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EVALUATION OF AIR FILTERS IN TRUCK VEHICLE ENGINES

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Summary. The paper presents the results of an examination of air filters used in Star trucks operated by the Polish Armed Forces. An effect of the used air filter on engine operation was analysed. Possibilities were presented to improve air filter operational properties with respect to prolongation of operation time between services.

Key words: Air filter, power, turning moment, exhaust gas smokiness, flow resistance.

INTRODUCTION

Depending on environmental conditions, the air sucked in from atmosphere by the induction system of combustion engine contains, among others, mineral impurities which induce an accelerated wear of engine elements. Diameter of these impurities does not exceed 0.1 mm. Accuracy of the separation of foreign solid bodies from air (mainly dust particles – sand granules and mineral and organic substances) determines the intensity of wear of most engine parts. Hence the necessity of using air filters [9,10,11,12].

Motor-car combustion-ignition engine manufacturers dedicate much attention to air filters and continuously aim at their improvement. This has led to the development of various filter constructions which differ in their structure, principle of operation, efficiency, filtering medium type or permeability loss rate. What is more, depending on expected operating conditions, the same model of engine is frequently equipped in different air filters with fittingly chosen properties [5,13,14].

Air filter should be characterised by the following properties that result from specific operational requirements:

- high dust removal efficiency,
- small flow resistance,
- large dust-holding capacity,
- small dimensions and weight,
- large mechanical service life, and
- easy service [1, 2].

For filtering the air sucked in by combustion engine, single-stage or multi-stage air filters are used. As a rule, motor-car engines are equipped in single-stage barrier air filters (with a porous barrier), whereas multi-stage air filters are being used in motor trucks and machines (also in farm

machines) operated under large dustiness conditions. In a multi-stage air filter, the first filtration stage is a mono- or a multi-cyclone, whereas a porous barrier is applied in the second one. In a multi-stage air filter, particles of larger diameters are being separated in cyclones. Particles of smaller diameters left in the air stream after passing the first stage are filtered in the porous barrier. This extends filter operation time until the assumed value of filter flow resistance is achieved, which is most frequently defined as a value of pressure loss on filter [14,17].

Air filters used in motor-car engines are required to be as accurate in filtering mechanical impurities from the air as possible. At the same time, flow resistance should be as little as possible. With excessive flow resistance, air movement throttling can bring about a decrease in the cylinder filling-up with fresh charge, which will result in a drop of power and turning moment and an increase in exhaust gas smokiness [7,8,13]. It is generally accepted that a power drop induced by flow resistance should not be larger than 3%.

Flow resistance is considerably dependent on the type of applied air filter, i.e. on its construction, overall dimensions or type of filtrating element [1].

Air filter construction and filtrating medium are chosen so as to obtain a maximum filtrating efficiency with the assumed flow resistance. This ensures a maximum service life to motor-car engines.

Depending on the operating conditions, air filter is also chosen in respect of its dust-holding capacity. Air filter dust-holding capacity determines its operation time between services [1, 9]. This is of paramount importance in the case when a motor-car engine is operated under conditions of large dustiness with simultaneous limitation of possibilities to service an air filter at any time. This can be illustrated by operation of STAR 660M2 motor trucks by the Polish Armed Forces in Sinai within the UN Missions. Motor truck operation under these conditions forced, among others, a three times more frequent air filter cleaning, whereas in the case of a sand storm the cleaning should have taken place during every oil change in the air filter [9].

The study aims at an evaluation of the effect of air filter type on operation parameters of combustion compression-ignition engine of the 359 type. The analysis of the obtained test results will allow for a determination of the usefulness of two air filter types for the 359 motor-car engines mounted in the Star trucks commonly operated by the Polish Armed Forces.

Basing on the examination results, which should be treated as preliminary ones, recommendations can be formulated for further complex studies aiming at an optimisation of the whole induction system of the 359 engine.

EXAMINATION

The examination included a determination of a number of external characteristics for a motor-car engine with a G-57 type air filter, air filter used in military vehicles (military air filter), military air filter with additional filtration stage (special air filter) and without an air filter.

The first air filter type is a standard air filter of the G-57 type used in Star trucks. It is a two-stage filter. The first stage is a washing out filter, in which mechanical impurities striking onto the surface of oil are stopped. The second stage is a membrane filter, on which small mechanical impurities are deposited.

The second air filter type is used in military vehicles. Its operation consists in the passage of air through a number of cyclones, on which larger mechanical impurities are deposited, wherefore they falling down to the bottom and thereafter through two filtering elements (oil-soaked steel wool). This filter has a considerably larger active area than the G-57 type air filter, therefore its efficiency

should be higher and flow resistance smaller. The view of this air filter and its certain components is presented in Fig. 1.

A special air filter is a modernised version of the military air filter. Its modernisation consisted in adding a third radial stage of air cleaning and application of the ejection system of solid impurities removal. A view of the special air filter and its additional components is presented in Fig. 2.

Examination was carried out on a typical engine test bed equipped in a water brake and a smokiness measurement apparatus. The HH-3 type water brake, with the whole control system, was used. The HH-3 type water brake is characterised by parameters sufficient for the testing of the 359 engine within its full range of rotational speed and loads. Power and turning moment determination errors should not exceed 5%. Exhaust gas smokiness was evaluated on the grounds of infrared radiation absorption coefficient measurement in a MDO 2 smokemeter.

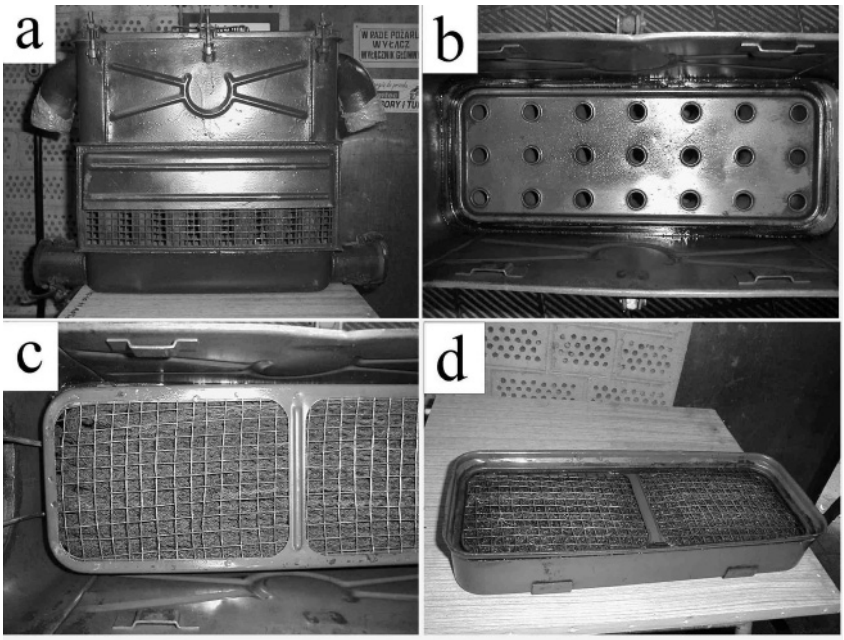

Fig. 1. General view and components of the military air filter: a) general view of air filter, b) internal view of air filter without filtrating element, c)internal view of air filter with filtrating element installed, d) view of filtrating element

While analysing the cumulative characteristics of external power presented in Fig. 3, it is actually difficult to find out any effect of this type of air filter on the power developed by the tested engine. The largest difference in power was about 5 kW and occurred at the speed of 2700 1/min. This makes about 4.7% of the highest power, therefore this difference can be assumed to be within measuring error range. It can also be observed that differences in the power reached by the engine with G-57 air filters and military air filter were practically negligibly small and similar to that of the engine without an air filter. The largest difference in this case was about 2 kW (2%) within the range of high rotational speeds. The engine with special air filter with a difference, as mentioned above, amounting to about 4.7% at high rotational speed and about 4% at a speed of 1000 l/min, is definitely inferior in this comparison.

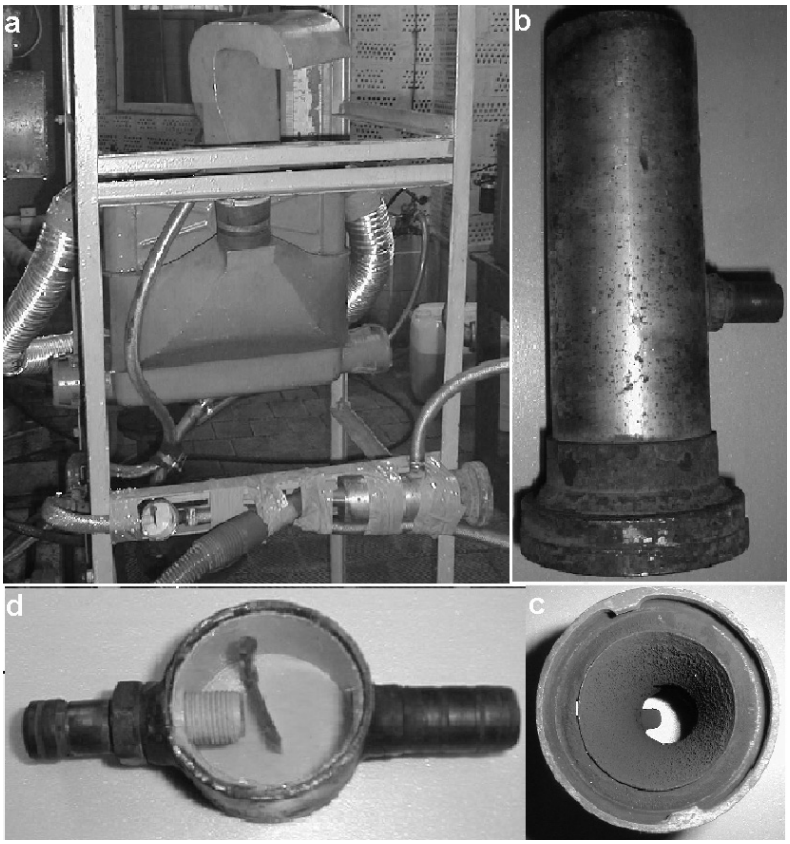

Fig. 2. View of the special air filter with accessories: a) general view of air filter, b) c) ejection reducer, d) ejection indicator

Figure 4 presents the cumulative characteristics of the turning moment. The highest turning moment, i.e. up to 415 Nm, was reached by the engine with g-57 air filter. The loss in relation to the turning moment obtained by the engine without an air filter was 3 Nm. Military air filter reached a maximum turning moment of 412 Nm. Therefore, the difference is smaller than 1 %. Maximum turning moments for engines without an air filter and with G-57 and military air filters occurred at the rotational speed of about 1750 l/min. The engine equipped in the special air filter reached the maximum turning moment at the speed of about 1500 1/min. The difference of maximum turning moment value between the military and special air filters is already larger and its value is 12 Nm (3%). These differences are respectively larger for the engine with G-57 air filter and without an air filter. However, attention should be paid to differences in the speed at which maximum turning moment occurs for the special air filter and the other examined cases. This difference amounts to 250 1/min. The author is of the opinion that this difference may be caused by an occurrence of dynamic supercharging effect. This effect could occur due to the rather large volume of the special air filter in which, in relation to the military air filter, a space where filtered impurities are collected has been considerably enlarged. Exactly in this case, a decrease of the rotational speed of the maximum turning moment favourably affects engine flexibility.

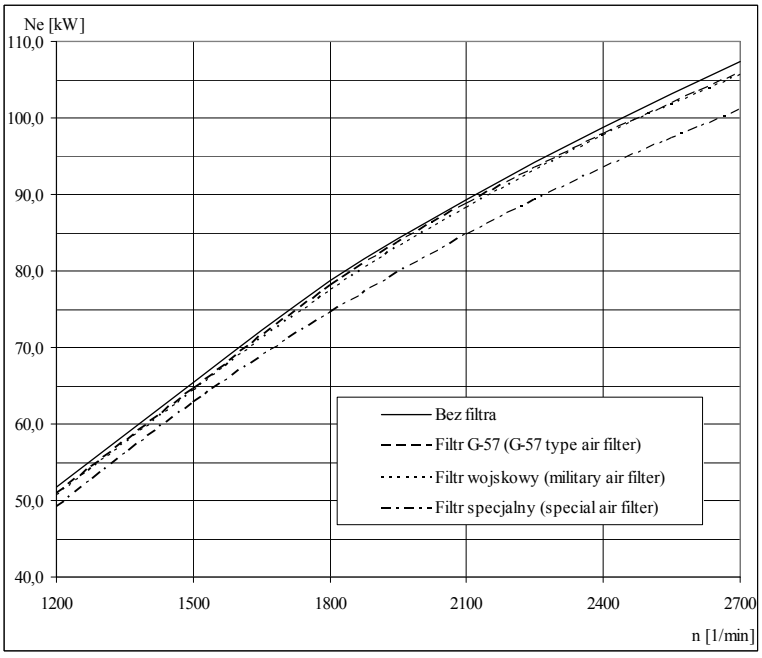

Fig. 3. Cumulative characteristics of external power $N_e = f(n)$

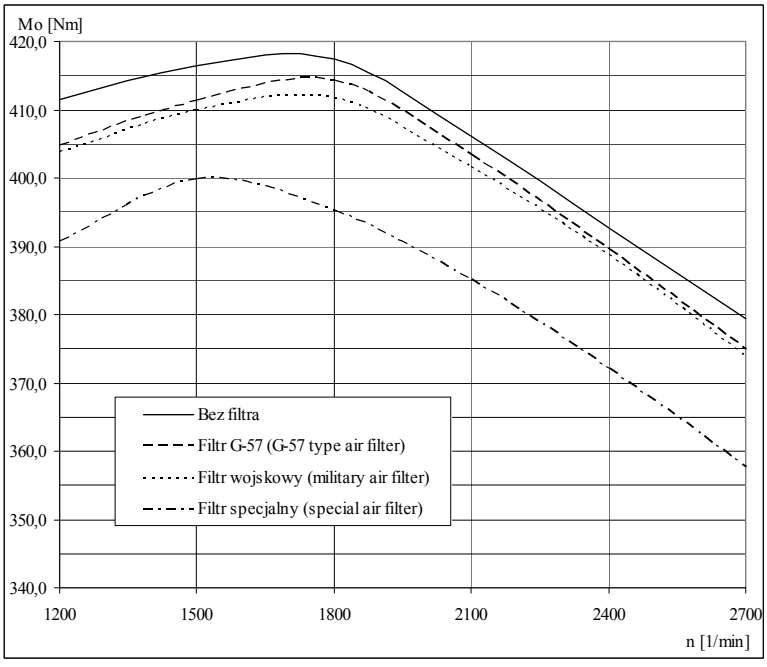

Fig. 4. Cumulative characteristics of the external turning moment $Mo = f(n)$

Figure 5 presents the cumulative characteristics of external infrared radiation absorption coefficient. As a matter of fact, basing only on this characteristic curve one can evaluate the tested air filters because differences between respective curves were significant and considerably exceeded measuring error limits.

The highest values of absorption coefficient, within the whole range of rotational speed, were characteristic of the engine with special air filter. The engine with military air filter turned out to be better in this respect, while the best one was the engine with G-57 air filter. Differences between military air filter and the special one were 0.2 1/m (about 7.7%) within the range of low rotational speeds, 0.05 1/m (4%) at 1800 1/min, and about 0.2 1/m (20%) at speeds above 2100 1/m. Differences between G-57 air filter and the military one were considerably smaller and were lower than 0.1 1/m (from 4 to 7%) within the whole range of rotational speed.

In order to see what caused just such a course of the turning moment and infrared radiation absorption coefficient, the characteristics of air filter pressure losses in the function of engine crankshaft rotational speed were made. Measurements were made with a U-pipe filled with water. The collective characteristic curve of pressure losses is presented in Figure 7.

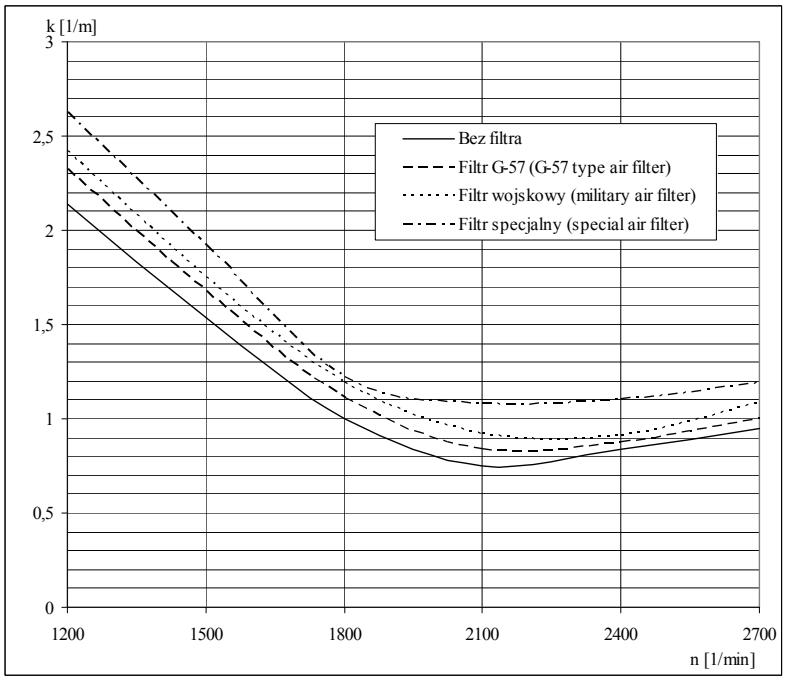

Fig. 5. Cumulative characteristics of external absorption coefficient k = f(n)

It results from this curve that smaller pressure losses are found on G-57 air filter than on the military and special ones. Difference in the losses increases together with an increase of engine crankshaft rotational speed. At the speed of 1200 1/min, the difference between military air filter and the G-57 one is 10 mm of water column, whereas at the speed of 2700 l/min this difference reaches 68 mm of water column. These differences for special air filter are respectively larger. Taking this fact into consideration, the engine with military air filter or with the special one can be assumed to have larger suction resistance and – which is connected with this – larger charge exchange work,

smaller filling efficiency, smaller power and turning moment, and larger exhaust gas smokiness. Moreover, a line collapse can be observed on the characteristic curve of the engine with special air filter at the speed of about 1750 1/min, which can be evidence of the above-mentioned occurrence of dynamic supercharging effect.

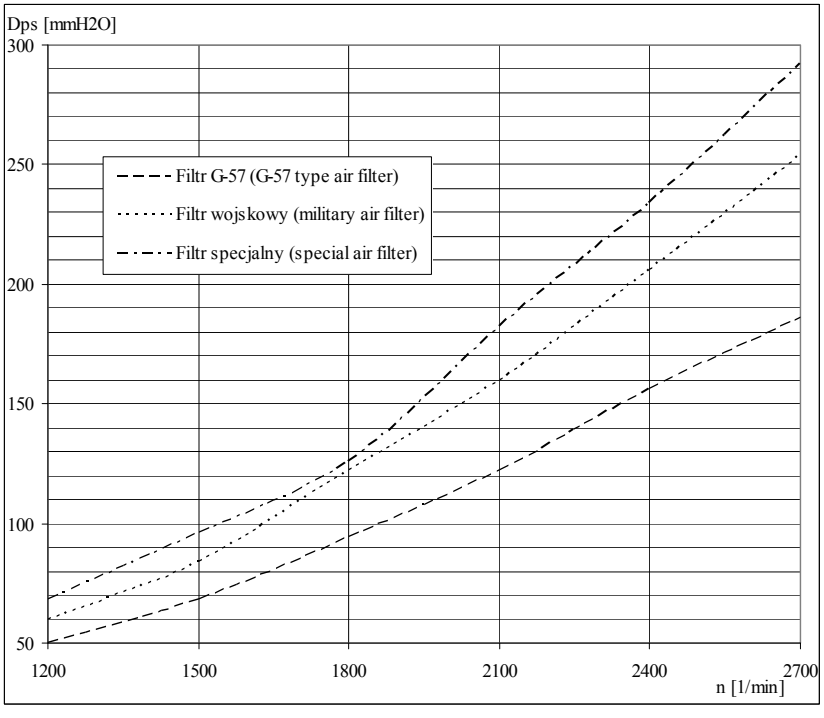

Fig. 6. Cumulative characteristics of external air filter pressure decrease $\Delta p_s = f(n)$

Also single-stage air filters, used in Alfa Romeo156 with a 1.9 JTD engine, Seat Leon 1.9 TDI and Škoda Octavia RS motor cars, were examined. In these motor-cars, factory and tuning BMC, tapered and CDA air filters were used. Tests were carried out on a chassis engine test bed where an effect of the used filter on basic engine operation parameters, such as engine power and turning moment, were examined.

In Alfa Romeo motor-car, the use of a tuning BMC air filter brought about an increase in engine power by about 5 %, with a simultaneous decrease in its turning moment by about 10 %. The use of a tapered air filter gave a 5% increase in engine power and a 3% increase in its turning moment.

The use of BMC air filters in Škoda and Seat motor-cars did not basically change anything (engine power increased by about 1 %, while the turning moment decreased by about 3 %).

CONCLUSIONS

When analysing the results of the carried out tests, the following conclusions can be formulated:

- effect of the tested air filters on engine power and its turning moment is small, with differences being contained within a range of measurement error;
- effect of the tested air filters on infrared radiation absorption coefficient is significant, with a difference coming to 20%;
- influence of the air filter on engine operation parameters is more significant at larger rotational speeds of engine crankshaft;
- pressure losses on air filter of the G-57 type were smaller than on the military one within the whole range of engine crankshaft rotational speed;
- engine with a special air filter obtained evidently the poorest operation parameters due to the largest pressure loss occurring on this filter;
- use of the tuning air filters does not bring the expected results without a complex modification of the induction system;
- tuning filters frequently have a smaller flow resistance at the cost of ability to filter impurities of smaller dimensions.

It can result from the carried out tests that an influence of an air filter on the filling coefficient, and thus on engine operation parameters, is most significant for large rotational speeds. For large rotational speeds, the kinetic energy of the flowing medium is large and the effect of wave phenomena in the induction system can be significant. Observation of the movement of water column in a U-pipe allowed for an assumption that flow resistance on air filter was not as important under dynamic conditions than under the steady-state ones. In order to confirm this assumption, a precise flow test of the whole induction system should be carried out, including measurement of medium speed and pressure in the induction system.

While evaluating the examined air filters, an operational aspect should also be taken into consideration. It may turn out here that a special air filter has important advantages in the case whe a vehicle user is anxious about long intervals between services. Equipping the special air filter in additional filtration stage from where mechanical impurities are sucked off by ejection causes that already less impurities get into the air filter itself, which results in its longer service life. The author proposes to enlarge the depth of the space from where the suction of mechanical impurities is taking place and to increase the diameter of the suction conduit, through which the suction efficiency should be increased.

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OCENA FILTRÓW POWIETRZA W SILNIKACH SAMOCHODÓW CIĘŻAROWYCH

Streszczenie. W artykule przedstawiono wyniki badań filtrów powietrza stosowanych w samochodach ciężarowych Star eksploatowanych przez Siły Zbrojne RP. Dokonano analizy wpływu zastosowanego filtra powietrza na parametry pracy silnika. Przedstawiono możliwości poprawy właściwości eksploatacyjnych filtra powietrza w zakresie wydłużenia czasu pracy między obsługami.

Słowa kluczowe: Filtr powietrza, moc, moment , zadymienie spalin, opory przepływu.