Valve cover made of PA6.6 GF35 from DuPont with integrated, highly efficient oil separation

LIGHTWEIGHT POLYMER VALVE COVER WITH INTEGRATED OIL SEPARATION

The reduction of emissions through lightweight components is one of the central objectives in engine and vehicle manufacturing. Plastics make an important contribution here, as they are not only lighter than metallic materials, but also bring along excellent conditions for a high level of integration. ElringKlinger has used this potential to develop a valve cover for the 1.6-l common-rail Gen 2 diesel engine from Volkswagen which exceed the requirements of the specifications with a new, integrated engine oil separation system.

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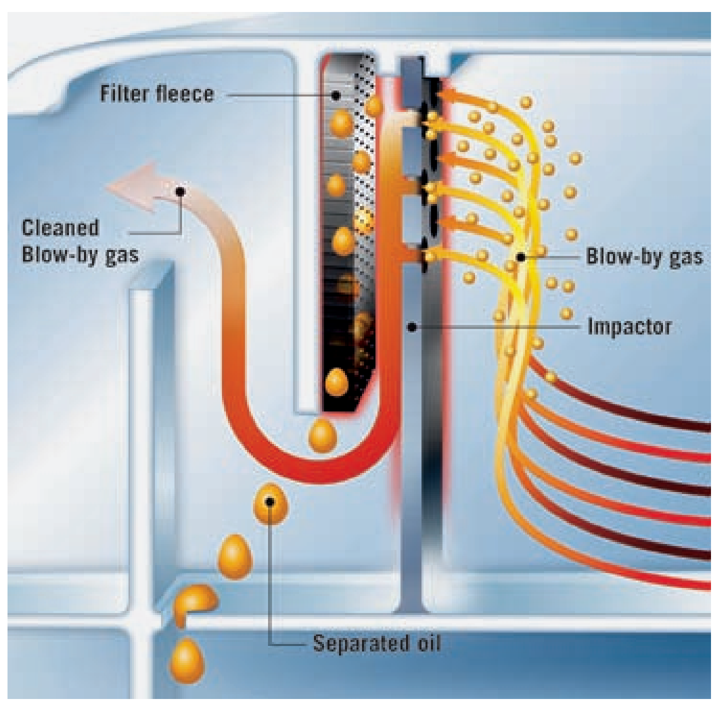
LOW WEIGHT

Cylinder head covers or valve covers made of polyamide with a glass fiber filling (PA6.6 GF35) are very popular due to their low weight. ElringKlinger has manufactured these kinds of PA covers since 1999 and currently produces 78 plastic valve covers in Europe, the NAFTA region and Asia. The injection technology with which the covers are manufactured provides a great deal of freedom for the integration of numerous functions in a module. In addition to oil sealing of the cylinder head, the fuel injectors and the bolting elements, these also include pressure management of the cylinder crankcase, if necessary a vacuum reservoir for actuating the turbine blade adjustment on turbochargers with a variable turbine geometry (VTG turbochargers), oil separation and the integration of standard components, such as the oil filler neck and the gasket and the fastening elements for the cover. The integration of these functions results in a pre-testable module that can be easily and safely installed.

With increasingly strict emission requirements, such as Euro 6 beginning in 2014, the requirements for the valve cover and the functional groups integrated in it also grow more demanding. On the one hand, the goal is to achieve additional weight reductions even at the low weight level of the plastic valve cover. On the other hand, development increasingly focuses on oil separation. The reason is the progress made in engine technology. For example, the continuous increase in efficiency in turbocharged downsized engines with direct injection is generally paired with higher pressure values in the combustion chamber. These conditions result in a change in the size range of the oil droplets in the blow-by gas which, for design reasons, flows out of the combustion chambers through the dynamic sealing system piston/piston ring/cylinder wall and into the crankcase. The oil droplets in this blow-by gas tend to become increasingly smaller as the pressure increases. This results in the fact that an increasing number of gas-carried oil droplets can no longer be effectively separated in the separation systems employed up until now. Due to their low mass, in particular small oil droplets pass through conventional passive separation systems (for example, cyclone or splash plate separators) with the air stream virtually unimpaired.

As it is vital to avoid a significant oil input into the intake air, the ever finer range of oil droplets poses new challenges for the developers. With insufficient separation, this leads to the engine loosing oil during operation, which then gets into the



❶ Impactor with matted fleece

intake system and can result in higher emissions and deposits on the turbo-charger, the intercooler and the inlet valves, as well as in impairments of the particle filter function. In the case of damage, this oil discharge poses a danger of directly affecting the engine performance, as this oil replaces the fuel in an uncontrollable manner. Due to these increasingly demanding requirements, ElringKlinger has developed an optimized plastic valve cover for the 1.6 liter common-rail Gen 2 TDI diesel engine from Volkswagen. Oil separation is carried out here with the impactor fleece unit with a soon-to-be-patented plastic fleece as a service-life component. In order, at the same time, to also produce this valve cover with integrated oil separation and vacuum reservoir in a lighter and virtually particle-free version, the MuCell injection process and hot gas welding are used for the first time for a component close to the engine. Flow-optimized polyamide types from DuPont were used for this development.

DESCRIPTION OF VALVE COVER

The geometry and functionality of the optimized valve cover are based on the specifications and requirements of the 1.6-l CR Gen 2 diesel engine from Volkswagen. It integrates crankcase ventilation, oil separation, crankcase pressure management, a vacuum reservoir and injector sealing and holds the standard components oil filler cap and the mounting screws. In addition, a heat shield plate is mounted on three plastic pins integrated in the cover and then riveted on during production.

The elastomer seal made of ethylene acrylate rubber (AEM) developed at ElringKlinger is used in the base of the cover. The injector seals of polyacrylate rubber (ACM) are also premounted in the upper section of the cover so that the cover can be assembled with all integrated functions in one step. At the same time, all seals are accessible and replaceable during servicing. All elastomers used are completely free of the vulcanization accelerator DOTG (N,N'-Di-o-tolylguanidin).

OIL SEPARATION

Today primarily passive separation systems are used to separate oil droplets from the blow-by gas. Actively driven separation systems, commonly used in commercial vehicles, cannot be implemented in passenger cars so far due to economic reasons [2].

BOUNDARY CONDITIONS

Measurements on the VW engine show a maximum in mass size distribution of the oil droplets ranging from 0.7 to 1.0 µm. The commonly used cyclone technology reaches its limits under these conditions especially in regard of the available pressure differences [3]. The realizable centrifugal forces in the cyclone are no longer sufficient to separate oil droplets smaller than 1.0 µm in diameter. Regardless of the available pressure difference, conventional impactors with splash plate also lack sufficient separating efficiency for the given droplet size distributions.

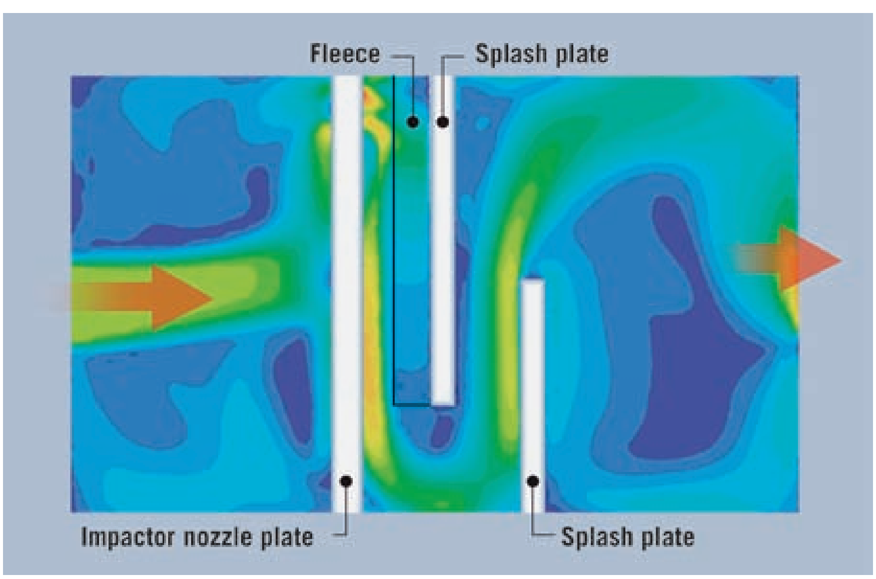
Therefore, ElringKlinger has developed an innovative separation technology for the VW valve cover. By combining an impactor with a fiber separator (randomly oriented fiber fleece) through which the flow passes partially, a good separation of oil drops less than 1.0 µm with a simultaneous low pressure loss can be realized [4].

WORKING PRINCIPLE OF THE IMPACTOR WITH FLEECE

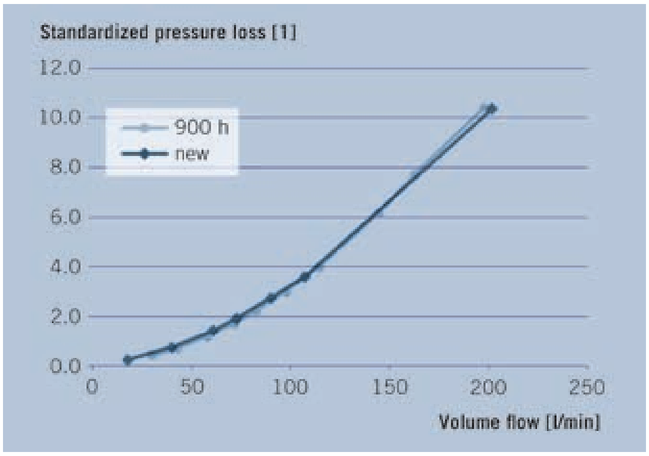
The design of the impactor is shown in ❶. The fleece made of special polyethylene terephthalate (PET), a splash plate and an adjacent deflector plate are located downstream the impactor plate. The impactor plate is equipped with bypass channels on the back. Many years of extensive experience in the development of elastomer materials was a major requirement for the selection and design of the fleece.

❷ shows the functionality of the separator using the example of a flow field simulation with the CFD program Fluent [1]. The blow-by volume flow from the crankcase first passes through the openings of the impactor plate. The constrictions in the cross section cause an acceleration of the volume flow during passage. After it passes the impactor openings, the accelerated volume flow hits the fleece, with the splash plate located behind it. Inside the fleece the gas flows around the individual fleece fibers, resulting in the separation and coalescence of the individual oil droplets.

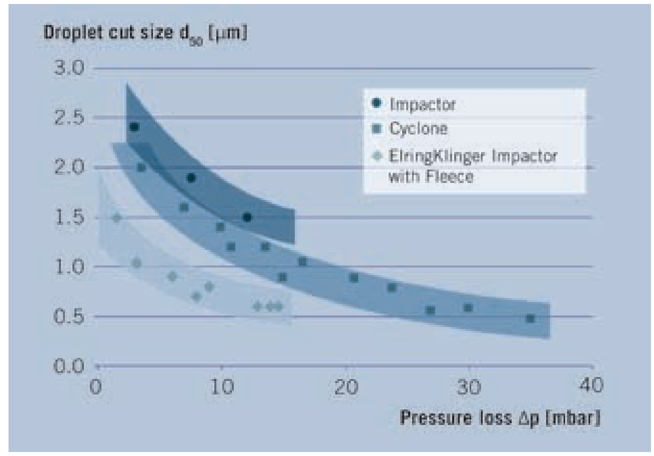
After passing a certain length of fleece, the gas steam exits the fleece and is entering the wave-shaped bypass channels running downward the entire inside length of the impactor plate. This ensures that the fleece lies in the secondary stream of the gas. Even with a theoretical clogging of the fleece, the operability of the venting system is maintained. However, special fouling and life cycle tests, both in the laboratory and on the engine, were unable to provoke any blocking of the fleece. Even after 900 h of cyclical continuous operation on the engine and a major increase of blocking components in the engine oil, the fleece



❷ Speed contours of the gas stream in the impactor with PET fleece calculated with the CFD program Fluent



❸ Pressure loss curve of the impactor with fleece before and after 900 h of cyclical continuous operation



❹ Separating limits and pressure losses of passive oil separating systems in comparison

still achieved the full separation capacity, ❸. Fiber losses or settling of the fleece material, which is dimensionally stable up to 150 °C, do not occur. Hence it is not necessary to service the fleece during the life time of the engine. One key contributor to the superior separation behavior of the fleece is that impurities in the oil (soot, particles) do not permanently settle on the fibers, but are instead carried out of the fleece by the oil.

The oil concentration inside the fleece increases from top to bottom. The coalesced oil drops flow off at the lower edge of the fleece and are finally separated at the downstream splash plate, which has an oil exit slit in its base. There the oil flows into a covered collection chamber in which it remains separated regardless of the dominating pressure and flow conditions. The collection chamber is sealed with a drainage valve, opening at a defined filling level to lead the separated oil back into the oil circuit.

Comparative measurements show that the impactor with a fleece achieves a considerably higher degree of separation with lower pressure losses than a cyclone separator, ❹. The cut size d50 hereby specifies the droplet size at which 50 % of all oil droplets are separated. By using the impactor with fleece, the oil masses after the separator can be decreased to considerably less than 0.5 g/h.

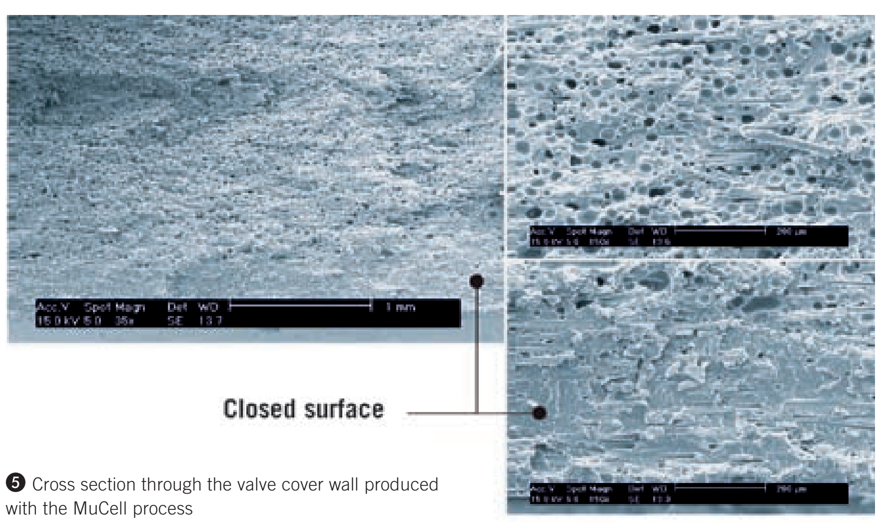
COVERED OIL COLLECTION CHAMBER

The covered oil collection chamber is primarily important for a safe and long lasting oil separation under worst case conditions. Therefore, Volkswagen defines a sufficiently high oil suction resistance in order to avoid oil escaping from the oil separator into the cylinder combustion chambers via the intake system. In the valve cover with an integrated impactor fleece separator, this oil suction resistance is four times the normal volumetric flow rate of up to 50 l/min.

MUCELL PROCESS – WEIGHT REDUCTION WITH PHYSICAL FOAMING

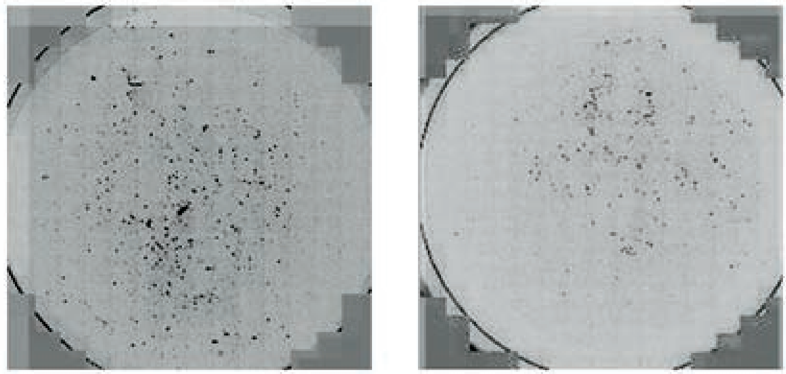
With wall thicknesses of just 2 to 2.5 mm, valve covers used in the past had reached the limits of a possible material thickness reduction. As, on the one hand, the valve cover is a component with force transmission (screwing, pressing and sealing) and, on the other hand, there are production-related limits for the correct filling of the injection mold, a further reduction in the wall thickness was initially not an option. In contrast to this, the related material PA6.6 GF35 should be retained due to its basic suitability. To enable further advances with regard to weight in this situation, the so-called MuCell process was used for the first time in an engine component.

Here the inert gas nitrogen is fed in a supercritical state into the polymer melt and then dissolves there. Following this the injection mold is filled approximately 95 % with the material and the mold is closed. As a result, the melt is no longer under injection pressure, the dissolved gas forms microscopic bubbles in the entire mold volume and fills the mold evenly, ❺. As the



❺ Cross section through the valve cover wall produced with the MuCell process component surface very quickly solidifies in direct contact with the mold, no gas phases are formed there. The component surface is solid and dense. With this process Elring-Klinger succeeded in reducing the total weight of the optimized valve covers with the same geometry by 5 to 8 %. Due to the sandwich effect of the closed gas bubbles, virtually the strength of the original solid component is retained in the process. Another major advantage of the MuCell process is the fact that the component shows fewer distortions after cooling down.

Welding length ca. 400 mm (surface ca. 300 cm²)



	Particle mass	Particles size: 150 – 400 µm	Particles size: > 400 µm
Vibration welding	0.9 mg	ca. 300	ca. 200
Hot gas welding	0.2 mg	ca. 10	...

6 Comparison of the particle counts for friction welding and hot-gas welding

JOINING TECHNIQUE OF MODULE COMPONENTS OPTIMIZES CLEANLINESS

The optimized valve cover consists of a total of two housing parts and additional smaller components inside the cover. However, a single welding process is sufficient to securely connect all parts to each other. The 400 ml vacuum reservoir (up to 900 mbar vacuum) for actuating the blade adjustment in the VTG turbocharger is also closed during welding. With plastic valve covers, this welding process was generally carried out by welding together corresponding abutting edges, for example with ultrasound or friction welding. The disadvantage of this path-based process lies in the fact that the liquefied edge zones of the edges protrude in an umbrella shape during welding and fray or form rough edge geometries in the process, which then tend to break out. Even if great care is taken, for example when a special welding edge geometry is used, at best only low-particle manufacturing is possible with this process. Later during operation it is therefore possible for small plastic particles to get into the air or oil stream.

To avoid this above all in view of turbocharger blade adjustment, and to be able to comply with the specifications of the vehicle manufacturers with regard to freedom from particles (cleanliness), the valve cover is welded with the innovative hot gas process. After inserting the individual components in the two housing halves, the welding edges of the two submodules are brought up to the welding temperature with geometrically exactly matched hot-air nozzle curtains. Then the nozzles are pulled back and the mold is closed under pressure. With this process welded seams with a closed, and therefore clean, edge geometry are formed which are also virtually particle-free later during operation, 6.

SUMMARY AND OUTLOOK

The new cylinder head cover design of ElringKlinger described in this article provides reduced weight and increased oil separation efficiency required by modern high performance diesel engines like the 1.6 liter CR diesel engine by Volkswagen. With the decreasing diameter of oil droplets in the blow-by gas the fractional separation efficiency needs to be adjusted accordingly.

Since the required total pressure drop of the separation system is limited by the available vacuum in the crankcase, the common cyclone technology is not the method of choice in this case. Therefore, ElringKlinger uses an impactor with a partially flow-through fleece on a splash plate in the plastic valve cover for this 2 VW engine. With just 2 to 3 bar pressure loss this highly efficient system provides the required reduction of oil quantity in the MVEG cycle to considerably less than 0.5 g/h downstream the separator. Thus the complete system's level of separation is above 90 %.

At the same time, the usage of the MuCell process enables a weight reduction of the cylinder head cover by 5 to 8 %. Regarding the stringent cleanliness specifications, especially required for diesel engines with a VTG turbocharger, the applied hot-gas welding process ensures virtually particle-free production.

With further increase in engine efficiency, a further shift towards smaller oil droplet sizes can be expected. In the midterm, average droplet sizes in the submicron range (< 0.5 µm) are a realistic scenario. Therefore, the advanced engineering group at ElringKlinger is working on a further reduction of ultra-fine oil emission while keeping the pressure losses of the separation system low. One key enabler of this is promoting droplet coalescence in both passively and actively driven separation systems.

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