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Practical realisation and experimental results of ultrasonic filters used in air filtration

Dan Niţoi[1,*], *Zoia* Apostolescu[1], *Gabriel* Iacobescu[1], and *Corneliu* Rontescu[1]

[1]University Politehnica of Bucharest, Splaiul Independenţei no. 313, Bucharest, Romania

Abstract. Article presents the researches performed in order to achieve an air filter based on the ultrasonic cavitation phenomenon. This filter can be used in purification of polluted air from the highly polluting processing technology of an industrial shop (paint shops, foundries, welding constructions, forging, etc.). Practical realization elements of ultrasonic filter based on cavitation phenomenon and experimental results are described and presented. Experimental researches have shown an increased efficiency of using this type of filter (retention of microparticles larger than 1.0 μm, smoke retention and increase of duration of filter operation more many years). Besides these, advantages of using ultrasounds in the pollutant air filtration and purification process and an ultrasonic filter designed are presented.

1 Design and realization of the ultrasonic system used for industrial air filtration using the ultrasonic cavitation phenomenon

1.1 Design and construction of the cavitation bath used in air filtration

In the field of ultrasonic air filtration there is relatively little research and the present paper aims to awaken the practical experiments done for this purpose. Because the main phenomenon used in the ultrasonic filtration process is ultraacoustic cavitation, a phenomenon that occurs at the propagation of ultrasonic waves through a liquid medium, the team has carried out a series of researches on ultra-acoustic cavitation bath design [1-2].

Taking into account the air flow, these dimensions were considered useful for the operation of a small working water tank. The depth of the tray in which the liquid is located is 350 mm. As a result of the research on acoustic cavitation, the design of the water tank in which the industrial air filtration is produced, the geometric dimensions of which are shown in Figure 1.

A ten-element ultrasonic transducer network was placed on the bottom of the water tank as shown in Figure 2. As can be seen from Figure 2, the distances between the ultrasonic transducers have been designed so as to achieve an optimal transfer of ultrasonic energy to the liquid medium in which industrial air filtration will occur through ultra-acoustic cavitation [3].

*Corresponding author: nitoidan@yahoo.com

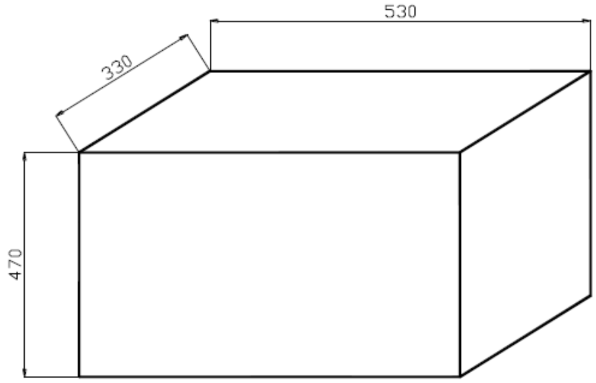

Fig. 1. The water tank dimensions of the experimental filtration system

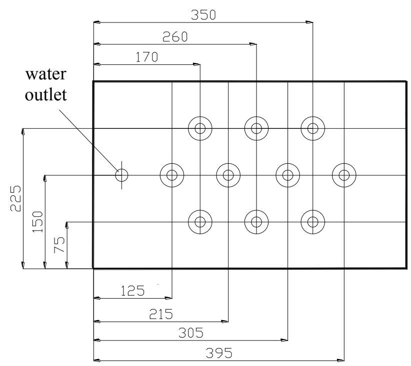

Fig. 2. Positioning the ultrasonic transducers on the bottom surface of the cuvette

In order to produce the ultrasonic cavitation phenomenon with an optimal intensity, Figure 3 shows the practical realization of the transducer positioning in the lower part of the water tank [4-7].

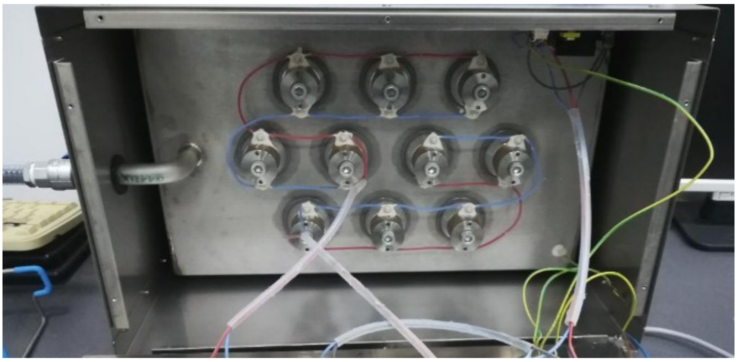

Fig. 3. Positioning the ultrasonic transducers on the bottom surface of the water tank

The design of the ultrasonic transducer element, as shown in Figure 3, has led to the realization of such a transducer, whose construction is shown in Figure 4.

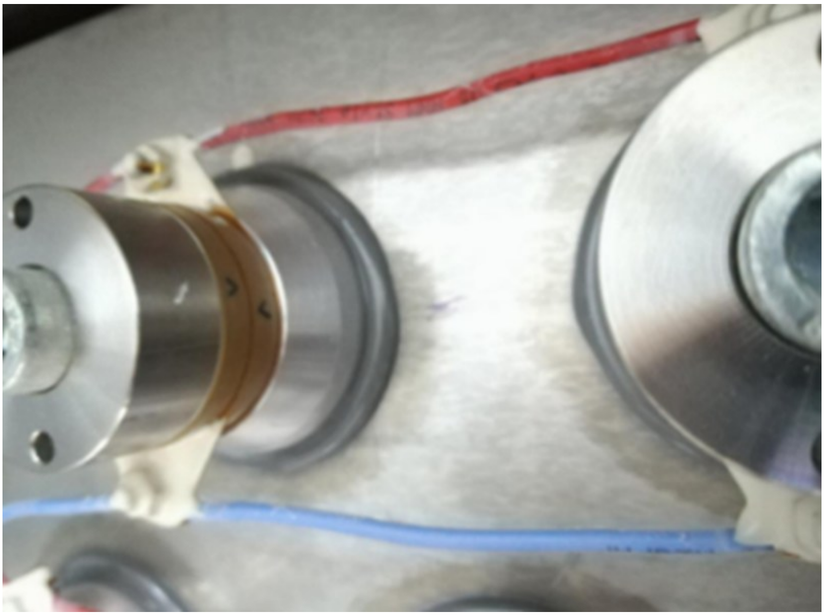

Fig. 4. Construction of the ultrasonic transducer

The operation of the ultrasonic filter system involves the introduction of the air to be filtered into the liquid tank and the removal of the purified air from the tank. In order to achieve the inlet and outlet of the air, the upper part of the tank is also presented in Figure 5. By the right circular hole, the air to be filtered at the pressure p = 0.4 atm (pressure determined experimentally) is introduced, and the left-hand tubing is used to extract the filtered air.

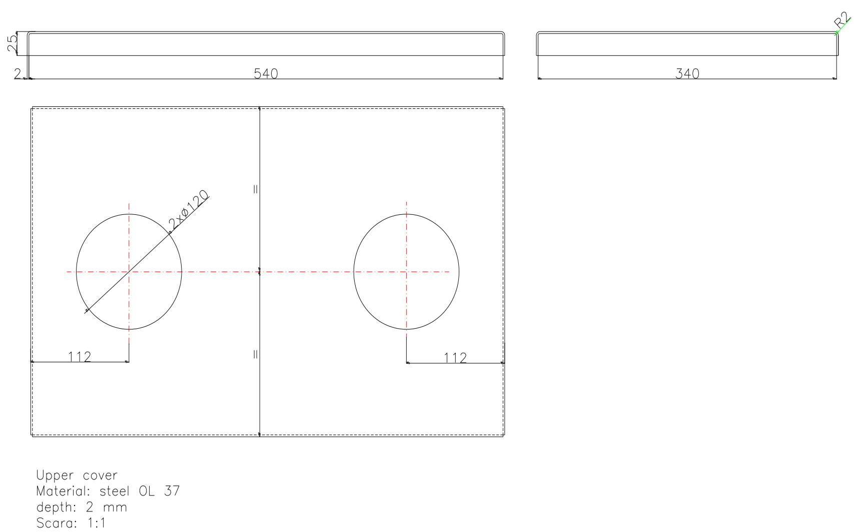

Fig. 5. Presentation of the contaminated air inlet area (left), and the evacuation of purified air on the right

The practical water tank realization is presented in Figure 6. The two tubes for the inlet and outlet of the air are presented. As can be seen, in the experiments carried out, the air intake is made through the tubing on the right side of the tank, while the left tube provided the evacuation of the filtered air.

Fig. 6. Ultrasonic cavitation filtering system

1.2 Working frequency of the ultrasonic transducers

Considering the finite element modeling in which the most useful vibration modes were determined (f = 22419.3 Hz, 22419.9 Hz, 26232 Hz; 27319 Hz) a work frequency f = 28283 Hz was used for the experiments (Figure 7).

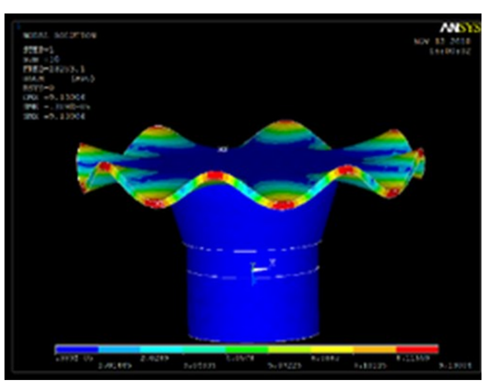

Fig. 7. Transducer vibration mode at frequency f = 28283 Hz

In this situation, the vibrations are of traveling wave, there being 8 vibration peaks that excite the surface of the water tank in which the ultrasonic cavitation process takes place. As can be seen from Figure 8 around this frequency, the ultrasonic system also offers maximum power.

Fig. 8. Setting the working frequency at f = 28000 Hz.

2 Experimental results

For the validation of the air filtration system using the cavitation-ultrasonic phenomenon three sets of analyzes for the exhaust air from the painting shop were made. The main subject of the analyzes is the measurement of volatile organic compounds. Because of the technological process of painting, the second determination was done total powder. For the expression of these compounds was considered to measure total organic carbon as efficacious. Below are the tables of measurements presented and the conditions in which they were made. In Table 1 there are presented the environmental data during measurements.

Table 1. Environmental data

No.	Component	MU	Measured value
1	Average temperature	^{0}C	0;1;1
2	barometric pressure	hPa	1025;1022;1027
3	average atmospheric humidity	Un%	96;100;93

According to the presented environmental data, in Tables 2, 3, 4 there are presented the performed measurements.

Table 2. Average value of pollutant concentrations – first set

No.	Name	MU	Meaured value	Limit value	Standard method
1	volatile organic compounds expressed by total organic carbon	mgC/Nm^3	1.15	150	SR EN 12619:2013
2	total powders	mg/Nm^3	1.64	50	SR EN 13284-1 2018

Table 3. Average value of pollutant concentrations – second set

No.	Name	MU	Meaured value	Limit value	Standard method
1	volatile organic compounds expressed by total organic carbon	mgC/Nm^3	1.36	150	SR EN 12619:2013
2	total powders	mg/Nm^3	1.81	50	SR EN 13284-1:2018

Table 4. Average value of pollutant concentrations – third set

No.	Name	MU	Meaured value	Limit value	Standard method
1	volatile organic compounds expressed by total organic carbon	mgC/Nm^3	1.22	150	SR EN 12619:2013
2	total powders	mg/Nm^3	1.78	50	SR EN 13284-1:2018

3 Conclusion

Analyzing the results, we conclude that the results of the measurements are within the limits provided by the legal norms in force under the specified conditions. The estimated measurement uncertainty does not affect the result of the sample and its compliance with the admissible limit values. Under these conditions it can be considered that ultrasonic cavitation filtration method is a viable method that proves its effectiveness for the intended purpose.

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