
# Blue Tron – Electrically Driven Disc Separator for Passenger Car Applications

Developers of modern combustion engines are confronted with ever greater challenges due to more and more demanding $CO_2$ targets. In this article Hengst demonstrates the performance capability of electric disc separators regarding highly efficient oil separation and negative crankcase pressures in all engine operation points.

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## KNOWN APPLICATIONS FOR ELECTRIC DISC SEPARATORS

The disc separator's mode of action has been well-established in the industry for many years. After first making use of the high separation efficiencies in industrial applications due to the density differences of liquids to be separated in thin columns of a stacked rotor out of individual discs, this concept was soon used successfully for the separation of liquid drops from gaseous media [1]. Due to the flexibility of the energy supply, the electric drive had already established itself in the industry early on as an advantageous form of the rotary drive. Electric disc separators with air flow rates from 500 to 2500 m³/h are used today, for example, in machining centres, to clean the housing air off oil and cooling lubricant particles. The advantage of this technology compared to conventional air cleaning using filters is that the systems, as components with long-life, are very low-maintenance and that the separated cooling lubricant can be re-used [2].

This ideal combination of a highly efficient fine oil separator based on a rotating disc stack and a flexible, efficient and maintenance-free electric drive for the de-oiling of the blow-by gas of commercial vehicle diesel engines was made ready for series production by Hengst for the first time in 2012. To this end, the very massive and large construction design established in the industry had to be reduced to a dimension acceptable in vehicle design, which is distinguished by significantly more compact dimensions, greatly reduced material usage, cost-effective components as well as processes and components which can be manufactured through high-volume production. At the same time, the significantly higher requirements regarding ambient temperatures, media resistance and external vibration excitations are met in the combustion engine environment.

## ACTIVE CRANKCASE VENTILATION

Developers of modern combustion engines are facing ever greater challenges due to $CO_2$ targets, which are becoming more and more demanding throughout the world. To achieve these goals while at the same time satisfying the customers' demands regarding performance, downsizing engines with a supercharger have long been established in both gasoline and diesel engines.

Due to the high power density, these engine concepts require, in addition to increased boost and mean effective pressures, higher temperatures in the combustion chamber and the exhaust gas system. As a result of the use of low-viscosity lubricating oils the average droplet size of the fine oil particles in the blow-by gas has more than halved in the past fifteen years, **FIGURE 1** [3]. Even if the finest oil particles (<<1 µm) when compared with the coarse oil particles (>1 µm) only make up a small fraction of the total mass of the oil discharged through the crankcase ventilation, they lead to considerable engine problems if

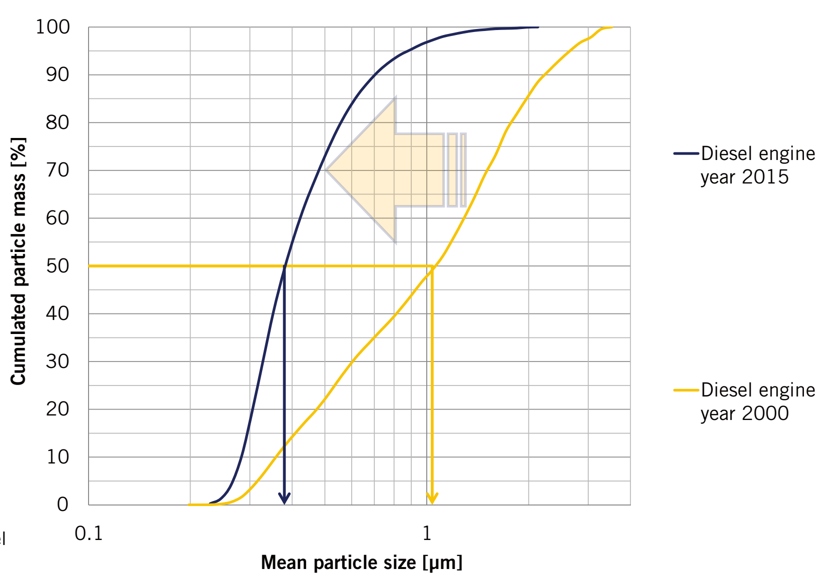


**FIGURE 1** Development of the raw gas particle spectra of passenger car diesel engines (© Hengst)

separation is inadequate. In the case of supercharged gasoline engines, they can favour low-speed pre-ignition (LSPI) effects in the combustion chamber at low speeds and high loads, which cause considerable engine damage [4]. In many cases, the maximum torque of the engines must be reduced in these engine operation points to prevent this.

In the case of modern diesel engines, however, the distortion of engine components in the intake tract is the greatest problem associated with insufficient fine oil separation. The very fine oil particles, which are surface-activated due to high shearing forces, carbonise and coat components such as turbochargers, intercoolers and air flaps in a short time, which quite often leads to measurable losses in engine performance. Since these effects are favoured by high temperatures, the engine developers are often forced to limit the air temperature downstream to the compressor below a critical value independent of the boost pressure limitation.

With active oil separators, such as the hydraulically driven disc separator Blue Disc [3] or the electrically driven variant Blue Tron, both problems are considerably minimised compared to passive separation systems by the significantly increased separation efficiency of fine oil particles. In addition to this important function, both active systems also meet the requirement of ensuring a negative pressure in the crankcase, which is significantly better than conventional separators. While passive separation systems obtain the energy required for the oil separation from the pressure difference between the crankcase and the intake duct, the gas flow for disc separators is generated by the rotating disc stack. The volume flow of the combustion engine is thus actively conveyed from the crankcase.

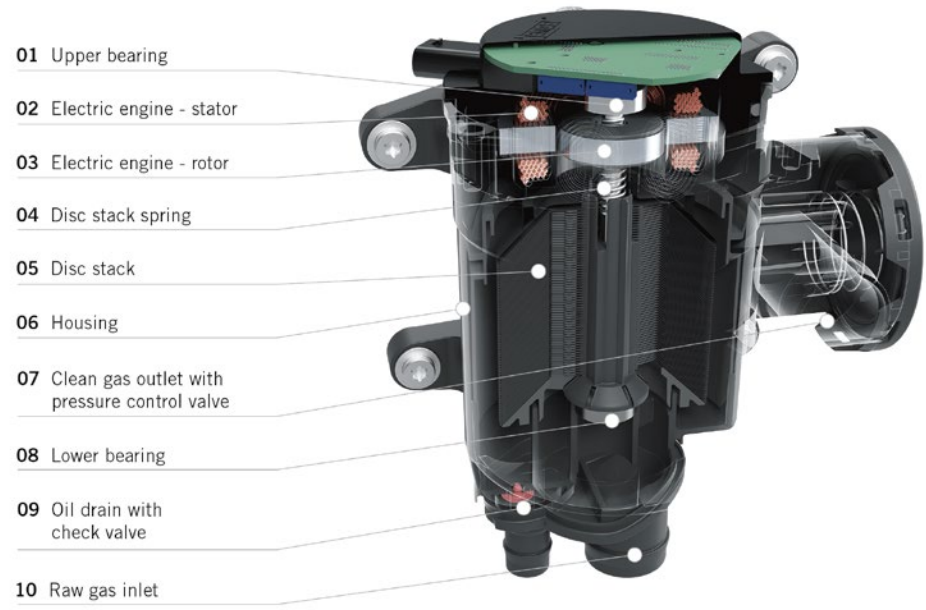


**FIGURE 2** Sectional view of the Blue Tron (© Hengst)

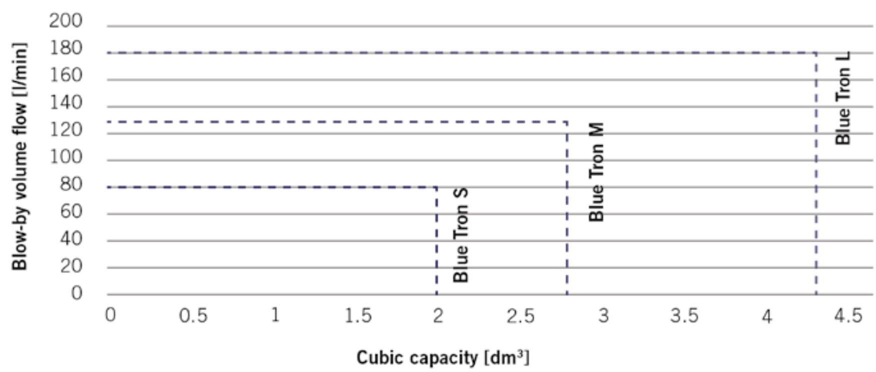


**FIGURE 3** Functional definition of the Blue Tron disc separator modular system (© Hengst)

## THE BLUE TRON-CONCEPT

Before Hengst could develop an electrically-driven disc separator for use in passenger cars, the company first had to pool its experience gained from the commercial vehicle series. A brushless DC motor with encapsulated design has proven to be the preferred solution regarding resistance against aggressive blow-by compositions, which occur increasingly often due to the use of alternative fuels, and the prevention of ignition sources in the blow-by flow. A maintenance-free ball bearing combination which has been validated for more than 20,000 h, a proven plastic disc design with special material and wall thickness composition as well as an optimised gas and oil conduit at the outlet of the disc stack can also be transferred from the commercial vehicle variant. However, issues specific to the passenger car application must also be applied to the product design. The size and weight targets must be mentioned here in particular. In addition to a reduced disc diameter, an innovative disc tensioning concept helps to minimise the construction size of the rotor. The direct integration of the bearings in the electric drive's stator and the housing, as well as a very thin-walled housing design, makes allowance for ambitious weight targets.

The concept of the disc separator, where blow-by flow passes through it from the inside to the outside, is also used for passenger car applications since the conveying characteristics of the blow-by gas, which are adjusted as a result of this, compensate for the slight disadvantages of particle separation elsewhere. The reduction in the separation efficiency, which results from the reduction in diameter of the separator discs to passenger car dimensions, is offset by an increase in the maximum disc separator speed from 12,000 to 16,000 rpm. The standard pressure and oil return control components on the raw gas or the clean gas side of the disc separator can be integrated depending on the specific applica-

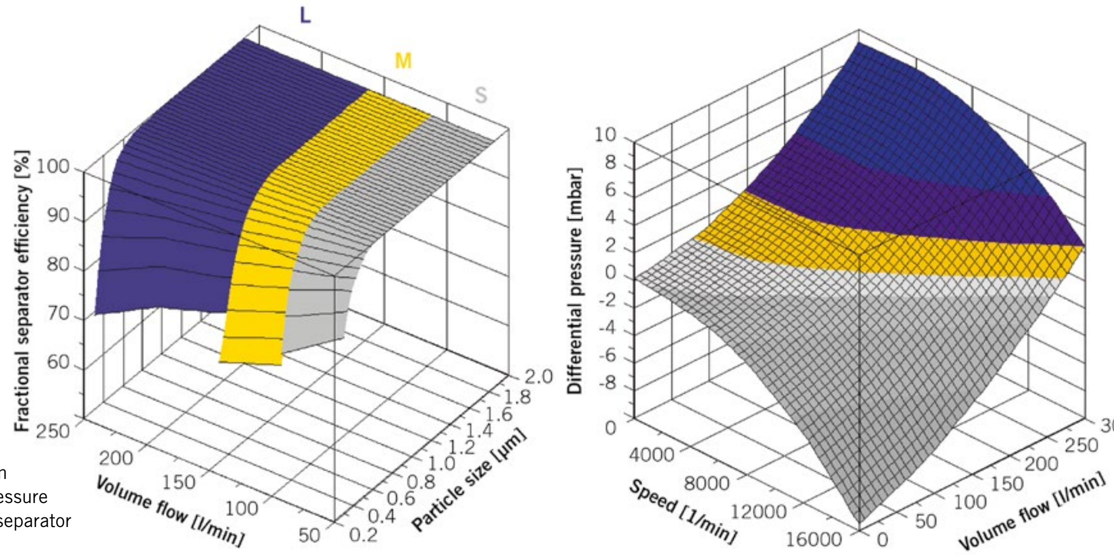


**FIGURE 4** Fractional separation efficiency and differential pressure profile of the Blue Tron disc separator modular system (© Hengst)

tion, the installation situation or the interface design, **FIGURE 2**. To provide a modular solution for a wide range of engines at short notice, a modular system comprising three Blue Tron sizes has been defined. This is depicted in **FIGURE 3** with reference to the blow-by quantity and the engine's displacement. Standing and lying variants are defined for all disc separator sizes, whereby any angular position can be generated from these.

The size selection can be geared to the engine parameters shown in **FIGURE 3**, but should also be considered because of the following factors: the desired conveying behaviour and the particle spectrum occurring in the raw gas. As depicted in **FIGURE 4**, a larger disc separator provides an increased conveyance of the gas from the crankcase to the engine's intake system in addition to an improved separation efficiency for the same blow-by flow rate. The variants of the modular system described above are designed in such a way that a 90 % separation of 0.4 µm particles at a specific blow-by flow rate is achieved.

## FUNCTION POTENTIAL FOR CRANKCASE VENTILATION AND ENGINE OPERATION

In addition to the absolute improvements regarding the separation efficiency and crankcase pressure management compared to passive inertial separators, the electrically driven disc separator also has further advantages. Due to the drive which is independent of the internal combustion engine, the separation efficiency can be set using to individual engine operating points and in a needs-based manner. Compared to hydraulically or pneumatically driven active separators, advantages are shown here for fine particle spectra and low engine speeds, in the switching range between partial and full load and for high engine speeds and low loads. In the latter case, hydraulically and pneumatically driven systems generally consume considerably more energy than is necessary. In addition to the adaptation of the disc separator operation to the separation efficiency

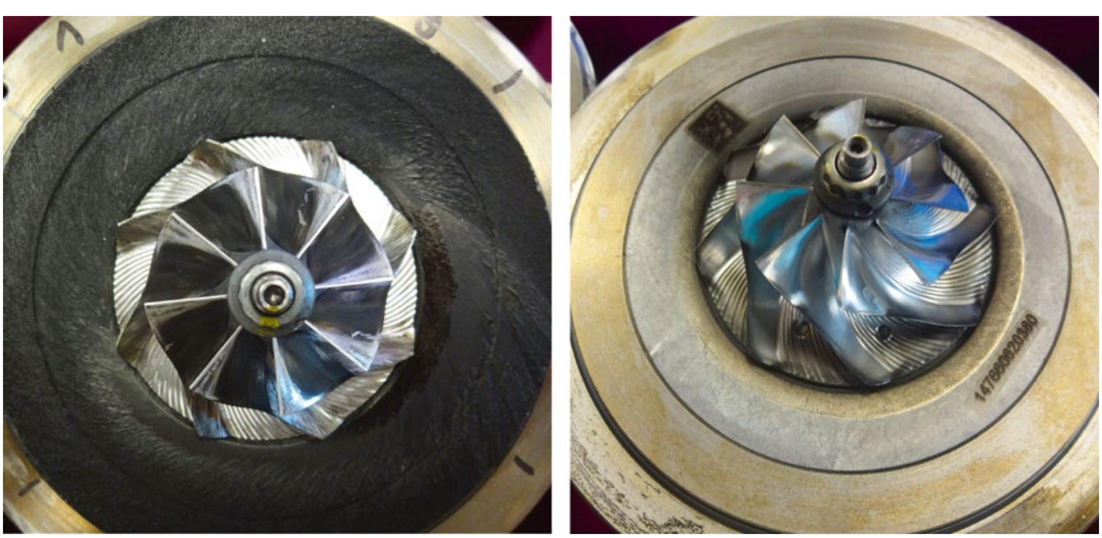

**FIGURE 5** Compressor after an endurance run leaving deposits with a passive separator (left) and an electric disc separator (right) (© Hengst)


**FIGURE 6** Combination of a hydraulic disc separator Blue Disc with an Energetic oil filter system (© Hengst)

and crankcase pressure, further control scenarios can be considered as a result.

These potentials at the system level naturally account for some advantages at the overall engine level. The highly de-oiled blow-by thus reduces the formation of deposits in the engine's intake duct. Hot engine components such as compressors and valves as well as intercoolers and throttle valves, in particular, are kept clean, **FIGURE 5**. As a result, the engine maintains its efficiency over a longer operating time. In addition, only an almost oil-free blow-by enables the further optimisation of $CO_2$ emissions from the internal combustion engine using higher compression end temperatures and higher boost pressures. Given the increasingly more stringent exhaust gas legislation with a special consideration of the Real Driving Environment (RDE) and the emission behaviour over the vehicle's current service life, the drastic reduction of the entry of oil from the crankcase ventilation helps to counter the ash-based degradation of the exhaust gas after treatment systems (see research projects M1416 and M2016 of Forschungsvereinigung Verbrennungsmotoren FVV). In the case of supercharged Gasoline engines with direct fuel injection, current studies show a relevance of the entry of oil from the crankcase ventilation [5]. Since August of this year, this effect is investigated more closely in the FVV project 'Oil input into combustion'.

The pressure build-up in the crankcase, which is improved by the active conveying behaviour, can have a positive effect on the oil return of the turbocharger, but can also simplify the design of the contacting seals on camshaft and crankshaft [6]. The cause of this is a constantly low crankcase pressure level, which is optimally below the intake pressure upstream to the compressor. The electric speed control enables very constant crankcase pressures at all operating points.

## OUTLOOK

Current tests on various engines demonstrate the performance capability of electric disc separators regarding highly efficient oil separation and negative crankcase pressures extending to all engine operation points. How the control system for electric disc separators in a serial application will be designed is currently under discussion. A speed controller based on the occurring particle spectrum or crankcase pressure appears worthwhile in principle [7]. In addition, in the case of stationary engine operation, speed variations on the disc separator are conceivable which, together with the evaluation of a crankcase pressure signal, could enable a diagnosis of the ventilation system with respect to leak tightness [8].

Although applications of an electric disc separator as a standalone engine component are currently discussed only, the modularisation concepts of Hengst plan to combine this ventilation system with a Hengst oil filtration system, **FIGURE 6**. In addition to minimising the installation effort for our customers, the focus here is primarily on the reduction of interfaces, system weight and the number of connecting elements.

**BIBLIOGRAPHY**

**[1]** Anderson, S. M.: Electrically Driven Cream Separator, US Patent 2,265,053, 1941
**[2]** https://www.3nine.de/oelnebelabscheider/, called on 21 July 2017
**[3]** Kuzgunoglu-Hennecke, M. et al.: Active crankcase ventilation for passenger car engines. In: MTZ 77 (2016), no. 3, p. 38-45
**[4]** Mayer, M; Hofmann, P.; Williams, J.; Tong, D.: Influence of the Engine Oil on Pre-ignitions at Highly Supercharged Direct-injection Gasoline Engines. In: MTZworldwide 77 (2016), no. 6, p. 36-40
**[5]** Niizato, T. et al.: Honda's new Turbo GDI engine family for global applications, 37th International Vienna Engine Symposium, 2016
**[6]** Paulisch, A.; Heilig, M.; Knezic, P.: Dynamic shaft seal with high vacuum tolerance. In: MTZ 78 (2017), no. 06, p. 52-56
**[7]** Skoog, J.: Device and Method for Cleaning Crankcase Gas; US Patent US 9,243,528 B2, 2016.
**[8]** Pursifull, R. D. et al: Crankcase Breech Detection for Boosted Engines; US Patent Application 2010/0147270 A1, 2010

## THANKS

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