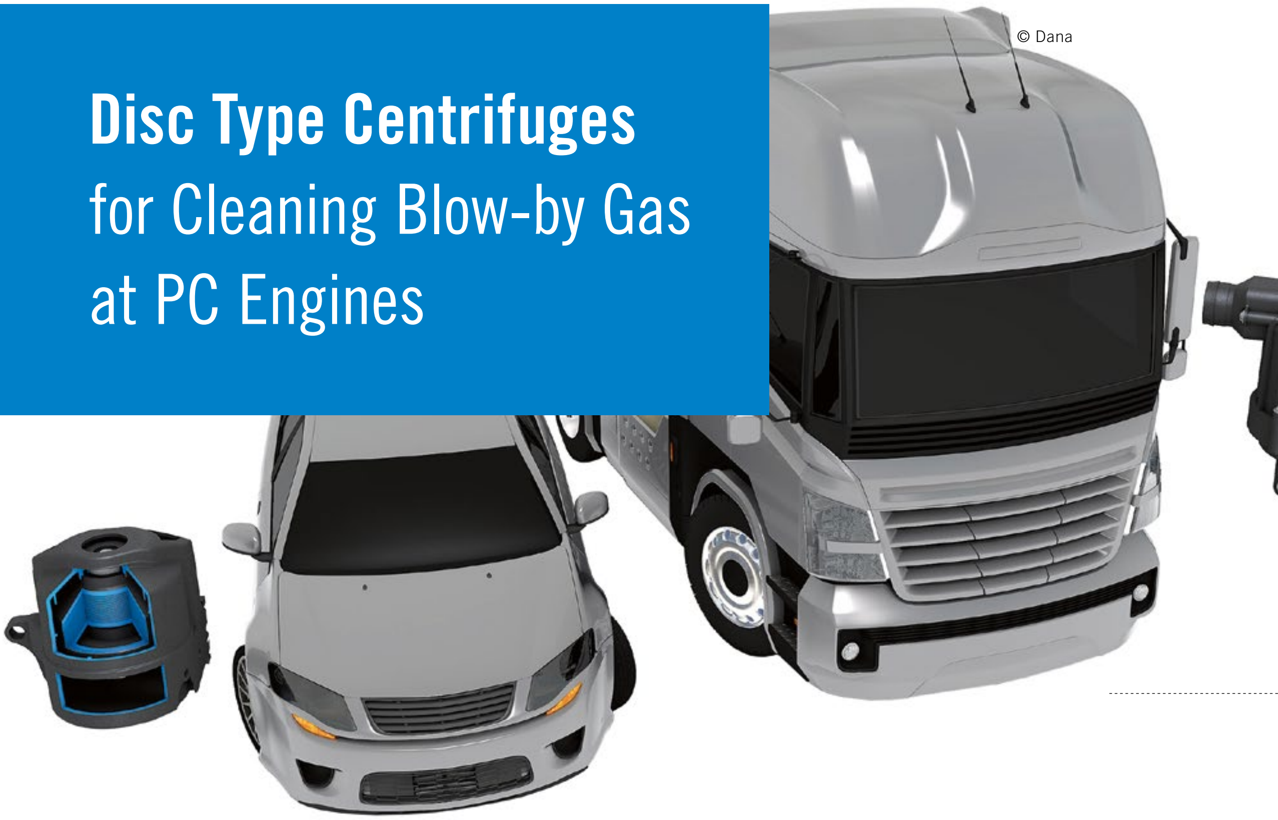
Disc Type Centrifuges for Cleaning Blow-by Gas at PC Engines



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Limit values for cleaning the blow-by gas become more stringent, oil particles are becoming smaller. Reinz from Neu-Ulm in Germany, a subsidiary of the U.S. American company Dana, has therefore developed – jointly with 3nine – a disc type centrifuge for combustion engines which separates especially oil particles smaller than 0.6 μm from the blow-by gas, and that at nearly 100 %.

INCREASING REQUIREMENTS FOR OIL PARTICLE FILTRATION

The evolution of passenger car engines advances at great strides: The quest is on for more efficiency, more power at lower fuel consumption. Cylinder pressures and oil temperatures therefore increase to achieve enhanced efficiency. The number of lubrication points and oil injection nozzles for friction optimisation in the drive train, and thus the circulating oil volume in the engine, increase. Low-viscosity motor oils are therefore used increasingly. This presents new challenges to crankcase ventilation and systems for cleaning the blow-by gases.

Blow-by gases cannot be avoided. They occur automatically in gasoline and diesel engines, especially when the combustion gas flows past the piston rings into the crankcase, carrying oil droplets along in the direction of the intake passage during ventilation. The problem: The tiny oil particles, smaller than 1 μm especially when using low-viscosity motor oils, would be deposited during their return to the intake manifold on engine components, amongst others on the throttle valve housing, the exhaust gas turbocharger, the intake valves or the charge air cooler. This would reduce the life and power of the engine in the long run. If the oil

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FIGURE 1 Dana disc type centrifuge for truck applications (left) and for passenger car applications (right) (© Dana)

droplets enter the combustion chamber and ignite there too early, knocking effects are produced in addition to uncontrolled combustion.

Removing the fine oil particles from the blow-by gas before it is returned to the combustion air is therefore more important than ever in the framework of crankcase ventilation. Target values are specified, at this, by the OEMs. If the tolerated maximum was around 5.0 g/h roughly ten years ago, up to 0.25 g/h oil discharge and less is sometimes requested today.

PASSIVE SEPARATING SYSTEMS REACH PHYSICAL LIMITS

Even adaptive passive oil mist separating systems, used in passenger car engines and working according to the impact or inertia principle – and usually more cost-efficient – often achieve only relatively small separation rates, especially with small particles. These systems only work efficiently when the differential pressure between intake passage of the engine and cylinder crankcase, as well as the flow rate of the blow-by gas, are accordingly high: the greater the acceleration and deflection, the finer the separable oil particles. The constant de-throttling of the intake tract reduces the differential pressure as energy source for passive oil mist separators. The systems reach more and more their physical limits when used in advanced combustion engines. Passive systems are hardly able to remove oil particles from the oil mist that are smaller than 0.6 µm. However, this is required on the background of engine development and changing legislation.

DOWNSIZING OF ACTIVE DISC TYPE CENTRIFUGES FROM TRUCK APPLICATIONS

Employing blowers or steam ejectors to increase the effectiveness of passive systems, is one solution. Another currently very promising approach are so-called disc type centrifuges that have been used in trucks already for some time and which have meanwhile entered the application field in passenger car engines as well, **FIGURE 1**. These are oil mist separating systems, attached to the engine or integrated into components such as oil pan or cylinder-head cover, and integrated in the circulation of crankcase ventilation. Their use as stand-alone system can also be realised. Their core element is a rotor, driven electrically or hydraulically via oil pressure, and where on its shaft in the centre of the housing several conically shaped discs are arranged as stack at close distance to each other.

With the active disc type centrifuge from Dana the same action principle as with classic disc type centrifuges becomes effective once rotating. Rotation pushes the gas out of the intermediate spaces between the discs. The oil particles heavier than gas are then deposited on the discs. They agglomerate into droplets, are flung by the centrifugal forces against the stationary outer walls of the separator, collected via spiral-shaped drainage grooves and returned to the oil circulation. The pressure in the crankcase is reduced through the suction of the disc stack. The development of the disc type centrifuge has produced additional innovations, amongst others a system for the drainage of the drive oil and the design for the integration of the disc stack into the cylinder-head cover.

The advantage of the active disc type centrifuges: Contrary to passive systems separation increases with decreasing flow rates of the blow-by gas and is not very sensitive to pressure conditions of the engines. In addition, they generate a pumping effect that counteracts the pressure losses and are maintenance-free, compared to pure, partially active, filter systems.

INNOVATIVE DISC TYPE CENTRIFUGES TACKLE ALSO VERY SMALL OIL PARTICLES

Innovative disc type centrifuges tackle also oil particles smaller than 0.6 µm.

This is exactly where the research and development work of Dana Inc. together with the specialists from 3nine, Stockholm, come into play. A weight-optimised active disc type centrifuge was developed where its full plastic housing can be attached to the side of the engine or integrated into the cylinder-head cover. Compared to competitive systems, this system achieves greater efficiencies. Especially the hydraulically powered version of the disc type centrifuge scores with lower power consumption, higher rotational speeds, short response times and weight savings. Even small oil particles, specifically those smaller than 0.6 µm, can thus be separated at nearly 100 %.

A ball bearing and a friction bearing are used – a combination that especially for this Heron turbine system generates less friction compared to free ball bearings. Because the oil particles in the blow-by gas provide for the continuous lubrication of the ball bearing, the friction losses are reduced even further. An optimised, conical disc design maximises the separating surface and therefore contributes to increased efficiency. It also prevents sooting effects effectively.

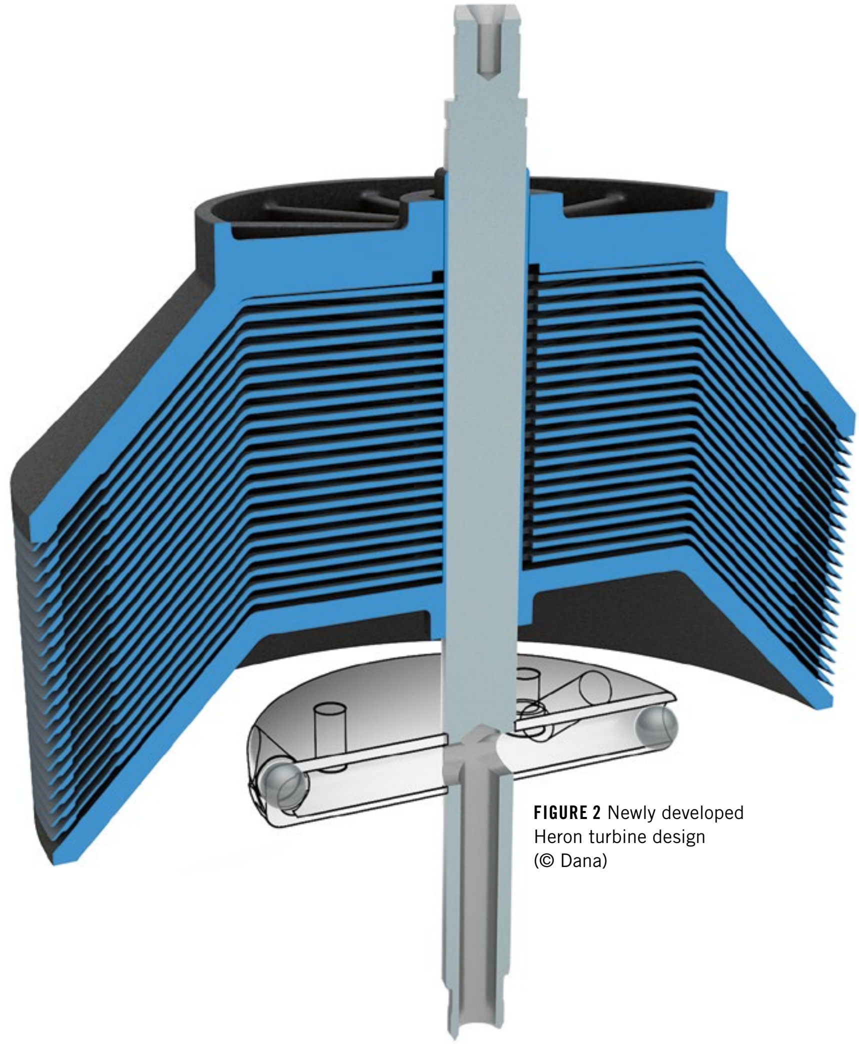

FIGURE 2 Newly developed Heron turbine design (© Dana)

DISC TYPE CENTRIFUGE ROTATES WITH HIGH REVOLUTION

The core innovation is the drive system from Heron turbine and contactless seal between drive and separating chamber. The drive oil, which is drawn from the engine oil circulation, flows here through the hollow drive axle in the direction of the turbine, **FIGURE 2**. It sits under the disc stack, protected by a plastic separating wall, which contains the contactless seal. The turbine features a balanced geometry and tangentially directed nozzle. If the drive oil flows through the nozzle, turbine and disc type centrifuge begin to rotate because of the repulsion

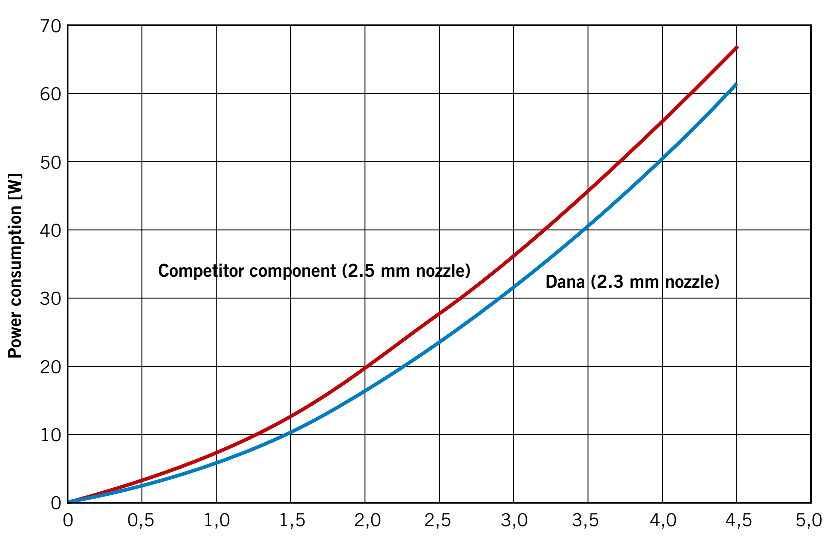

FIGURE 3 Power consumption depending on the engine oil pressure (© Dana)

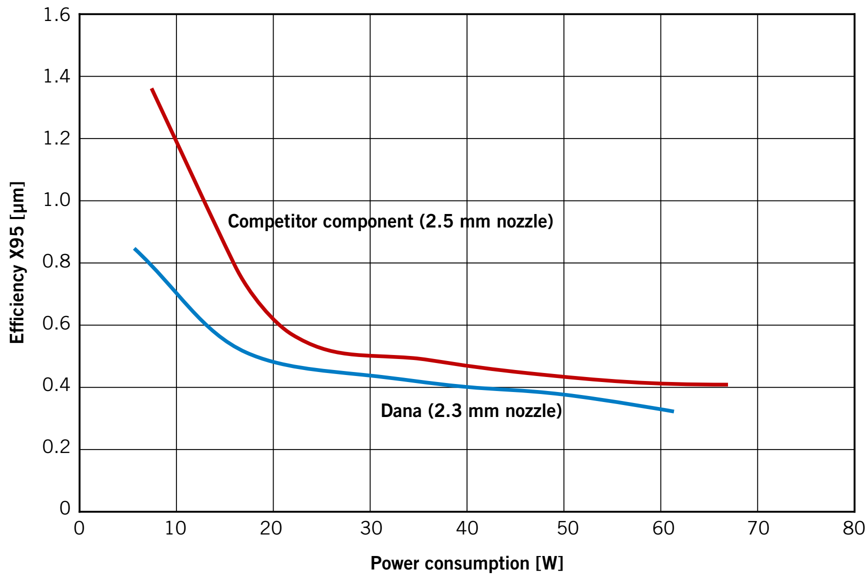

FIGURE 4 Effectiveness X95 value depending on the power consumption (© Dana)

effect with up to 12,000 rpm. Because of the nozzle, that has also been optimised, malfunctioning caused by turbulences is reduced to a minimum. By adapting the nozzle geometry, this turbine system can be flexibly adapted to the respective customer requirements. The system operates more efficiently especially at low oil pressures and presents major advantages over known systems with stationary nozzles. The rotational speed-dependent pressure curve in the oil circulation, in combination with the correlated Heron turbine, presents an energy-saving adaptive drive concept, which corresponds exactly to the engine requirements on separation over wide ranges.

HIGH SEPARATION EFFECTIVENESS AND LOW POWER CONSUMPTION

Using test methods designed especially for active systems, the engineers were able to prove the low power consumption of the new disc type centrifuges. They experimented here using separators with different nozzle diameters and numbers of discs. For truck separators with a nozzle diameter of 2.3 mm at an oil pressure of 4.5 bar, for example, a power consumption of roughly 62 W was generated. By comparison, a system of the competition, working with slightly larger diameter of 2.5 mm, achieved a higher power consumption of nearly 67 W at lower separating effectiveness, **FIGURE 3** and **FIGURE 4**. The scope of power consumption, depending on the application scenario, ranges from 50 to 70 W for trucks (25 to 50 discs) and 5 to 20 W for passenger cars (15 to 25 discs). The active disc type centrifuges can be designed for blow-by quantities of up to 600 l/min (for truck applications).

The high separating efficiency of the separator could be proven in tests. The separators work most effectively at high rotational speeds, **FIGURE 5**. If the X95 value, corresponding to the diameter of those particles which are separated to 95 % and thus constituting an indication for the separating effectiveness (the lower the

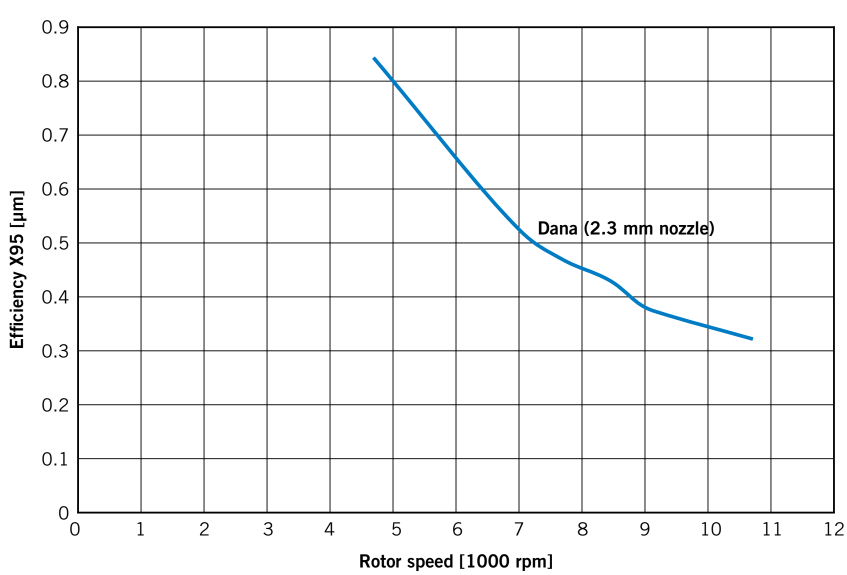

FIGURE 5 Effectiveness X95 value depending on the rotor speed (© Dana)

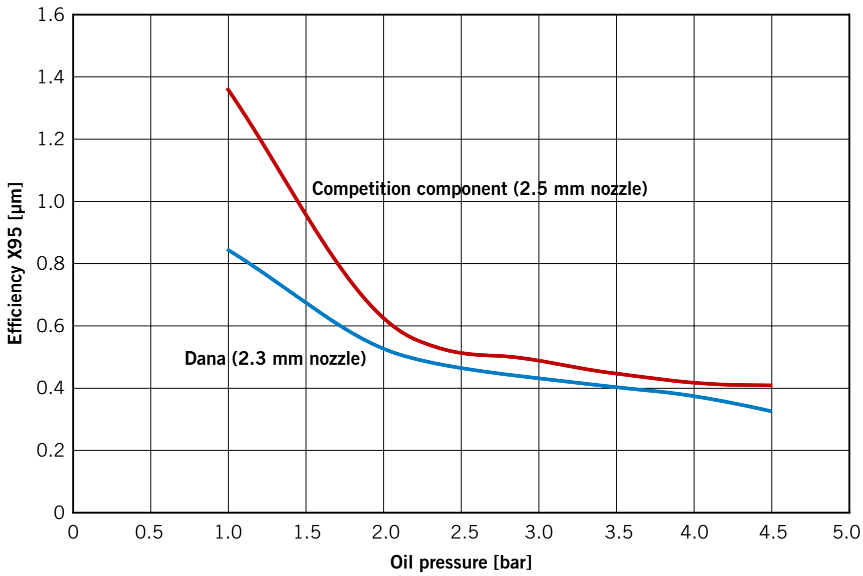

FIGURE 6 Effectiveness X95 value depending on the engine oil pressure (© Dana)

more effective), lies nearly at 0.8 µm at a speed of roughly 5000 rpm, it drops already below 0.4 µm at 10,000 rpm.

The tests demonstrated that the separators work clearly more effectively across the complete operating range in the oil pressure characteristic map than previous systems on the market. The X95 value at an oil pressure of 1 bar thus lies around 0.9 µm – with a competitive system examined it lies, by contrast, at over 1.3 µm, **FIGURE 6**. With passenger cars, the oil discharge amount after the separator, even at full load points, can be lowered up to 0.085 g/h and below – a value that falls far below the requirements presented. Because the OEMs continually reduce the energy consumption of oil pumps by lowering the total oil pressure and, in addition, work with low-viscosity oils, the newly developed active disc type centrifuge can fully assert its high efficiency here at low oil pressure.

Development and test phase have meanwhile been concluded. The active disc type centrifuges for truck and passenger car applications have been developed ready for series production, and nominations for the use of hydraulic systems have already been obtained. Designs with electric motor drive are in the initial prototype phase and series nominations are expected in the near future.

SUMMARY

The following developments seem unstoppable for the construction of passenger car engines: One the one hand, there are more stringent laws regulating cleaning of the blow-by gases and, amongst others, stipulate higher separation values and negative pressure in the crankcase. On the other hand, there are OEMs, lowering the total oil pressure in the engine in order to reduce the energy consumption of the oil pumps while relying on increasingly thinner oil at the same time, which leads to respectively fine and difficult to separate oil particles in the blow-by gas. In addition, the trend of downsizing leads to increasingly high oil temperatures and combustion pressures. On this background, passive oil separating systems reach their limits. Innovative active disc type centrifuges with optimised disc design and improved drive technology, by contrast, achieve a high pump pressure even at low oil pressure and reduced power consumption and a separation efficiency of nearly 100 %, even for oil particles smaller than 1 µm.