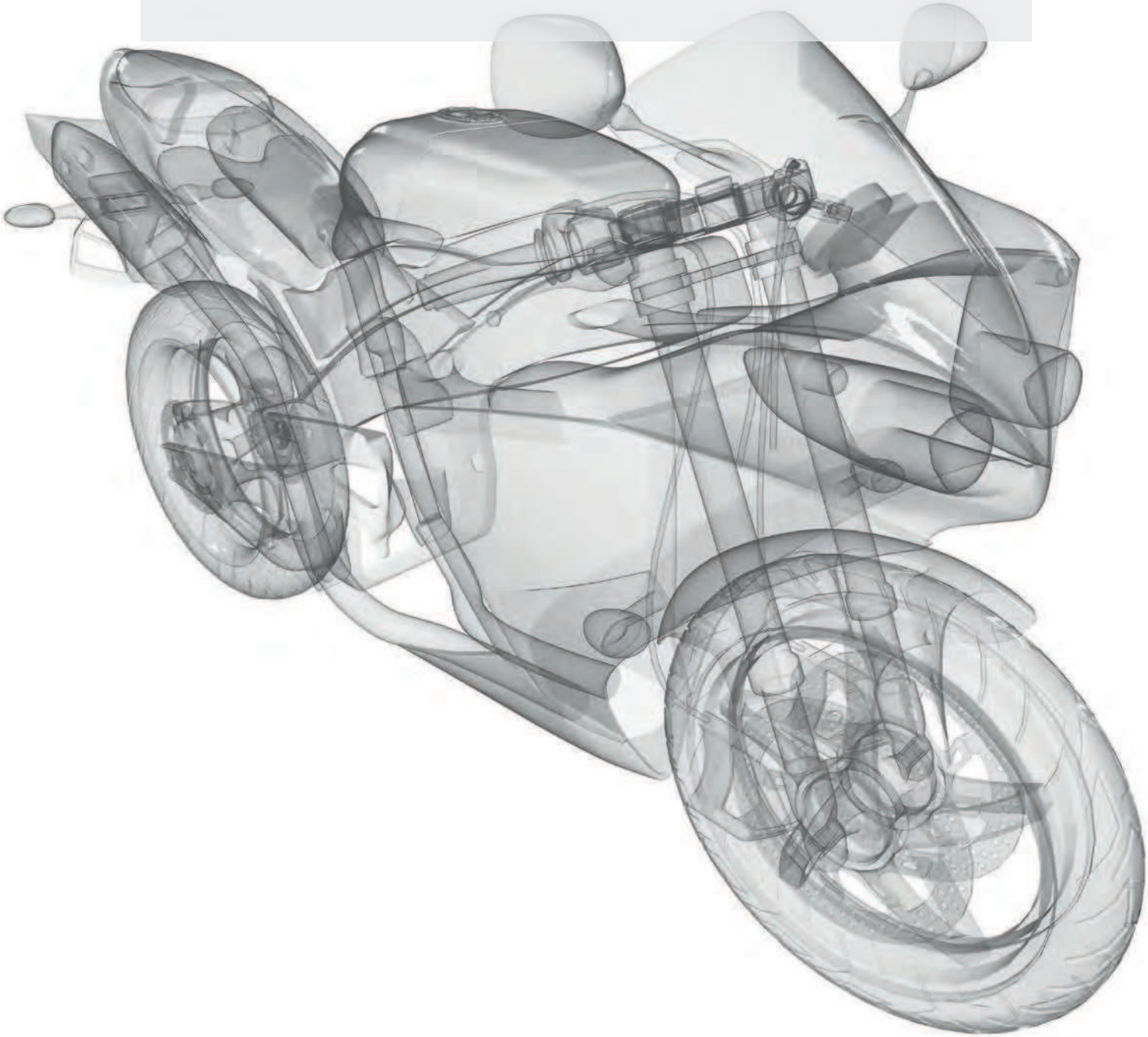
MAHLE

Driven by performance

Solutions

for small engines and electric drive systems



About MAHLE

With its products for combustion engines and their peripherals as well as solutions for electric vehicles, the leading international automotive supplier MAHLE addresses all the crucial issues related to the powertrain and air conditioning technology—from engine systems and components to filtration to thermal management. MAHLE products are fitted in every second vehicle worldwide. And MAHLE components and systems have been success-ful on every race track in the world for decades. The company's innovative products are also used off the road—in stationary applications, for mobile machinery, as well as in railroad, marine, and aerospace applications.

In 2015, the group generated sales of EUR 11.5 billion with around 76,000 employees. Today, MAHLE is represented in over 34 countries with 170 production locations. Its strategic objective is to be a technological driving force for efficient mobility. At 15 major development locations in Germany, Great Britain, Luxembourg, Slovenia, the USA, Brazil, Japan, China, and India, more than 5,000 development engineers and technicians are working on innovative solutions.

MAHLE Small Engine Components

The development of pistons and piston systems has always been part of our core competence. Today, MAHLE is the only manufacturer worldwide to develop and produce all key components in house. Comprehensive systems competence, extensive production experience, and continuous development activities form the basis for technologically innovative systems solutions. In our product segments, we are among the largest suppliers worldwide to manufacturers of professional hand-held power equipment. Our engine components also ensure that motorcycles and recreational vehicles run reliably. With modern development tools, we support our customers in the development of powerful engines with lower emissions right from the beginning.

MAHLE Letrika

In the fall of 2014, MAHLE acquired the Slovenian company Letrika, which develops and produces starter motors, alternators, and electric motors as well as electric drive and mechatronic systems. With its starter motors and alternators, MAHLE Letrika is a significant player in the global market, especially for agricultural and construction machinery. They also constitute the industrial core of electric drive systems used, among others, in industrial trucks and in electric vehicles such as the Renault Twizy, golf carts, and modern electric scooters.

MAHLE Electric Drives Japan Corporation

In June 2015, MAHLE acquired the majority share in Kokusan Denki. MAHLE Electric Drives Japan Corporation, headquartered in Numazu, near Tokyo, develops and produces electric DC motors for ABS and EPS units, BLDC motors for steering assistance, and electric motors for industrial applications. Another major division comprises ignition components, alternators, and fuel injection systems for small engines, which are essentially used in motorcycles, small commercial vehicles, and recreational vehicles.

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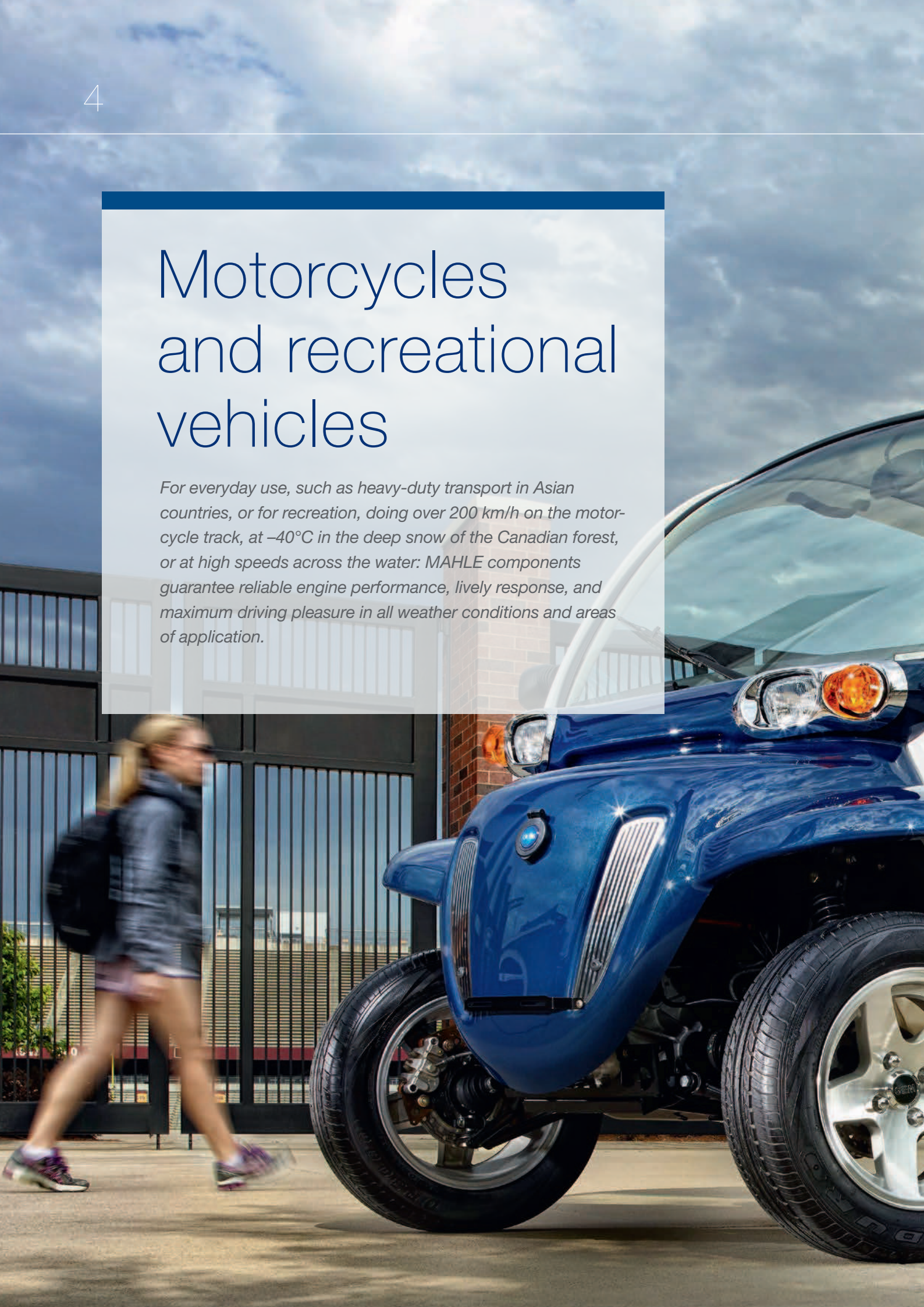
PICTURE CREDITS

KD Busch (p. 2/3 + products), Polaris (p. 4/5, p. 7, bottom center), Mercury (p. 6, bottom right), BRP (p. 6, bottom left and center), shutterstock: Luisma Tapia (p. 7, bottom left), istockphoto: ItchinToGoFishin (p. 10/11), Dmitry Vereshchagin (p. 12, bottom left), Husqvarna (p. 12, bottom right), Solo (p. bottom 13, left), shutterstock: cyran (p. 13, bottom right), Marian Garai (p. 14/15), pingvin57 (p. 16, bottom left), gearstd (p. 16, bottom center left), Honda (p. 16, bottom center right), stefan1179 (p. 16, bottom right)

Motorcycles and recreational vehicles

For everyday use, such as heavy-duty transport in Asian countries, or for recreation, doing over 200 km/h on the motorcycle track, at –40°C in the deep snow of the Canadian forest, or at high speeds across the water: MAHLE components guarantee reliable engine performance, lively response, and maximum driving pleasure in all weather conditions and areas of application.



HIGH-PERFORMANCE ENGINE COMPONENTS, MECHATRONIC AND ELECTRIC DRIVE SYSTEMS DEVELOPED FOR THE SPECIFIC DEMANDS OF MOTORCYCLES AND RECREATIONAL VEHICLES

Power cell units

The power cell unit (PCU) consists of the piston, piston pin, piston rings, cylinder liner, and/or conrod. Power cell units are developed as complete modules. They offer high functionality and efficiency because the individual components are optimally coordinated.

Cylinders, cylinder liners, crankcases

Aluminum cylinders, cylinder liners, or crankcases
— MAHLE is a specialist in the realization of all kinds of aluminum cylinders. The MAHLE Nikasil® cylinder bore surface plating offers optimal tribological conditions and guarantees a long lifetime.

Pistons

As the largest piston manufacturer worldwide, MAHLE offers cast as well as forged lightweight and at the same time robust aluminum pistons, designed according to our customers' individual engine specifications. Several aluminum alloys and surface plating solutions are available.

Camshafts

MAHLE offers cast camshafts, camshafts made from bar stock, or forged and assembled camshafts. The assembled camshafts play a very important role in meeting current and future CO_2 legislation for modern LV engines, as these are also available as low-friction camshafts (LFC) equipped with roller bearings and as CamInCam® camshafts, which allow independent intake and exhaust cam phasing in SOHC engines or valve opening duration modification in DOHC engines. Furthermore, MAHLE assembled camshafts can be mounted in a cam carrier or a cylinder head cover with closed bearing supports.

APPLICATIONS

Personal watercrafts

Snowmobiles

Outboard engines

Air and liquid filtration products

MAHLE offers customized air cleaners, air intake modules, and several filter media to achieve optimized clean air and guarantee performance. Furthermore plastic head covers, oil mist separators, and fuel filters are essential for efficient filtration.

Bearings

MAHLE has bearing solutions for the increased loads placed on engines by measures to reduce CO_2, such as stop-start systems, oils with lower viscosity in combination with high-resistance polymer coatings, lead-free high-performance alloys, and sputter coating or multilayer sputter coating with various alloys within the working surface coating for ultrahigh loads.

Ignition coils and CDI/TCI units

Ignition coils are used in ignition systems to generate high voltages that produce sparks in the spark plugs to ignite air-fuel mixtures in combustion chambers.

CDI (Capacitor Discharge Ignition) and TCI (Transistor Controlled Ignition) units from MAHLE are electronic ignition systems suitable for all kinds of small engines. TCIs constantly provide electric power to the ignition coil. If the circuit is cut, a spark is generated to ignite the air-fuel mixture in the combustion chamber. Due to its ignition characteristics, TCIs are the first choice to lower emissions.

In a CDI unit, the discharge of a high-voltage capacitor is used—via ignition coil and spark plug—to ignite the air-fuel mixture in the combustion chamber. Due to its ignition characteristics, CDI units are an optimal solution for requirements of small engines (e.g., motorcycles, ATVs, hand-held devices, etc.).

Motorcycles and scooters

ATVs and side-by-sides

Personal mobility

Actuators

MAHLE actuators are used to open and close exhaust valves/flaps and thus control the engine sound as well as the exhaust gas flow. They are found in a variety of applications, such as in snowmobiles, personal watercrafts, and ATVs/UTVs:

- Engine brake in ATVs/UTVs
- 2WD/4WD switching in ATVs/UTVs
- Exhaust gas flow control of two-stroke engines for snowmobiles, ATVs, and UTVs
- MAHLE also offers waterproof actuators

ABS motors

MAHLE provides ABS (Antilock Brake System) motors for motorcycles. The highly efficient motors with compact dimensions ensure maximum traction in all driving conditions by preventing the wheel of a motorcycle from locking when braking.

Fuel injection systems

MAHLE fuel injection (FI) systems comprise the electronic control unit, sensors, fuel pump, injector, and throttle body. FI systems define the optimal fuel quantity as well as the ignition and injection timing required for the respective driving/load situation to ensure comfortable driving pleasure. Furthermore, the optimal fuel supply improves fuel efficiency and leads to reduced emissions. MAHLE FI systems can be supplied as both battery- and batteryless systems.

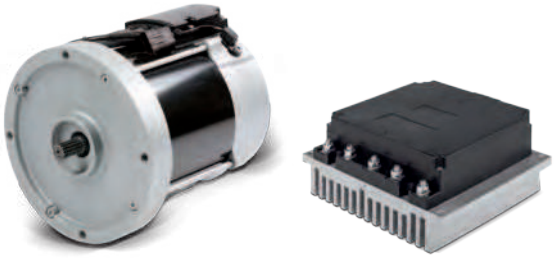
ACGs and Voltage Regulators

ACGs are permanent magnet generators that are directly connected to the engine crankshaft to generate power from engine rotation. This is used as a power source for a variety of electrical and electronic components that are for a range of functions including charging the battery and powering control units. Pickup coil provided outside ACG sends out signals according to movement of teeth on outer circumference of ACG rotor to ignition control unit to calculate engine speed. ACG rotor provides inertia moment to stabilize engine rotation.

Regulators convert the alternating current output by generators to direct current while also maintaining a constant charging voltage for the battery.

EPS motors

MAHLE electric power steering (EPS) motors are highly efficient brushless motors that assist the driver in safely steering the vehicle. This technology not only increases the comfort for drivers and enables innovations such as automated parking, but also increases fuel efficiency compared to hydraulic systems. Hydraulic systems are continuously powered, whereas EPS systems only assist when desired by the driver. The fuel savings reach up to 6% and reduction of CO_2 emissions amount to about 8 g/km.

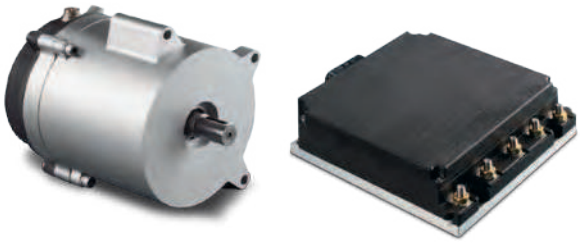


Low-voltage drive systems (for electric vehicles)

Low-voltage AC drive systems based on the battery-powered asynchronous motor are designed to drive electric vehicles with battery voltages from 24V to 80V. The brushless design of an asynchronous motor offers practically unlimited life without maintenance. Excellent driving characteristics and additional configurable functions in the microprocessor-based control unit enable adjustment of the system in a wide range of different electric vehicles.

AC induction motors with a compact design are four-pole motors with an aluminum/copper squirrel cage rotor and three-phase winding on the stator. Their robust and brushless construction with superior output represents the best traction solution for battery-powered electric cars.

Electronic controllers convert DC voltage to three-phase alternating voltage at the required amplitude and frequency to supply AC motors. They are designed on the basis of high-speed DSP processors that enable indirect field-oriented control in real time and innovative power storage. The combination of such hardware and sophisticated software results in excellent adjustability of high dynamics and efficiency of the asynchronous drive. The installed CANopen protocol and additional inputs/outputs allow adjustment to the changing requirements of different installations.



Low-voltage drive systems (for electric motorcycles)

Electric drive systems consisting of highly efficient electric motors and dedicated electronic controllers are designed to operate in a variety of electric vehicles, particularly electric motorcycles. The motor includes high-energy permanent magnets and low-loss materials to reach motor efficiency levels of over 90%. The motor speed/torque characteristics are convenient for a direct belt drive configuration or for different gearbox solutions and can be adjusted to the required vehicle top speed and uphill gradeability.

In the typical IPM motor configuration, this motor features excellent torque and power density. Up to 1 kW/kg can be achieved. As it is a brushless design, it will require no maintenance during its entire lifetime of typically over 20,000 hours.

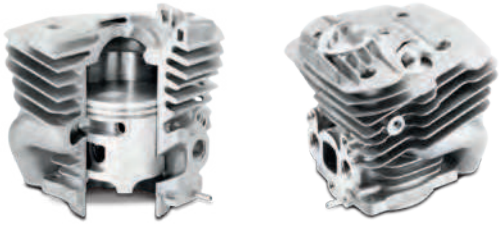
Electronic controllers are programmed to drive the electric motor with efficient field-oriented vector control and are suitable for the most attractive modes of operation such as normal forward drive, ECO mode, booster mode, reverse drive, and regenerative braking. Other generally used controller functions are fully programmable for excess temperature and excess current as well as overvoltage and undervoltage protection. The controller is capable of CAN communication.

Lawn & garden, forestry, and construction products

Professionals around the world appreciate small engine components from MAHLE for their reliability and durability. Chain saws are often used in remote areas and have to function perfectly under extremely tough conditions. Finnish lumberjacks bury their saws in the snow, for example, in order to avoid having to carry them to the job site every day. Our filters or piston and cylinder assemblies for small engines handle even these challenges with ease today. They are specially tailored to meet our customers' requirements.

The same goes for our electric motors. They are also highly efficient, feature excellent power density, and require minimal maintenance.

HIGH-PERFOMANCE ENGINE COMPONENTS, MECHATRONIC AND ELECTRIC DRIVE SYSTEMS DEVELOPED FOR THE SPECIFIC DEMANDS OF LAWN AND GARDEN, FORESTRY, AND CONSTRUCTION PRODUCTS

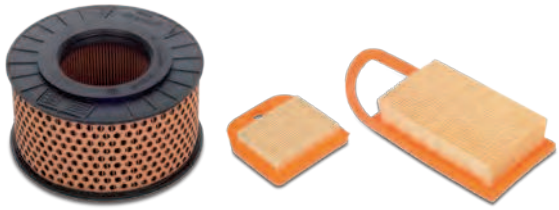


Two- and four-stroke cylinders

Air-cooled aluminum cylinders with an optimal weight/power ratio using the latest technologies to reduce emissions and fuel consumption are one of MAHLE´s specialties. Nikasil® cylinder bore surface plating guarantees a long lifetime even under rough conditions.

Two- and four-stroke pistons

As the largest piston manufacturer worldwide, MAHLE offers cast as well as forged lightweight and at the same time robust aluminum pistons, designed according to our customers' individual engine specifications. Several aluminum alloys and surface plating solutions are available.



Air filters and heat exchangers

MAHLE air filters with excellent retention—thanks to specific filter media—support the engine function and lifetime. Heat exchangers control the flow and prevent overheating.

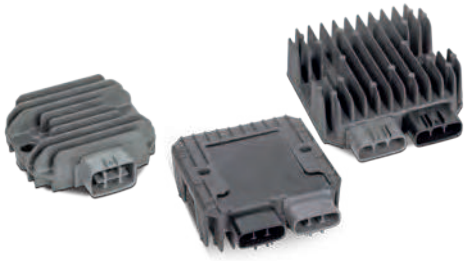
Geared DC motors

Used in agricultural machinery and mid- to large-size combines, in particular. Some combine models cut the rice stalks, separate the rice grains from the rice heads, and transport the grain through a smokestack-like tube (auger) to the waiting truck. In this application, the motors gently turn the auger to keep it lined up with the truck.

APPLICATIONS

Mowing machines

Chain saws



Voltage regulators

Regulators convert the alternating current output from generators to direct current while also maintaining a constant charging voltage for the battery.

Dynamos with integrated voltage regulator

One feature of this generator is the regulator-integrated design and its use for driving pulleys. Magnets are used to generate alternating current, which is then converted into direct current by a regulator that additionally adjusts the voltage to supply electricity to the battery.

Ignition coil with integrated CDI/TCI

The flywheel magneto for this application is a rotor with a magnet to generate energy in the associated ignition coil to generate sparks in the internal combustion engine.

Ignition coils are used in ignition systems to generate high voltages from a low-voltage source. From the high voltage, sparks are generated in spark plugs to ignite air-fuel mixtures in combustion chambers. The MAHLE ignition coils with integrated CDI (Capacitor Discharge Ignition) or TCI (Transistor Controlled Ignition) provide ignition characteristics that suitable for all kinds of requirements of lawn and garden products.

Imbedded Permanent Magnet (IPM) Motors

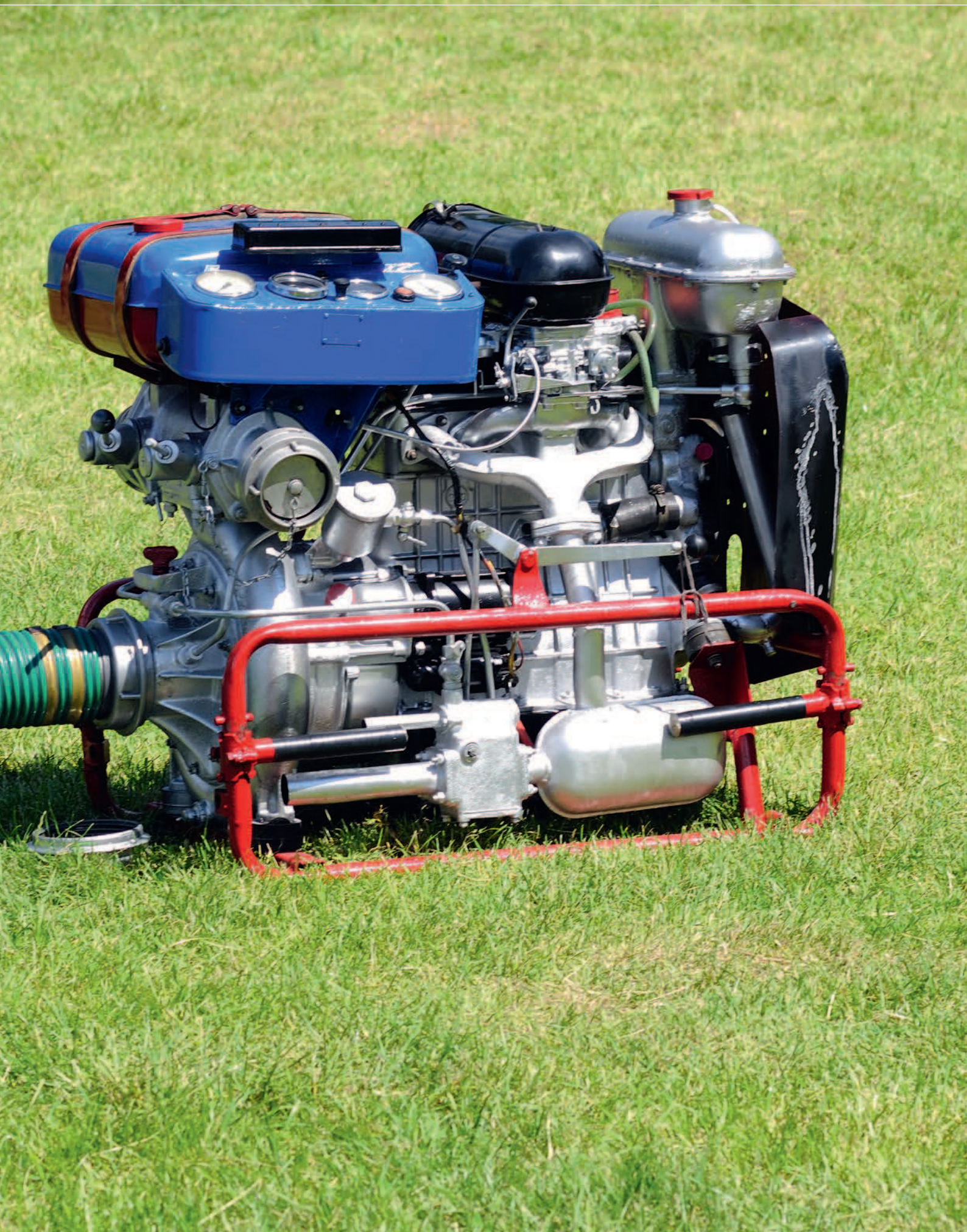
In the typical IPM motor configuration, this motor features excellent torque and power density. Up to 1 kW/kg can be achieved. As it is a brushless design, it will require no maintenance during its entire lifetime of typically over 20,000 hours.

Power cutters

Trimmers

Multipurpose and stationary engines

Wherever generators and water pumps are employed, it is most important that they run reliably. After all, they are often used to prevent major catastrophes. It is hard to imagine what would happen if fire departments or relief organizations could not count on their equipment. MAHLE components guarantee long service life and high performance —with efficient, low-cost operation.



HIGH-PERFORMANCE ENGINE COMPONENTS AND MECHATRONIC SYSTEMS DEVELOPED FOR THE SPECIFIC DEMANDS OF MULTIPURPOSE AND STATIONARY ENGINES

Pistons
Lightweight and robust. Offered including piston ring set and piston pin.

Filters
MAHLE offers customized air intake modules as well as air and liquid filter elements. Several filter media guarantee a distinguished filter function even under specific high-performance conditions.

Iron liners
Cast iron liners with optimized honing for excellent wear behavior.

Inverter generator systems
MAHLE inverter generator systems produce electrical energy from the rotation of an internal combustion engine and convert the frequency/voltage output of engine generators to the frequency/voltage required by electric consumers.

APPLICATIONS

Fire pump

Portable generator

Multipurpose engine

Genset

Dynamos with integrated voltage regulators

This brushless generator from MAHLE with an integrated voltage regulator provides direct current to electric and electronic consumers. Due to its design, it is very durable and requires very little space.

Flywheel and ignition coil with integrated CDI/TCI

Flywheels are rotating disks that store kinetic energy. Their purpose is to smoothen the pulsing energy of combustion engines and to enable an easy start from standstill. Furthermore, they provide the magnetic flux needed by ignition coils to generate sparks that ignite air-fuel mixtures in combustion chambers. The ignition coils come with integrated electronics for CDI/TCI-type ignitions. CDI (Capacitor Discharge Ignition) and TCI (Transistor Controlled Ignition) units from MAHLE are electronic ignition systems. TCIs constantly supply the ignition coil with electric power. If the circuit is cut, a spark is generated that ignites the air-fuel mixture in the combustion chamber.

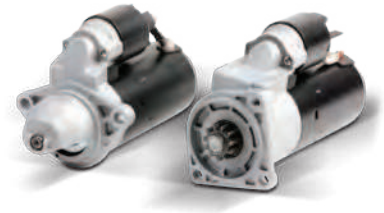
In CDI units, the discharge of a high-voltage capacitor is used —via ignition coil and spark plug—to ignite the air-fuel mixture in the combustion chamber.

Voltage regulators

Voltage regulators convert the alternating current output of generators to direct current required for electric and electronic consumers. In addition, voltage regulators act as overvoltage protection by limiting the maximum voltage produced by the generator.

Fuel injection systems

MAHLE fuel injection (FI) systems for general-purpose engines are electronic control units responsible for the amount of fuel, the ignition, and as injection timing. The optimal fuel supply improves fuel efficiency and results in reduced emissions. Moreover, MAHLE FI systems can be used for batteryless systems.



AZE permanent magnet gear reduction starter motors

These are starter motors for diesel engines in light commercial vehicles, small tractors, agricultural machinery, ships, stationary generator sets, and other applications. Delivering a high specific power output, they feature excellent cold-crank capability with low current drain from the battery. The highly efficient drive assembly ensures the idle run of the pinion. It is possible to directly drive starter motors more easily due to their comparatively reduced weight and size. The starter motors are characterized by high reliability and long service life.

AAG compact alternators

AAG compact alternators are designed to meet a wide range of engineering specifications and applications. They are used for applications with higher electrical requirements and limited mounting space such as small tractors, small agricultural and construction machinery.

MAHLE WORLDWIDE

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