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DEVELOPMENT FILTER

Reduction of oil mist emissions from internal combustion engines

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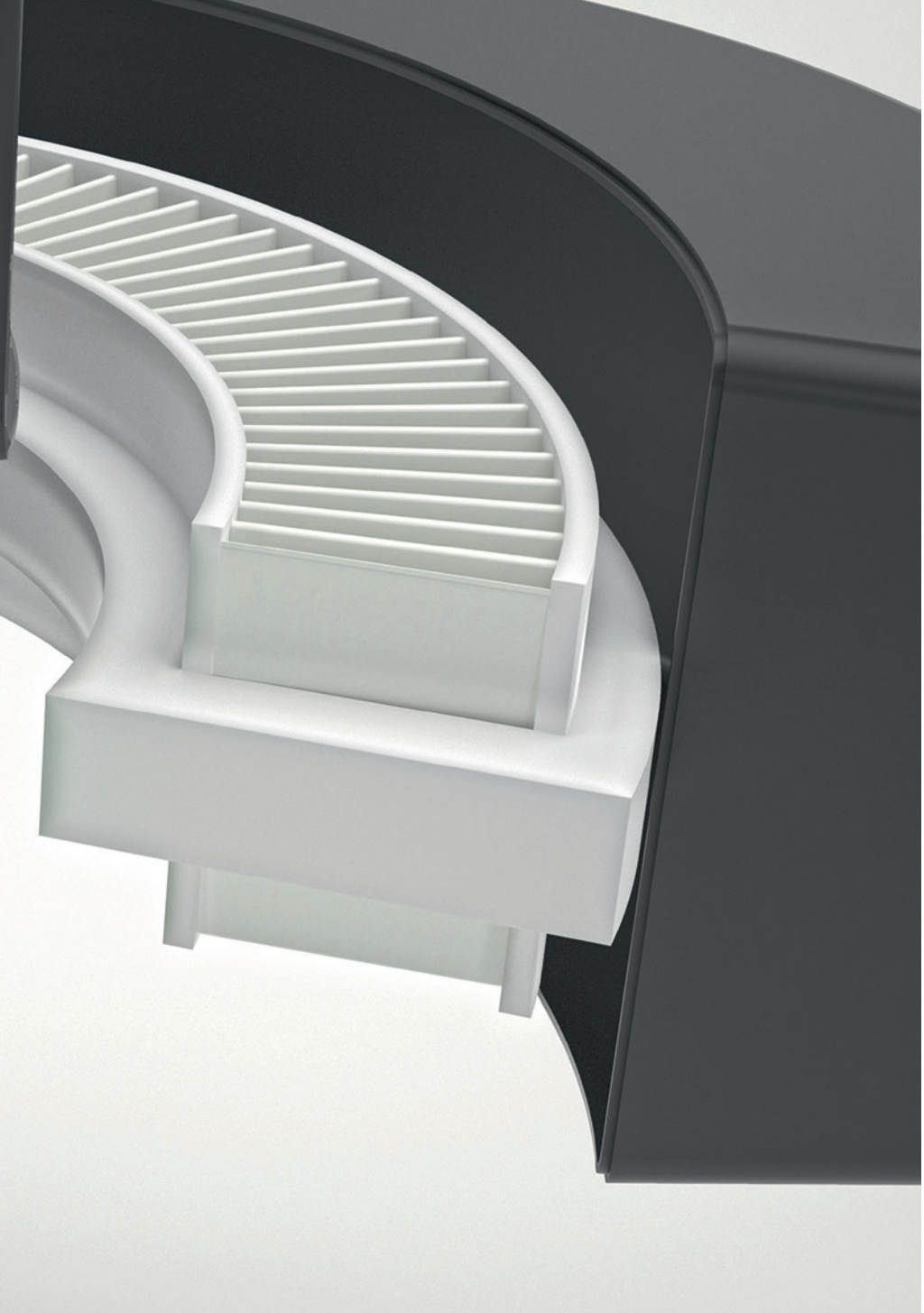
Downstream Filter Elements for Disc Stack Separators

Active separators based on disc stack technology separate oil particles from the blow-by gas, and thereby reduce the oil mist emissions of internal combustion engines. Rotera Automotive (formerly 3nine Automotive) combines this technology with a highly efficient downstream filter element to achieve even higher separation rates close to 100 %, thereby reducing the residual oil content in the blow-by gas to levels that can hardly be measured.



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The sales stop of the combustion engine has been initiated, but when this will actually be implemented is an open question. Politicians and an increasing number of manufacturers are citing 2030, 2035 or 2040 as the phase-out date; in countries without suitable infrastructural framework conditions for a switch to electricity, the phase-out may be even later. Therefore, it makes sense to further reduce emissions from internal combustion engines in order to meet upcoming local legislations. The European Commission is still discussing the matter, but the new Euro 7 emissions standard is expected to be finalized in 2022 and will probably enter into effect as early as 2025. Equivalent directives in the USA and China point in the same direction. Optimizing crankcase ventilation is one important factor in complying with future emission limit values by minimizing the amount of residual oil in the blow-by gas and reducing crankcase pressure to a level below atmospheric pressure.

PASSIVE OR ACTIVE – OPEN OR CLOSED?

Crankcase ventilation systems can be either operating passively or actively, **FIGURE 1**. Passive systems can only use the flow energy from the blow-by gas to separate the oil mist, whereas active

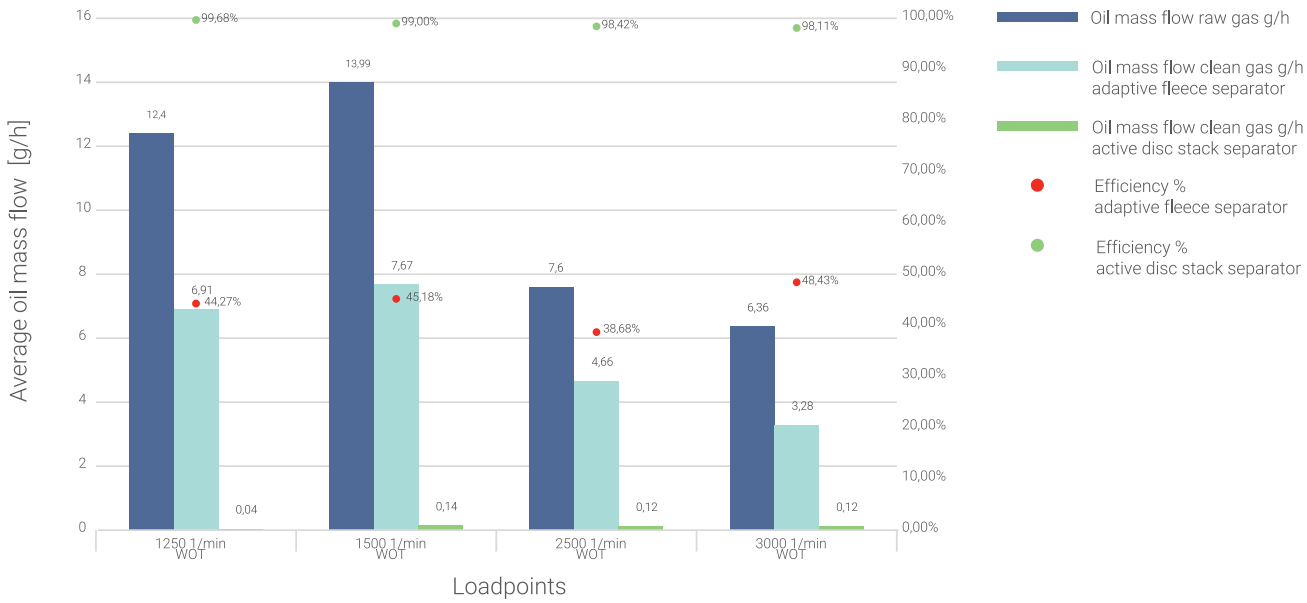

FIGURE 1 Efficiency of passive/active oil mist separator systems (© Rotera Automotive AB)

systems, such as hydraulically or electrically driven disc stack separators, are independent of the flow energy, hence separate the oil particles continuously on a high level. Furthermore, operating with disc stack separators, the vacuum that the technology generates, supports the achievement of the crankcase pressure target value, which is below atmospheric pressure.

Both drive solutions can be designed either as an open or closed version. The increasingly stricter emission directives and regulations can realistically only be met by closed crankcase ventilation systems, which are reflected in current and future exhaust emission standards. When it comes to open systems, the clean gas, which is composed of combustion gas as well as remaining oil particles, is discharged into the atmosphere. In closed systems, it is recirculated through the combustion engine's intake passage. Residual oil flow up to approximately 0.3 g/h is primarily based on the smallest particles, smaller than 0.6 µm, which cannot, even by active-driven systems, be completely separated.

For open systems, the issue with particles not being separated is that they are emitted into the atmosphere. In closed systems, the residual oil particles can interfere with the combustion process, cause pre-ignition or "super knocking", and can impair efficiency. Among others, deposits in the intake

FIGURE 2 Hydraulic and electric drive concept for disc stack separators (© Rotera Automotive AB)

passage caused by coked or cracked oil residues can increase the flow resistance in the intake passage and reduce the efficiency of the turbocharger. In a long-term perspective, oil deposits can cause components such as the turbocharger or intake valves to fail completely. For these reasons, it is essential to filter even the finest oil particles out of the blow-by gas.

FILTERS FOR THE FINEST PARTICLES

The solution is a highly efficient filter element downstream of the disc stack separator, which also filters out particles below 0.6 µm and thus the last remaining quantities of oil. The developers of this combination of disc stack separator and filter element (patent pending) have already been significantly involved in the development of an adaptive oil separation solution [1], the adaptive diaphragm for efficient blow-by gas cleaning [2], and disc stack separators for cleaning blow-by gas [3]. The high-efficiency filter element can be designed as a lifetime or service component, depending on the size and filter material. The filter has regenerative properties, can discharge itself to some extent when the engine is off – thereby returning the separated oil into the oil circuit.

HYDRAULIC OR ELECTRICAL?

The filter element can be combined with both hydraulic and electric-drive systems, **FIGURE 2**. As an example, using a disc stack separator in truck engines with an oil entrainment of 8 g/h reduces the residual oil quantity to 0.3 g/h. Combined with a downstream filter element, it is reduced to below 0.01 g/h. Hydraulically driven disc stack separators equipped with downstream filters achieve higher separation efficiencies than electrically driven disc stack separators without filters, **FIGURE 3**. Positive side effects are a reduction of the engine's total oil consumption by the quantity of oil separated and that the requirements for crankcase pressure are met.

FILTER DESIGN

The downstream filter element is placed in a row after the disc stack separator – either the separator and filter are combined to a single component, or the filter is attached as a separate box or installed at a suitable location respectively depending on the installation space conditions. Both variants have benefits. In the first case, installation effort is reduced to a single part; in the second case, the filter can be better adapted to a tight installation space and, if designed as a service component, it is easier accessible.

The filter design is customer-specific and adapted to the installation space, composition of the blow-by gas, particle sizes, temperatures, and the desired service lifetime, among others. For this

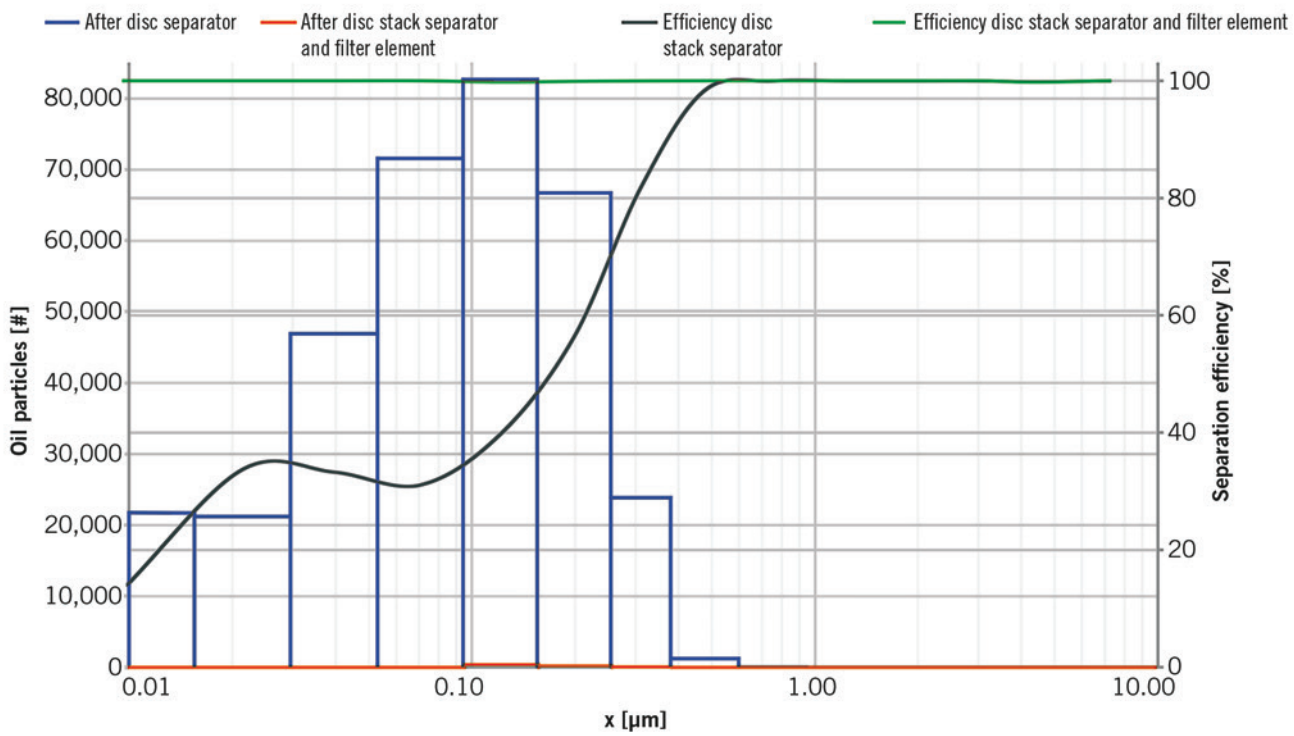

FIGURE 3 Oil separation efficiency – active system versus active system with filter at 195 l/min blow-by (© Rotera Automotive AB)

FIGURE 4 Various sizes and applications (© Rotera Automotive AB)

reason, the customer's engine is always analyzed in detail before the filter is designed. For example, the blow-by gas from gasoline engines is much more chemically aggressive than that from diesel engines, and the filters in truck engines require a much longer service life than those in passenger car engines.

The filter itself is made of Polyethylene Terephthalate (PET) or polyamide (PA) and in addition, can be coated with Teflon (PTFE), depending on requirements. The decisive factor is an ideal compromise for the specific application between filter performance, pressure drop and requirements for lifetime, depending on the particle load or amount of blow-by. The specially developed filter material offers maximum efficiency at minimum pressure loss, and its influence on the resulting crankcase pressure is barely measurable. Furthermore, depending on the customer's requirements for installation space, it must be possible to integrate the filter into the disc stack separator housing or install it in a suitable, maintenance-friendly location.

Since the filter element only collects the residual oil downstream of the already highly efficient disc stack separator, the component has a very long service life. Depending on the application, replacement may be completely unnecessary or only necessary after a specified number of oil changes. Filter load condition can also be determined by way of

pressure (differential) sensors, so that the filter will only have to be replaced when necessary. In addition, separated oil drains from the filter back into the oil circuit when the engine is not running. This self-cleaning effect can be optimized with the aforementioned Teflon coating for the filter material.

EXTREMELY FLEXIBLE FIELD OF APPLICATIONS

The patent-pending combination of disc stack separator and downstream filter element opens a wide range of possible applications. It is also possible to retrofit existing hydraulic or electric oil separation systems with the filter element. It is also worth considering the replacement of electrically driven disc stack separators without filters with hydraulically driven disc stack separators equipped with downstream filters due to the higher separation rates at acquisition costs which are around 10 % lower.

In general, the system can be combined with any kind of combustion engine – including e-fuels or hydrogen-powered ones – as well as hybrid drive. It can also be used for car, truck or off-highway engines, including generators and power plant engines, **FIGURE 4**.

SUMMARY

The innovative new crankcase ventilation system from Rotera Automotive consists of a disc stack separator in combination with downstream filter element. It reduces oil mist emissions and makes a contribution to improve the overall emissions of internal combustion engines. All laboratory and engine bench tests were successful; a patent has been applied for.

This system constitutes one of the best solutions for oil mist separation for the combustion engine's entire life, as it essentially reduces oil discharge to zero. Alongside its conventional application as a system for gasoline, diesel and hydrogen engine crankcase ventilation, the described technology is also used in fuel cell and battery-powered vehicles, where it also makes a contribution.

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