УДК 677.11.021
DOI https://doi.org/10.32846/2306-9716/2023.eco.1-46.14

MECHANICAL SELF-CLEANING DUST COLLECTOR

Kuznietsov S., Venher O., Semenchenko O., Bezpalchenko V., Ivkina E.
Kherson National Technical University
Instytutska St., 11, 29016, Khmelnytsky, Ukraine
ksieko1@gmail.com, super-elenavenger@ukr.net,
Oksana.Semenchenko@gmail.com,
bezpalchenkov@ukr.net, liza_ivkina@ukr.net

Long-term stay of a person in a dusty environment causes occupational lung diseases. The level of dustiness of industrial premises affects the health of people, labor productivity and product quality. Therefore, cleaning the air from dust in enterprises is a paramount and important task. In production workshops, the dust content of the air often exceeds the maximum permissible concentrations. The paper presents the results of research on the purification of ventilation air from dust using a self-cleaning mechanical filter. We have proposed and tested a mechanical dust collector with a self-cleaning filter. Compared to analogues, it better captures fine (aerosol) dust from the air with the help of a filter element, which is made in the form of a rotating disk. During operation of the dust collector, dusty air passes through the device and dust particles are retained on the filter surface. They form a filter layer, the thickness of which increases with time. At the same time, the aerodynamic resistance of the filter increases and its performance decreases. The optimum cleaning effect is achieved with a certain constant thickness of the dust layer on the filter disc. To adjust the thickness of this layer, a special knife is provided in the dust collector. Various parameters of the dust collector operation were studied. Such as the filter regeneration time, the absolute and specific amount of dust collected, the effect of the dust collector operation time on the thickness of the filter layer, the effect of the filter layer thickness on the filter resistance, the effect of the aerodynamic resistance of the filter on its performance. The proposed self-cleaning design of the filter contributes to the creation of a stable aerodynamic mode of operation of the air purification system. It allows you to reduce the dust content of the production area by 9-10 times, with a degree of air purification of 90%. In addition, the filter allows you to capture fine dust, which poses the greatest danger to human health. *Key words:* dust collector, air purification from dust, self-cleaning mechanical filter.

Механічний пиловловлювач з фільтром, що самоочищується. Кузнєцов С.І., Венгер О.О., Семенченко О.О., Безпальченко В.М., Івкіна Є.С.
Довгочасне перебування людини в запиленому середовищі викликає професійні захворювання легень. Від рівня запиленості виробничих приміщень залежить здоров'я людей, продуктивність праці, якість продукції. Тому очищення повітря від пилу на підприємствах є першорядним та важливим завданням. У виробничих цехах запиленість повітря часто перевищує гранично допустимі концентрації. В роботі викладені результати досліджень по очищенню вентиляційного повітря від пилу за допомогою механічного фільтра що самоочищається. Нами запропоновано та випробувано механічний пиловловлювач з фільтром, що самоочищається. В порівнянні з аналогами він краще вловлює дрібний (аерозольний) пил з повітря за допомогою фільтруючого елементу, який зроблений у вигляді обертового диска. При роботі пиловловлювача запилене повітря проходить через апарат і частинки пилу затримуються на поверхні фільтра. Вони утворюють шар, що фільтрує, товщина якого з часом збільшується. Разом з цим зростає аеродинамічний опір фільтра та його продуктивність знижується. Оптимальний ефект очищення досягається при певній постійній товщині шару волокнистого пилу на фільтрувальному диску. Для регулювання товщини цього шару, в пиловловлювачі передбачений спеціальний ніж. Досліджувалися різні параметри роботи пиловловлювача. Такі як час регенерації фільтра, абсолютна і питома кількість пилу, що уловлюється, вплив часу роботи пиловловлювача на товщину фільтруючого шару, вплив товщини фільтруючого шару на опір фільтра, вплив аеродинамічного опору фільтра на його продуктивність. Запропонована конструкція фільтра, що самоочищається, сприяє створенню стабільного аеродинамічного режиму роботи системи очищення повітря. Вона дозволяє знизити запиленість виробничого приміщення в 9–10 разів, за ступенем очищення повітря 90%. Крім того, фільтр дозволяє вловлювати тонкодисперсний пил, який становить найбільшу небезпеку для здоров'я людини. *Ключові слова:* пиловловлювач, очищення повітря від пилу, фільтр що самоочищається.

Formulation of the problem. It is known that a long stay of a person in a dusty environment causes occupational lung diseases. The level of dustiness of industrial premises depends on the productivity of labor, the quality of products and, most importantly, the health of people. Therefore, cleaning the air from dust at enterprises is a paramount and important task [1; 2].

Analysis of recent research and publications. At present, various dust collection systems from the air are used in production plants. One such system is the pneumatic extraction of dust, its transportation through pipelines with subsequent separation from the air [3; 4]. Such systems do not always work effectively. Therefore, the concentration of dust in the working area of production facilities often exceeds the maximum permissible standards.

Formulation of research objectives. The purpose of the research was to develop and test a mechanical self-cleaning filter to capture fine dust from the air. The scope of the assignment included;

- manufacture of a prototype mechanical self-cleaning filter.
- testing a mechanical self-cleaning filter when cleaning the ventilation air in the production room.

- testing a mechanical self-cleaning filter when cleaning the air from the equipment.

Statement of the main material. Studies on the purification of ventilation air from dust were carried out in an installation, a general view of which is shown in Fig. 1. The installation consists of a fan 2 operating from an electric motor 1. A filter 3 made of organic glass is mounted on the suction socket of the fan. The filter has the shape of a circular disc and is perforated with holes of 5 mm. On the outside of the filter is a nylon mesh. A knife 4 fixedly attached to the shaft 6 is closely adjacent to the fixed filter. The blade is closely attached to the filter surface by a spring 5. The shaft passes through the sleeve 7 and is rotated by the electric motor 9 through the reduction gear 8. The knife shaft and the fixed filter are located in the hopper 10, intended for dust collection.

When the unit is operating, dusty air enters through the open top of the hopper 10, passes through the filter 3, and then is vented to the atmosphere by means of a fan. Dust particles are retained on the surface of the filter, forming a filter layer. As the dusty air passes through the filter, the thickness of the filter layer increases, its aerodynamic resistance increases, and productivity decreases. There comes such a moment when the resistance of the filter increases so much that the movement of air practically ceases. The layer of textile dust formed on the filter surface plays a dual role. On the one hand, it is a filtering element, which increases the degree of gas purification, on the other – increases the resistance of the filter and reduces the performance of the fan. Therefore, the optimal option would be a constant presence on the disk of a layer of fibrous dust of a certain thickness.

The procedure for carrying out the experiments consisted in the fact that dusty air was passed through the filter for a certain time [5]. The trapped layer of dust was removed from the filter element and weighed on an analytical balance. Knowing the amount of dust and the concentration of dust in it, as well as the amount of dust removed from the filter element, determined the efficiency of the apparatus (weight method).

The filter regeneration time in the experiments varied from 0 to 8 hours. Initially, the filter underwent continuous regeneration with a constantly rotating knife. After that the knife for dust removal was switched on after

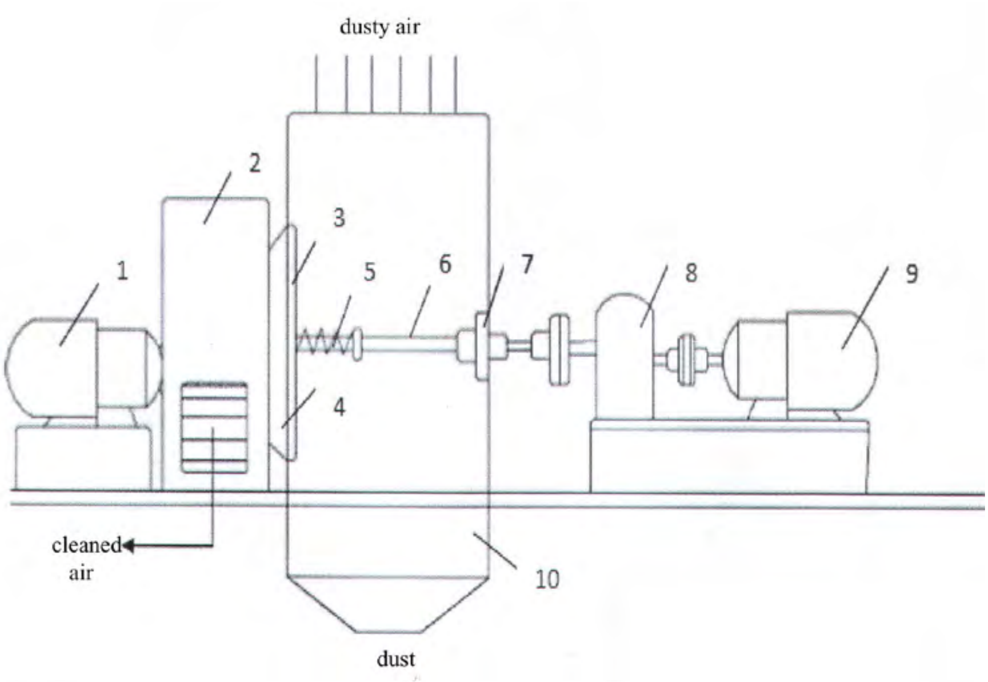
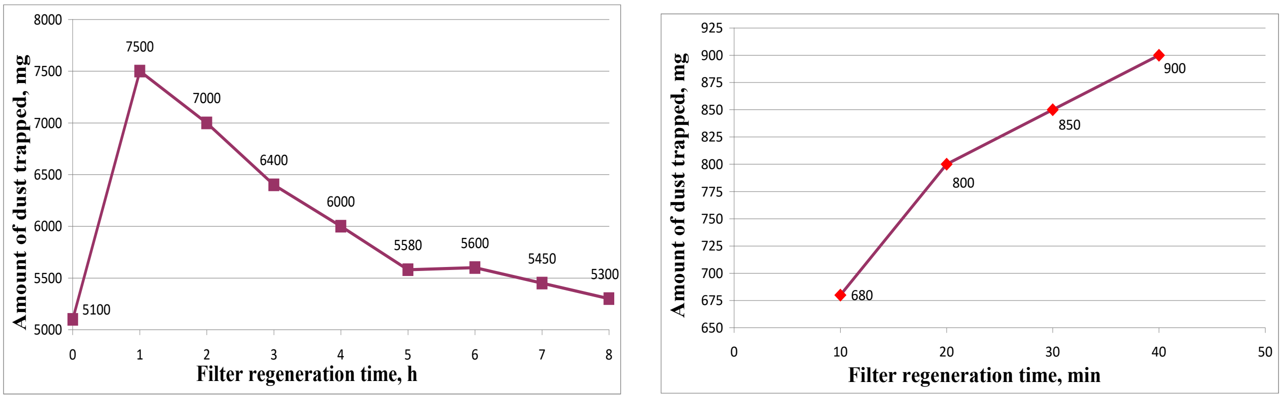


Fig. 1. General view of the experimental setup: 1 – electric motor; 2 – the fan; 3 – the filter; 4 – the knife; 5 – a spring; 6 – shaft; 7 – the bushing; 8 – reducer; 9 – the electric motor; 10 – hopper for dust collection

Table 1

Absolute and specific amount of dust captured on the unit

№	Indicators	Filter regeneration time, h								
		0	1	2	3	4	5	6	7	8
1	The amount of dust trapped by the installation during the test, mg	5100	7500	7000	6400	6000	5580	5600	5450	5300
2	Average amount of captured dust, per 1h, mg	630	937	875	800	750	725	700	681	662



a *b*

Fig. 2. Dependence of the amount of dust trapped on the filter regeneration time

Table 2

The influence of the operating time of the installation on the thickness of the filter bed

Operating time, h.	1	2	3	4	5	6	7	8
Thickness of the filtering layer, mm.	1	1,75	2,4	2,9	3,3	3,6	3,8	4,0

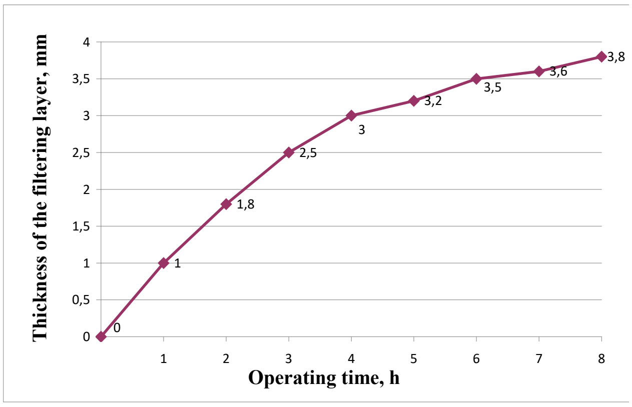


Fig. 3. Influence of the operating time of the installation on the thickness of the filter layer

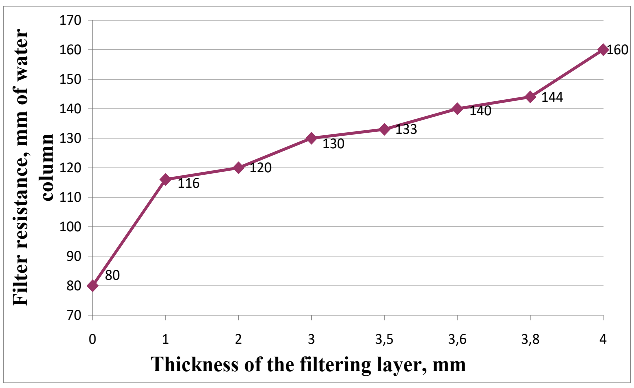


Fig.4. Effect of the thickness of the filter layer on the resistance of the filter

an hour, two, etc. In each case, the dust collected from the filter was weighed and the total amount was determined. Then the amount of dust collected in 1 hour was calculated. The operating time of the installation in all cases was 8 hours. The results of these studies are given in Tab. 1 and in the graph of Fig.2.

It can be seen from the graph that in the first series of experiments with continuous filter regeneration, air purification was insufficient (637 mg/h). This is explained by the fact that in the absence of a layer of dust on the grid, its "slip" through the filter cells [6; 7] is observed. As the thickness of the dust layer increased, the amount of dust trapped increased and reached a maximum (0.37 mg/h) with a regeneration time of 1h. By this time a layer of 1mm thick was formed on the filter. This was enough to achieve almost complete dust collection. With a further increase in the regeneration time, the degree of gas purification increased, but at the same time the resistance increased and the productivity of the installation decreased by air, so that the total amount of dust trapped was reduced. With a regeneration time of 2 hours, the amount of dust trapped was reduced to 875 mg, after 3 hours – 800 mg/h and so on.

As the filter works, a filter layer of dust forms on its surface. Moreover, the longer the operating time, the greater the thickness of the filter material layer. However, the relationship here is not straightforward. Tab. 2 and the graph in Fig. 3 show the change in the thickness of the filter material layer on the filter disk, depending on the filter operation time.

From the data given, it can be seen that the increase in the thickness of the filtering layer is not the same in time. So for the first hour it was 1 mm; for the second 0,75; for the third – 0,65; the fourth is 0,5, and so on. Reduction in the increase in the thickness of the dust is associated with a decrease in the capacity of the filter due to the growth of its resistance.

The influence of the thickness of the filter layer on the filter resistance is shown in Tab. 3 and in the graph of Fig.4.

Table 3

Effect of the thickness of the filter layer on the resistance of the filter

Thickness of the filtering layer, mm	0	1	1,75	2,4	2,9	3,3	3,6	3,8	4,0
Time of formation of the filtering layer, h	0	1	2	3	4	5	6	7	8
Filter resistance, mm of water column	80	120	125	130	135	140	145	150	160

Table 4

Effect of filter resistance on its performance

Filter operating time, h	0	1	2	3	4
Thickness of the filtering layer, mm	0	1	1,75	2,5	2,9
The resistance of the filter, mm of water column	80	120	125	130	135
Average air velocity from anemometer measurements, m/h	4,8	2,2	2,1	1,9	1,85
Plant capacity, m^3/h	100	450	400	380	350

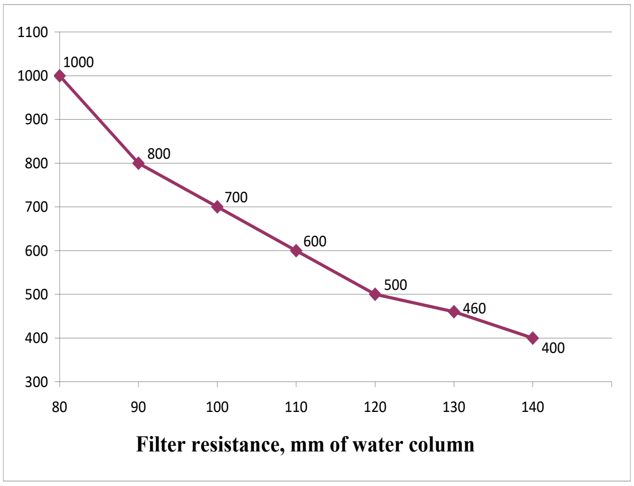


Fig. 5. Effect of filter resistance on performance

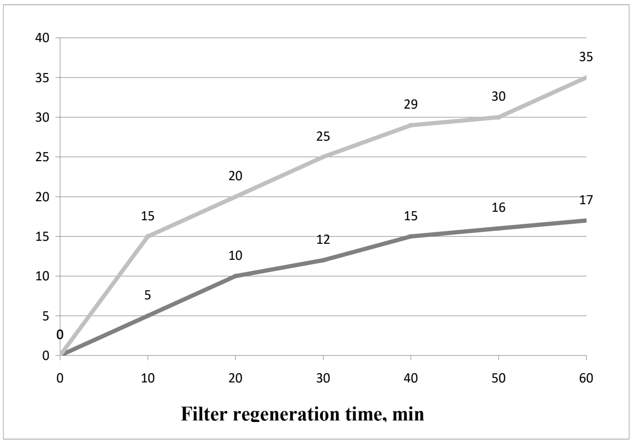


Fig. 6. Effect of filter regeneration time on performance

The data show that the resistance of the filter increases with time. So, if the filter without a layer of fibrous dust had a resistance of 80 mm of water column, then after one hour of its operation the resistance increased by one and a half times and amounted to 120 mm of water column, and after 8 hours of filter operation it increased to 160 mm of water column, became 2 times more than the original. This leads to a decrease in the throughput of the filter.

The technique of these experiments was that the velocity of the air emerging from the filter was measured. Knowing the air velocity and the diameter of the channel, the filter capacity was determined. The measurements were made for different thicknesses of the filtering layer (Table 4 and graph, Fig. 5).

The given data testify that with increase in resistance the filter performance sharply decreases, especially after the first hour of operation. Without a layer of dust on the filter, its resistance was 80 mm of water column, which corresponded to an average air velocity of 4,8 m/s and a capacity of 1000 m^3/h. After an hour, when a 1 mm layer of dust formed on the filter, and its resistance increased to 120 mm of water column, the air velocity decreased from 4.8 to 2,2 m/s, and the productivity to 450 m^3/h, respectively.

After 4 hours of operation, the thickness of the dust layer on the filter was 2.9 mm, which increased the filter resistance to 135 mm of the water column, the average air velocity decreased to 1.85 m/s, and the productivity to 350 m^3/h, almost three times. From this it should be concluded that the filter should not allow the formation of a layer of dust more than 1 mm. To do this, it is necessary to regenerate the filter once per hour.

Conclusions

1. The proposed design of a self-cleaning filter contributes to the creation of a stable aerodynamic operation of the dust collection system.
2. The device allows reducing dust content in 9–10 times.
3. With a stable aerodynamic mode, the degree of air cleaning from dust is 90%.
4. The dust collector can be used to clean air from fine dust.

REFERENCES

1. Луцик О.Д., Іванова АЙ., Кабак К.С., Чайковський Ю.Б. Гістологія людини. Київ : «Книга плюс», 2010. С. 401–446.
2. Закон України «Про охорону атмосферного повітря» від 16 жовтня 1992 року № 2707-XII / База даних «Законодавства України». URL: http://zakon.rada.gov.ua/laws/main/2707-12.

3. Обстеження систем аспірації та вентиляції ЦВО-1, ЦВО-2 та розробка рекомендацій по підвищенню ефективності їх роботи для зниження викидів забруднюючих речовин в атмосферу та запиленості на робочих місцях. Отчет о НИР / Криворожский технический университет: №ГР 0106U008416. Кривой Рог, 2006. 130 с.
4. Корнієнко Д.Г., Приміський В.П. Автоматична система очистки пробопідготовки газоаналізаторів димових газів. *Технологический аудит и резервы производства*. Харків. 2015. № 1/3(21). С. 29–32.
5. Левченко О.Г., Грищенко С.А., Ковтун І.М. Методи нейтралізації токсичних речовин у зварювальному виробництві. *Вісник Національного науково-дослідного інституту охорони праці*. 2003. Вип. 6. С. 19-23.
6. Перелік і коди речовин забруднюючих атмосферне повітря. 2021 р. 43 с.
7. Смирнов М.Ю., Защепкіна Н.М., Гаврилюк В.В. Розробка програми для розрахунку концентрації пилу в приміщенні. *«Погляд у майбутнє приладобудування»*: матеріали XI Всеукраїнської науково-практичної конференції студентів та аспірантів (Київ, 15–16 травня 2018 року). Київ : КПІ ім. Ігоря Сікорського, 2018. С. 320–323.