

## Applications – Power train – Transmission and driveline

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## 9 Transmission and driveline

Significant amounts of aluminium are not only applied in the engine, but also in the rest of the powertrain, i.e. in the transmission and the various driveline components. Most important aluminium applications are the various housings, but aluminium is also used for different functional components (e.g. hydraulic components of automatic transmissions, drive shafts, etc.).

Aluminium is mainly chosen for its lightweighting effect. Further decisive factors are its excellent heat dissipation characteristics, the very good machinability of aluminium alloys as well as the feasibility to efficiently produce highly complex, thin-walled components. Most aluminium housings for applications in transmission and driveline are produced by high pressure die casting, but also other sophisticated casting techniques can be applied.

An important competitor of aluminium for lightweight housings is magnesium. Magnesium alloys are highly suited to manufacture thin-walled parts in very complex geometries by high pressure die casting. Thus, for housing applications, magnesium offers a weight reduction over aluminium of about one third. Magnesium has all the mechanical and physical properties needed for this application. Apart from cost issues, the big remaining problem is the corrosion resistance which requires the selection of specific magnesium alloys with a closely controlled impurity content. On the other hand, aluminium screws are necessary to ensure that housing sections, brackets and stiffeners made from magnesium can be securely fitted and assembled (see section “Aluminium fasteners” below).

### **9.1 Driveline concepts**

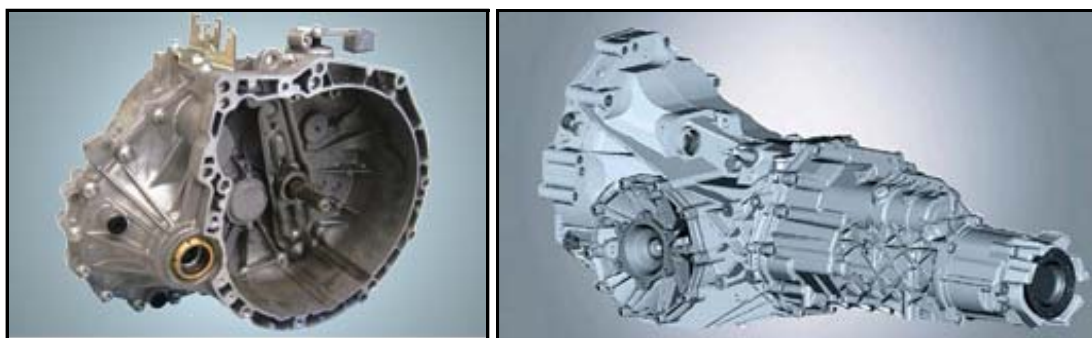
The driveline of a motor vehicle consists of the parts of the powertrain excluding the engine and the transmission. The configuration of the driveline, i.e. the portion of the powertrain after the transmission, depends on the various choices of wheels to be powered by the engine: front-wheel drive, rear-wheel drive and all-wheel drive.

In a vehicle with a front-wheel drive system, the engine, the transmission and the drivetrain are all located in the front and thus, there is more passenger space in the cabin. This type of driveline has a reduced complexity since all components are close to each other leading to a more compact design. On the other hand, it means that the vehicle's major weight is concentrated in the front. Rear-wheel drive vehicles usually offer a better balanced weight distribution and therefore superior braking and handling performance.

The all-wheel drive is the most sophisticated driveline available today. Modern all-wheel drive systems have fluid-filled differentials and advanced electronics which enable to send power equally to all four wheels or to transfer torque into the wheels with most traction. The all-wheel drive configuration can also be designed with a bias to either the front or rear wheels. As a result, the driving dynamics are very much improved. It must be differentiated by full time and part time all-wheel drive. A part-time all-wheel drive vehicle is essentially a two-wheel drive. Once there is a loss of traction, the power is sent to all the four wheels by a hydraulic, mechanical or electrical switching system.

### 9.2 Transmission

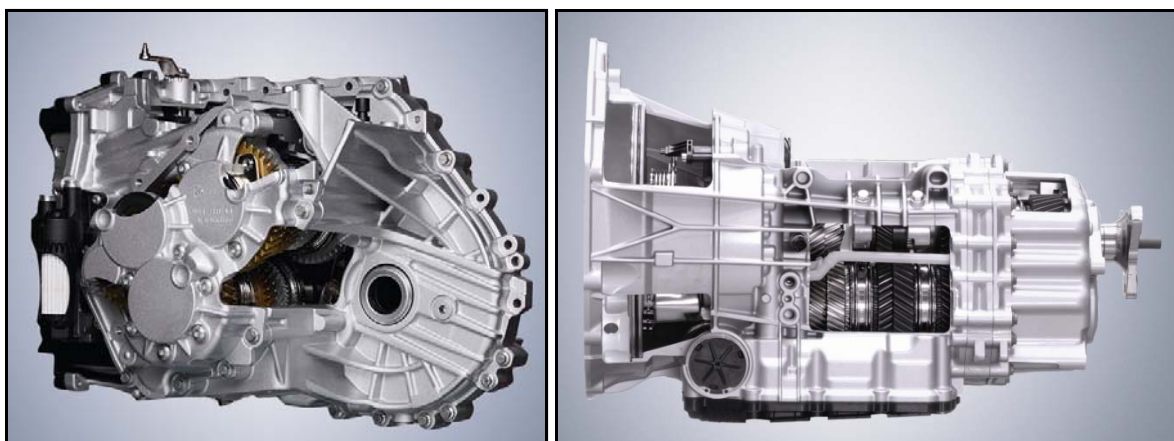
The transmission (gearbox) is one of the central components of every vehicle. It adapts the output of the internal combustion engine to the drive wheels and allows the vehicle to accelerate from rest to high speed by changing gears while the engine operates within its most effective range. The transmission is generally connected to the crankshaft of the engine through the clutch. The clutch is needed to disconnect the engine when the car is stopped and to smoothly engage the spinning engine to a non-spinning transmission. The output of the transmission is transmitted via the driveshaft to one or more differentials, which in turn drive the wheels.



**Manual 6-speed transmission for front wheel drive cars (left) and all-wheel drive cars (right)**

**Source: Getrag**

There are two primary options: manual and automatic transmissions. Whereas in case of manual transmissions, the application of aluminium is usually limited to the gearbox (transmission housing), automatic transmissions offer additional application potential. Automatic transmissions use hydraulics to select gears and rather than using a clutch, i.e. a fluid flywheel or torque converter is placed between the engine and the transmission. Furthermore, modern automatic transmissions use sophisticated electronic control systems.



**Six-speed dual clutch automatic transmission for high torque front-transverse transaxle applications (left) and seven-speed in-line variant**

**Source: Getrag**

The high functional density of modern automatic transmission systems, whose size is virtually limited by existing packaging restrictions, means that the individual components have to fulfill more functions.

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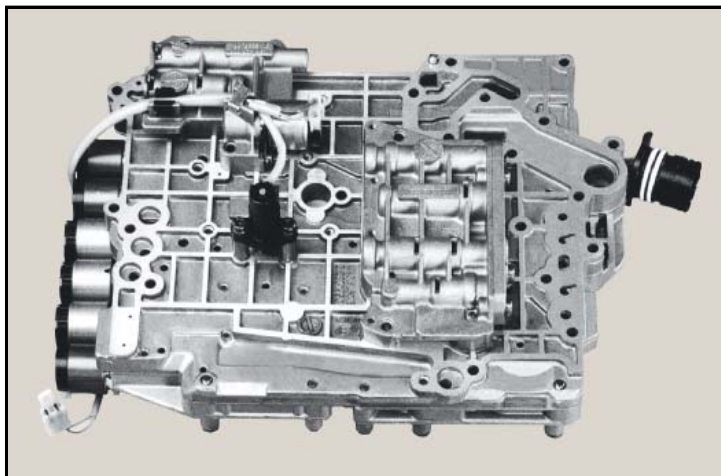
This causes high demands on the development of the housing and the other components as well as on the planning of the entire production process.

As an example, in case of the ZF 8 HP gearbox housing shown below, all production steps – from casting to mechanical machining, from deburring to inspection of the finished part – take place in a fully automated production line. The oil ducts in the ditch plate and valve body must meet very high tolerance requirements in order to achieve the short shifting times and high shifting precision of the transmission. The gearbox housing has to be provided with cast oil ducts through which hydraulic oil flows when it is in operation. To avoid expensive drilling on the unfinished component, concealed steel tubes are cast into the housing as oil pipes. Depending on the transmission version, robots locate one or two tubes automatically in the die before the melt flows in.



**Gearbox housing for the ZF 8 HP automatic transmission**

**Source: Honsel**



**Mechatronics module for automatic transmissions**

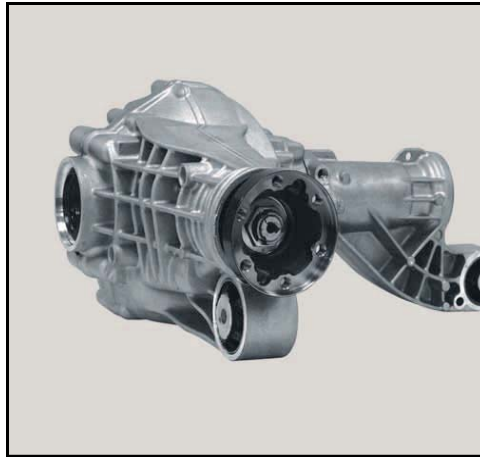
**Source: ZF**

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The mechatronics module combines the electronic transmission control unit and the hydraulic shifting device as a single unit within the transmission. The electronic transmission control unit uses data regarding the driving conditions and behavior which are collected by sensors to ascertain when the driver would like to shift gears, to determine which gears are needed and when would be the best moment to change gears. The hydraulic shifting device is then responsible for implementing those changes.

### 9.3 Housings for driveline components

There are several components within the driveline where aluminium is used, again preferentially for housings. Most important are the housings for the differential, i.e. the device that splits the engine torque two ways, allowing each driven wheel to spin at a different speed. All-wheel drive vehicles need a differential between each set of drive wheels, but they need one between the front and the back wheels as well, because the front wheels travel a different distance through a turn than the rear wheels.



**Front axle drive unit for use in SUVs**

**Source: ZF**

The front axle drive unit is mounted on the subframe via an integral rubber support and is located offset sideways adjacent to the internal combustion engine. The support tube fitted at the side is used on one hand for mounting the front axle drive unit and on the other hand facilitates arrangement of the driveshaft interface to suit the available installation space.



**Front axle drive unit for use in all-wheel drive vehicles**

**Source: ZF**

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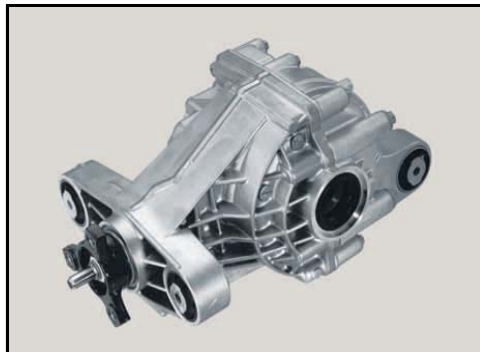
The shown front axle drive unit achieves a small installation width by the longitudinal partition of the aluminium housing. The drive unit is mounted to the side on the internal combustion engine.



**Power take-off unit**

**Source: ZF**

In an all-wheel drive vehicle with front transverse drive and transmission, the power take-off unit transfers the torque to the rear axle. It is responsible for delivering maximum performance in a very tight space.



**Rear axle drive unit for passenger cars with standard driveline**

**Source: ZF**

The rear axle drive unit with integral mounting brackets and rubber support for a standard drive line consists of an aluminium housing with a transverse split line which has been specially designed to fit the available installation space.

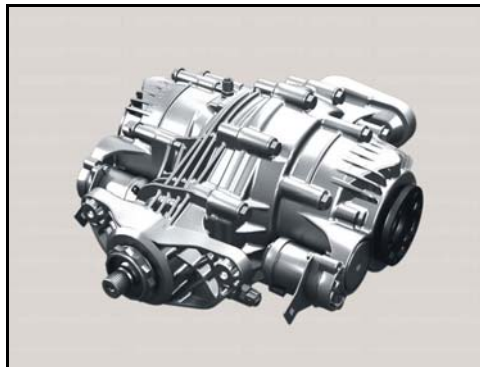




**Rear axle drive unit for passenger cars with permanent all-wheel drive**

**Source: ZF**

In all-wheel drive vehicles, it is possible to design the rear axle drive unit in an appropriately small size due to the distribution of the torque between the front and rear axles. In conjunction with the aluminium housing, this leads to a very low weight.



**Vector Drive rear axle drive unit**

**Source: ZF**

For improved driving dynamics, the Vector Drive rear axle drive allows a controlled uneven torque distribution between the two drive shafts by the electromechanically actuated multi-disk brake of the modulation transmission. The right- and left-hand wheels then accelerate at different speeds and the vehicle is given additional steering. This “screwing motion” lends support to the vehicle steering and stabilizes the car during sudden swerving without having to apply any of the wheel brakes.

### 9.4 Aluminium drive shafts

The drive shaft (propeller shaft) transfers the power produced by the engine from the transmission to the rear axle or front axle. The drive shaft is an assembly of one or more tubular shafts connected by cardan joints, constant velocity joints or flexible joints. The number of tubular pieces and joints depends on the distance between the gearbox and the axle and/or the presence of under-body features (e.g. exhaust pipes) that need to be negotiated.

On some four-wheel drive vehicles, one drive shaft is used to power the rear wheels (as in a rear-wheel drive) and a second drive shaft is used to power the front wheels. In this case, the second drive shaft is placed between a transfer gearbox and the front axle.



**Aluminium drive shaft, evaluated for BMW 5 series models**

Drive shafts are made from steel, aluminium or composite tubes connected by steel or aluminium links. The application of aluminium in drive shafts is most interesting for rear wheel or all-wheel drive cars, both for the tubes as well as for the cardan links. The reason for using lightweight materials in drive shafts is the reduction of inertia forces as well as vibration damping. The fact that all parts have rotational symmetry and that friction welding permits joints between aluminium and steel has resulted in drive shafts consisting of seam-welded aluminium tubes and forged steel (or aluminium) cardan joints. The slightly increased diameter of aluminium drive shafts leads to their preferred application in SUVs and other type of vehicles where sufficient under-body space is available and package restrictions are not as severe as in standard passenger cars. Both extruded and longitudinally welded aluminium tubes can be used. Cardan joints are generally forged aluminium components.



**Forged aluminium cardan joint**

**Source: Otto Fuchs**

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Drive shafts are available in one-, two- and three-piece designs with various options for intermediate bearings, slip devices, crash optimisation, vibration damping and plunge capacity.



**One-piece front drive shaft**

**Source: GKN**

This type of drive shaft is typically used in four-wheel drive vehicles, usually light trucks and SUVs, to deliver torque from the transfer case to the front differential.



**One-piece aluminium rear drive shaft**

**Source: GKN**

Rear-wheel drive vehicles require a longer drive shaft from the transmission to the rear differential. The aluminium tube, welded to steel stub shafts, is used in order to keep weight to a minimum. The benefits of a one-piece drive shaft include the elimination of a center bearing and the associated hardware. Noise, vibration and harshness are all improved, manufacturing and assembly are less complicated and the reliability is improved.



**Two-piece rear drive shaft**

**Source: GKN**

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This is the most popular rear drive shaft configuration for rear-wheel and all-wheel drive vehicles. It incorporates a bearing and support in the centre and can be designed to include a variety of crash features. The three joints used in this type of drive shaft are selected specifically to suit the plunge, angle, NVH and crash requirements of the vehicle.



**Three-piece drive shaft**

**Source: GKN**

Three-piece drive shafts are increasingly used in sophisticated rear-wheel and all-wheel drive vehicles where the highest levels of NVH refinement are required and where the drive shaft has to fit within a complex vehicle under-body layout.



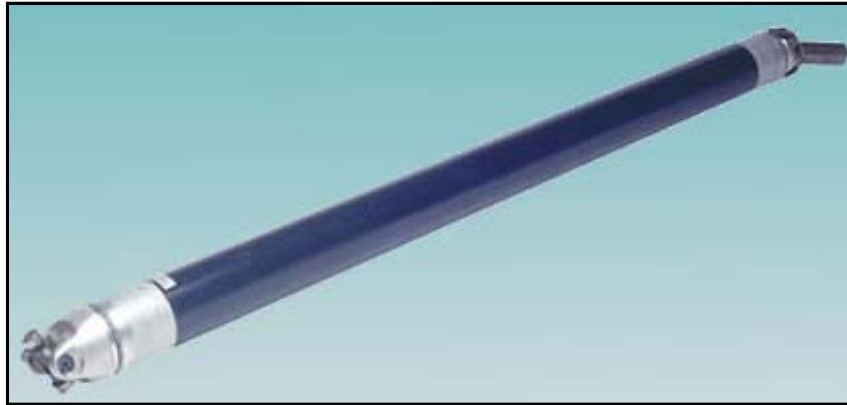
**Crash optimised drive shaft**

**Source: GKN**

The crash optimised shaft embodies a predictable progressive fracture behaviour on impact, thus reducing the risk of injury and damage to critical vehicle safety features. Crash optimisation is accomplished by designing the drive shaft to meet all requirements from low load/low energy absorption to high load/high energy absorption. In particular, drive shafts in aluminium and composite fibre can be produced to provide the specific energy absorbing characteristics.

Drive shafts for special applications are made from aluminium Metal Matrix Composite (MMC) material, e.g. an aluminium matrix reinforced with boron carbide. The use of aluminium MMCs allows to raise the critical speed of the drive shaft by further reducing the inertia. Other possibilities are offered by composite drive shafts based on aluminium tubes, e.g. a graphite/fibreglass/aluminium tube. Such concepts are developed as a response to the industry demands for greater performance and efficiency.

Today, the majority of the drive shafts are still made from steel. Aluminium and aluminium composite drive shafts are used when their specific advantages, in particular their lower weight (inertia), can be fully exploited and their installation does not present any additional problems.



**Composite drive shaft**

**Source: Strongwell**

The lightweight, one-piece driveshaft featuring fibreglass/carbon fiber reinforced vinyl ester pultruded over an aluminium tube was applied on General Motors 1988 model GMT-400 pickup trucks.

### 9.5 Aluminium fasteners

In certain automotive applications, the use of magnesium instead of heavier materials is an established lightweighting measure. Magnesium is generally used for die cast components, in particular for housings, but also structural parts. Thus there is a need for fasteners and screw fasteners to join magnesium parts together, but also with aluminium and/or steel parts.

Magnesium elements place special challenges on screw fastening. When steel screws are used, the low rigidity values of the backing run and the nut thread require deep penetration depths or large head support surfaces. This creates screw lengths than can rapidly counter the weight advantage gained from the material. The very differing heat expansion characteristics of the combined materials can also quickly result in loss of clamp force, putting the functional properties in jeopardy. Contact corrosion places a further burden on the quality of the fastening. Furthermore, relaxation processes can lead to loss of clamp load, particularly where the location of the fasteners is subjected to a high temperature loading. This is caused by the higher expansion coefficients of magnesium against steel. Magnesium applications in engines and gear boxes are subjected to temperature changes between -30°C and 150°C. Thus when steel screws are used, the screw fastening is subjected to a thermally induced additional load, which then normally results in a relaxation process in the magnesium part creating a drop in clamp load at higher operating temperatures.

For applications with magnesium, aluminium alloys fasteners offer definite advantages over steel screws. These include substantial weight savings, high connection strength, lower loss of clamp load when subjected to temperature cycles, avoidance of galvanic corrosion and appreciable potential for saving costs. In contrast to steel screws, additional corrosion and surface protection measures are mostly unnecessary.



**Aluminium screw in a magnesium part**

**Source: Ribe**

Aluminium screws are approx. 65 % lighter than steel screws of the same design. The smaller length of thread engagement of the screw reduces the amount of material used for the connection, which also offers extra weight advantages. For example, the use of aluminium screws in a magnesium gearbox can save up to 500 g in weight.

Aluminium screws are generally made from Cu-containing AlMgSi alloys, e.g. EN-AW 6056. An optimum heat treatment process combines high mechanical strength with good ductility and high corrosion resistance. Ultra-high strength AlZnMgCu alloys have also been tested successfully, but are not yet applied in practice.