

# MAHLE n e w s

A F T E R M A R K E T

MAGAZINE FOR TRADE, WORKSHOP, AND ENGINE REPAIR

www.mahle-aftermarket.com

Vehicles and components are becoming more and more intelligent and efficient, which means trade and repair shops must become more and more competent. To help you rise to this challenge, we have set ourselves up as your solutions provider: MAHLE Aftermarket provides you not only with high-quality products but also with complete solution packages for vehicle maintenance and repair. In this edition of the **MAHLE Aftermarket news**, we have picked a few to look at them in more detail: you will learn more about the increasing electrification of the vehicle and what we are doing to support you in this area. We will present our two

new subsidiaries, real specialists in their field, whose broad knowledge we are excited to share with you. In our technology section, we will give you insight into two-stage turbocharging—a key technology towards increased efficiency. We'll show you how our wonderfully simple idea of a fleece end cap on the oil filter guarantees a perfect seal while protecting the environment and saving time. In addition, we present the new MAHLE turbocharger kits, which make not only the repair process but also the ordering process a good deal easier. We hope you'll find it an exciting read, empowering you with new solutions.

3/2015

*More efficiency.*

**MORE INTELLIGENCE.  
MORE COMPETENCE.**

THE FUTURE OF THE AUTOMOTIVE AFTERMARKET IS LADEN WITH CHALLENGES.

THE SOLUTION LIES IN THE SYSTEM. More about this throughout the magazine—e.g. on pages 4, 6, 7, 12, and 16.

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Managing Director of  
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Member of the MAHLE  
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BEHR®

CLEVITE®

KNECHT  
FILTER®

MAHLE®  
ORIGINAL

## Dear readers,

In order to become a successful company in the long run—and be a reliable partner to our customers—we have to really think outside the box. That's why we at MAHLE Aftermarket have defined an orientation framework covering the most important topics for the future: on the basis of what we are doing today, where do we want to be in five to ten years? How will we maintain our strong commitment to quality and service in the future? How can we continue meeting our customers' growing requirements in the parts business—as well as for repair solutions and services—in the best possible way? And, of course: how can we help you fulfil your day-to-day trade and repair shop tasks quickly and competently?



Olaf Henning,  
Managing Director of  
MAHLE Aftermarket GmbH  
and member of the MAHLE  
Management Committee.

Our mission is to remain the first-choice supplier in the automotive aftermarket for you, our customers. As a genuine solutions provider, we want to support you and offer you everything you need to work efficiently and profitably: high-quality products in original equipment quality. Repair shop equipment that increases your service competence. And services that are uncompromisingly geared towards your needs and help you with your day-to-day work in the repair shop: hotlines, training, documentation, or—in very concrete terms—when we apply our practical knowledge to assist you with turbo-charger replacement or in your work on an air conditioning circuit.

However, we can only do this with a fundamental component: our employees. They are the ones who represent our vision, who live out our values—with every encounter, every action, every dialogue. Our employees' identification with the company is the foundation of what makes up the MAHLE brand: quality, innovation, and reliability.

The highlights of this issue of **MAHLE Aftermarket news** will illustrate how we put our ideas into practice in everything we do. What concerns us above all is the topic that drives and challenges our entire industry: increasing the overall efficiency of vehicles, a reality that is directly linked to the increasing electrification of the vehicle. On the next double page, you will find out how MAHLE is giving significant impetus to this trend. Naturally, we are also thinking of our new subsidiary MAHLE Letrika, which will turn the MAHLE Aftermarket truck portfolio into a complete range—initially to include starter motors and alternators, with a focus on electronic drive systems in the future. Alongside the electrification of the vehicle, the importance of thermal management is also gaining momentum. MAHLE is excellently positioned in this area too. We have further expanded this operating line with the newest member of the MAHLE family: the thermal management business of the US automotive supplier Delphi Automotive, which we will present to you in this issue.

**“ YOU CAN'T REACH YOUR GOAL  
UNLESS YOU HAVE ONE! ”**

Of course, pursuing a customer-oriented mission also means being open and growing together with you, our customers. We want to learn from you, in order to make good things even better. In this process of ongoing optimization, we rely on your feedback: tell us how we can continue to improve ourselves for you. Let us walk the path of successful cooperation together—to a goal that further strengthens and promotes our partnership.

I hope this issue will prove to be stimulating reading.

Sincerely,

Olaf Henning



# Pushed to the LIMITS

CANADIAN RACING DRIVER BRUNO SPENGLER IS A FAMILIAR FACE IN THE GERMAN TOURING MASTERS (DTM). ACTIVE IN THE DTM SINCE 2006, HE BECAME A DTM CHAMPION WITH BMW TEAM SCHNITZER IN 2012 AND CURRENTLY DRIVES FOR BMW TEAM MTEK. A FEW WEEKS AGO, THE GOOD-NATURED RACING DRIVER ATTENDED AN EVENT AT THE MAHLE GROUP HEADQUARTERS IN STUTT GART—AND ANSWERED A FEW QUESTIONS ON TECHNOLOGY, DOWNSIZING ON THE RACE TRACK, AND HIS CURRENT DTM SEASON.

**MAHLE Aftermarket news:** What do you think makes motorsport so unique?

**Bruno Spengler:** What fascinates me about motorsport is, firstly, the speed and the adrenaline when you're driving. The other thing is the competition—that's something that has always appealed to me, ever since I was little. Motorsport combines it all: competition, speed, technology, loud engines, teamwork, and adrenaline. Of course, you don't realise the significance of teamwork when you're that young. But for me it's a big factor. It's an individual sport because you're alone in the car—but without your team you can't achieve anything.

**MAHLE Aftermarket news:** This year, you're starting your eleventh season in the DTM. Over time, not only the rules but the vehicles, too, have seen some substantial changes. The requirement to make the cars aerodynamic is clearly recognisable, and the outward appearance of the DTM car is dominated by technological optimisation. What impact do these changes have for the drivers?

**Bruno Spengler:** The aerodynamic features make a big difference. If even one flap is missing, the car would be noticeably slower. The vehicles have been developed in a wind tunnel and their design really pushes the boundaries in all areas: engine, aerodynamics, chassis. Just to illustrate: in the DTM, the 24 drivers' qualifying times are within one second of each other. That means the cars are really pushed to their limits and relatively close together. If your car is missing one aerodynamic feature, you lose time straight away and don't stand a chance. Of course, the driver and the team have to function perfectly, just like the car. When everything falls into place and nothing unexpected occurs, then it usually goes relatively well.

**MAHLE Aftermarket news:** If we look at motorsport in general, a lot has been happening in recent years: diesel, hybrid drives, and downsizing are appearing more and more frequently, even in the major racing series. How would you cope with a possible move in the DTM—for example, from the current V8 engines to small four-cylinder engines?

**Bruno Spengler:** Depends what they sound like (laughs). I have nothing against four-cylinder engines. You can do great things with a four-cylinder engine. Of



course, the V8 is something special, and always will be. Let's just see what happens in the future. I may be surprised.

**MAHLE Aftermarket news:** So the sound is very important to you, as much as it is associated with the emotion of motorsport?

**Bruno Spengler:** I think sound is very important in motorsport. When you're sitting in the stands and you can hear the roaring of the cars, then it's a lot more fun—the fans will certainly agree. But you have to move with the times, too, and be open to new approaches.



*Future mobility:*  
**MORE ELECTRICS FOR MORE EFFICIENCY**

**VEHICLE ELECTRIFICATION AS A CONTRIBUTION TO FURTHER CO<sub>2</sub> REDUCTION**

In the future, vehicle electrification will make an increasingly important contribution towards efficient mobility. Starting with the conventional standard powertrain, MAHLE sees potential for a CO<sub>2</sub> reduction of up to 65 percent thanks to the many options that electrification offers. The consideration must not be restricted to immediate support of the combustion engine, with boosting, start-stop functionality, or hybridisation, for instance. More far-reaching measures in the vehicle are also needed, such as thermal management or the electrification of auxiliary components.

**POWERTRAIN: MODIFICATIONS WITH SUSTAINABLE EFFECT**

Even relatively small steps in electrification can achieve a sustainable effect in the combustion engine powertrain with a conventional 12 V electrical system. For example, electric actuators enable faster and more precise control of the combustion engine. Simply by replacing the pneumatic wastegate actuator with an electric variant, which MAHLE has been supplying for large-scale production

applications since 2009, CO<sub>2</sub> savings of approximately two per cent can be achieved. Rounded out by additional "easy" electrification steps, such as electric thermostats, EGR valves, power steering motors, and stop-start functionality, CO<sub>2</sub> savings of up to eight per cent in total can be demonstrated, without intervention in the electrical system and without electric drive motors.

**ELECTRIC AUXILIARY COMPONENTS:  
 LIGHTENING THE LOAD OF THE COMBUSTION ENGINE**

The electrification of auxiliary components provides further off-loading and support to the combustion engine. When uncoupled from the belt drive, not only do these provide packaging advantages owing to discretionary placement options, but mechanical losses in the combustion engine are also eliminated. The energy for electric auxiliary components can be produced by means of recuperation. In addition, they operate independently of engine speed and pressure and can therefore be designed purely based on specific requirements and with extreme precision. For example, an electric main cooling pump provides the possibility of completely suppressing the coolant flow during the



engine's warm-up phase simply by remaining disabled. The combustion engine can thus reach its optimal operating temperature more rapidly, and critical cold-start emissions can be drastically reduced. The coolant pump can then be operated on a fully variable basis based on the driving situation. Its use results in a possible CO<sub>2</sub> reduction of up to five per cent in total. Particularly in conjunction with the 48 V electrical system, MAHLE anticipates a high prevalence of electric auxiliary components and is continuously expanding its portfolio to include electric coolant pumps, air conditioning compressors, radiator fans, and more high-potential systems, for example.

#### **FULL HYBRIDISATION: A CHALLENGE FOR THERMAL MANAGEMENT**

Full hybridisation, with the advent of plug-in hybrids, is placing new demands on thermal management in the vehicle: lithium-ion batteries, in particular, must be continuously maintained within a temperature window. MAHLE was a pioneer in this field, with series production of the first refrigerant-based battery cooling systems already in 2009. Today, thermoelectric battery conditioning is almost ready for series production. But cooling and temperature control of drive

components are not the only crucial factors in high-voltage applications; interior air conditioning must also be maintained while the combustion engine is not running. High-voltage PTC heaters and electric air conditioning compressors from the MAHLE portfolio are essential systems to cover these requirements.

#### **MAHLE: COMPETENCE IN THE COMPLETE SYSTEM**

The various degrees of powertrain and vehicle electrification will gain more widespread acceptance, depending on the vehicle class and its price sensitivity, and thus contribute to increasing efficiency. With its comprehensive portfolio in the areas of thermal management, electric actuators, and auxiliary components, as well as electric drives with electronic controls, MAHLE has been present on the market in countless series production applications for many years and is preparing for the future continuing electrification of the powertrain in various forms. This includes further expanding its overall systems expertise, product portfolio, and thus its added value. As the automobile becomes increasingly electrified, MAHLE will therefore be ready, providing significant contributions.

# NEW IMPETUS ON BOARD WITH LETRIKA

**THE MAHLE FAMILY WELCOMES A HIGHLY PROMISING ADDITION: THANKS TO THE SLOVENIAN MECHATRONICS SPECIALISTS FROM LETRIKA, MAHLE AFTERMARKET CAN OFFER AN EXPANDED PRODUCT RANGE FOR AGRICULTURAL AND CONSTRUCTION MACHINERY.**

For a number of years, MAHLE has been advancing technologies to further reduce fuel consumption and emissions. The focus has also been on the electrification of auxiliary components—which in turn places heavy demands on mechatronic components such as starter motors, alternators, and electric motors. Thanks to the integration of Letrika in the family of companies, MAHLE has expanded its competence in this segment: as of January 2016, MAHLE Aftermarket will be distributing starter motors, alternators, and electric motors for agricultural and construction machinery under the MAHLE Original brand, thereby expanding its service offering.

“Our aftermarket customers will also benefit from Letrika’s integration in the MAHLE Group. The new subsidiary MAHLE Letrika builds on many years of product and service expertise, particularly in the agricultural and construction machinery sector. This means that in addition to expanding the portfolio to include alternators, starter motors, and electric motors, MAHLE Aftermarket

will also be offering technical information and support, repair instructions, and training courses”, comments Olaf Henning, Member of the MAHLE Management Committee and Managing Director of MAHLE Aftermarket GmbH. “In the long term, our expertise with regard to engine components, filters, and turbochargers for trucks will complement MAHLE Letrika’s competence wonderfully. We see great potential with our global distributors here.”

#### **MORE SUPPORT, MORE SERVICE, MORE SYSTEMS**

For trade and repair shops, many tasks will be simpler, as they now have access to a product portfolio that encompasses the agricultural and construction machinery segment—everything from a single source in the usual original equipment quality. In the future, dealerships and repair shops will benefit from the extensive product and service expertise of the MAHLE Letrika specialists as well as their comprehensive technical support.

The benefit for customers who have already collaborated with Letrika will be double: the integration will give them access to the global capabilities of the MAHLE logistics network and therefore to the rapid availability of components and systems... while allowing them to maintain their dialogue with their usual sales contact person at Letrika—making everything flow as seamlessly as possible.

#### **LETRIKA—MECHATRONICS COMPETENCE**

Letrika ranks among the most innovative companies in Slovenia, and received the German Industry Award in 2014. Of its 2,400 employees, 1,600 work at the headquarters in Šempeter pri Gorici, where there is also a research and development centre measuring 3,600 sqm. As early as 1960, components for motor vehicle electric systems were being produced there. Today, it manufactures not only alternators and starter motors for electric drive systems but also complete mechatronic systems for passenger cars, trucks, agricultural and construction machinery, and marine applications. Another good prospect is the strong development and manufacturing expertise in electric motors, which was proved with the Renault Twizy city car and thus represents an integral part of MAHLE’s future strategy.

#### **MAHLE LETRIKA—THE ADVANTAGES AT A GLANCE**

- Competence in construction and agricultural machinery—with starters, alternators, and electric motors
- Additional offering of technical information and comprehensive technical support, repair instructions, and training courses
- High level of development and manufacturing expertise in electronics and mechatronics—for over 50 years
- Complete mechatronic systems for all vehicle types in the future
- High-performance logistics network



*During the transitional phase, both old and new packaging will be on the shelves. To make things simpler, the Letrika part numbers will also be printed on the new packaging.*

# DELPHI

## THERMAL IS NOW PART OF THE MAHLE Group

The anti-trust authorities have approved MAHLE's acquisition of the thermal business of the automotive supplier Delphi Automotive PLC as of 1 July 2015. As a result, the Stuttgart-based group is expanding its strategically important Thermal Management business unit.

Through the now-completed acquisition, MAHLE is strengthening its commitment in a promising sector, since a comprehensive, energy-efficient thermal management system is as much in demand for combustion engines as for electric drives or fuel cells.

The product portfolios of both companies are an excellent match with regard to HVAC modules and engine cooling components. MAHLE places particular importance on Delphi Thermal's compressor business, which has thus far been missing from its own range. It will now be rapidly integrated into the group as a new business segment. Air conditioning, powertrain cooling, and heat exchangers for stationary applications, however, will become part of the Thermal Management business unit. In 2014, MAHLE generated around 40 per cent of its total sales from the new business segment, which was created following the takeover of Behr in 2013.

13 Delphi Thermal production plants in Poland, Slovakia, Hungary, the United States, Mexico, Brazil, China, and India, as well as three major research and development centres in the United States and Luxembourg have now been added to the group's approximately 150 production locations. As a result of the takeover, the roughly 7,500 employees of Delphi Thermal are expected to bring the total number of MAHLE employees worldwide to over 75,000 by the end of 2015.

Group sales should be rising just as sharply with the acquisition of Delphi Thermal: MAHLE anticipates total sales of around EUR 11.5 billion for 2015 provided that the global economic situation remains stable.

"By successfully concluding this takeover, we significantly improve our market position and move into positions 1–3 in the essential product segments of the thermal management business worldwide", explains Wolf-Henning Scheider, Chairman of the Management Board and CEO of the MAHLE Group since 1 July 2015. "Furthermore, by joining forces, new opportunities are arising for us. The Delphi Thermal portfolio ideally supplements our product range and systems competence. This also allows us to further expand our production footprint in Europe, North and South America, and Asia." Dr. Jörg Stratmann, Head of the Thermal Management business unit and member of the Management Board of the MAHLE Group, adds: "Following the intensive preparation of the last weeks, we will now devote all our energy to the upcoming integration tasks. And we are looking forward to welcoming the new employees, who will further strengthen our team with their skills and experience. As the second largest global thermal supplier, we will now be able to offer our customers even better solutions."

In a subsequent step, it is intended to acquire the joint venture Shanghai Delphi Automotive Air-Conditioning System Co. Ltd. (SDAAC) located in China. The negotiating parties expect this separate transaction to be concluded by 2016.

### HOW CAN REPAIR SHOPS AND TRADE OBTAIN THERMAL PRODUCTS?

We have a specialist for this product group: our joint venture Behr Hella Service.

Thermal Technology Parc in Ostrow/Poland



Downdraught and cross-flow radiators



Air conditioning system with heating, ventilation, and air conditioning technology



Mini air conditioning compressor (CVC)



**MAHLE**  
ORIGINAL

**TURBOCHARGER**

<b>For passenger cars</b>	Opel Vectra B 2.0 DTI, Astra G 2.0 DTI; 2.0 L, 4 cylinders, 74 kW (engines: X20DTH, Y20DTH)
<b>Part no.</b>	011TC14248000 (MAHLE Original)

**PISTON**

<b>For commercial vehicles</b>	Volvo FH 400, FM 360, FMX 400, and many more; 12.8 L, 6 cylinders, 264–368 kW (engines: Volvo D 13 B 360/400/440/500)
<b>Characteristic features</b>	MONOTHERM® piston, graphitised & phosphatised
<b>Part no.</b>	037 PI 00110 000 00 (MAHLE Original)



**FUEL FILTER**

<b>For passenger cars</b>	Ford B-Max, C-Max, Fiesta, Focus, Galaxy, Mondeo, Transit; Volvo C30, S40, S60, S80, V40, V50, V60, V70; 1.4–1.6 L, 4 cylinders, 51–85 kW (engines: T1DA, T3DB, T1GA, T3JB, F6JD, NGDA, UGJC, D4162T)
<b>Part no.</b>	KL 780 (both MAHLE Original and Knecht)



**FUEL FILTER**

<b>For vans</b>	Ford Tourneo, Transit; 2.2 L, 4 cylinders, 74–114 kW (engines: DRF4, DRFF, DRFG, CVFF, DRRC, DRRB, DRRR, DRF5, CYRA, CYRB, CYRC, CVRA, CVRB, CVRA, USR6, CV24, CVR5, UYR6, CYF4, CYFF, PGFA, PGFB)
<b>Part no.</b>	KX 387D Eco (both MAHLE Original and Knecht)



**CABIN AIR FILTER ELEMENT**

<b>For passenger cars</b>	Fiat 500, 500L, 500X; 0.9–2.0 L, 4 cylinders, 62–125 kW (all 500 series engines); Jeep Renegade; 1.4–2.0 L, 81–125 kW
<b>Part no.</b>	LA 889 (both MAHLE Original and Knecht)



**THERMOSTAT**

<b>For passenger cars</b>	Audi A1, A3, TT; Seat Leon; VW Golf, Polo; 2.0 L, 4 cylinders, 162–200 kW (engines: BHZ, BWJ, BYD, BZC, CDLA, CDLB, CDLC, CDLD, CDLF, CDLG, CDLH, CDLJ, CDKA, CDMA, CFGC)
<b>Part no.</b>	TI 6 80 (both MAHLE Original and Behr)



YOU CAN FIND DETAILED INFORMATION ABOUT THE NEW PRODUCTS IN THE REGULARLY UPDATED ONLINE CATALOGUES AT [WWW.MAHLE-AFTERMARKET.COM](http://WWW.MAHLE-AFTERMARKET.COM)

**THERMOSTAT**

<b>For passenger cars</b>	Opel Astra, Cascada, Corsa, Insignia, Mokka, Zafira; 1.4 L, 4 cylinders, 88–103 kW (engines: A 14 NEL, A 14 NET, B 14 NET)
<b>Part no.</b>	TM 36 103 (both MAHLE Original and Behr)



**AIR FILTER ELEMENT**

<b>For passenger cars</b>	Fiat 500, Panda; 0.9 L, 2 cylinders, 44–66 kW (engines: 312 A4.000, 312 A2.000, 312 A7.000)
<b>Part no.</b>	LX 3535 (both MAHLE Original and Knecht)



**MAIN BEARING SET**

<b>For passenger cars</b>	Seat Arosa, Cordoba, Ibiza 4/5; Škoda Fabia, Octavia; Audi A1, A2, A3; VW Eos, Golf, Lupo, Passat, Polo; 1.4–1.6 L, 4 cylinders, 37–132 kW (engines: AEE, AKK, APE, AQQ)
<b>Part no.</b>	029 HS 21018 000, 029 HS 21018 025, 029 HS 21018 050 (MAHLE Original)



**FUEL FILTER**

<b>For passenger cars</b>	Citroën Berlingo, C3, C3 Picasso, C4, C4 Cactus, C4 Aircross, C4 Picasso, C5, DS3, DS4, Jumpy; Peugeot 207, 208, 2008, 308, 3008, 508, 5008, Partner; 1.4–1.6 L, 4 cylinders, 50–84 kW (engines: DV4C, DV4TD, DV6C, DV6CTED, DV6DTED)
<b>Part no.</b>	KL 788 (both MAHLE Original and Knecht)



**CYLINDER LINER**

<b>For commercial vehicles</b>	Renault Magnum DXi 13 520.26; Volvo 9700, FMX 420, FM 500, and many more; 12.8 L, 6 cylinders, 256–397 kW (engines: Renault DXi 13440/13480/13520; Volvo D 13 C 420/460/500/540; Volvo TAD 1360/1361/1362 VE)
<b>Characteristic features</b>	With roller-burnished flange area
<b>Part no.</b>	037 LW 00102 001 51 (MAHLE Original)



**“LARGE” TURBOCHARGER SET**

<b>For passenger cars</b>	Audi A3 TDI; Seat Leon TDI S; VW Golf TDI; 1.9 L, 4 cylinders, 85 kW (engines: AUY/AJM); Audi A3 TDI; VW Bora TDI, Golf TDI; 1.9 L, 4 cylinders, 74 kW (engines: ATD)
<b>Characteristic features</b>	Contains turbocharger, turbocharger mounting kit, and oil line
<b>Part no.</b>	030TL15310000 (MAHLE Original) 030 TL 15310 030 (MAHLE Original)



# *Double the* PRESSURE

**Two-stage turbocharging represents a key technology for increasing performance in combustion engines—providing maximum torque over an extremely broad speed range. At the same time, it offers a further reduction in fuel consumption and emissions.**

Intake—compression—power—exhaust: a four-stroke combustion engine has been working according to the same principle for more than a hundred years. A decisive factor for achieving better efficiency is improving charge exchange in the cylinder: the more fresh air is supplied to the combustion chamber during the first combustion cycle and the more completely the exhaust gases are discharged from the combustion chamber after the combustion cycle, the more efficiently the engine can run.

To increase the efficiency of naturally aspirated engines, the charge exchange has been improved by increasing the size of the cross-sectional area of the air intake channels in particular, as well as the exhaust gas channels. The keyword is “multi-valve technology”. However, no matter how many valves let fresh air into the combustion chamber and how large the air ducts in the cylinder head are, the differential pressure can reach a theoretical maximum of one bar (at sea level); in practice the differential pressure is significantly lower. This means that naturally aspirated engines are reaching their limits; to optimise combustion and increase efficiency further, more air must be available in the combustion chamber than the engine alone can take in. This is why turbocharging is becoming so trendy.

#### **THE COMPRESSOR: MORE PRESSURE FOR MORE ENGINE EFFICIENCY**

To increase the air supply into the combustion chamber, the use of a compressor has proved effective. The principle behind it is that fresh air is no longer taken in by the movement of the piston but, instead, is pressed into the combustion chamber with the help of a blower. This can lead to an overpressure of several bars. The more air is fed into the engine, the greater its performance.

Nowadays, compression is normally generated by an exhaust gas turbocharger. Its turbine obtains its energy from the waste heat and the residual pressure of the hot exhaust gases. The energy supply costs virtually zero—without turbochargers, the hot exhaust gases would be blown out unused.

In order for the turbocharger to build up pressure correctly on the compressor side, the impeller and turbine must rotate very quickly: depending on their size, they can reach between 80,000 and well over 300,000 revolutions per minute in automotive applications. Each turbocharger is designed to achieve a specific maximum speed; exceeding this will lead to irreparable damage. This design means that the turbocharger rotates too slowly at low engine speeds (and thus low exhaust gas velocities and temperatures) and the engine cannot supply the optimal quantity of fresh air. This translates into a delay in the engine's power delivery and slow vehicle acceleration—the characteristic “turbo lag”.

#### **VARIABLE TURBINE GEOMETRY—HIGHLY VERSATILE**

To expand the speed range in which the turbocharger operates efficiently, variable turbine geometry (VTG) has been used for some time. These turbo-

charger types have adjustable guide vanes on the intake side. Depending on the requirements, they guide the exhaust gas flow to the turbine wheel so that it accelerates rapidly and rotates quickly. This expands the speed range of the engine in which the turbocharger can work effectively.

Achieving spontaneous turbocharger responsiveness is a challenge, particularly with large turbochargers: their turbines, shafts, and impellers have a correspondingly large mass that has to be accelerated first. A number of approaches can be used in practice to generate optimal boost pressure at both low and higher engine speeds.

#### **POWERFUL YET DEMANDING: THE SCREW COMPRESSOR**

One possibility is to use a screw compressor (compressor) for the low speed range of the combustion engine. The screw blower is driven directly by the crankshaft—e.g. via a timing belt. At higher engine speeds, an exhaust gas turbocharger is used. At the same time, the screw compressor is separated from the powertrain in order to protect the turbocharger from overspeeding. This is usually achieved by means of a magnetic clutch. The clear advantage of the screw compressor is its high response speed. However, it obtains its energy from the crankshaft, thus draining power from the engine.

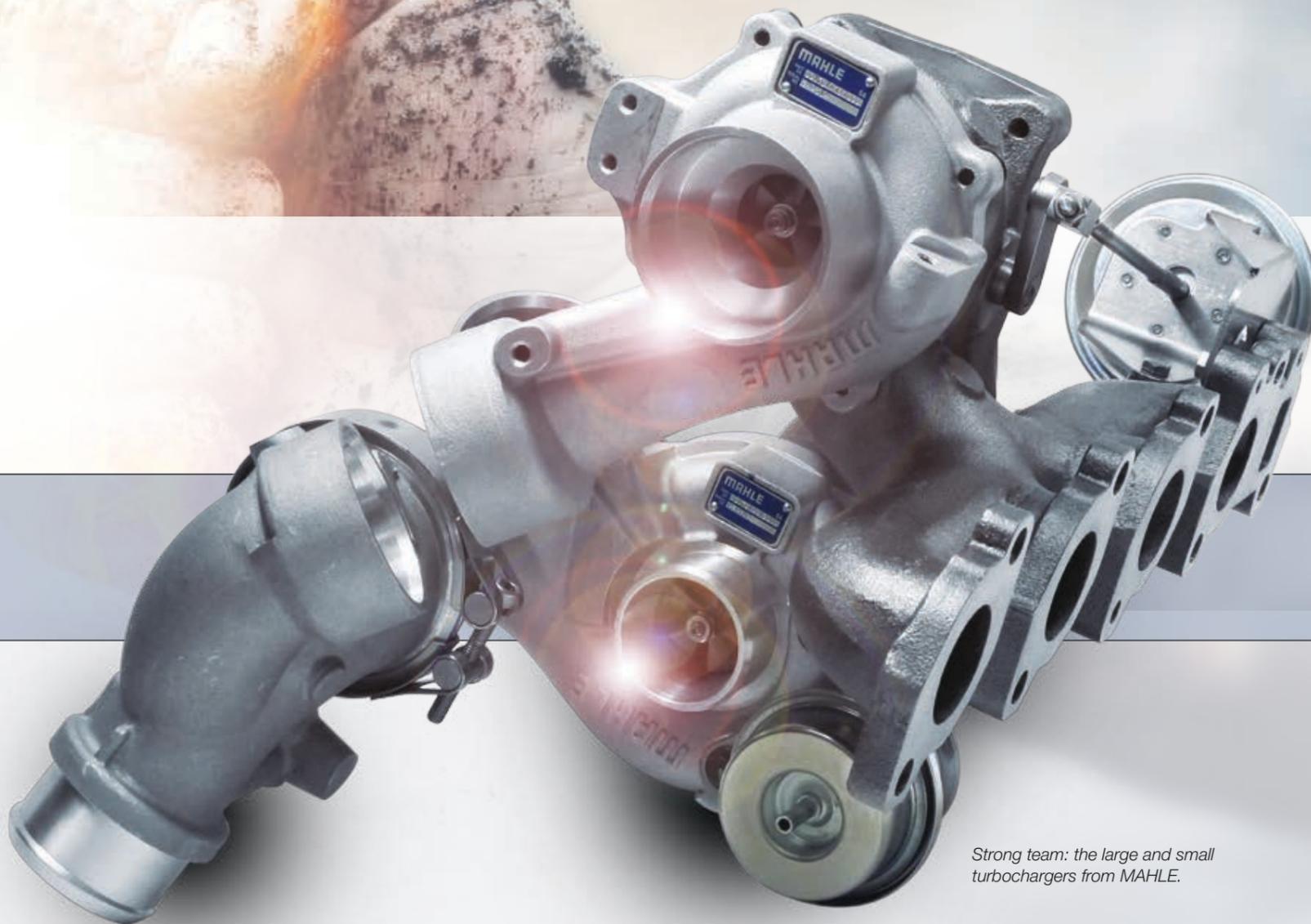
#### **EFFECTIVE AND UNDEMANDING: THE TURBO TEAM**

Since energy loss must be minimised at all costs in order to further improve engine efficiency, multi-stage turbocharging is becoming increasingly important. This approach combines two exhaust gas turbochargers with different dimensions.

**Stage 1 – high-pressure stage:** The small exhaust gas turbocharger operates at low engine speeds. With its small turbine wheel and impeller, it has a low mass and thus offers highly spontaneous responsiveness.

**Stage 2 – low-pressure stage:** At medium to high speeds, the exhaust gas flow is guided to the larger turbocharger via a wastegate valve. At the same time, the exhaust gas supply to the small turbo is automatically reduced. If the combustion engine is operated at maximum speed and power output, a second wastegate valve opens and guides some of the exhaust gas directly into the exhaust system in order to protect the large exhaust gas turbocharger from overload. A spring-loaded switching valve between the two turbochargers also regulates the charge air (fresh air) to ensure a harmonious, smooth transition from the small to the large turbocharger.

The use of the two turbochargers is adjusted exactly to the relevant operating situation; the driver is not aware of the switching between the two turbochargers. Thanks to this intelligent interaction, the engine has the optimal quantity of fresh air in a wide speed range.



*Strong team: the large and small turbochargers from MAHLE.*

#### THE WINNING DUO: DRIVING FORCE FOR CURRENT AND FUTURE ENGINE CONCEPTS

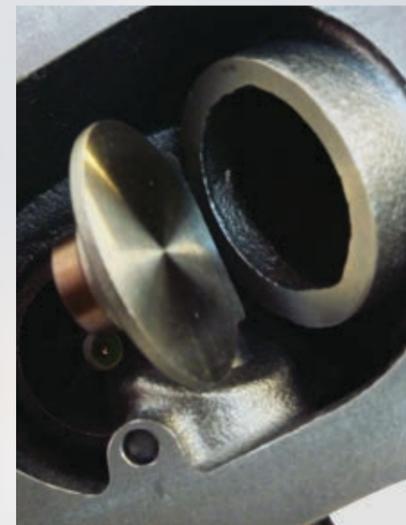
Besides optimising combustion in a broad engine speed range, staged charging opens up additional possibilities: with high boost pressure even at low engine speeds, the entire speed range can be shifted “down”. This in turn makes it possible to achieve lower maximum speeds. Multi-stage turbocharging therefore also plays a significant role in running the combustion engine efficiently over the entire speed range.

The downsizing trend is set to continue, since compliance with even more stringent exhaust emission standards in the future and further reducing fuel consumption are top priorities on the agenda. Engines with even smaller displacements, however, can only be given enough torque and power output with the help of supercharging. This means that an overall analysis of the complete system is more important than ever. Firstly because increasing the pressure and temperatures in the combustion chamber permanently increases the mechanical and thermal load of all engine components—particularly that of the pistons, bearings, and connecting rods. Secondly, because even optimal temperatures in the engine block and cylinder head, as well as in the charge air line, play a significant part in making the combustion engine highly efficient.

As an OE systems supplier, MAHLE develops and manufactures not only sophisticated components for the crank mechanism but also complete thermal management systems that are tailored to the new requirements, thus enabling optimal interaction between all components involved in the powertrain. With this comprehensive expertise, MAHLE will continue to actively advance the development of engine technology—towards sustainable mobility.



*Cool connection: the spring-loaded switching valve between the two turbochargers.*



*Opens reliably: the wastegate valve protects the large turbo from overload.*

#### At a glance:

##### MAHLE TURBOCHARGERS

- Manufactured, validated, and tested in accordance with OE standards
- Guaranteed straight from the factory
- Continuously updated range
- Strong market coverage
- Complete turbocharger kits (turbocharger, mounting kit, and optional oil line)
- Special kits for particularly demanding applications (e.g. replacement of intake manifolds)
- Support from MAHLE Aftermarket product experts
- Technical information (e.g. fitting instructions, damage diagnosis, repair assistance, Technical Messenger)
- Training for dealers and repair shops

# INTIMATE CONNECTION

**MAHLE OX OIL FILTERS ARE EQUIPPED WITH A CLEVER DETAIL: WHEN ASSEMBLED, THE FLEECE END CAP ACTS AS A SEAL—AN AMAZINGLY SIMPLE SOLUTION THAT REMAINS RELIABLE THROUGHOUT THE PRODUCT LIFE.**

An oil filter has an important responsibility: it has to protect the oil circuit from contamination of any kind, in order to preserve both the quality of the lubricant and the power output and economic efficiency of the engine in the long term. Thanks to the combination of internally developed high-performance filter media and design details, oil filters from MAHLE offer reliable protection

against contaminants of varying sizes—from minute soot particles and ultrafine metallic abrasions to larger particles. Designed as full-flow filters, they can absorb significantly more dirt than can accumulate between oil changes. This ensures a lower differential pressure throughout the lifetime of the filter element.

### SEPARATION THROUGHOUT THE LIFE CYCLE

The key challenge in oil filter design is to ensure that all of the engine oil is guided through the filter medium and thus kept clean. Not even the smallest quantity of oil is allowed to find its way past the filter element; reliable separation of contaminated and filtered oil—i.e. on the dirty side and the clean side—is essential in order to protect the engine. MAHLE has developed and patented a solution for this demanding task: the fleece end cap technology. Thanks to high-quality materials and perfectly fitting connecting parts, it guarantees a perfect seal in MAHLE OX oil filters. The piece of fleece thus acts both as an end cap and as a seal between the dirty and clean sides.

MAHLE uses an environmentally friendly manufacturing process to connect the fleece end caps to the filter media, without the use of toxic adhesives or solvents. The fleece is plasticized by means of the ultrasonic welding process—micro-friction between the filter medium and fleece end cap generates so much heat energy locally that the molecules of the different materials are “welded” together. This connection holds firm throughout the life of the filter, provided that all rules and prerequisites are complied with.

### ENVIRONMENTALLY FRIENDLY INSERT

Filter inserts from the OX and OX-ECO range are a particularly environmentally friendly and economical solution for repair shops: instead of replacing the entire filter, only the contaminated insert is removed from the filter housing and replaced. The eco model (OX ECO) is also metal-free. It is manufactured exclusively from filter paper and plastics that can be incinerated in an environmentally friendly manner. These filter inserts can be disposed of in combined heat and power plants, thereby generating heat—all that remains is a small pile of ashes. This not only conserves resources but also eliminates the need for expensive waste separation of the individual materials. As early as 1996, MAHLE won first prize from the Federation of German Industries (BDI) for this innovation.

the quality of the filter, the engine oil must meet the automobile manufacturer’s specifications exactly.

### The rubber O-ring must be correctly in position

Even the highest-performance oil filter can only work and seal reliably if it has been installed correctly. During assembly of the oil filter, it is therefore crucial to always check for correct positioning of the rubber O-rings, such as those found on the screw-type cover. It is recommended that these be always moistened with fresh engine oil during assembly.

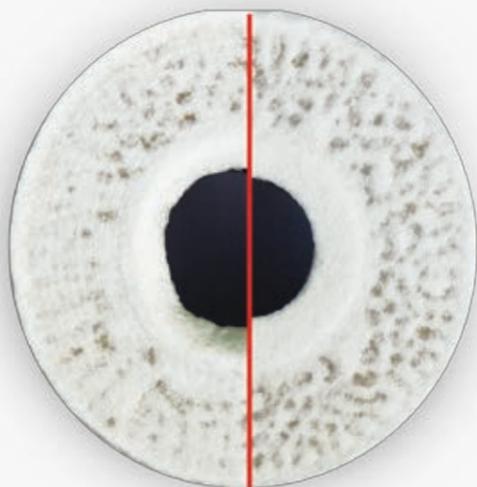
### Oil as an installation aid

With OX filters in particular, the oil can also be useful elsewhere: the new filter can be inserted even more easily if there is a thin oil film on the fleece end cap. This can significantly reduce the slightly greater effort required during assembly. It also lowers the risk of the material being overstretched—the part of the end cap moistened with oil slides even more easily into the optimal position.

### The fleece end cap: “too small” becomes just right

At first glance, the hole in the fleece end cap of the new, unused filter seems too small—it differs from that of the used filter by two to three millimetres. The reason becomes evident when you set it down on the filter: the piece of fleece around the hole is also an end cap. This means that during assembly of the filter, it is placed between the standpipe (housing and cover) and inner tube (filter) in such a way that it is clamped and pressed in. The result: an optimal seal between the dirty and the clean sides. No oil can get through; the entire oil flow follows the path through the filter medium... and is therefore reliably cleaned.

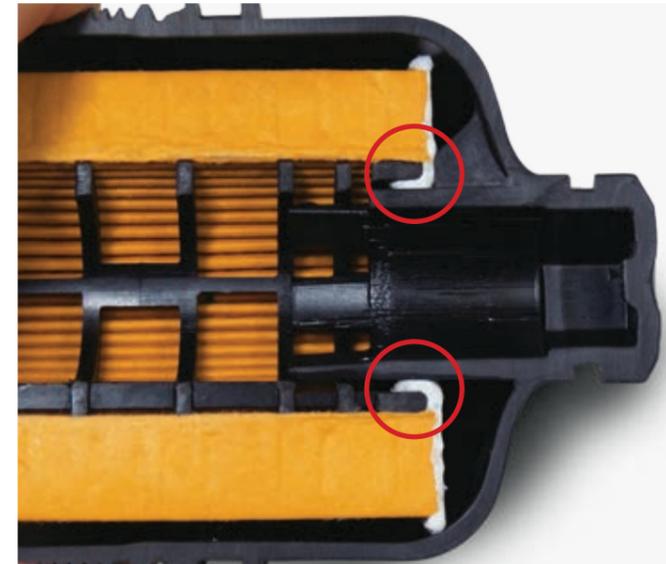
Filter inserts with fleece end cap technology are one of the countless examples of the way in which MAHLE implements environmentally friendly, economical,



No cause for alarm: the size difference of the hole. On the left, the fleece end cap of a used filter; on the right, that of a new filter.



When assembled, the fleece (white) is pressed in between the inner tube (yellow) and the standpipe (red) so as to build a complete and reliable seal.



A perfect seal: the folded fleece end plate.

### SERVICING: DON'T WAIT TOO LONG!

The best oil filters also eventually reach their limits: even if they are nowhere near their dirt-holding capacity, the filter media are subject to natural ageing due to the high thermal stresses and the chemical loads resulting from combustion residues. This not only leads to the filter medium becoming brittle but can also cause the paper to decompose if used for an excessively long period of time, resulting in consequential damage because of the clogged oil channels. Therefore, in order for the oil filter to function correctly, it is very important to replace it promptly in accordance with the maintenance intervals prescribed by the automobile manufacturer. Exceeding these intervals poses a risk of serious engine damage!

### OIL FILTER REPLACEMENT—WHAT IT COMES DOWN TO

#### The choice of filter and engine oil

In line with the latest maintenance and repair requirements, MAHLE Aftermarket offers a comprehensive, constantly maintained OX filter range in original equipment quality, with the two brands MAHLE Original and Knecht. In addition to

yet practical solutions for its partners in the automotive aftermarket—thanks to its innovative strength, comprehensive systems expertise, state-of-the-art production processes, and outstanding repair shop competence.

#### At a glance:

#### MAHLE FILTRATION TECHNOLOGY WITH FLEECE END CAP

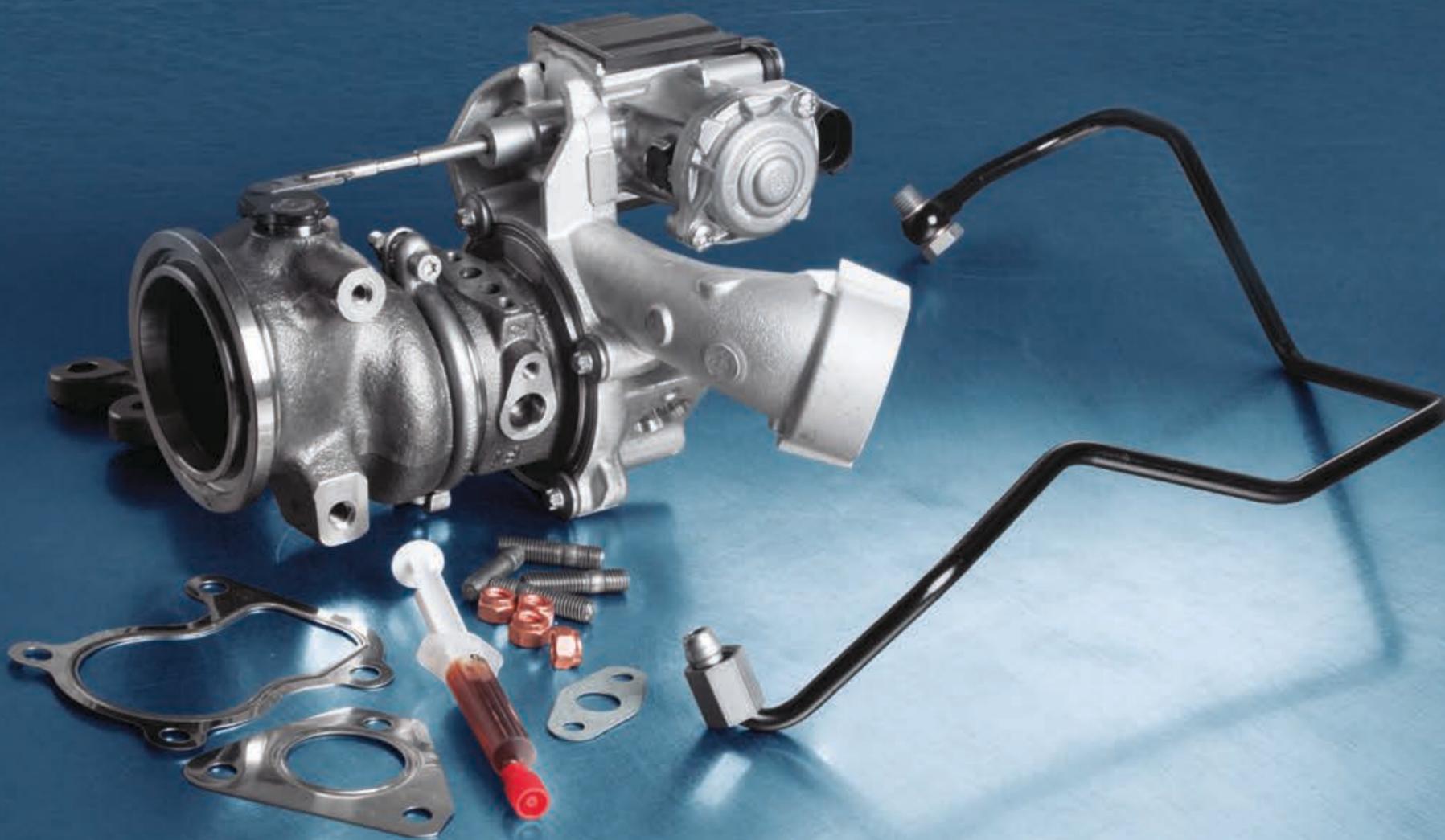
- Developed by MAHLE and patented for a broad spectrum of applications
- Absolutely secure sealing throughout the life of the filter
- Installed and proven a million times over in original equipment
- Comprehensive, continuously updated range in OE quality for the aftermarket
- Economical and easy-to-install filter inserts available
- Transfer of expertise through a broad range of technical information and exclusive training for dealerships and repair shops

# Customized REPAIR PACKAGE

THE NEW MAHLE TURBOCHARGER KIT—AS UNIQUE AS THE DIFFERENT DAMAGE SCENARIOS

Regardless of the damage scenario, the mounting kit and potentially the oil line have to be replaced along with the turbocharger. To simplify the work process

for the repair shop, MAHLE turbochargers are now also available as complete kits—tailored to the damage scenario and repair requirements.



Turbochargers, mounting kits, and oil lines can also be obtained separately, as can the medium kit, consisting of the turbocharger and mounting kit. The complete information can be found in TecDoc.

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