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Assessment of possibility to improve dust suction efficiency from multicyclone air filter of track vehicle

K e y w o r d s

Air filter, dust sucking – off, vehicle engine.

S ł o w a k l u c z o w e

Filtr powietrza, odsysanie pyłu, silnik pojazdu.

S u m m a r y

The dust sucking-off from the deduster of multicyclone of the caterpillar vehicle two-stage filter process organisation is presented. There is shown the influence of sucking-off degree on dedusting effectiveness of inertial deduster. Experimental researches of multicyclone construction influence on uniform rate of the dust sucking-off from the individual cyclones were carried out. There was made the analysis of effectiveness improvement possibilities of dust sucking-off from the multicyclone deduster. There is shown the design of deduster modification consisting of deduster chamber segmentation on independent, isolated one from another sucking-off canals. To every canal there are allocated some individual cyclones. Heights of sucking-off canals on its outlet h_1, h_2, h_3, h_4 are computed under the criterion of the same air flow drag through the canals. Suitable flow computations are carried out using a computational model of dust settler worked out by the author. There was carried out a three-stage experimental evaluation of introduced constructional changes of multicyclone dust settler on values of sucking-off streams Q_{SC} from individual cyclones.

1. Introduction

In motor vehicles and engineering machinery operating in an environment highly laden with dust, the adequate cleanness of the intake air required to

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achieve assumed durability of combustion engines is assured by the use of the two-stage air cleaners operating in a multicyclone arrangement with a downstream porous filtration medium [1, 11, 14]. The two-stage air cleaning systems are also used in the intake air supply systems of turbocharged helicopter engines [2, 7].

During the interval corresponding to 1000 km mileage between repairs of T-72 tank operating in the air heavily laden with dust (more than 1 g/m^3) the multicyclone dust separator can separate more than 150 kg of foreign matter from the engine intake air. Storing such an amount of debris in the scavenge box is not advisable not only for the lack of space and unnecessary load imposed on the air cleaner structure but also because of the possible back-suction of the foreign matter due to vehicle vibrations and air stream flow fluctuations resulting from quick changes of the engine speed. For this reason, in multicyclone air cleaners of vehicle engines operating in heavily dusted air, particularly tanks and combat vehicles, permanent removal of the dust separated in the scavenge box (by ejection) is used. Discharging small amounts of air and, at the same time, exhausting the airborne debris from the multicyclone scavenge box overboard, noticeably improves dust separation efficiency of the multicyclone.

In a popular multicyclone type with a common scavenge box, however, where the removal of dust from the space common for all cyclones (i.e. a separation chamber), is performed by means of one or two suction connector pipes, the separation efficiency can be somehow lower than one might expect from the suction intensity applied. Multiple experiments prove that, while this solution of removing dirt from the scavenge box is the simplest, its efficiency can be lower by as much as 10% as related to the individual cyclones making up the multicyclone dust separator [6, 10]. This drop in efficiency may result from the non-uniformity of suction among individual cyclones as well as from the interaction of the swirling streams spiraling from the cyclones down into the common scavenge box.

Thus, the efficiency of the multicyclone dust separator depends not only on its design properties and flow characteristic but equally on the uniformity of distribution of the aerosol among the cyclones and on the proper organisation of the separated dust ejection removal. It is deemed, therefore, that further research on improvement of removing dust by ejection from the multicyclone scavenge box is needed.

2. Organization of the process of dust ejection from multicyclone scavenge box

Typically, the multicyclone under consideration is made up of parallel-arranged small cyclones of diameters not exceeding 40 mm in a number ranging from a few up to a few hundred. The cyclones used can be either of the tangential or axial inlet reverse-flow-type or the axial inlet straight-through-type.

In a multicyclone connected using tangential or axial inlet reversal cyclones arranged vertically, the scavenge box is situated at the bottom while the filtration medium is situated on the top, as shown in Fig. 1a. This kind of air cleaner is used in the T-72 and PT-91 [9, 10] tanks. In a multicyclone made up of axial inlet straight-through cyclones, the filtration medium is situated below the multicyclone, the scavenge box being arranged on its side, as shown in Fig. 1b. This kind of air cleaner is employed in the Leopard 2 tank [13].

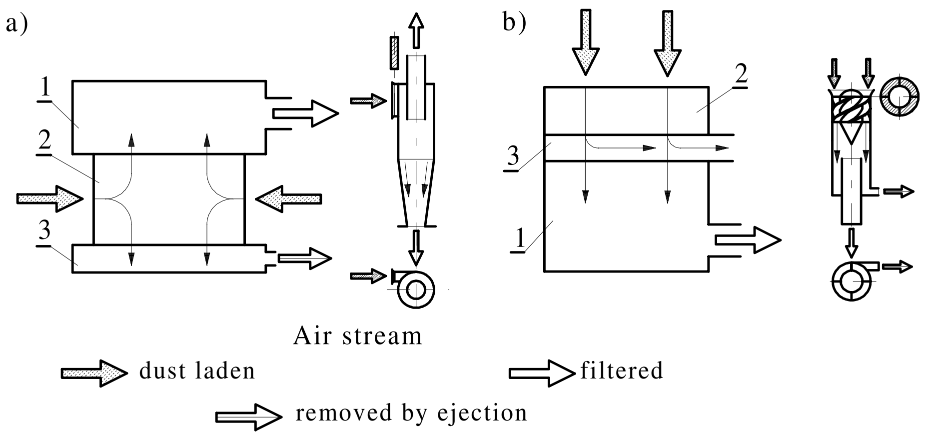

Fig. 1. Possible configurations of multicyclone-porous filtration medium in the air filtration system depending on cyclone type: a) tangential or axial inlet reversal cyclones b) axial inlet straight-through cyclones, 1 - porous filtration medium, 2 - multicyclone, 3 - scavenge box
Rys. 1. Konfiguracje systemu filtracji powietrza „multicyklon – przegroda porowata" w zależności od rodzaju cyklonów: a) cyklony zwrotne z wlotem stycznym lub osiowym, b) cyklony przelotowe z wlotem osiowym, 1 – przegroda porowata, 2 – multicyklon, 3 – osadnik pyłu

The task of removing dust from the separation chamber, or, the scavenge box, is performed by an ejection system consisting of a multicyclone scavenge box, an appliance to generate flow of air (to provide the ejector's effect) and exhaust piping to remove the dust overboard. The dust ejection is performed by creating a suction stream of air Q_{SF} derived from the dust laden inlet air stream Q_{OF} entering the multicyclone dust separator. This suction stream Q_{SF} flowing through the scavenge box carries away the dust particles entrapped in it and via exhaust piping, it is discharged overboard of the vehicle.

$$Q_{0F} = Q_{GF} + Q_{SF} \tag{1}$$

where: Q_{GF} - discharge air stream (filtered), or engine inlet air

Practical implementation of the ejection dust removal system brings about serious problems of the technical nature. Various ways of generating the suction stream are known. Commonly, special fans or blowers are used [13]. Such installations, however, have the disadvantage of having to be powered by an electric motor or, less often, from the engine crankshaft. In the latter case, the performance of the fan depends on the engine speed and the fan installation directly on the engine may be inconvenient for the installation of dust separator. The electrical drive, even though more practical, presents a significant load to the electric power generator of the vehicle. Also, the permanence of operation required from the fan imposes high requirements as to its reliability. An electrically driven fan for ejection removal of dust from the air cleaner scavenge box has been employed in the Leopard 2 tank. Both solutions described above, however, require energy from the engine and load it. For this reason, many air cleaner installations employ suitable ejectors making use of the energy from a stream of compressed air or the exhaust gas of the combustion engine to create the needed suction stream of air, see [2] and [3, 4, 9], respectively.

The measure of the intensity of dust removal by ejection from the scavenge box of a multicyclone (cyclone) is the ejection ratio m_o which is usually defined as the ratio of the stream volume Q_S in the suction system and the discharge stream volume Q_G of the multicyclone (cyclone) or the discharge stream Q_{GF} of the air cleaner (engine air intake), the latter being applied if the multicyclone is used as the first stage of air cleaner. The ejection ratio is then defined by the following formula [1, 3, 4, 12, 15]:

$$m_0 = \frac{Q_S}{Q_G} = \frac{Q_{SF}}{Q_{GF}} 100\% \tag{2}$$

The authors of relatively few research works dealing with the influence of the ejection ratio m_0 on the efficiency of inertia type dust separators agree that by increasing the m_0 the dust separation efficiency φ is made to grow intensively up to a certain level beyond which the dust separation efficiency hardly grows any more in spite of m_0 value increase [1, 2, 6, 7].

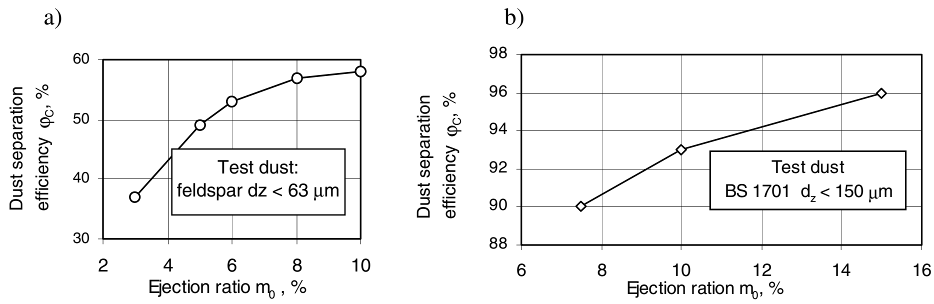

Fig. 2. Influence of ejection ratio m_0 on dust separation efficiency: a) inertia dust separator [5], b) axial inlet straight-through multicyclones [2]

Rys. 2. Wpływ stopnia odsysania m_0 na skuteczność odpylania: a) odpylacza bezwładnościowego [5], b) multicyklonu cyklonów przelotowych z wlotem osiowym [2]

For the inertia-type dust separator, a change in the ejection ratio m_0 within the range 3÷6% causes the dust separation efficiency to grow two times higher as compared with the growth corresponding to a change of m_0 within the range of 6÷9%, see Fig. 2a [5]; for the multicyclone air cleaner, its dust separation efficiency improvement corresponding to an increase of ejection ratio m_0 within 7,5÷10% is significantly better than that corresponding to a change of m_0 = 10÷15%, see Fig. 2b [2].

As a result of the tests with a prototype of an axial inlet straight-through-type cyclone based multicyclone, the author found that the increase of dust separation efficiency corresponding to m_0 change of 2÷8% is more intensive than that corresponding to changes in m_0 amounting to 8÷20%, see Fig. 3 [8].

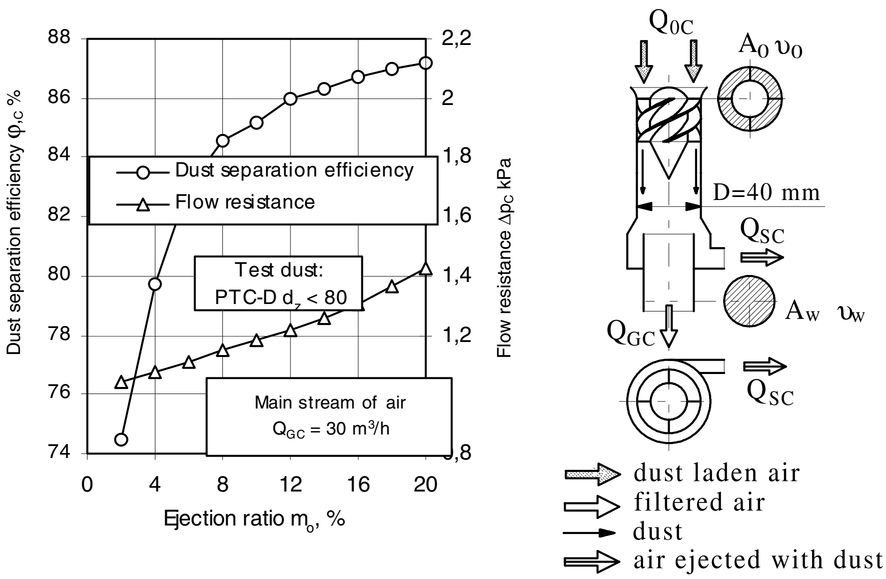

Fig. 3. Influence of ejection ratio m_0 on dust separation efficiency and flow resistance of the axial inlet straight-through multicyclone [8]
Rys. 3. Wpływ stopnia odsysania m_0 na charakterystyki cyklonu przelotowego z wlotem osiowym [8]

From the efficiency characteristics curves $\varphi = f(Q_G)$ plotted for a radial dust separator shown in Fig. 4, it can be seen that the improvement of dust separation efficiency resulting from the change of m_0 within 4÷8% is times higher than that corresponding to identical change of m_0 only within the range 0÷4% [4]. However, for the inertia-type dust separators, the concomitant of the increase of m_0 value is an inherent increase of the resistance of flow, resulting from higher air velocity υ, as given by the formula $\Delta p_C = f(\upsilon^2)$.

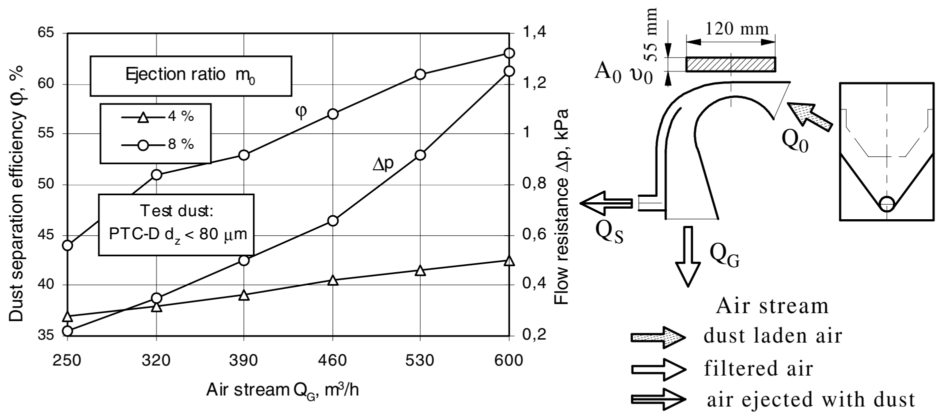

Fig. 4. Characteristic curves $\varphi = f(Q_G)$ and flow resistance $\Delta p = f(Q_G)$ of radial dust separator for various ejection ratio m_0 [4]

Rys. 4. Charakterystyki skuteczności odpylania $\varphi = f(Q_G)$ oraz oporu przepływu $\Delta p = f(Q_G)$ odpylacza promieniowego dla różnych stopni odsysania m_0 [4]

The quoted results of the tests only prove the commonly known principles applied to the ejection removal of dust from dust separators. For the existing solutions of cyclones and multicyclone dust separators, the ejection ratio m_0 lies mostly within the range between 8 and 15% [1-4, 12, 14]. So, there is a defined range of optimal ejection ratio values m_o, a deviation from which can impair the cyclone's operation efficiency, resulting in more engine energy wastes.

The multicyclone consisting of cyclones having a common scavenge box shows somehow lower dust separation efficiency as related to each individual cyclone separately which can be attributed to non-uniform distribution of aerosol among individual cyclones, that is to say, to various flow velocities through them or even to possible flow reversals in the cyclones situated at the peripheries of the multicyclone [1, 16]. The finish of the cyclone's internal surfaces has a significant influence on the suction uniformity, i.e. its accuracy and alignment in the multicyclone, the way the aerosol enters each cyclone and the way the suction air stream is discharged from the scavenge box. Improper organisation of the separated dust ejection removal can also contribute to non-uniform suction among cyclones, impairing the separation efficiency.

The separation efficiency can also be adversely affected by the interaction of swirling streams discharged from the cyclones entering the common scavenge box. Vortices that develop can lead to a creation of local underpressure zones making ejection of the air from such zones difficult.

From the experimental tests aimed at evaluating the influence of ejection ratio m_0 on dust separation efficiency $\varphi_C = f(\upsilon)$ and flow resistance $\Delta p_C = f(\upsilon)$ for a single axial inlet straight-through cyclone and a multicyclone dust separator made of 24 such cyclones enclosed in a cuboid cartridge, show that the dust separation efficiency of the multicyclone as related to a single cyclone is by 5÷7% lower, irregardless of the ejection ratio [6].

3. Experimental testing of dust suction uniformity from a single cyclone

Test purpose was to determine multicyclone and dust decanter construction influence on Q_{SC} value of a stream sucked from a single cyclone of multicyclone air filter of a combat vehicle – BWP-1. Multicyclone is made of 39 cyclones with adjoining inlet, set in three columns, 13 cyclones each. Main components of injection system of dust suction from multicyclone are: dust settling tank, where separated dust is collected, suction duct connecting dust settling tank with ejector located at the exhaust inlet. As a result of exhaust flow, suction stream Q_{SF} is formed, being part of an inlet stream Q_{0F} to the multicyclone. Suction stream flowing through settling tank chamber lifts dust grains and carries them away outside the vehicle.

The suction streams Q_{SC} of the individual cyclones in the multicyclone air filter MF72 were determined using an indirect method consisting in measurement of the cyclone inlet stream Q_{0C} which, for the discharge stream $Q_{GC} = 0$, assumes value of $Q_{0C} = Q_{SC}$. Such situation will take place when discharge ports of all cyclones are plugged. The only stream flowing through the multicyclone then will be the suction stream Q_{SF}, being a sum of all suction streams Q_{SC} of the individual cyclones, see Fig. 5.

$$Q_{SF} = \sum_{j=I}^{J} \sum_{k=1}^{K} Q_{SC_{jk}} \tag{3}$$

where: I, II, III, ...j....J – are the numbers of cyclones in a column - number of rows
1, 2, 3,...k...K – are the numbers of cyclones in a row - number of columns

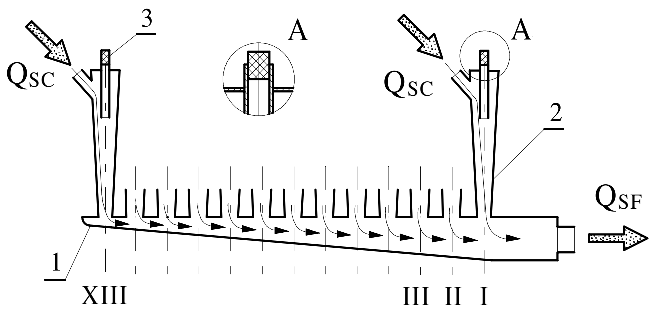

Fig. 5. Diagram of air suction stream flow through MF72 multicyclone with cyclone exits plugged: 1 - scavenge box, 2 - cyclone, 3 - plug closing flow.
I, II, III, ... VII – indicate the numbers of cyclones in a column
Rys. 5. Schemat przepływu strumieni powietrza przez multicyklon BWP-1 podczas odsysania przy zamkniętych otworach wylotowych cyklonów: 1 – osadnik pyłu, 2 – cyklon, 3 – korek zamykający przepływ. I, II, III, ... ,XIII – numer kolejnego cyklonu w kolumnie

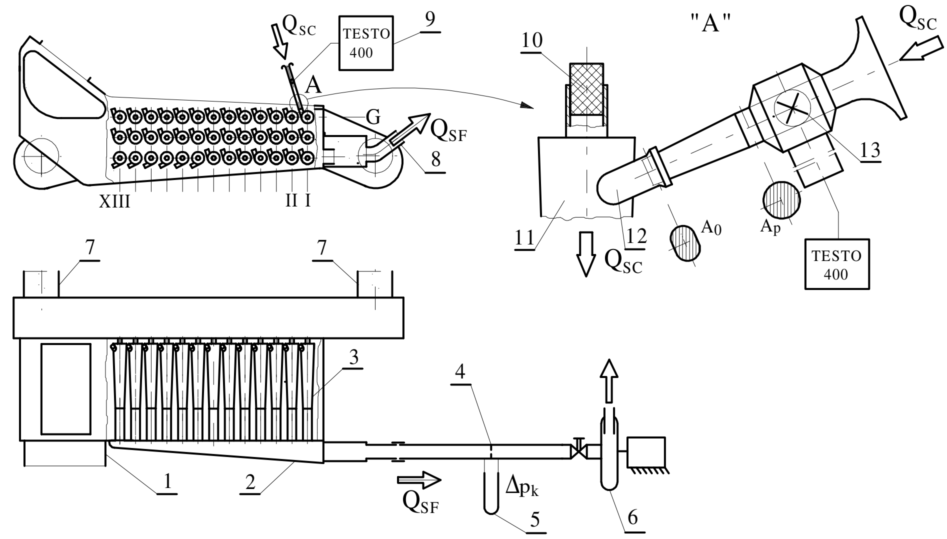

Fig. 6. Diagram of a test stand for measurement of value of a stream sucked from a single cyclone of multicyclone air filter of the BWP-1: 1 – air inlet to the filter stub pipe, 2 – dust settling tank, 3 – multicyclone, 4 – measuring orifice plate for suction stream, 5 – U-tube manometer, 6 - suction fan, 7 – air outlet from the filter stub pipe, 8 – dust suction stub pipe, 9 – TESTO 400 device stopper

Rys. 6. Schemat stanowiska do pomiaru wartości strumieni odsysanych z pojedynczych cyklonów multicyklonu filtru powietrza BWP-1: 1 – króciec wlotu powietrza do filtru, 2 – osadnik pyłu, 3 – multicyklon, 4 – kryza pomiarowa strumienia odsysania, 5 – manometr U-rurka, 6 – wentylator ssawny, 7 – króciec wylotu powietrza z filtru, 8 – króciec odsysania pyłu, 9 – przyrząd TESTO – 400 korek zamykający

Tests have been carried out using a special test stand (Fig. 6) for three established values of a main suction stream Q_{SF} = 200, 100, 50 m^3/h, resulting from the engine air demand for characteristic rotational speed and accepted suction ejection degree m_0 = 16%. Required suction stream Q_{SF} during tests has been made using suction fan.

Q_{SC} values of a stream sucked from a single cyclone have been determined with indirect method using fan probe (placed at the cylindrical measurement duct) measurement of air flow at the inlet to cyclone.

For established value of a main suction stream Q_{SF}, measurement duct with probe has been connected with inlet stub pipe. For each cyclone with 15 seconds interval, 7 speed values of flowing air υ_{pjk}, have been measured and the mean value has been calculated $\overline{\upsilon}_{pjk}$. Value of an air stream flowing through the stub pipe has been calculated using the following dependance:

$$Q_{SCjk} = \overline{\upsilon}_{pjk} \cdot A_p \tag{4}$$

where: A_p – section area of cylindrical probe measurement duct.

Due to lack of inlet stub pipe access for all cyclones, Q_{SC} streams have been determined for only one (upper G) cyclone column. Since the other two cyclone columns are in close vicinity, parallel to tested column it was accepted that the values of stream sucked from those cyclones will not vary from measured Q_{SC} values for upper column.

For better tracking of test results (Fig. 7) Q_{SC} values for other cyclones have been connected with a straight line. The highest Q_{SC} values of sucked streams have been registered independently from main sucked stream Q_{SF} value for cyclones located closest to the suction stub pipe. With increase of distance from the suction stub pipe, Q_{SC} values systematically decrease. For the last (13[th]) cyclone, Q_{SC} values are approx. 35% smaller for Q_{SF} = 200 m^3/h and approx. 25% smaller for Q_{SF} = 50 m^3/h.

This type of ejection system for dust suction does not provide same degree of suction form all cyclones.

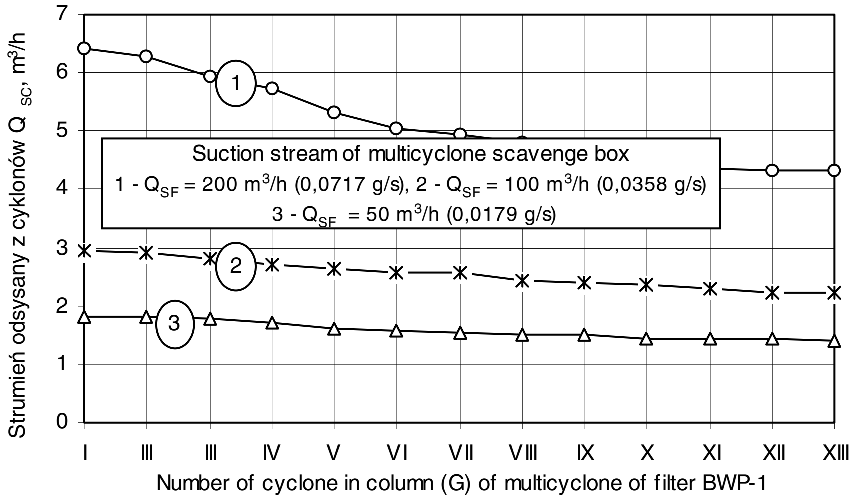

Fig. 7. Sucked stream values Q_{SC} from a single cyclone of upper column of multicyclone air filter of the BWP-1

Rys. 7. Wartości strumieni odsysanych Q_{SC} z pojedynczych cyklonów górnej kolumny multicyklonu filtru powietrza BWP-1

4. Considerations of possible improvement of the dust removal uniformity from the multicyclone dust separator

The tests carried out so far show that the variations in values of the suction streams of the individual cyclones may mainly be caused by the differences in the stream flow resistance of the individual cyclones in the scavenge box over the distance "cyclone - suction pipe". This is determined above all by different lengths of the said distances, resulting from the position of each cyclone relative to the suction pipe, by interaction of the walls of the scavenge box with the suction streams of the cyclones situated close to the walls and possibly by the presence of turbulation zones in the whole suction stream in the scavenge box.

In the course of the theoretical and experimental research work conducted by the author, three principal methods for possible improvement of the suction stream distribution uniformity in the individual cyclones were defined [3, 4, 10]:

- *the arrangement symmetry method* consisting in designing the scavenge box in such a way as to assure symmetrical position of all cyclones in relation to the suction pipe, see Fig. 8.
- *the equal resistance flow method* consisting in adjusting the resistance of flow by deliberate and appropriate throttling of streams of those cyclones with the flow resistance lower than the other cyclones in order to achieve equal flow resistance for all cyclones.
- *the combination method* consisting in an appropriate combination of the above methods.

Since the only possibility to achieve symmetry is to arrange all cyclones circumferentially, the consequence of the symmetry method in case of a dust separator having large number of cyclones will be the disproportionately big size of the scavenge box plate on which the cyclones are mounted.

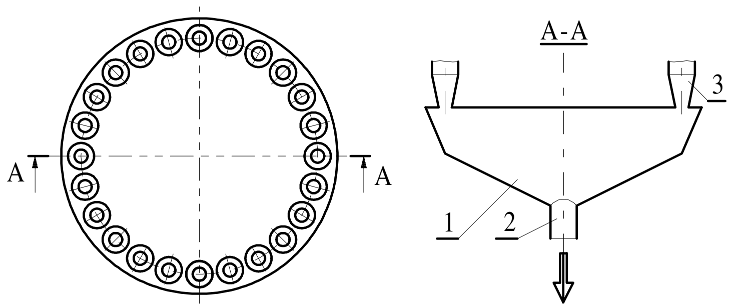

Fig. 8. Scavenge box assuring symmetric position of all cyclones in relation to the suction pipe: 1 - scavenge box, 2 - suction pipe, 3 – cyclone

Rys. 8. Schemat osadnika z zachowaniem symetrii położenia wszystkich cyklonów w odniesieniu do króćca odsysania: 1– osadnik, 2 – króciec przewodu odsysania, 3 – cyklon

Therefore, except for dust separators with a relatively small number of cyclones, this method is impractical since the engine compartment of a vehicle does not usually offer enough space.

The equalization of the cyclone suction streams flow resistance can be performed through throttling and directing the selected streams by the following means:

- adding a baffle to the multicyclone scavenge box, (Fig. 9).
- using throttling elements placed on the discharge ends of selected cyclones (Fig. 10).
- dividing the whole scavenge box into separated channels, (Fig. 11).

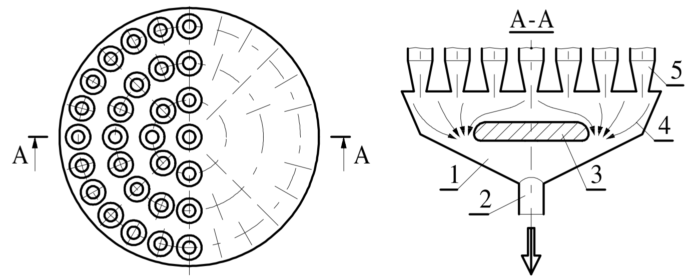

Fig. 9. Scavenge box with indirect suction pipe connection: 1 - scavenge box, 2 - suction pipe, 3 - baffle, 4 - directions of stream flow, 5 – cyclone

Rys. 9. Schemat osadnika z wlotem pośrednim do przewodu odsysania: 1 – osadnik, 2 – króciec przewodu odsysania, 3 – przegroda (deflektor), 4 – linie prądu strumienia, 5 – cyklon

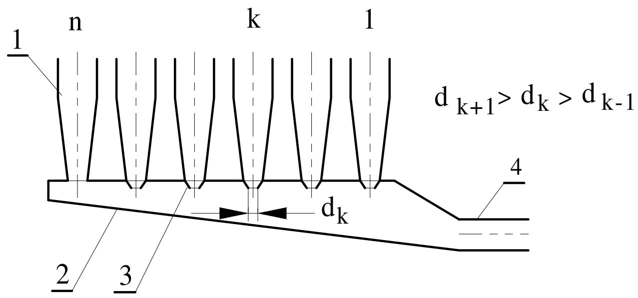

Fig. 10. Throttling cap selection principle: 1 - cyclone, 2 - scavenge box, 3 - throttling cap, 4 - suction pipe

Rys. 10. Zasada doboru nasadki dławiącej: 1 – cyklon, 2 – osadnik, 3 – nasadka, 4 – króciec odsysania

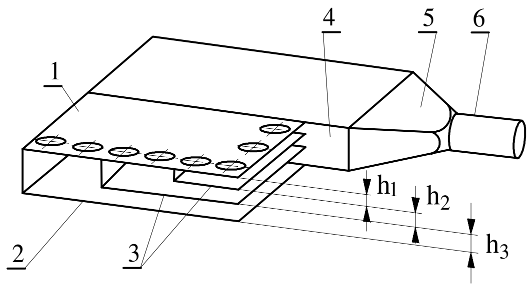

Fig. 11. Example of settling tank division into separate channels: 1 - plate for mounting cyclones, 2 - bottom of scavenge box, 3 - partitions, 4 - vertical wall, 5 - auxiliary channel, 6 - suction pipe

Rys. 11. Przykład podziału osadnika na niezależne kanały: 1 – płyta mocowania cyklonów, 2 – dno osadnika, 3 – przegrody, 4 – ściana pionowa, 5 – kanał przejściowy, 6 – króciec odsysania

The selection of method and the practical application depends not only on their efficiency but also on the design of the multicyclone, space limitations and on the feasibility of making appropriate tests. Therefore, it may well be assumed that an efficient solution will involve two or more listed solutions.

Out of the methods mentioned above, the one consisting in dividing the scavenge box into separated suction channels serving defined groups of cyclones is especially suitable for modification of the scavenge boxes of the existing air cleaners already in service which otherwise would not provide required dust separation efficiency. A sketch of such division is illustrated in Fig. 11. h_1, h_2, h_3 heights of the channels created by partitions should be selected so as to achieve equal resistance of flow for all channels. To achieve a full uniformity of flow resistance of the channels by only mathematical calculations is rather impossible due to a rather complex flow process. Therefore, the final adjustment of the channel heights is made experimentally.

The number of cyclones assigned to and served by each individual suction channel of the scavenge box should not be too big. There can be 3...4 cyclones installed over the width and 1...4 over the length of the channel, depending on its height in the area where the suction connector will be situated. In case there are more cyclones over the width of the scavenge box, it should be divided with a vertical partition *4* – Fig. 11, so that the segments created in such way, contain the required number of cyclones. Each segment should be provided with a separate suction pipe. Described solution resembles the modular design of the filter, however, in this particular case the module can contain more cyclones than the one described earlier.

5. Project of organization of dust suction from multicyclone dust collector's settling tank of mechanical vehicle

Suggested idea of sucking dust from multicyclone settling tank, consisting in settling tank division into segment, and dividing segment into independent suction ducts for sucking dust from specified number of cyclones has been realized based on dust settling tank of multicyclone air filter from BWP-1 combat vehicle.

Dust settling tank chamber of multicyclone has been divided with internal walls into three equal a widths. Each width contains column of 13 cyclones and is a segment – a module. BWP-1 multicyclone segment's settling tank chamber has been divided into four suction ducts with height of h_1, h_2, h_3, h_4 at the outlet (Fig. 12), calculated based on equal air stream flow resistance. First three channels have been assigned with three cyclones each, and the last (fourth) channel consists of four cyclones. Proper flow calculations have been made according to algorithm (Fig. 13) using calculation model of dust settling tank from the study [10].

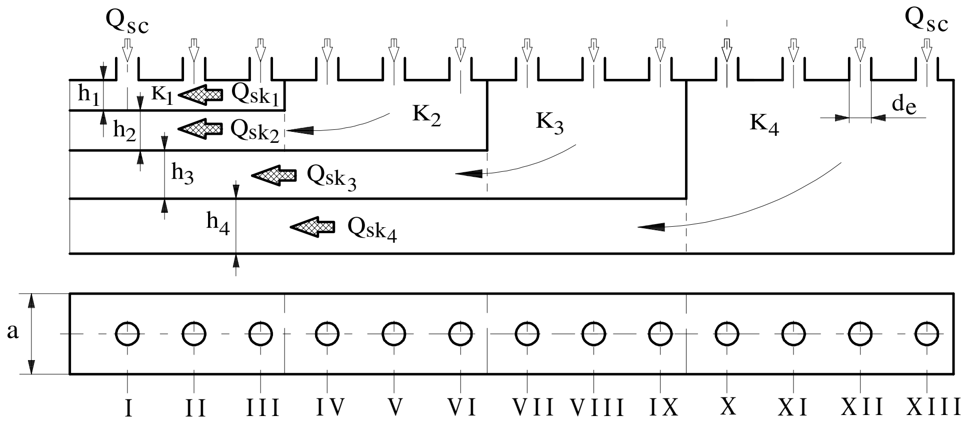

Fig. 12. Schematic diagram (for calculations) of a segment of BWP 1 multicyclone dust settling tank
Rys. 12. Schemat ideowy (do obliczeń) segmentu osadnika pyłu multicyklonu BWP 1

Directly from the cyclones, through openings with diameter *de,* for *K* chamber of each suction channel, an air stream (with separated dust particles) of the following size flows:

$$Q_{Ski} = Q_{SCi} \cdot i_{Ci} \tag{5}$$

where: Q_{SCi} – air stream sucked from a single cyclone of the *i* suction channel,
i_{Ci} – number of cyclones included in suction channel.

Main issue for settling tank flow calculations was to establish pressure loss at the suction channels of settling tank segment. Two main reasons of pressure loss in the actual object – suction channel has been considered. These are whirls of air stream occurring for sudden changes of flow channel section and friction of air at the channel walls.

During air stream flow through the suction channel from the dust settling tank segment (fig. 12) three different pressure losses has been assumed:

- Δp_e – local pressure loss occurring during flow through the openings with d_e diameter at the upper wall of Q_{SC} streams chamber from cyclones to rectangular segment chamber. Local pressure loss is created as a result of stream speed reduction and stream mixing,
- Δp_w – local pressure loss occurring during Q_{Sk} stream flow to the channel with inlet located at the side wall of a chamber. Crosswise dimensions of outlet channel (inlet) are smaller than the dimensions of side wall of a chamber. In this case there is a flow through the channel with sudden section narrowing,
- Δp_k – pressure loss resulting from friction during stream flow through the channel with fixed section.

Summary pressure loss during air flow stream through *i* suction channel is characterized with the following dependance:

$$\Delta p_{si} = \Delta p_{ei} + \Delta p_{wi} + \Delta p_{ki} \tag{6}$$

Flow calculations amount to assessment of pressure loss for each suction channel, with assumed flow and selected suction channel height, so the pressure loss is similar for all channels. Solution of those equations is possible using method of successive approximations. Algorithm of calculations (Fig. 13) of

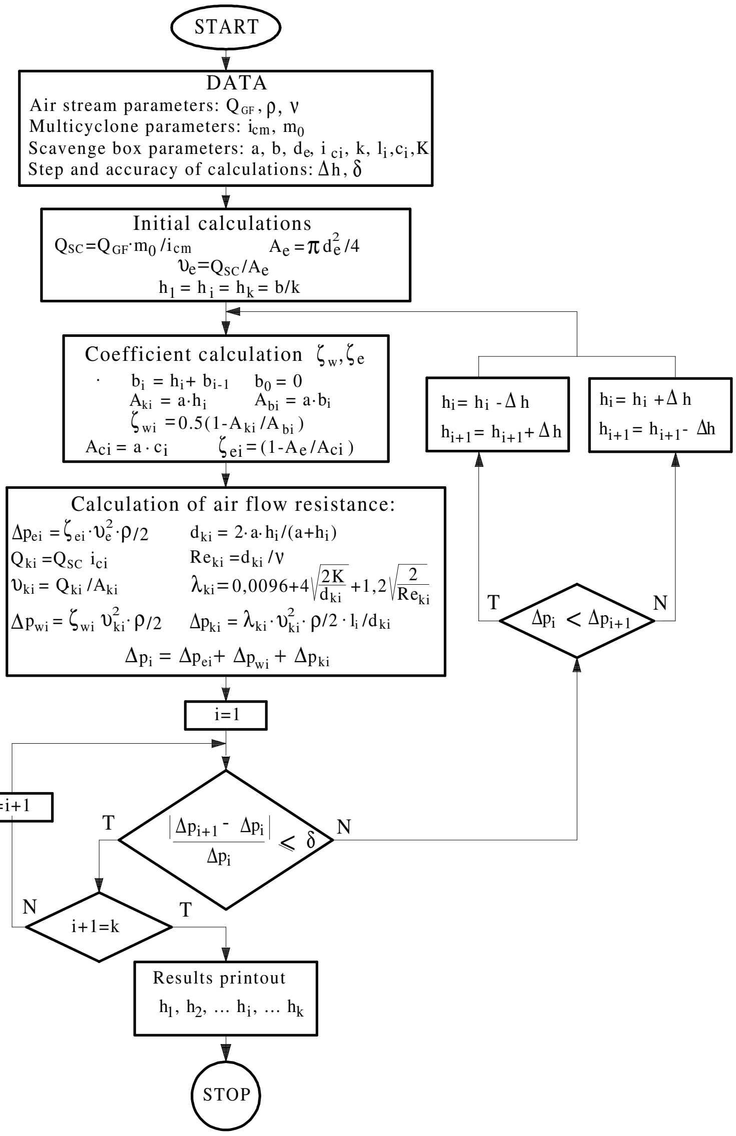

Fig. 13. Algorithm for calculating channel heights of scavenge box segment
Rys. 13. Algorytm obliczeń wysokości kanałów komory odsysania segmentu osadnika pyłu

suction channels height h_i at the outlet from the dust settling tank segment has been prepared.

Calculated channel heights have the following values: h_1 = 8,5 mm, h_2 = 13 mm, h_3 = 17 mm, h_4 = 21,5 mm respectively. Such dimensions of dust settling tank division are used for construction of dust settling tank segment. Three segments of this type will form a BWP-1 air filter multicyclone – Fig. 14. Verification flow tests have been carried out using a single segment.

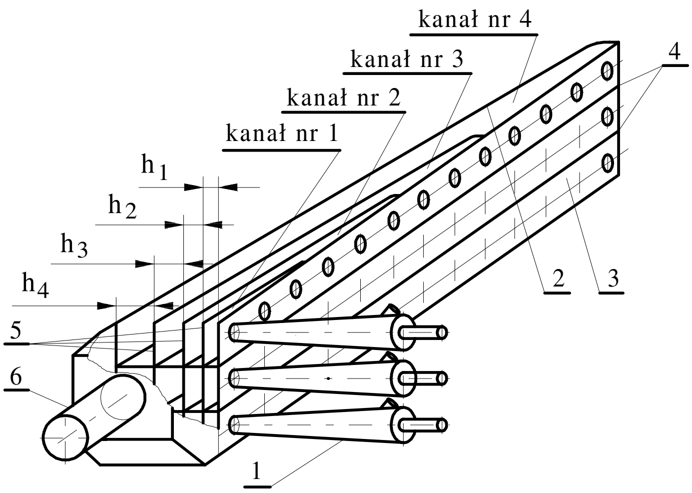

Fig. 14. Schematic diagram of dust settling tank of BWP-1 air filter multicyclone after dividing chamber into segments and suction channels: 1 – cyclone, 2 – settling tank bottom, 3 – settling tank upper plate, 4 – segment division wall, 5 – channel partitions, 6 – suction stub pipe, h_1, h_2, h_3, h_4 – suction channels height at the outlet

Rys. 14. Schemat ideowy osadnika pyłu multicyklonu filtru powietrza BWP-1 po podziale komory na segmenty i kanały odsysania: 1 – cyklon, 2 – dno osadnika, 3 – płyta górna osadnika, 4 – ściana rozdzielająca segmenty, 5 – przegrody kanałów, 6 – króciec odsysania, h_1, h_2, h_3, h_4 – wysokości kanałów odsysających na wylocie

6. Experimental test of a dust suction system from multicyclone segment

Test subject was dust suction ejector system from multicyclone segment, being a separated column of 13 cyclones with settling tank and after modernization of suction channels. Test purpose was an experimental assessment of influence of constructional changes of multicyclone dust settling tank on suction stream Q_{SC} values. Tests have been carried out at the test stand (Fig. 6) and according to method specified in item 3. Main suction stream from Q_{SS} segment was a one third of a Q_{SF} stream.

Dust suction ejector system from multicyclone segment has been tested using three versions of dust settling tank division into channels: A, B and C. A version with dust settling dank divided into parallel partitions into four suction channels with height of h_1 = 8,5 mm, h_2 = 13 mm, h_3 = 17 mm, h_4 = 21,5 mm has been presented in Fig. 15. Each channel (1, 2 and 3) sucks streams from three cyclones. Channel 4 is assigned with the last four cyclones.

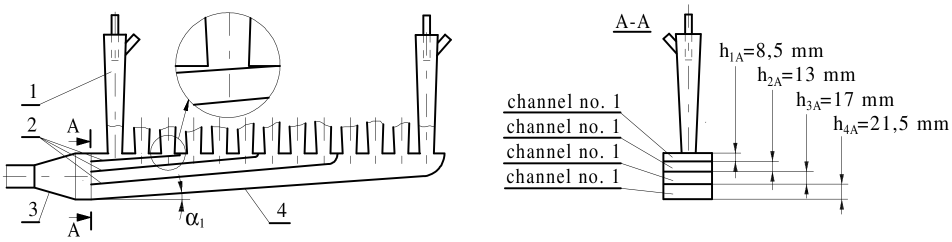

Fig. 15. Diagram of modernized multicyclone dust settling tank – version A: 1 – cyclone, 2 – channel partitions, 3 – suction stub pipe, 4 – settling tank bottom.
Rys. 15. Schemat zmodernizowanego osadnika pyłu segmentu multicyklonu – wariant *A*: 1 – cyklon, 2 – przegrody kanałów, 3 – króciec odsysania, 4 – dno osadnika

Q_{SC} values of a stream sucked from the first three cyclones (channel no. 1) are approx. 40% smaller than before introducing channels – Fig. 16 in version *A* of segment's dust settling tank modernization. Q_{SC} values of streams sucked from other three cyclones (channel no. 1) are insignificantly smaller. For the remaining cyclones (channel no. 3 and no. 4) increase of Q_{SC} values of sucked stream is significant.

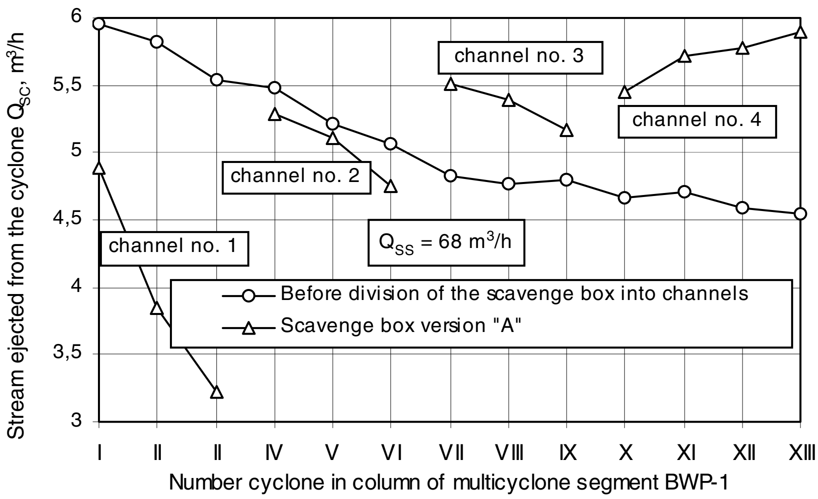

Fig. 16. Q_{SC} values of streams sucked from a single cyclone before division into suction channels with modernized dust settling tank (version *A*)
Rys. 16. Wartości strumieni odsysanych Q_{SC} z pojedynczych cyklonów segmentu przed podziałem na kanały odsysania i ze zmodernizowanym (wariant *A*) osadnikiem pyłu

There was a significant diversity between sucked stream values from the cyclones within a single suction channel with the same value of a main suction stream Q_{SS}. The largest difference occurred at the cyclones included in the channel no. 1. Stream sucked from cyclone no. 3 is 30% smaller than stream sucked from cyclone no. 1. For other channels those differences were 7%, 6% and 6% respectively.

Cause of this large difference between Q_{SC} streams of a first and third cyclone is a construction of channel no. 1. Its height as a result of partition located parallel to the slanting settling tank bottom is reduced to 1 mm at the end section, containing outlet of the third cyclone. Such construction caused restraining of air stream flow from cyclone no. 2 and 3. In order to reduce this effect, partition of the 1st canal has been set parallel in the distance h_1 to the upper dust settling tank plate - *B* version of segment's dust settling tank modernization (Fig. 17). Partitions of other channels and settling tank bottom has been made parallel to the partition of a first channel maintaining distance h_1, h_2, h_3 and h_4.

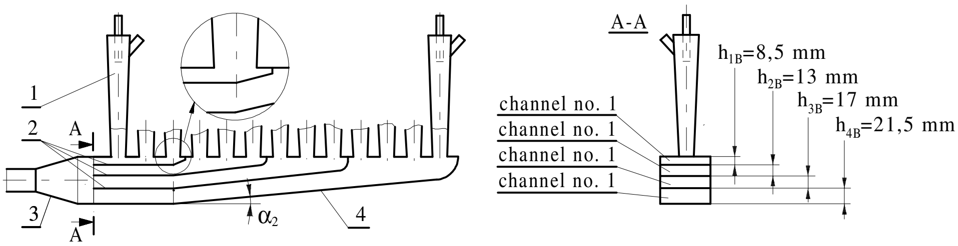

Fig. 17. Diagram of modernized multicyclone segment's dust settling tank – version B:
1 – cyclone, 2 – channel partitions, 3 – suction stub pipe, 4 – settling tank bottom
Rys. 17. Schemat zmodernizowanego osadnika pyłu segmentu multicyklonu – wariant *B*:
1 – cyklon, 2 – przegrody kanałów, 3 – króciec odsysania, 4 – dno osadnika

Test showed (Fig. 18) significant (compared to A version) decrease of sucked stream values from cyclones at the channel no. 4 and increase at the channel no. 1. At the cyclones of other two channels there were insignificant changes of Q_{SC} values. Also significant reduction of differences between extreme Q_{SC} values of sucked stream from the cyclones within a single channel occurred. Difference for channel no. 1 is now 9% and for other approx. 4%. It is possible to notice a significant difference between mean values of streams sucked from the cyclones in adjacent channels. The smallest mean value occurred at the channel no. 1 and the largest at the channel no. 4. Difference between them is 17%. In order to reduce the difference, C version of modernization of segment's dust settling tank has been prepared, consisting in change of cross section area of channel no. 1, no. 3 and no. 4 by changing their height.

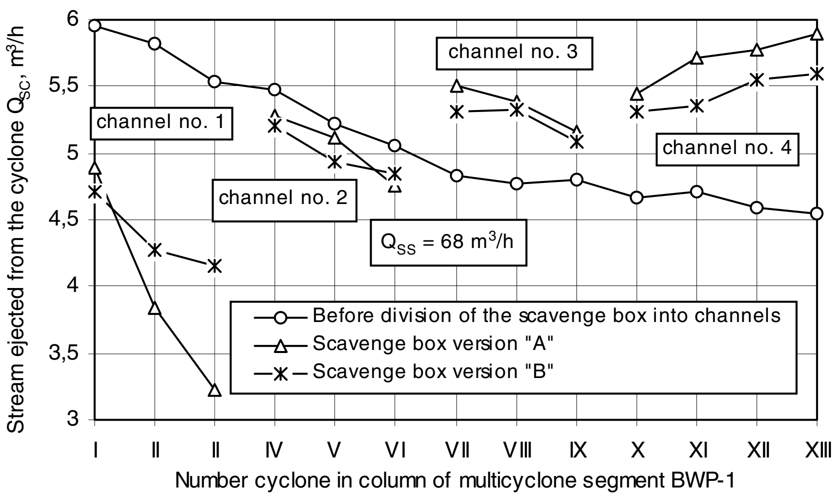

Fig. 18. Q_{SC} values for streams sucked from a single segment's cyclone before dividing into suction channels and with modernized dust settling tank (A and B versions)
Rys. 18. Wartości strumieni odsysanych Q_{SC} z pojedynczych cyklonów segmentu przed podziałem na kanały odsysania i ze zmodernizowanym (warianty *A* i *B*) osadnikiem pyłu

New channel heights: h_{1C} = 10,5 mm (2 mm more), h_{2C} = 13 mm, h_{3C} = 16 mm (1 mm less), h_{4C} = 20,5 mm (1 mm less).

Results of *C* version (Fig. 19) of dust settling tank indicates significant reduction of (differences between the highest and the lowest Q_{SC} value) Q_{SC} values

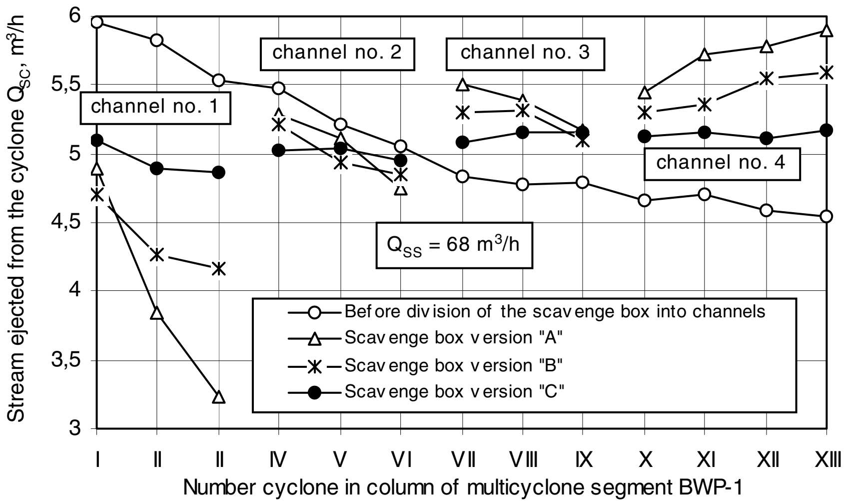

Fig. 19. Q_{SC} values of streams sucked from single segment's cyclone before dividing into suction channels with modernized dust settling tank (version *A*, *B*, *C*)
Rys. 19. Wartości strumieni odsysanych Q_{SC} z pojedynczych cyklonów segmentu przed podziałem na kanały odsysania ze zmodernizowanym (warianty *A*, *B*, *C*) osadnikiem pyłu

of streams sucked from cyclones within a single suction channel. Differences are not larger than 8% for channel no. 1 and 3% for other channels. Also a significant reduction of differences between mean values of streams sucked from cyclones in adjacent channels has been obtained. Difference between channel no. 1 and channel no. 4 is 4%. Obtained results has been considered satisfactory and the third modification version as final.

7. Conclusions

1) Values of streams sucked from a single cyclones (within a multicyclone with common dust settling tank) are diversified independent from the Q_{SF} value of a main suction stream, but depend on multicyclone dust settling tank construction, e.g. using a single dust suction stub pipe from the settling tank.
2) Largest values of sucked streams occur for cyclones located closest to the suction stub pipe. With increase of a distance of the location of cyclones from the suction stub pipe there is a reduction of Q_{SC} stream values. Q_{SC} stream sucked from the last (13th) cyclone has a value 25÷35% smaller compared to Q_{SC} stream sucked from the 1st cyclone.
3) Suggested multicyclone dust settling tank construction consisting in division into segments and division of settling tank into independent, isolated suction channels with assigned cyclone groups is a good way to reduce differences between values of streams sucked from a single cyclone. In this case, differences between values of streams sucked from extreme cyclones do not exceed 8% for channel no. 1 and 3% for other channels – Fig. 19.
4) Due to difficulties with reduction of differences between Q_{SC} values of the first channel streams it is suggested that his channel contains less cyclones than other segment's channels. It forces use of a greater number of suction channel and complicated dust settling tank construction.
5) Calculation model used for numerical calculation of dust settling tank dimensions enables preliminary selection of suction channel heights. Final channel height selection must be made during experimental flow tests of a real segment of dust settling tank. It elongates the design stage but enables obtaining high consistence of suction stream values.

Presented conclusions from very wide flow tests of a multicyclone inlet air dust collector of an engine from a combat vehicle popular in the Polish Army are universal. Prepared research technology may be used for recognition of flow characteristics of any multicyclone dust collector (not only cyclones with adjoining inlets), and prepared means of dividing settling tank into segments may be used in inlet air dust collectors for engines of other devices providing highest dust collecting efficiency ever while maintaining restrained resistance of a flow thorough the filter and ejector system of separated dust.

Issue of providing effective multicyclone operation (bank of cyclones) through proper gas distribution is known [16] but not at the scale considered by an author of this study.

Praca wpłynęła do Redakcji 21.09.2006 r.

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Ocena możliwości poprawy efektywności odsysania pyłu z odpylacza multicyklonowego filtru powietrza pojazdu gąsienicowego

S t r e s z c z e n i e

Przedstawiono organizację procesu odsysania pyłu z osadnika multicyklonu filtru dwustopniowego pojazdu gąsienicowego. Pokazano wpływ stopnia odsysania na skuteczność odpylania odpylacza bezwładnościowego. Wykonano badania eksperymentalne wpływu konstrukcji multicyklonu na równomierność odsysania pyłu z pojedynczych cyklonów. Przeprowadzono analizę możliwości poprawy równomierności odsysania pyłu z odpylacza multicyklonowego. Przedstawiono projekt modyfikacji osadnika pyłu polegający na podziale komory osadnika na niezależne, odizolowane od siebie kanały odsysania.

Wysokości kanałów odsysania na wylocie h_1, h_2, h_3, h_4 dobrano obliczeniowo pod względem jednakowych oporów przepływu strumienia powietrza przez kanały. Odpowiednie obliczenia przepływowe wykonano wykorzystując model obliczeniowy osadnika pyłu opracowany przez autora.

Przeprowadzono trzyetapową eksperymentalną ocenę wpływu wprowadzonych zmian konstrukcyjnych osadnika pyłu multicyklonu na wartości strumieni odsysania z pojedynczych cyklonów.