-L: 2284-9521

Current Trends in Natural Sciences (CD-Rom)
ISSN: 2284-9521
ISSN-L: 2284-9521

INDUSTRIAL AIR PURIFICATION SYSTEM USING ULTRASONIC VIBRATION

Dan Nițoi [1,*], Gheorghe Amza [1]

[1]University Politechnica of Bucharest, Splaiul Independentei no. 313, sect.6, Bucharest, Romania

Abstract
The paper presents a detailed analysis of the main disadvantages presented by the classic devices of filtration and purification of gases of any nature and the most important characteristics of the ultrasonic air filter. Following the analysis of the main phenomena that occur in the propagation of ultrasounds it is proposed to use the effects of their propagation in the filtration and purification process and the construction of ultrasonic filters operating on the principle of "ultrasonic agglomeration" on the principle of "ultrasonic shaking" or combined. By "ultrasonic agglomeration" of fine particles, their initial mass increases by coalescence of 2500 to 3500 times compared to the mass of the primary particles, being easily captured by the filter element, and by "ultrasonic shaking" the phenomenon of stomping of the cartridge filtering or clogging, performing cleaning during operation, without requiring interruption of gas transport and removal of the filter. In the paper are presented two types of ultrasonic filters with possible use in gas filtration and purification: cyclone ultrasonic filter and vertical ultrasonic filter. For the first one it is proposed only the schematic diagram but for the second type the schematic diagram and practical realization are presented.

Keywords: air, purification, ultrasonic, vibrations

1. INTRODUCTION

The article presents a part of the work carried out by authors in the field of ultrasound applications, namely industrial air filtration. Based on long experience in the field of theoretical study and practical achievements, the authors have come to the design and execution of an industrial air filtration system based on the production of mechanical vibrations in the ultrasonic field. This achievement is in line with the strong tendencies of sustainable development at present, in which it is desired to create a natural environment in which the current generation, and especially the next, to live.

As current industrial filters are known, they are based on materials with a strong impact on people's health, such as active carbon or glass fiber. Over time, they become embarrassed, and besides the fact that they no longer perform the filtering process, they act in the most unfortunate way by particle contamination of human operators operating in the areas adjacent to their installation. The process of changing a filter already used with a new filter itself involves emanating into the workplace an extremely large number of harmful particles followed by their inhalation.

In this respect, renouncing their use is a very important goal and a first step has been made by designing and making this type of filter in which the air to be filtered will pass through a very fine array of holes and based on ultrasonic wave properties industrial air could be cleaned at the exit having an advanced degree of purification. Usual gas purification processes can be based on the

*Corresponding author, E-mail address: nitoidan@yahoo.com

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following processes or unitary operations: absorption into a liquid called absorbent, absorption on a solid material called absorbent, fractionation, crystallization and filtration, chemical conversion of impurities, special processes. The most commonly used filter and gas purification devices are filters of different shapes and categories, which are characterized by the following elements:

- gas flow transported and which are taken over by the filters;
- particle diameter that can be retained;
- maximum temperature of the gases brought into the filters;
- degree of retention or the efficiency of the filter;
- annual maintenance costs.

In order to reduce some of the disadvantages of classical filters and to substantially improve the gas filtration process, the research contained in this paper proposes the use of ultrasonic waves in the filtration and purification process, following the analysis of the main phenomena occurring in the propagation of ultrasonic waves through a gaseous medium.

2. CONTRIBUTIONS TO THE DESIGN OF ULTRASONIC FILTERS TO BE USED IN GAS FILTRATION.

To design such filters, it is necessary to know the particularities of ultrasonic wave propagation in a gaseous medium (Joseph, 1999; Ahmad and Akdogan, 2008; Kikuchi, 2009; David and Cheeke, 2012; Nakamura, 2012).

Analyzing the main phenomena and effects of ultrasound propagation through gaseous media and taking into account the kinetics of the natural gas filtration process, a series of filters were designed to perform the filtration and design operation with increased efficiency.

In choosing the appropriate filter, the following considerations were considered:

- the construction is as simple and easy to install in the working zone;
- do not require important structure changes in positioning and fixing elements when replacing the classic filter with an ultrasonic filter;
- not require dismantling to clean the filter element, cleaning periodically when the pressure drop reaches a limit value by commanding the operation of the ultrasonic transducer;
- to allow the restraint of the finest particles resulting in pure natural air to the final consumer (in some technological processes);
- have a much longer operating life than conventional filters in the sense that the ultrasonic activated filter elements have a higher reliability;
- to create stationary waves to allow not only the very fine particle retention but also the drying of the gases so that in the measuring, checking and metering instruments the natural gas can flow without impurities and dry;
- allow easy maintenance, the operating costs of which do not exceed the costs of the classic ones.

The first type of ultrasonic filter shown is designed so that stationary ultrasonic waves are excited in the filter body (Figure 1) and periodically when it is necessary to clean the filter to resonate. Due to the producing a stationary ultrasonic vibration field, a specific coalescence phenomenon occurs and the possibility of retaining this type of filter is very high. Fine and very fine particles are collected in the pressure nozzles where they form larger particles that are then trained on the outer trajectories being projected onto the filter wall and sent to the drain device for solid and liquid impurities. Also, ultrasounds during their propagation by making successive zones of pressure and depression will also lead to the continuous extraction of existing liquid or vapors in the gas stream. In the figure 1 this first filter type is presented.

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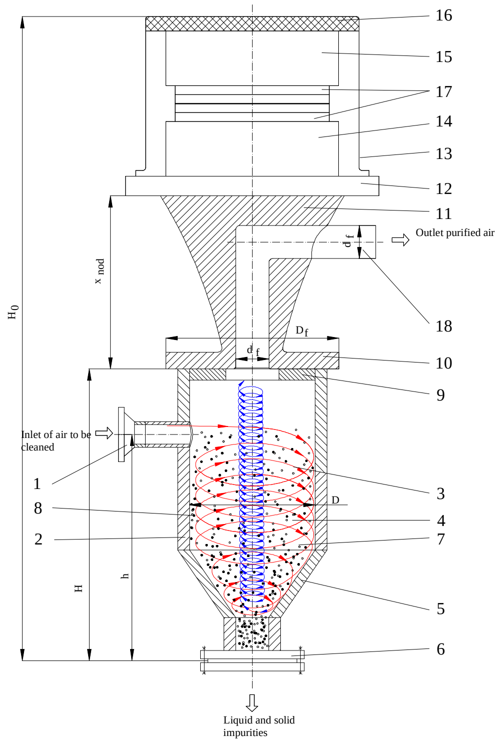

Figure 1. Ultrasonic filter design

1 - inlet of air to be cleaned; 2 - filter wall; 3 - helical air current; 4 - solid impurities; 5 - conical decantation wall; 6 - leakage tank for solid and liquid impurities; 7 - liquid particles; 8 - dust particles deposited on the filter walls; 9 - sealing ring; 10 - radiant flange; 11 - ultrasonic energy concentrator; 12 - nodal flange; 13 - ultrasonic transducer; 14 - radiating element; 15 - reflector; 16 - acoustic insulation; 17 - piezoceramic elements; 18 - outlet of purified air.

3. DESIGN AND CONSTRUCTION OF AN AIR FILTER BASED ON ULTRASONIC VIBRATIONS

The schematic diagram of the ultrasonic filtration system shown in figure 2. It consists of two main parts (presented according to the vertical position in which the system is mounted during operation), namely (Amza et al., 2016):

- in the upper part there is the ultrasonic transducer that aims to transform the electric oscillations into mechanical oscillations in the range f = 18 .... 100 Khz. These oscillations are reflected and then amplified and transmitted to the conical ultrasonic concentrator.

- In the lower part of the construction there is the vibrating disk with a very fine network of holes mounted at the top of the concentrator. The diameter of the holes is d = 0.2 mm. The disk perform mechanical oscillations of ultrasonic frequency and the air passing through the orphanages is cleaned in over 96%. Very small impurities are collected in the syringe tank. These fall into the extreme, inferior part of the system, by gravitational force, and get inside it. For additional mechanical cleaning, after the air has been passed through the sieve with holes, it is passed through the cylindrical particle filter.

Since the diameter of the holes in the perforated disc is very small, there is a danger that they may become clogged with the micro-particles of the air to be cleaned. This will not happen because of the phenomenon of ultrasonic shaking that will always keep the holes inside the disk very clean. This type of ultrasonic filter works in vertical position, but in the figure 2, the presentation is in the horizontal position considering the article presentation (Gururaja et al., 1985; Nascentes et al., 2001; Amza et al., 2015; Amza et al., 2016).

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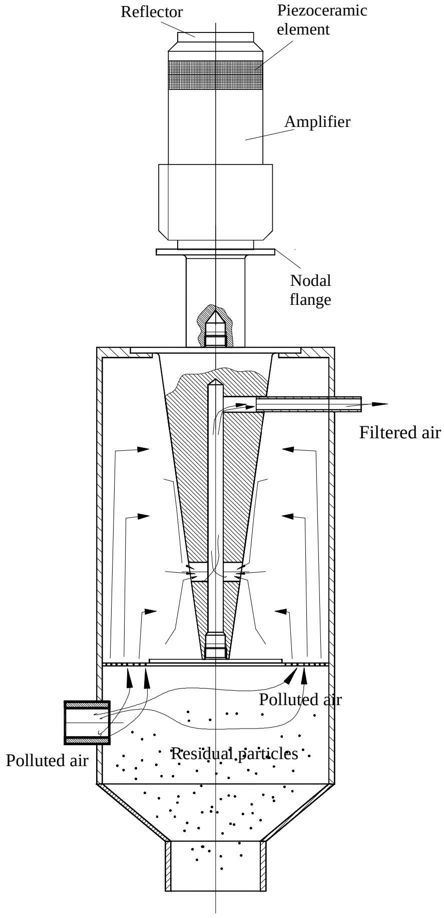

Figure 2. Ultrasonic filter system

According to the schematic diagram presented in figure 2, the main constructive elements of the ultrasonic filter, elements to be presented in this article are:

1. - Ultrasonic transducer, presented in the figure 3;

Figure 3. Ultrasonic transducer

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2. - Ultrasonic amplifier, presented in the figure 4;

Figure 4. Ultrasonic conical amplifier

3. - Vibratory disc with holes, presented in the figure 5;

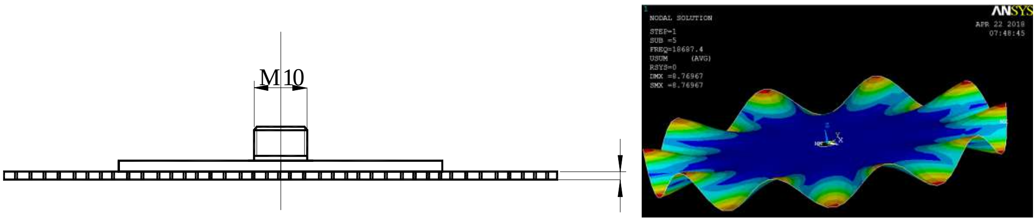

Figure 5. Vibratory disk at vibration frequency f = 18688 Hz

4. - Nodal flange, presented in the figure 6.

Figure 6. Nodal flange

4. QUALITY OF AIR FILTERED

For certifying this new filtering system an Megalizer 9600 instrument was used to measure the air quality resulting from filtration with the new system. Some of the measured values of chemical components are presented in Table 1.

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Table 1. Concentrations of noxes and suspended particles measured with Megalizer 9600 instrument

Day no.	Measured value						
	NO_2 ppm	SO_2 ppm	CO ppm	NO_x ppm	acetone mg/mc	powders mg/mc	butyl acetate mg/mc
1	0.32	0.15	3.9	2.5	13	0	3.1
2	0.35	0.78	4.7	2.6	16	3	3.5
3	0.44	1	4.2	2.5	16	3	1.9
4	0.28	0.72	4.8	2.5	15	2	1.8
5	0.37	0.49	5.3	2.6	14	2	1.8
VLE	10	1515	30	50 cumulative	1210	10	150
Medium Conc.	0.352	0.628	5.58	2.54	74	0.2	2.36
	96.5	98%	81.4	95%	98.7	99%	98.4

5. CONCLUSIONS

Following the analysis of the results obtained by the measurements, the following conclusions can be drawn:

1. It is noted that there are no exceed of the limit measured values for any polluting substance in the case of using of the ultrasonic vibration filtering system, the degree of retention being in the range of 95 ... 99%, in some cases (powders in suspension) even 100% on some days;
2. The ultrasonic filter system has the advantage that filter change is not necessary and the life of the new filter type depends only on the life of the piezoceramic elements that make vibration of the disc with holes in the ultrasonic field.

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*Corresponding author, E-mail address: nitoidan@yahoo.com