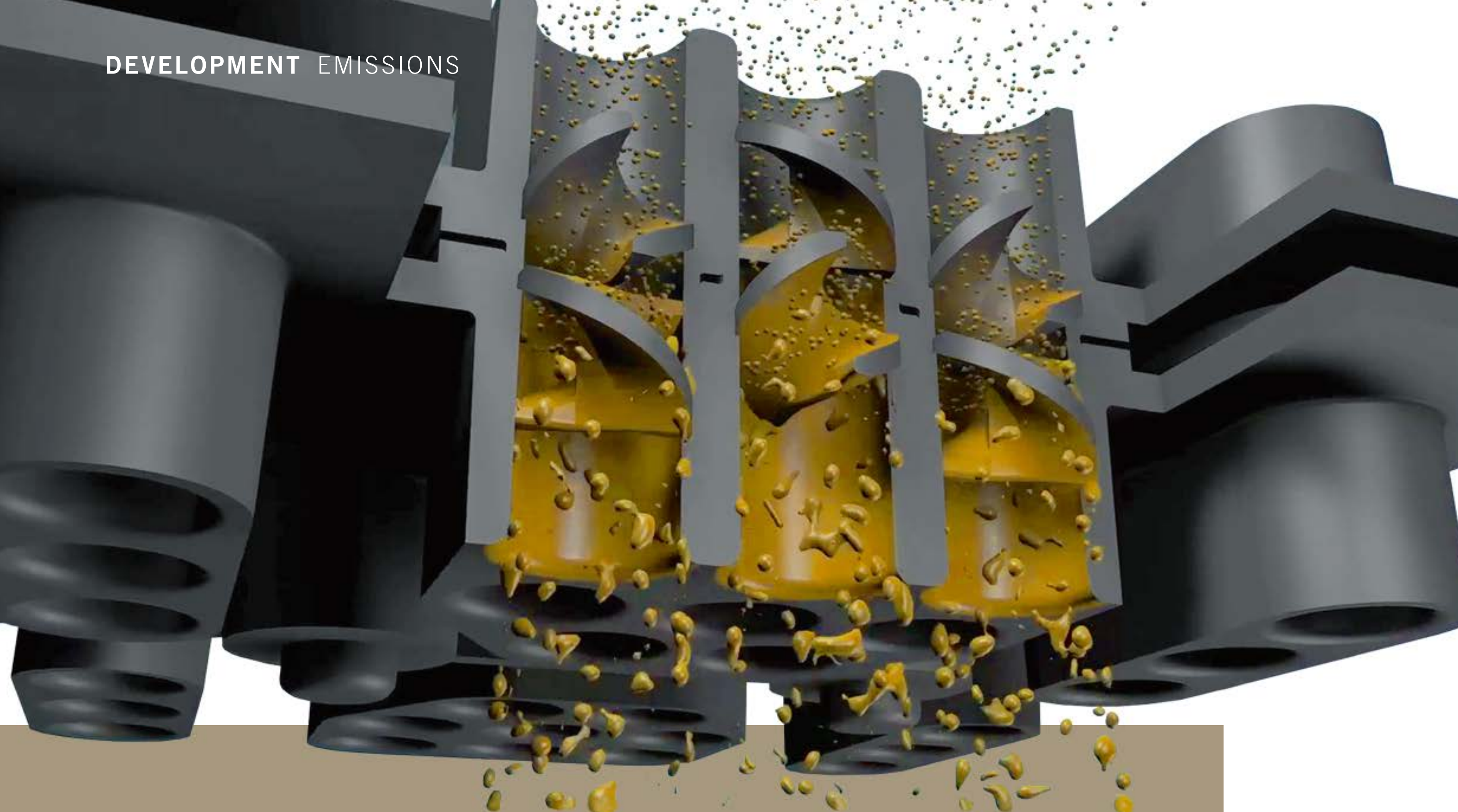

Adaptive Oil Separation
for Efficient Crankcase Ventilation

The trend towards combustion engines with increasing mean pressures results in oil particles in the blow-by gas which are finer and finer. Oil separation systems separate these fine oil particles out of the blow-by gas, thus fulfilling an important function in the crankcase ventilation. With its new Multitwister technology, Reinz has expanded the oil separator by adding an adaptive solution which actively influences the pressure curve and increases its efficiency even further.

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ONGOING CHALLENGES IN OIL SEPARATION

The general trend towards downsizing seems like it will never stop. However, this technology has a major drawback: finer oil particles in the blow-by gas. Due to the design, a mixture of these particles and combustion gas leaks past the piston and into the crankcase. The purpose of oil separation is to completely separate these oil particles from the blow-by gas in order to guarantee the best crankcase ventilation and cleanest exhaust gases possible. This is the only way to meet the demanding requirements of emissions legislation – which will only become more stringent in the future. What's more, efficient oil separation systems make for longer intervals between oil changes and protect components more effectively.

The smaller and smaller oil particles pose new challenges to developers. If the blow-by gas is sucked back out of the crankcase and fed into the combustion, the unseparated oil in the intake air will get into the intake tract. The possible consequences are deposits in the turbocharger and at the intake valves, as well as higher emissions. In addition, automobile and engine manufactures stipulate lower limit values for coarse and fine oil particles in the blow-by gas in the full load range – even over the entire engine characteristic map, as is the case with some manufacturers. About ten years ago, the permissible maximum was approximately 5.0 g/h, followed by a phase in which 1.0 g/h was considered the standard value. Nowadays, original equipment manufacturers demand specs no greater than 0.5 g/h in the oil discharge – and sometimes even 0.25 or less.

The combination of tiny oil particles and low limit values makes oil separation more and more complicated. Oil separators will have to become more efficient if future requirements are to be met dependably.

THE EVOLUTION OF OIL SEPARATION SYSTEMS

Multitwister technology from Reinz-Dichtungs-GmbH ranks among the smallest yet most effective oil separation systems for crankcase ventilation. The standard version of the injection-moulded part is made up of parallel-connected axial cyclones (boreholes/channels) with two 180° guide spirals with opposed rotation. As was previously the case, this configuration is achieved by connecting two identical "twister plates" to one another with the boreholes in a laterally inverted manner so that the opposing spirals converge. The blow-by gas, which is full of oil mist, is accelerated in a rotation while flowing through, causing the majority of the oil droplets to hit the outer walls, where they form a film. Turbulence caused by inversion of rotation within the Multitwister increases its performance even further. The end of the pipe now dependably discharges the even better separated quantity of oil, thus reintroducing the oil to the lubrication circuit in a highly environmentally friendly manner.

SYSTEM WITH ENHANCED EFFICIENCY

The most significant advancement of the Multitwister MT 2.0 is its increased efficiency, **FIGURE 1**. A decisive factor in the efficiency of an oil separator is how many of the coarse and fine oil particles it mixes out of the gas mixture flowing through it. This data describes the X50 value in relation to the number and quality of oil particles upstream of the oil separator. The newly developed system improved the Multitwister's performance, reducing the X50 value from 1.0 to 0.65 µm – at the same pressure loss. This improved value makes the system markedly more environmentally friendly: the more efficiently an oil separator works, the more oil can be fed back into the circuit.

The Multitwister MT 2.0 is robust, reliable, maintenance-free and is built into the valve bonnet and oil separator modules. It is highly flexible in volume regardless of its position, so that it can be installed at any location. Its 20 % increase in efficiency puts the Multitwister MT 2.0 in the top class of passive oil separation systems.

IMPROVED GEOMETRY

The main question in refining the Multitwister was: How can the design and efficiency be optimised without changing the size and shape? After all, the opportunities for changing the installation situation – and thus the valve bonnet – are marginal (if any), since the standardised outer contour of the Multitwister can only be inserted and welded in.

The development engineers pursued various innovative approaches with the same outside geometry, which they put into practice using CAD adaptations, flow simulations (CFD calculations), numeric and statistical methods and prototype analyses. The internal configuration of the Multitwister MT 2.0 presents the following optimisations:

- reduced wall thicknesses
- optimised twister diameters
- improved helix geometry within the individual channels
- efficient modular design for rapid serial production.

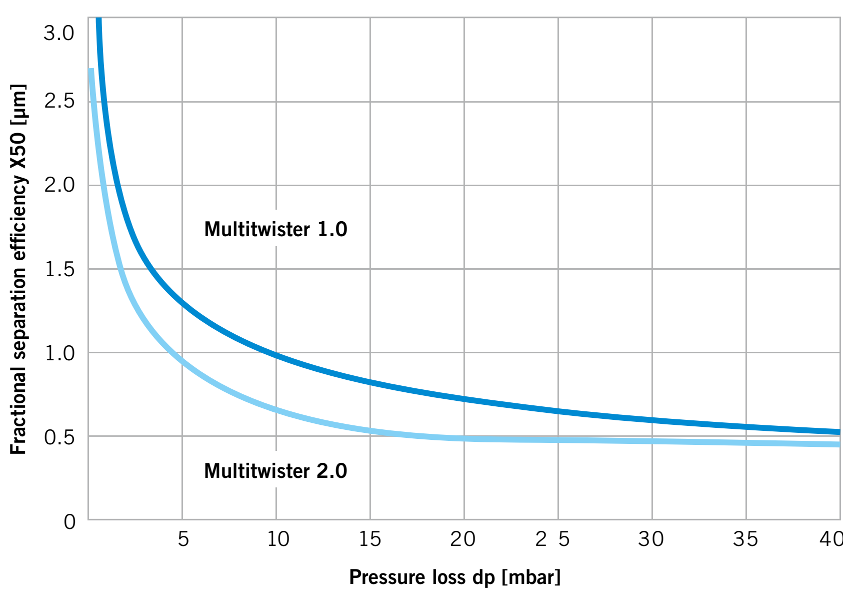
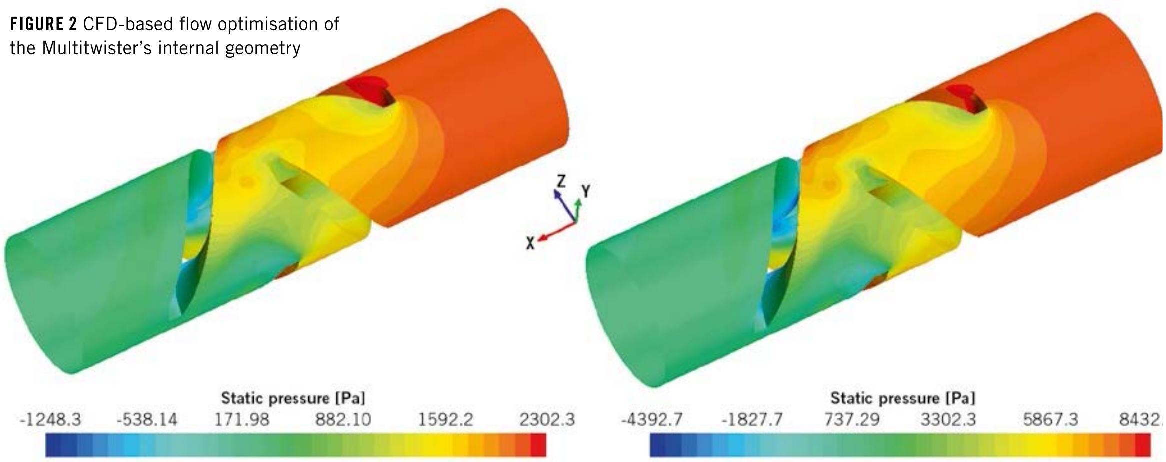


FIGURE 1 Increase in the Multitwister's efficiency from Version 1.0 to 2.0

FIGURE 2 CFD-based flow optimisation of the Multitwister's internal geometry



The increased efficiency is especially the result of the improved helix geometry in conjunction with the optimised borehole diameter. The reduced flow resistance and the reduced pressure loss it entails markedly improve the efficiency of oil separation.

During the development phase, the engineers phased the "old" configuration of the Multitwister by modifying the helix geometry curve step-by-step. In order to reduce the flow resistance, the wall thickness was reduced from its original 0.9 to 0.15 mm and, in the final step, the borehole diameter was adapted to 2.0 mm. This makes for a lower flow resistance while keeping the deflection and acceleration of the oil particles the same and increasing the efficiency by 30 %.

All design modifications are based on flow simulations with subsequent prototype tests at the company's proprietary testing facilities. After all, the ratio of the aperture diameter to the wall thickness in the helix geometry had to be implemented in practice so the component could be reliably produced in serial production. Numeric calculation with CFD software played a decisive role in configuring the Multitwister, **FIGURE 2**. In order to make effective use of the flow simulations, the flow chambers were derived directly from a 3D CAD model and visualised with finite elements. The quotient of pressure loss and flow speed served as a guideline in this process. The goal was to keep pressure loss as low as possible and increase flow speed at the same time. The so-called radial speed determines the quality of oil separation. It also accelerates the particles towards the wall and enables the actual separation.

Over several test phases, the development team determined designs with various wall thicknesses and borehole diameters, which constituted a major advancement in efficiency. These specs were transferred to prototypes, measured in a laboratory and tested at our testing facilities. The Multitwister MT 2.0 and the adaptive Multitwister MT 3.0 described in the following are the results of a complete development chain with CAD, CFD, interpretation of the results, implementation in components as well as laboratory and testing facilities.

A twister plate with a wall thickness of 0.15 mm poses a special challenge for tool technology. The goal was to produce the complex component in a simple but reliable process. Reinz uses fibreglass-reinforced polyamide 6.6 for injection moulding – a highly resistant, antihydrolysis, standard-tested material for hot oil applications. This material has already proven itself in practice in valve bonnets and oil separator modules with resounding success.

The advantage of the Multitwister design over oil separation systems with non-woven solutions lies in its unlimited resistance to substances found in the blow-by gas. In contrast to non-woven materials, Multitwister shows no signs of sooting or aging processes. Multitwister even performed flawlessly in a test with extremely short drives in the winter time to check its behaviour in cold weather. Another benefit of Multitwister made of polyamide 6.6 is that it is free of residual

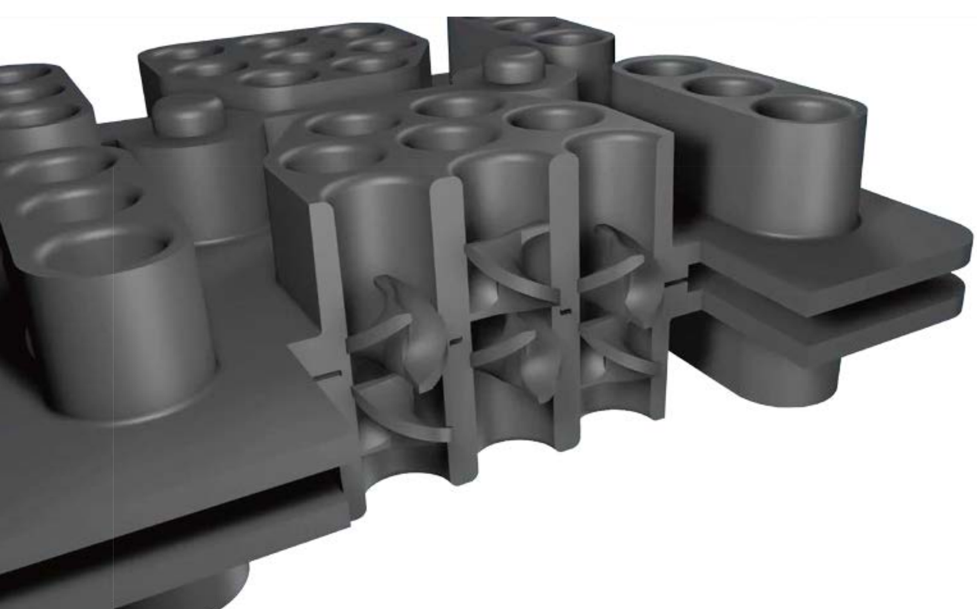


FIGURE 3 Adaptive Multitwister MT 3.0 as standard insert part

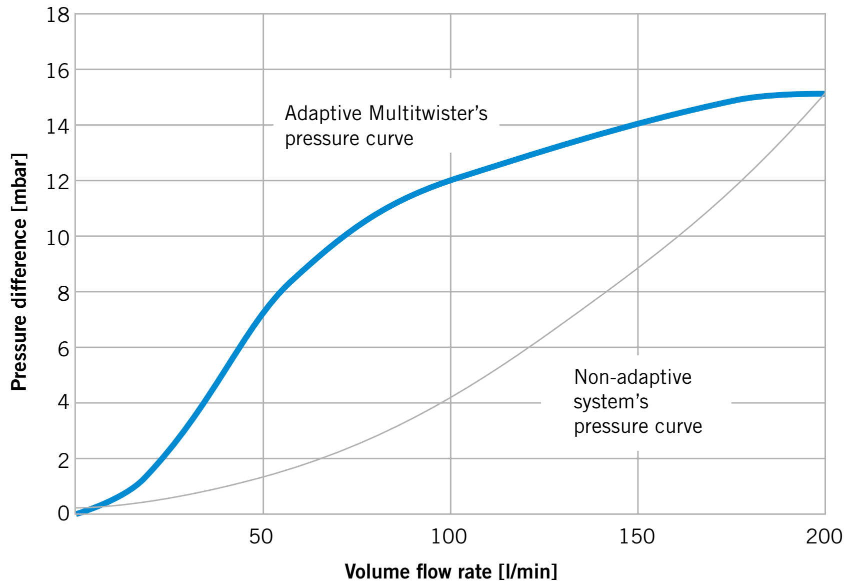


FIGURE 4 Comparison of pressure curves of adaptive and non-adaptive oil separation systems

dirt. While non-woven fibres can separate, Multitwister completely fulfils engine manufacturers' residual dirt requirements. Long-term results have shown that Multitwister is just as efficient after ten years of use as it does when new.

ADAPTIVE SYSTEM

The Reinz Multitwister MT 3.0, **FIGURE 3**, expands the spectrum of options by adding an adaptive version. A downstream, pre-tensioned valve plate opens and closes a defined number of Multitwister channels, thus optimising the pressure curve. The opening and closing action is controlled by the pressure of the volume flow. Fewer channels are open in areas where the volume flow is low. The higher the volume flow rate is, the more channels are released. Adjusting the volume flow rate makes the Multitwister more effective, especially at low volume flow rates – which clearly improves total oil separation over the entire characteristic map.

The developers had a special aspect to take into account when developing the adaptive technology based on the Multitwister MT 2.0: The CFD calculations required special simulation models due to the combination of flow and mechanics. These models first had to simulate the oncoming flow at the component, the resulting pressure loss, then the force on the switching device, and finally the renewed pressure drop when the switching device is opened. In addition, the pressure will vary depending on how far the gap between the switching device and component is set. **FIGURE 4** shows a comparison of pressure curves of adaptive and non-adaptive oil separation systems.

The oil separation is generally configured for the maximum or nominal volume flow rate specified by the OEM, and thus configured at a point. The static geometry did not optimise the oil separation, although the pressure conditions would permit this. The adaptive Multitwister MT 3.0 provides entirely new results in this respect. The Multitwister MT 3.0 is upgraded to a three-stage oil separation system in one variant: Only six of a total 22 channels are opened, and they separate oil quickly and efficiently when quantities of blow-by gas are low. If the volume flow rate reaches a defined level, eight more channels will be opened. The remaining eight channels are only opened once the maximum volume flow rate has been reached. The number of channels as well as the switching points are individually configurable.

SUMMARY AND OUTLOOK

Cost and weight reasons make passive oil separation systems remain the most efficient solution for car engines on the medium term. So the goal is to make these systems more efficient. The adaptive Multitwister MT 3.0 is an important step in this direction. Reinz is currently working on a new development which combines oil separation and pressure regulation in a single component. This system creates the conditions for using the maximum vacuum for oil separation at every load level. An integrated system like this is already being used in a preliminary development engine to regulate the crankcase pressure over the entire characteristic map, yielding results with considerably less oil discharge.