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Transmission Oil Filters for Innovative Drivetrains and e-Axles - Compact, Efficient, Reliable

Marius Panzer, Dr. Alexander Traut, Claudia Wagner, Dr. Richard Bernewitz

MANN+HUMMEL GmbH, Schwieberdinger Strasse 126, 71636 Ludwigsburg, Germany

marius.panzer@mann-hummel.com

Summary

Reducing system complexity and installation space is a major trend in sensitive automatic transmissions as well as in highly integrated e-axles. In addition, the requirements towards oil cleanliness and differential pressure of the lubrication and cooling circuit become more challenging. To protect all system components starting from the oil pump a new generation of pleated suction-side filters has been developed. The new concept provides up to 60 % better filtration performance and it increases the degrees of freedom for the lubrication circuit significantly. Offering an ultra-compact and flexible installation space, lowest differential pressure or highest filtration efficiencies for system reliability.

Keywords: transmission, cooling, efficiency, electric drive, pumps

1 Introduction

Driving pleasure without emissions is a constant trend. With a rising number of congested cities, high levels of air pollution and stricter statutory requirements, companies are working towards even more sustainable solutions. And car buyers are on board: in Germany and other countries across Europe more and more vehicles are being registered with alternative drives, not anymore fully based on internal combustion engines (ICE).

Mobility related companies are focused on the electrification of the powertrain. In this respect the highly integrated e-axle is a particularly promising concept for BEV's with increasing growth rates. Up to 2023 the annual market growth rate will be at around 35% for front and 46% for rear e-axles. Leading to a demand of 4.5 million front e-axles and 3 million rear e-axles, respectively.

Figure 1 shows an e-axle – a system which combines the electric motor, the transmission/gear box and the power electronics. This saves installation space, components and wiring due to the fact that the e-axle is integrated directly on the drive axle. According to the system suppliers, this enables up to 20 percent less weight and between 5 and 10 percent higher efficiency. The easy scalability of the system makes it suitable for use in compact cars, sports cars up to large commercial vehicles.

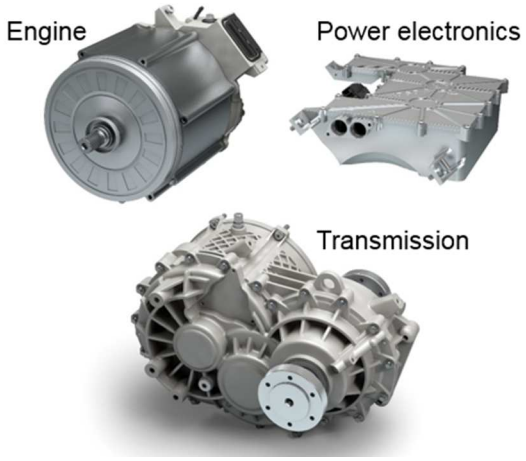

Figure 1: Set up of an e-axle, containing engine, transmission and power electronics (Source: Robert Bosch GmbH, www.bosch-presse.de [1])

2 Lubrication and cooling with the same oil – and the challenges

2.1 Particle contamination in the oil circuit

As all the drive components are integrated in an e-axle, a common oil circuit is sufficient for cooling and lubrication. However, this advantage has a drawback. Mechanical as well as electronic components are exposed to the same oil and metal particles and chips out of the transmission can penetrate the power electronics and electric motor and cause serious damage, which is illustrated in Figure 2. Not only abrasive wear out of the transmission but also the initial cleanliness of the system components play a major role for the oil cleanliness. Engine components like high speed bearings, directly controlled valves, clutch plates or position sensors are exposed to initial contamination. Referring to this, it has highest priority to remove all particles within very short time from the system. An increased and instant high oil cleanliness can as well increase the overall system efficiency by using higher efficient but more sensitive components in the systems.

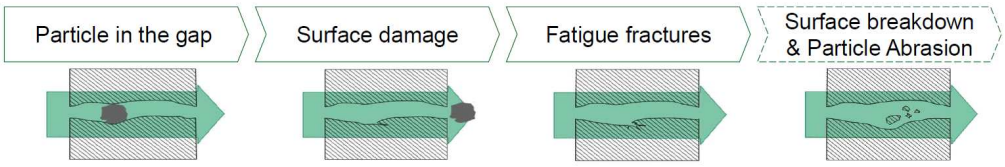

Figure 2: Mechanism of wear and damage by particles as a potential system risk.

Strongly depending on the used system components an oil cleanliness of up to 19/17/14 (acc. to ISO 4406) or filtration requirements up to 99.5% efficiency at 25 µm is needed to keep all system components in good condition over the whole system lifetime. Trying to protect all system components starting from the pump to the last lubrication point, the filter solutions are often at the suction side of the pump and in the “oil sump” of the system. Therefore it is of major importance to provide the lowest differential pressure possible and provide it over all operating conditions and the time. Especially an instant filtration efficiency and a low differential pressure do not come along with each other. Figure 3 shows how a high filtration efficiency usually leads to higher pressure drop levels and a lower dust holding capacity.

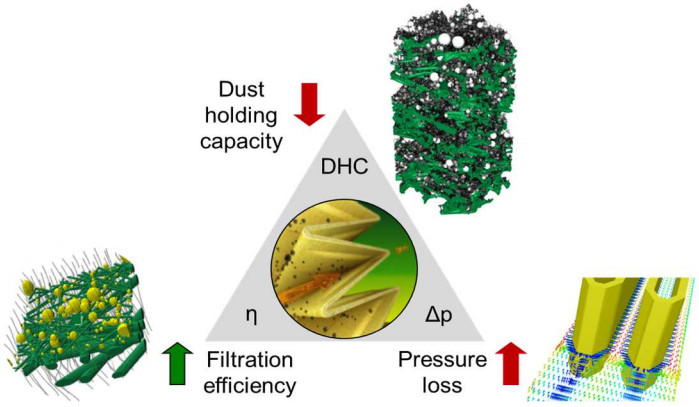

Figure 3: Schematic correlation between filtration efficiency, dust holding capacity and the differential pressure

3 The solution for a multi-objective optimization problem

For customer-specific suction-side applications, the use of proven pleating technology is the key driver. The pleated filter multiplies the degree of freedom for the customer: Depending on the focus, an ultra-compact design, with a long operating time or a lower differential pressure compared to solutions using flat filter media, can be realized. Furthermore, the system can be finely adjusted to improve filter efficiency or the dimensioning of the pump.

3.1 Increasing the energy efficiency

To account for all those three factors (oil cleanliness, differential pressure and dust holding capacity) new filter media were developed which require less space, as it is possible to exploit the proven pleating technology and to bring the needed filtration area to a maximum [2]. According to Darcy's law the volume flow is directly proportional to the increased filter area which decreases the differential pressure significantly while keeping the efficiency on an extraordinary level (Figure 4). An installation space of just 20 millimetres is enough for a pleated concept. In comparison to a flat, non-pleated filter media, the pleated variant enables a differential pressure which is up to 75 % lower. This gives the customer a larger degree of freedom with regard to higher filter efficiency or dimensioning of the pump, as the energy dissipation is minimized by the pleating technique.

Figure 4: The pleat technology enables highest filtration performances with up to 75 % less differential pressure maintaining the same filtration efficiency and installation space.

3.2 Improved system reliability

Keeping the parameters pressure drop (energy efficiency) and installation space constant, a further degree-of-freedom for the pleated filter design is to select a filter medium with a much higher filtration efficiency (*Figure 5*). To fulfill the high demands regarding the durability of the material and the application as a life time product, a 100% synthetic depth filter medium with a high chemical resistance is used. Furthermore, the pleated filter concept has no artificial bypass and guarantees a long-term dirt separation without the re-entrainment of relevant particles.

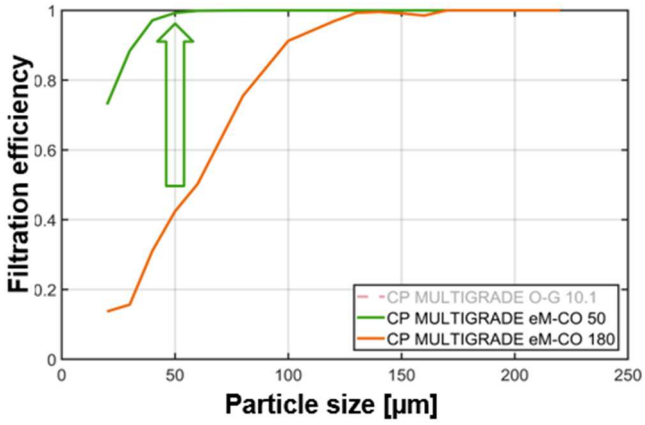

Figure 5: The pleat technology enables the use of a 100 times more effective filter media maintaining the same installation space and differential pressure.

3.3 Less installation space needed

Another advantage becomes apparent with regard to the compact design of an e-axle and it is also valid for the classic automatic transmissions. The mentioned pleating technique allows a very small filter design. Figure 6 illustrates that a minimum height of 20 milliliters is sufficient to reduce the needed installation space by 83%.

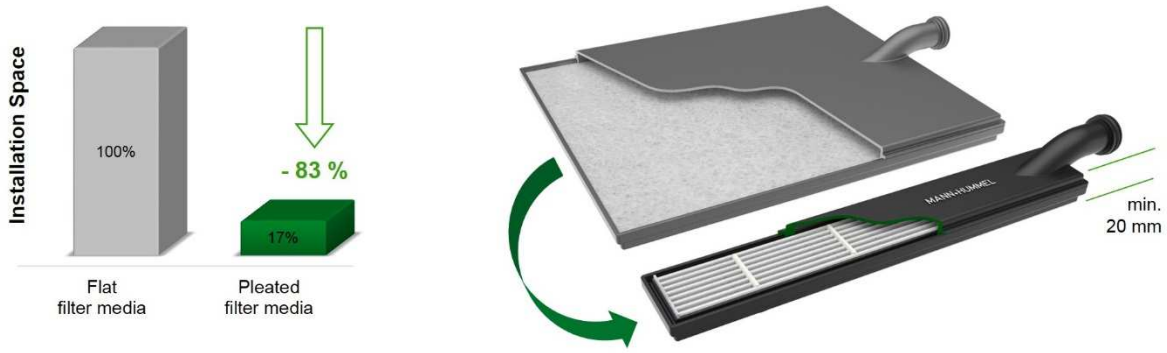

Figure 6: The pleat technology also enables highest filtration performances at up to 83 % less installation spaces, with at the same time reduced energy dissipation.

3.4 Maximum filter life time

The pleat technology, which results in a significant increase in filter area, can be also applied to achieve a maximum dust holding capacity where needed. Therefore a significant improvement in operating time and thus filter life time can be achieved. In the same time, the pressure drop level will be comparable to a non-pleated (flat) filter concept. Furthermore, the relative increase of the pressure drop during the whole life time of the filter is marginal compared to a non-pleated media or sieve concept (Figure 7).

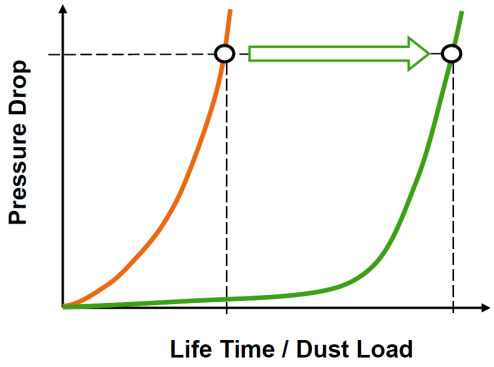

Figure 7: The life time and dust holding capacity of the filter can be increased significantly by pleating of the filter media.

3.5 New filter media portfolio for transmission oil filters

The filter media always retains its shape and performance, even when exposed to coldness or high differential pressure. Stability is ensured by a drainage grid or adhesive lines which maintain the ideal gap between the pleats. This enables more long-term use of the complete filter surface area. The use of a depth filter media enables the secure entrapment of the separated particles in the 3D fiber matrix (Figure 8). This prevents the re-entrainment and re-introduction of particles or even long chips into the system, a critical technical risk which is known from conventional drivetrains. The oil supply can also be permanently ensured without use of an uncontrolled filter bypass, which increases the system reliability.

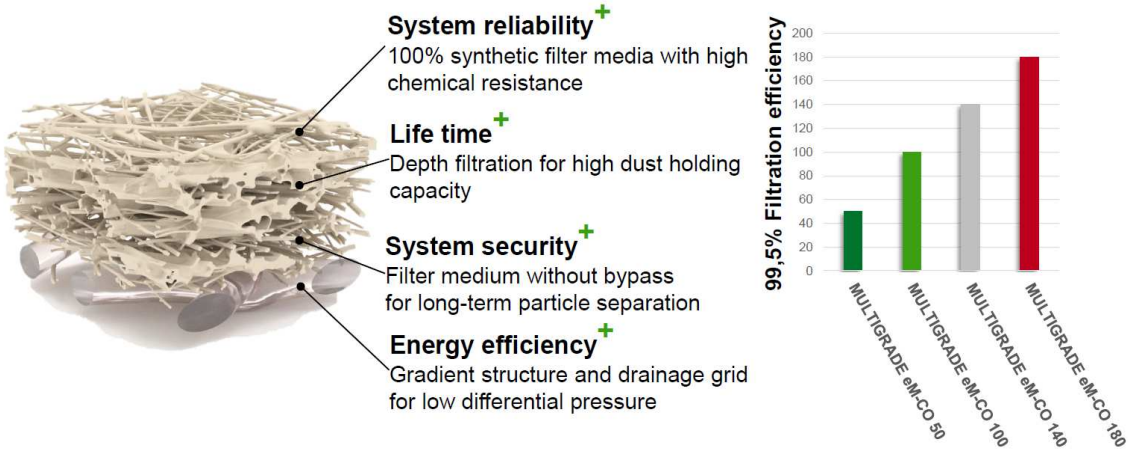

Figure 8:
Left side: Computer tomographic scan of the depth filter media with a drainage grid on downstream side.
Right side: Filtration efficiency for different transmission oil filter media grades.

3.6 Robust filter housing with efficient flow characteristics

The plastic housing of the transmission oil filter needs to have a sufficient stability over the whole life time. Therefore, plastics expertise and the use of modern simulation methods such as the finite element method (FEM) and mold filling simulations in the development process ensure that all components are able to withstand the highest mechanical requirements. The developers also exploited the possibilities of simulations with computational fluid dynamics (CFD) to enable efficient flow characteristics for the filter housing in particular in tight installation spaces to minimize loss of differential pressure. On request, additional functions can be easily and economically integrated in the plastic housing. An example here could be magnets which additionally separate the magnetized particles in order to extend the service life of the filter elements.

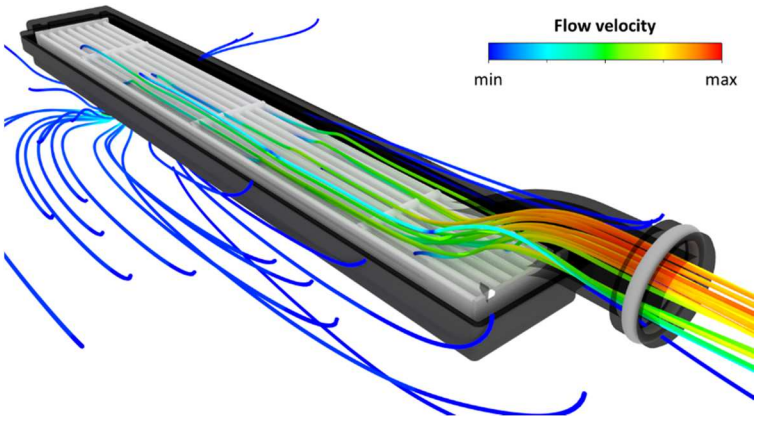

Figure 9: Visualization of velocity streamlines for the oil flow through a transmission oil filter. CFD-simulations enable an optimization and pre-validation of the filter design in the early stages of the product development and accelerate the development process significantly.

4 Conclusion

Energy efficiency or compactness are not the only challenges in innovative drivetrains and e-Axles. Beyond that, the cleanliness of coolants and lubricants in such systems plays an important role to protect all system components starting from the oil pump – from the first to the last mile in the vehicle life time.

This is why MANN+HUMMEL has been developed a new generation of pleated filters for the suction side. Depending on the customer demands different designs and filter media options can be offered which involve ultra-compact and flexible installation spaces, lowest differential pressure or highest filtration efficiencies for a perfect system reliability.

Acknowledgments

We would like to thank all contributing colleagues who are involved in this topic.

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Authors

Dr.-Ing. Richard Bernewitz studied process engineering at the KIT Karlsruhe, Germany. From 2009 until 2014 he worked as a research associate at the Institute for Bio- and Food Process Engineering where he also achieved his doctoral degree. From 2014 – 2016 he started his industrial career as a development engineer at MANN+HUMMEL GmbH in the department for development fuel filter elements. In 2016 he changed his position, now working as a manager in the development oil filter elements.

Co-Authors: Marius Panzer, Claudia Wagner, Dr. Alexander Traut