Continental
The Future in Motion

Belts and Components

Technology · Know how · Tips

Power Transmission Group
Automotive Aftermarket

ContiTech

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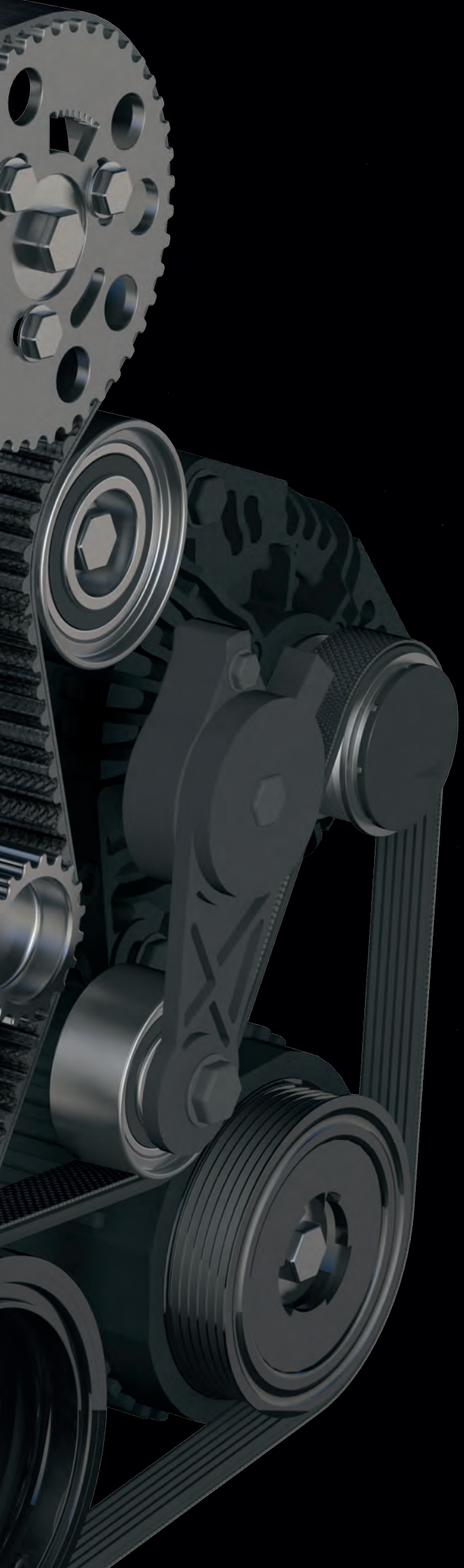

Introduction

High mechanical output on demand, completely independent of wind or water power – the spread of the steam engine unleashed the industrial revolution in the factories. The individual production machines were driven via steel shafts mounted on the ceiling of the building, pulleys and flat drive belts made of leather.

The first cars and motorcycles also used this power transmission principle. However, the flat belts in this application were soon replaced by something better: the V-belt with its trapezoidal cross-section transmitted the necessary forces with a significantly lower pretension and became the accepted standard for ancillary component drives.

The multi V-belt, a further development of the V-belt, has been taking over automotive applications since the early 1990s. Its long ribs enable it to transmit even greater loads. Its flat design allows multiple units to be incorporated and driven at the same time. This gives new impetus to the ever more compact design of engines. Timing belts have been used for synchronous power transmission to drive the camshaft in automotive engines since the 1960s.

The next generations of the old transmission belts are now high-tech products. To ensure that they function properly, the other belt drive components, such as tensioning pulleys, idlers and water pumps, must also be capable of withstanding the very demanding requirements. Our aim in this publication is to expand your technical knowledge relating to belt drives in passenger car engines and help you in making correct diagnoses.

Adrian Rothschild
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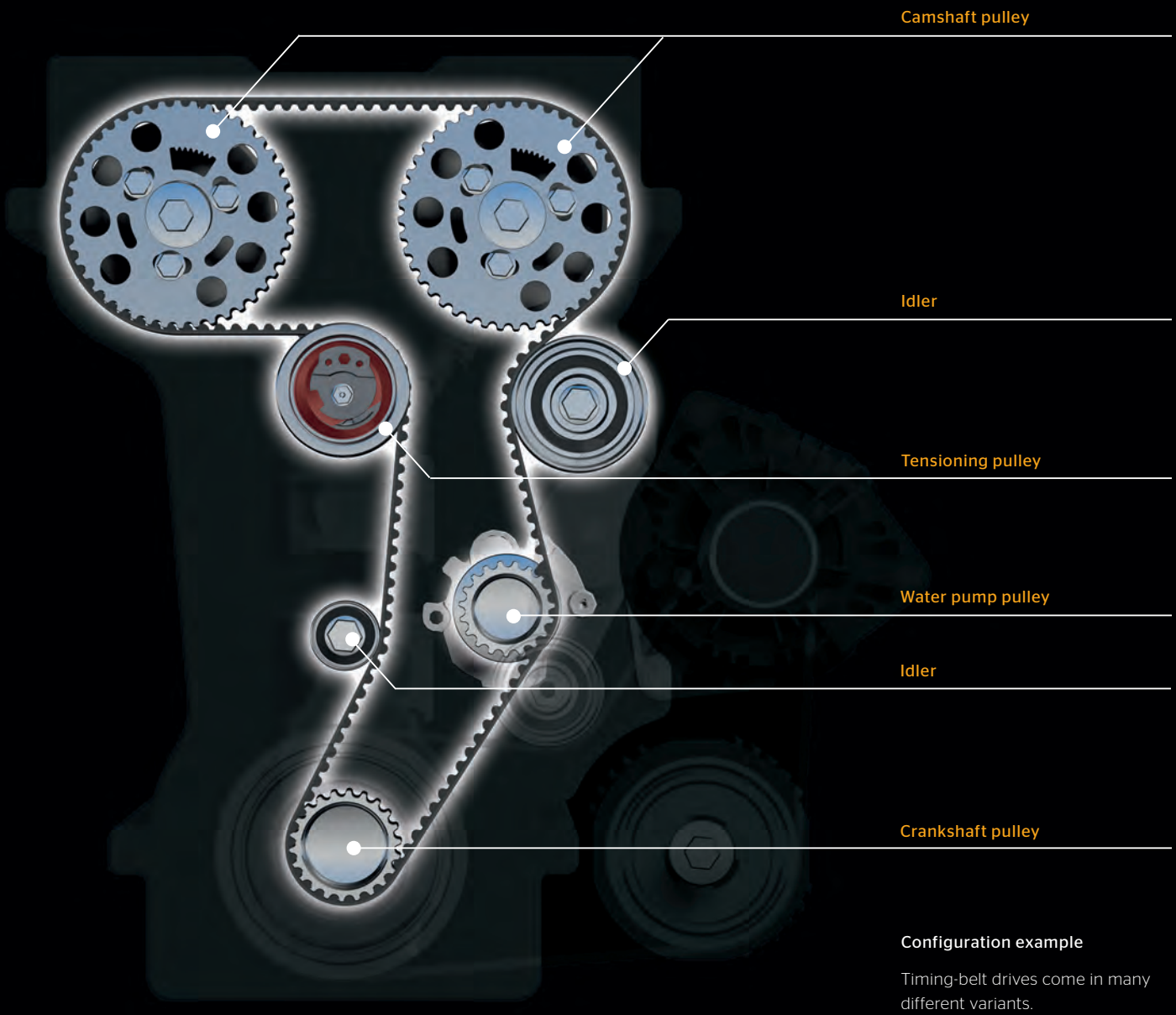
Timing belts

Timing belts guarantee absolutely synchronous power transmission since a positive-fit connection is created between the drive pulley and the belt by means of the teeth. In internal combustion engines they are used to drive camshafts, fuel injection pumps, balancer shafts and water pumps.



Configuration example

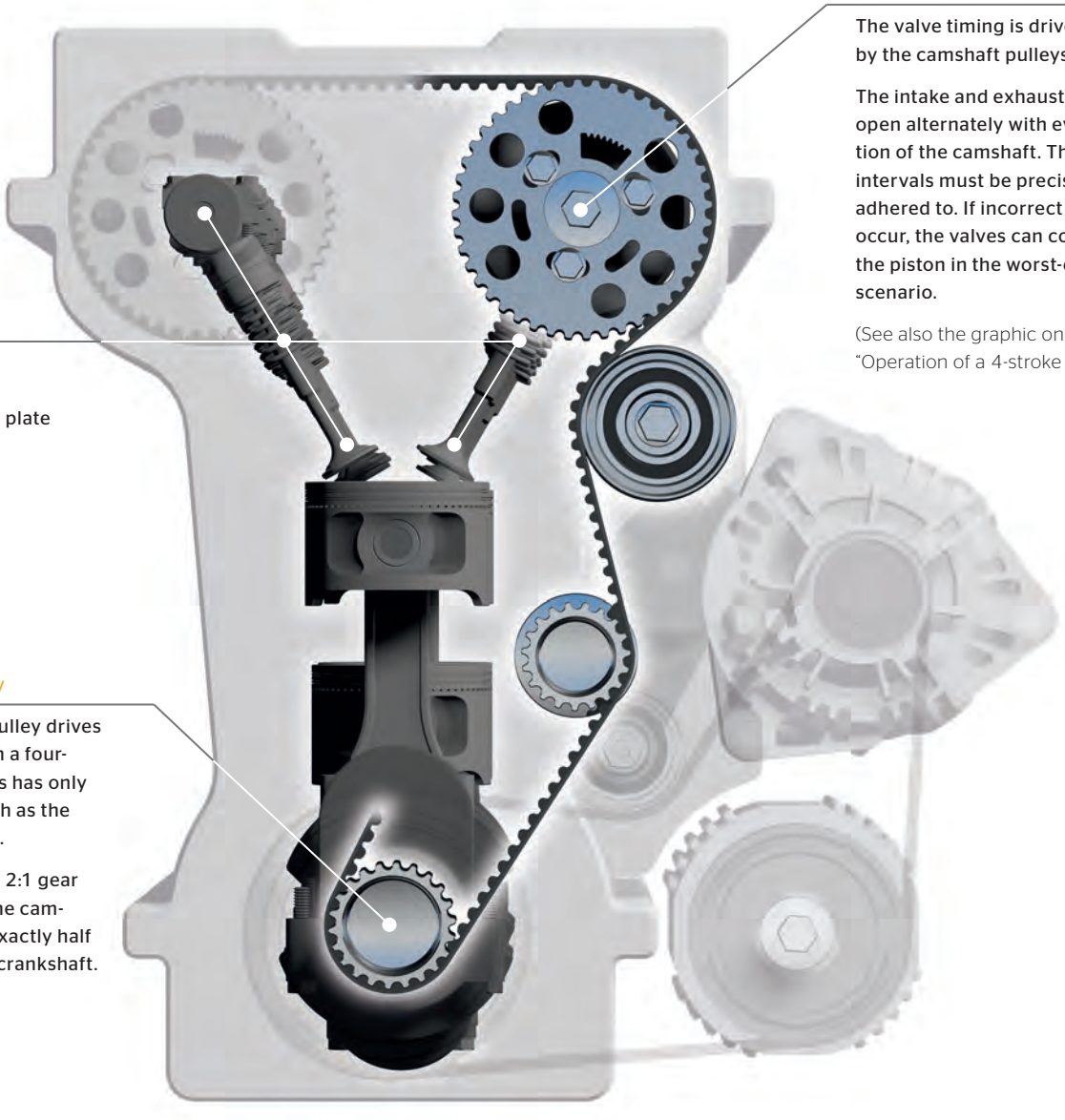
Timing-belt drives come in many different variants.

Function

The timing belt transmits the rotary motion of the crankshaft to the camshafts. Their cams operate transmission elements such as tappets, rocker arms or cam followers, which ultimately transfer the motion to the valves. Starting from the camshaft, the valves are therefore opened and then closed again through the force of the valve springs. This process enables the charge exchange process in four-stroke internal combustion engines to take place.

The valves have to be opened and then closed again in precisely defined time windows in order for the combustion chamber to be filled with gas or the fuel/air mixture and for the exhaust gases to be effectively discharged. If actuated at the wrong time, the engine does not deliver the required power and serious engine damage can be caused if the valves collide with the piston.

In a four-stroke engine (intake – compression – power – exhaust) the valves may only open with every second revolution of the crankshaft to generate the four strokes.
In this case, therefore, the crankshaft and camshaft rotate in the ratio 2:1. In other words, the camshaft rotates at half the speed of the crankshaft.



Camshaft pulley

The valve timing is driven by the camshaft pulleys.

The intake and exhaust valves open alternately with every rotation of the camshaft. The opening intervals must be precisely adhered to. If incorrect positions occur, the valves can collide with the piston in the worst-case scenario.

(See also the graphic on p.8 “Operation of a 4-stroke engine” .)

Valve timing

> camshaft
> valve spring
> valve stem with plate

Crankshaft pulley

The crankshaft pulley drives the timing belt. In a four-stroke engine this has only half as many teeth as the camshaft pulleys.

As a result of this 2:1 gear reduction ratio the camshafts rotate at exactly half the speed of the crankshaft.

Fabric backing

Highly stressed timing belts are reinforced on the back of the belt with a temperature-resistant polyamide fabric which also increases the wear resistance of the edges.

Elastomer body

This consists of a tough, fiber-reinforced polymer with embedded tension members. HNBR (hydrogenated nitrile butadiene rubber) elastomers are used for demanding drives with tough requirements relating to temperature, aging resistance and dynamic strength. This material is highly resistant to aging and can be used up to approx. 140 °C.

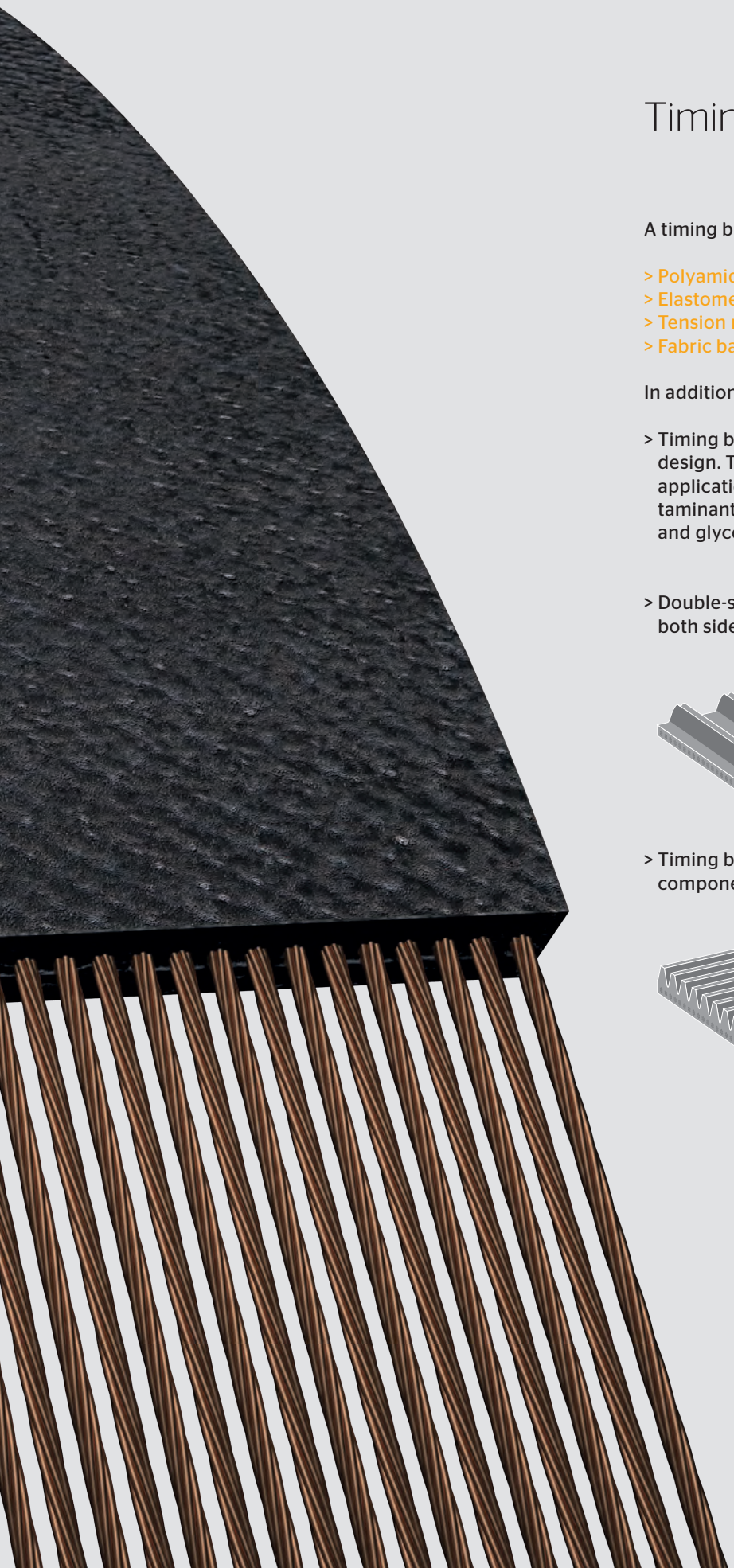
Tooth fabric

The polyamide fabric protects the teeth against wear and shear forces. Fabrics containing PTFE are used where the load demands are high.

Tension members

These are mainly made of high-strength glass fibers which are particularly longitudinally stable and capable of withstanding reverse flexing. To ensure that the belt runs neutrally, fibers with clockwise and counterclockwise twists are embedded in pairs.

Broken glass fibers impair the belt's load capacity to such an extent that a sudden failure may occur. For that reason, do not crimp or twist timing belts.



Timing belt design

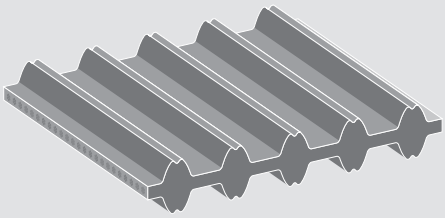
A timing belt is made up of four main components:

> Polyamide fabric
> Elastomer body
> Tension members
> Fabric backing (depending on finish)

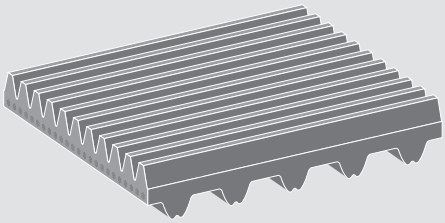
In addition, there are a few special cases, for instance:

> Timing belts which run in oil and enable a slimmer engine design. Their components are specially equipped for this application environment and are resistant to oil and contaminants in the oil such as particulates, fuel, condensation and glycol.

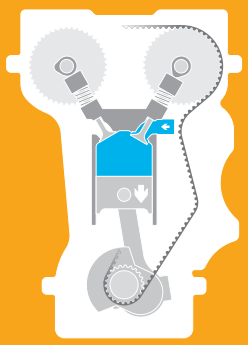
> Double-sided timing belts which allow positive-fit drive on both sides (e.g. for balancer shafts)



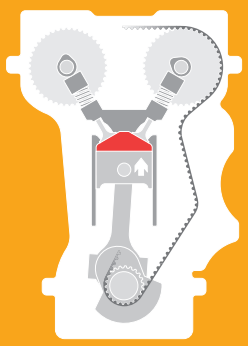
> Timing belts with a ribbed reverse for driving ancillary components



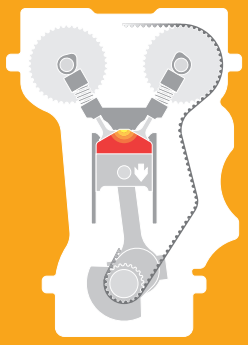
Operation of a 4-stroke engine:
The engine only runs properly if the rotary movements of the crankshaft and the camshafts are synchronized.



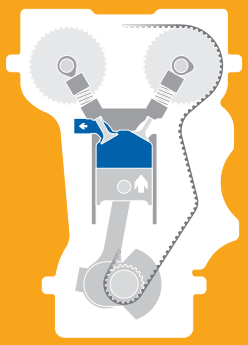
1st stroke (intake)



2nd stroke (compression)



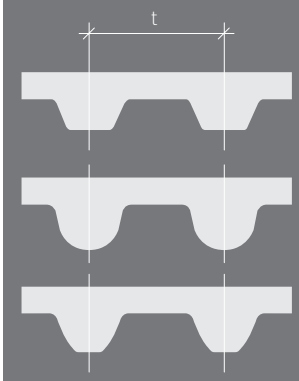
3rd stroke (power)



4th stroke (exhaust)

Profiles

The first timing belts used a trapezoidal shape which was already in use in industrial applications (L profile). As requirements relating to noise properties and load transmissions increased, curved tooth shapes (HTD and STD profiles) became established. The circular shape enables uniform distribution of the forces acting on the tooth and avoids tension spikes. The pitch (t) is the distance between two teeth and is generally 8 mm or 9.525 mm for camshaft belts.



Profile identification

Scale 2:1

HTD: High Torque Drive; profile which is optimized for the transmission of high loads, such as for diesel engines with a high fuel injection pressure

STD: Super Torque Drive; noise optimized, therefore mainly for gasoline engines

There are a large number of variations of these tooth shapes. For example, a groove on the tooth head can result in better noise properties since only two linear areas of contact occur between the tooth head and the belt pulley when meshing with the pulleys rather than full-surface contact.

Play safe

> Only fit timing belts that have been correctly stored and are not out-of-date.

> Only use timing belts with the correct profile.

> Never crimp or twist timing belts as this will damage the tension members.

> When fitting, follow the automaker's instructions and the handling tips given above.

> Always use the specified special tools.

Handling

Timing belts are high-performance components which are required to work reliably over a long service life under extreme operating conditions. Correct handling of the belts is very important to avoid damaging them before use.

Storage

- Cool (15–25°C) and dry.
- No direct exposure to sunlight and heat.
- In the original packaging.
- Not near highly flammable, aggressive media such as lubricants and acids.
- Maximum of 5 years (see use-by date on packaging).

Fitting

- Follow automaker's fitting instructions.
- Use specified special tools. Never use force, e.g. with a tire lever or similar, when fitting the belt around the pulleys. This will destroy the glass cord tension members.
- Do not crimp or twist. Never bend around a smaller diameter than the crankshaft belt pulley. This will damage the glass cord tension members.
- If necessary, set the manufacturer-specified belt tension using a tension tester. Twisting the belt through 90 degrees is only permissible for a very small number of vehicles and must not be assumed to be generally applicable.
- Protect the belt against the effects of oil (including oil mist) and other service fluids such as coolant, fuel and brake fluid. Do not use any sprays or chemicals to reduce belt noise.

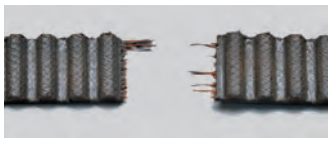
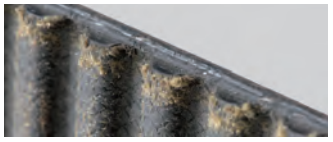
Maintenance and replacement

Timing belts are maintenance-free, i.e. they do not require retensioning. They endure high levels of stress as a result of the high temperatures in the engine compartment and the constant flexing and are subject to aging and constant wear. Their condition should be inspected as a precautionary measure during servicing in accordance with the vehicle manufacturer's specifications. Irregularities are then identified in good time. If the timing belt snaps while the engine is running, the engine valves and pistons can suffer high-impact collisions. In many cases this causes serious engine damage. To avoid that, a belt should be changed under the following circumstances:

1 > The maximum lifetime has been reached
A timing belt's inspection and change intervals are specified by the vehicle manufacturer. It should be replaced with a new belt after running for between 40,000 and 240,000 km. The intervals depend on the combination of belt type, engine variant and vehicle model. Thus, the same belts and engines in different models can also have different change intervals. This can be the result, for example, of different installation positions, transmission ratios and engine enclosures. Unless otherwise specified by the vehicle manufacturer, we recommend changing the belt after a maximum operational lifetime of seven years. As a result of the material's aging process, an old belt can no longer be assured of functioning correctly.

2 > The belt is damaged/worn
Damaged and/or worn belts must be changed. However, first remedy the causes. The adjacent table will help with diagnosis.

Timing belts damaged by incorrect handling must, of course, never be fitted or used.
(Please see the relevant notes on p.9.)

Problem	Typical fault pattern
Timing belt snapped	
Edge wear	
Fabric wear in tooth root	
Tooth flank wear, root cracks and shorn-off teeth	
Teeth and fabric detached from belt body	
Grooves on tooth side	
Teeth shorn off periodically in waves	
Cracks on back	
Damage to back	
Operating noise	

Cause	Solution
① Foreign objects in drive ② Contamination from coolant, oil or other fluids ③ Pretension too high ④ Belt crimped before or during fitting	① Remove foreign objects, check components for damage and change, if necessary; change belt ② Eliminate any leaks, clean belt pulleys, change belt ③ Change belt, set correct tension ④ Change belt and fit correctly
① Pulleys not parallel: belt running against flange ② Pulleys axially offset: timing belt cannot run aligned ③ Fault in flange of one pulley ④ Play in component bearings	① ② Check drive, align misaligned pulleys and change, if necessary; change belt ③ ④ Change idler/tensioning pulley, change belt
① Tension set too high ② Worn timing belt pulley	① Change belt, set correct tension ② Change pulley
① Tension too high/low ② Foreign objects in drive ③ Seized timing belt pulley or tensioning pulley	① Change belt, set correct tension ② Remove foreign objects, check components for damage and change, if necessary; change belt ③ Determine cause (e.g. defective bearing), remedy, change belt
① Bubbling of elastomer compound and decomposition of vulcanization resulting from chemical effect of service fluids	① Rectify leaks in engine or engine compartment (e.g. escape of oil, fuel, coolant etc.), clean pulleys, change belt
① Foreign objects in drive ② Faults on teeth of timing belt pulley caused by foreign bodies or tools during fitting ③ Timing belt damaged before/during fitting	① Remove foreign objects, check components for damage and change, if necessary; change belt ② Change timing belt pulley, change belt, fit correctly ③ Change belt and fit correctly
① Tooth pitches of belt and pulley do not match	① Check all pulleys for match with tooth pitch of belt
① Ambient temperature too high/low ② Contamination from coolant, oil or other fluids ③ Belt back overheated as a result of seized/tight reverse idler ④ Lifetime exceeded	① Remedy cause, change belt ② Eliminate any leaks, clean belt pulley, change belt ③ Change idler and belt, check that idler can rotate freely ④ Change belt
① Reverse idlers seized, plastic contact surface melted ② Contact with foreign object, i.e.: belt cover, incorrect positioned screws, washers, brackets etc.	① Change idler and belt, check that idler can rotate freely when drive is completely assembled ② Replace belt and bearings, ensure no foreign object can contact the running belt
① Tension too high: belt squealing/whistling ② Tension too low: belt striking guard ③ Noise caused by worn/defective pulleys/water pump ④ Belt pulleys not aligned	① ② Set correct tension ③ Change defective components, change belt ④ Align pulleys and idlers and change if necessary; change belt

Changing timing belt

When changing the belt, all the steps specified in the vehicle manufacturer's instructions must be carried out. It is essential that any special tools specified as necessary be used. This ensures that the relative positions of the crankshaft, camshaft and, if appropriate, fuel injection pump to each other are not changed. Under no circumstances may force or levering tools be used when mounting a timing belt on the pulleys. The running direction is unimportant unless it is indicated by a direction arrow.

Timing belt with markings

Some timing belts have timing indicator markings on the rear of the belt as an aid when fitting. The printed arrows designate the belt's running direction. The lines marked on the belt must align with the markings on the belt pulleys during fitting.

Determining and adjusting timings

The opening and closing times of the valves, i.e. the timings, only have to be reset if the relative position of the crankshaft to the camshafts is no longer assured (e.g. following the complete rebuild of the engine or if the timing belt snaps). The precise figures are defined by the vehicle manufacturer in degrees relative to the top dead center (° crank angle) (e.g. intake valve opens at 10° before TDC).

The valve opening and closing times can be verified using reference marks. The piston of one cylinder is positioned at top dead center (TDC) to do so. The vehicle manufacturer specifies which cylinder has to be positioned at TDC (often no. 1) The timings can be verified and set to the correct position using various markings on the engine block, the cylinder head, the timing belt cover, the belt itself and the belt pulleys. Apart from the camshafts, the position of mechanically driven distributors, balancer shafts and fuel injection pumps must also be taken into account.

Without further markings the TDC can only be adjusted by unscrewing a spark plug, glow plug or injector nozzle or by removing the cylinder head. A gauge is then used to find the TDC of the relevant cylinder by carefully turning the crankshaft a little at a time.

The engine may only be turned with a timing belt fitted to avoid damage caused by collisions between the pistons and the open valves. The prerequisite for this is that the timings are approximately correct. If this is not the case, all the valves must be closed and the valve actuation means, such as tappets, must be removed before turning the engine. If the first cylinder in a four-cylinder four-stroke engine is turned to TDC, the valves of the fourth cylinder must also be slightly open (overlap, charge exchange). The first cylinder has just finished its compression stroke and can be ignited (valves closed). The position of the valves can only be checked with the cylinder head cover removed or with an endoscope through the spark plug bore.

Play safe

> Never change the relative position of the crankshaft to the camshafts when changing the timing belt.

> Always follow the vehicle manufacturer's fitting instructions and specified change intervals. Risk of engine damage.

> Only turn the engine with the timing belt fitted.

> Always use the specified special tools.

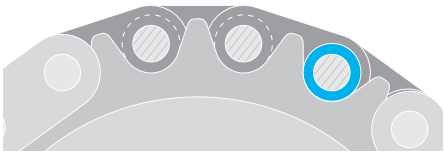
Timing chains

In addition to timing belts, timing chains are also used to synchronize the shafts in car engines. Valve control in commercial-vehicle engines is primarily performed using spur gears. Occasionally, line shafts or push rods are also used.

Timing belts have a particular advantage in terms of efficiency compared with timing chains. They are lighter and run with less friction, making it possible to reduce CO_2 emissions and save up to 0.1 liters of fuel per 100 kilometers.

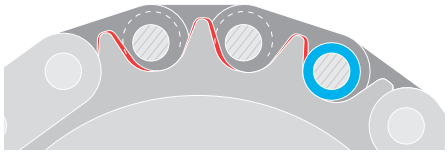
The tensile members also minimize linear expansion of the belt. Timing chains can lengthen as their service life increases, affecting the cylinder charge, gas exchange processes and, consequently, emissions performance. In this case, the timing chain must be replaced.

To ensure the correct functioning, the tensioning and guide elements as well as the gears in the timing chain drive must be replaced. Timing chains cannot be replaced with timing belts.



Timing chain and sprocket without wear marks

Timing chains can lengthen as a result of wear on the pins and inside the ferrules.



Additional wear on sprockets

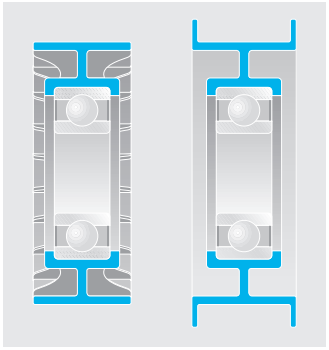
Timing belt drive components

The timing belt precisely controls the combustion process in the engine. For the timing belt to operate safely and reliably, various components are required to guide it and ensure the correct tension. All the belt drive components are subjected to extreme stresses in modern engines, such as vibrations or large fluctuations in speed and temperature. They affect the entire timing system and call for exacting quality standards.

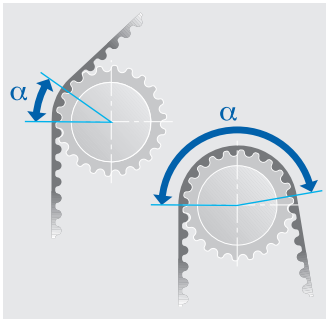
Idlers and guide pulleys

The position of the driven belt pulleys normally requires the timing belt to be guided using idlers and/or guide pulleys.

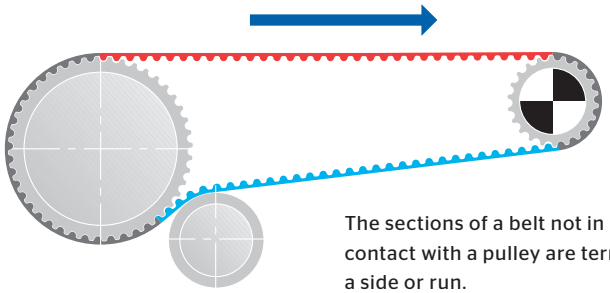
Further reasons for their use:
- To increase the arc of contact to ensure that as many teeth as possible are in mesh if high power outputs are to be transmitted
- To steady sections in the drive which tend to generate unwanted vibrations (e.g. in the event of long belt runs)



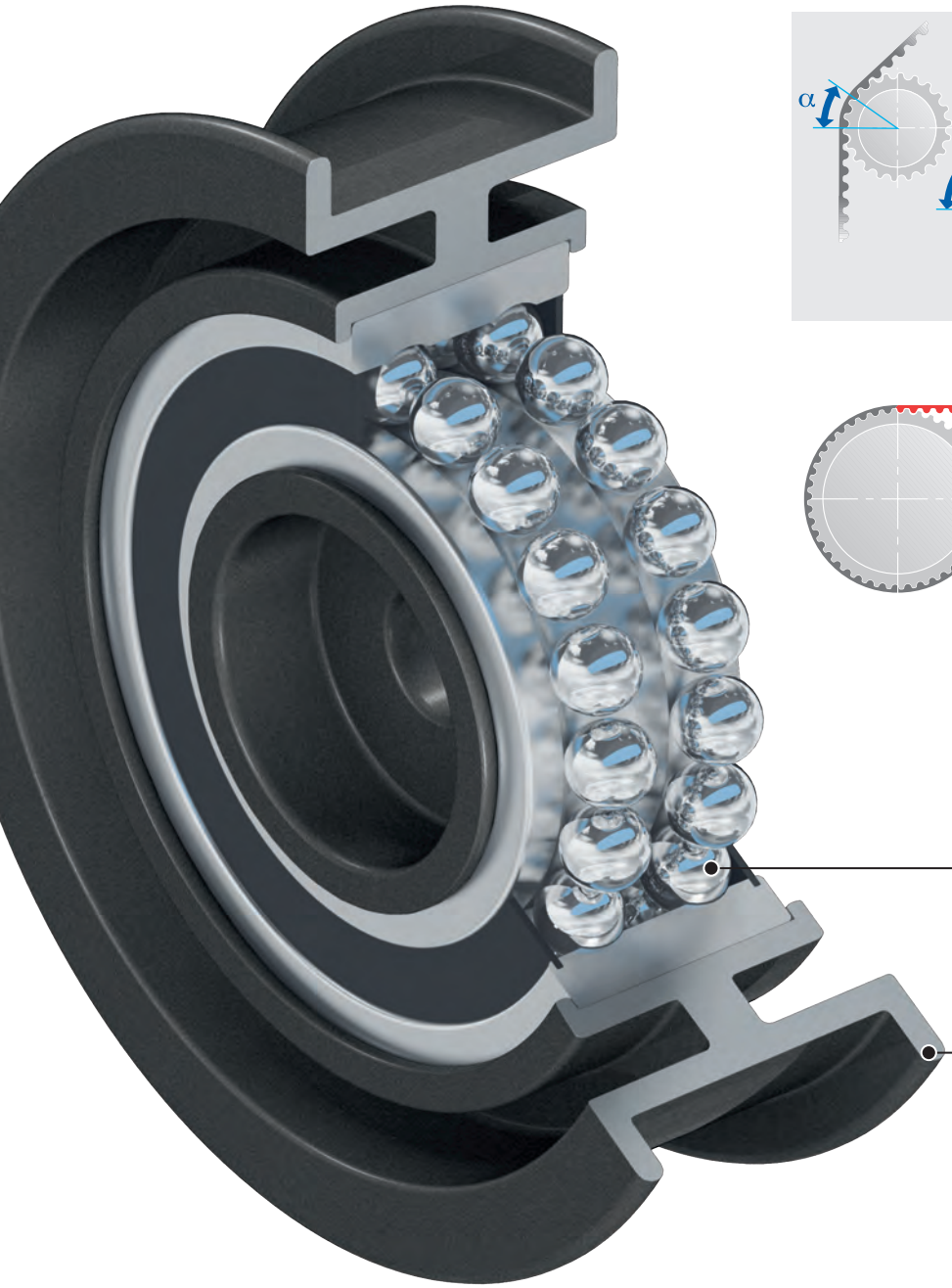
Idlers with flanges are termed guide pulleys. They keep the timing belt on the required track. If a flanged tensioning pulley is used, no additional guide pulley is required.
Left: Idler
Right: Guide pulley



The larger the arc of contact, the more teeth mesh with the pulley and the greater the loads that can be transmitted. In the case of multi V-belts, the contact surface area with the belt pulley increases analogously.



The sections of a belt not in contact with a pulley are termed a side or run.
Red: Load or tight side
Blue: Return or slack side



Deep groove ball bearing

Single- or double-row; with enlarged grease reservoir

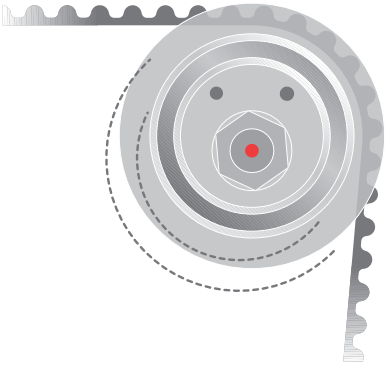
Outer ring

Made of steel or plastic (polyamide), smooth or toothed

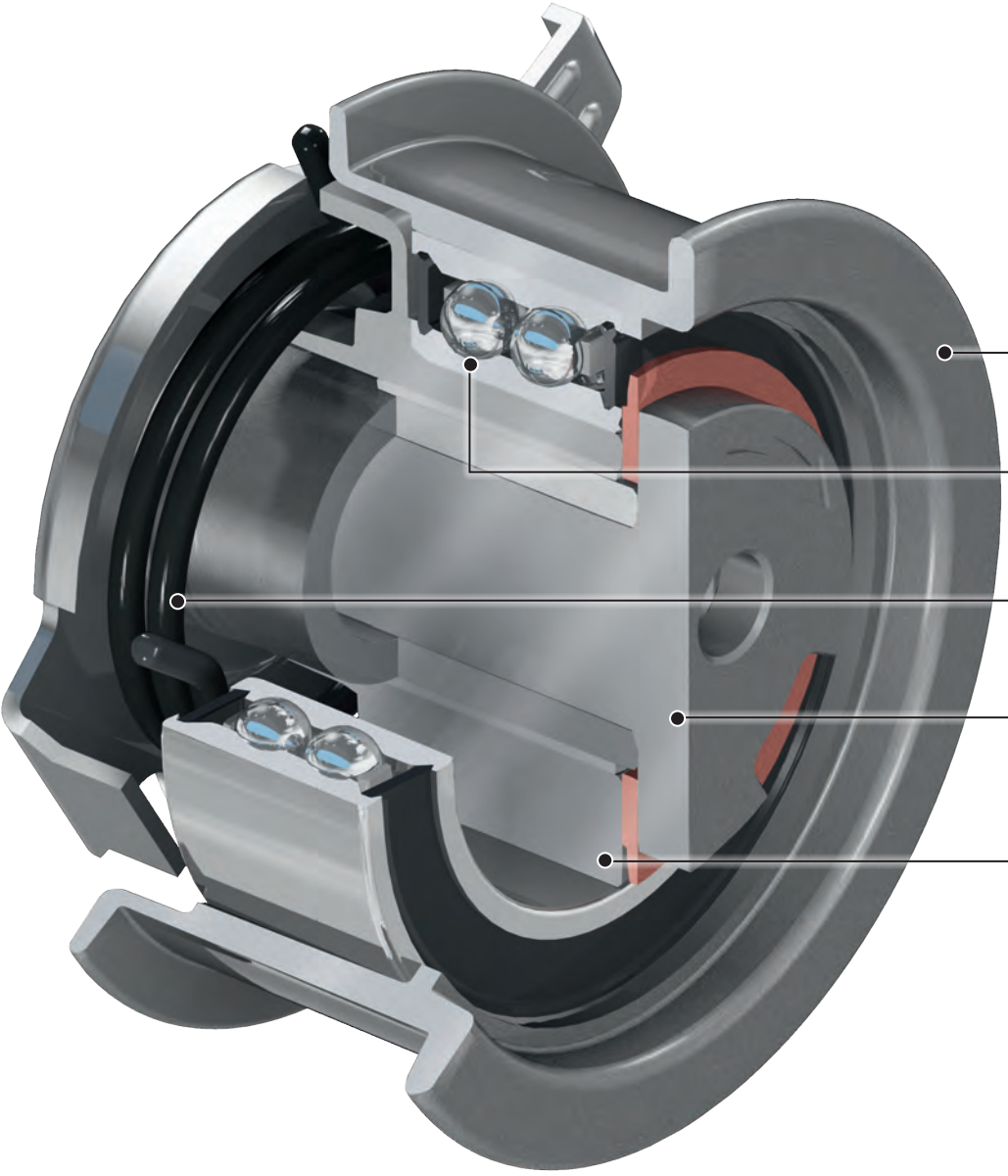
Tensioners

Various tensioning systems are used to generate the belt tension in the timing belt drive and keep it as constant as possible. They are fitted on the slack side.

- Short-term changes in tension occur as a result, for instance, of temperature and load differences.
- Long-term changes in tension are caused by wear and stretching of the timing belt.



Manual tensioning pulley
The entire pulley is turned via the eccentric fastening bore until the required belt pretension is achieved and the pulley is then fastened in that position. This simple system cannot compensate for changing factors (heat, wear) and performs no damping function. Other tensioning systems have therefore gained in popularity since the 1990s.



Semi-automatic tensioning pulley with double eccentric

Tensioning pulley

With steel outer ring

Ball bearing

Here in a double-row design

Torsion spring

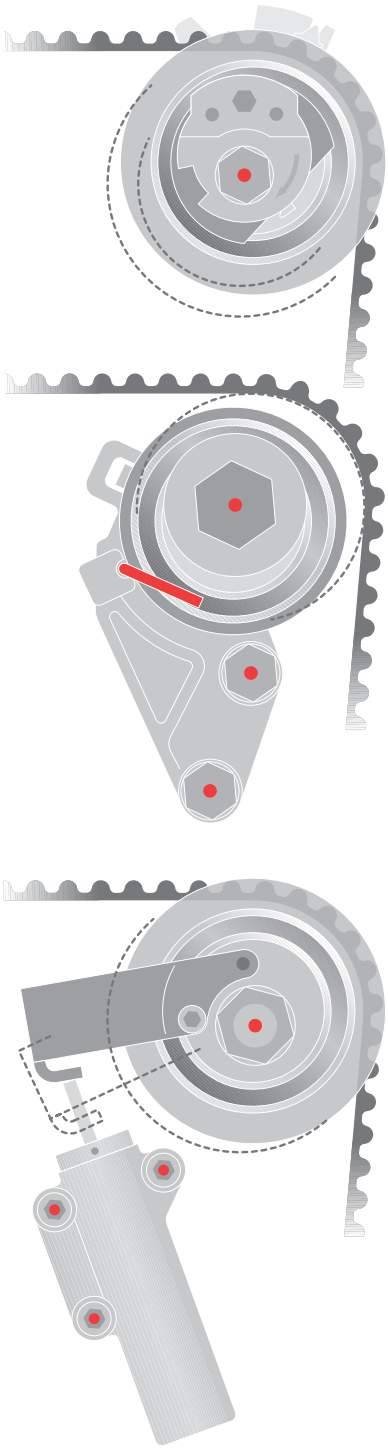
Generates pretension

Adjustment eccentric with adjustment shim

Inner eccentric, compensates for tolerances during fitting

Working eccentric

Outer eccentric, ensures dynamic tensioning function



The tensioning systems' pivots and attachment points are marked in red.

Semi-automatic tensioning pulley

The semi-automatic tensioning pulley compensates for both stretching of the timing belt and temperature- and load-dependent changes in tension by means of a spring assembly. As a result, the timing belt tension is more or less constant throughout the belt's lifetime. A mechanical damper unit minimizes spring and belt vibrations, which therefore extends the drive's lifetime and improves its noise properties. The semi-automatic tensioning pulley has to be manually tensioned during fitting.

Two designs:
In the design with a single eccentric the dynamic tensioning function and tolerance compensation are combined. With a double eccentric (as shown) the two functions are separate and can be precisely adapted to the drive. The double eccentric may only be tensioned in the specified rotational direction since the function of the pulley, despite apparently being correctly adjusted (nominal position, pointer on notch), is otherwise significantly limited or can fail completely.

Automatic tensioning pulley

This works like a semi-automatic tensioning pulley with a single eccentric, though is already pretensioned and secured (cotter pin or similar – marked in red in the drawing). Once all the components have been fitted, the securing device (cotter pin) is removed and the pulley automatically takes up the correct tension.

Tensioning damper system

Hydraulic tensioning systems are also used in the event of very high dynamic loads. In these, the tensioning pulley is mounted on a lever arm whose movement is damped by a hydraulic cylinder. A compression spring in the hydraulic cylinder generates the pretension. Such systems offer very good damping properties even with low pretension loads because of their asymmetric damping.

! Play safe

> Only tension timing belt drives when the engine has cooled to approx. 20°C.

> In addition to the belt, the other components of a drive system are also subjected to severe stresses and have to be changed.
Wear is not necessarily visible.

> Extreme precision is required when fitting all the timing belt drive components:
- No alignment errors
- No axial offset
- No skewed positions
- Observe the specified tightening torques

> Always use the specified special tools.

Water pumps

The high temperatures generated in an i.c. engine have to be dissipated in order to prevent damage as a result of overheating (defective cylinder head gasket, cracks in the cylinder head). Liquid-based cooling is the method of choice in automotive engineering. The thermally stressed areas of the engine block and cylinder head contain channels (cooling jacket) through which the coolant flows. This transports the generated heat to the radiator which discharges it into the atmosphere.
The water pump conveys the coolant in a circuit which ensures that surplus heat is continuously dissipated.

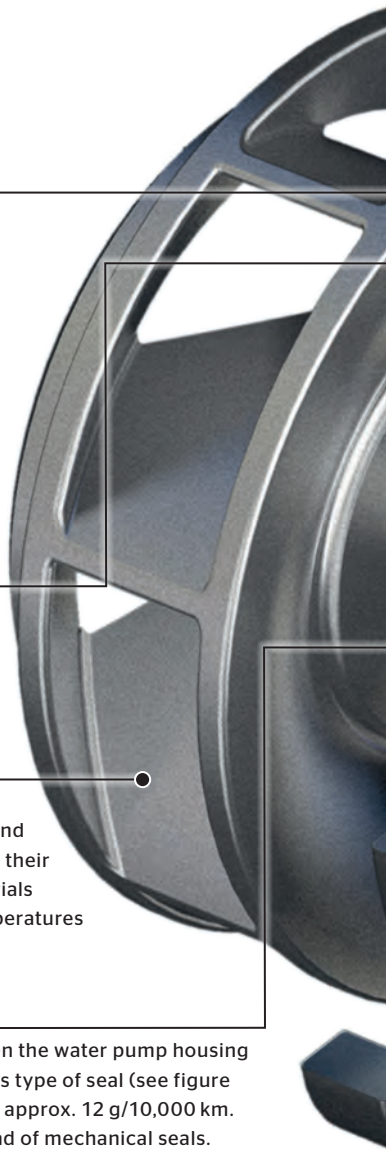
Coolant circuit

The coolant circuit comprises the cooling water channels in the engine block and cylinder head, at least one radiator with a fan/blower, the water pump, the thermostat, the expansion reservoir, the connecting hoses and any secondary circuits, e.g. for the heat exchanger in the passenger compartment heater or for the turbocharger cooling system.

The water pump is usually driven mechanically via the timing belt, V-belt or multi V-belt. The mechanical energy of the engine is transferred to the cooling medium as a hydraulic output.

An engine's power output improves with increasing operating temperature. For this reason the coolant circuit is operated at a pressure of up to three bar. This enables the coolant to be heated to over 100°C without boiling. In this way engines work at higher temperatures and thus more efficiently.

There are various development trends for better regulation of the engine temperature. Water pumps driven by an electric motor, switchable water pumps or controllable closure of the vanes of the impeller enable demand-driven control of the water pump, which enables a further increase in efficiency to be achieved and ensures the rapid heating of the engine to the desired operating temperature.



Trap with cover

The nature of the design means that tiny amounts of coolant can escape. Many water pumps therefore include a trap or a discharge hose.

O-ring

To seal the pump housing to the engine. Apart from O-rings, flat seals or gaskets made of various materials are also used.

Impeller

To ensure the water pump's hydraulic function. There are enclosed (as shown) and open impellers, whose design determines their hydraulic properties. Various metal materials or plastics which can withstand high temperatures are used.

Mechanical seal

Responsible for the hydraulic seal between the water pump housing and the pump shaft (integral bearing). This type of seal (see figure at bottom right) has a low permeability of approx. 12 g/10,000 km. Lip seals are also occasionally used instead of mechanical seals.

Housing

Hermetically sealed body in which the bearing and mechanical shaft seal are mounted. This absorbs the resulting forces and must be perfectly sealed to the engine. Housings are made of diecast aluminum or, more rarely, of cast iron or polymers.

Integral bearing

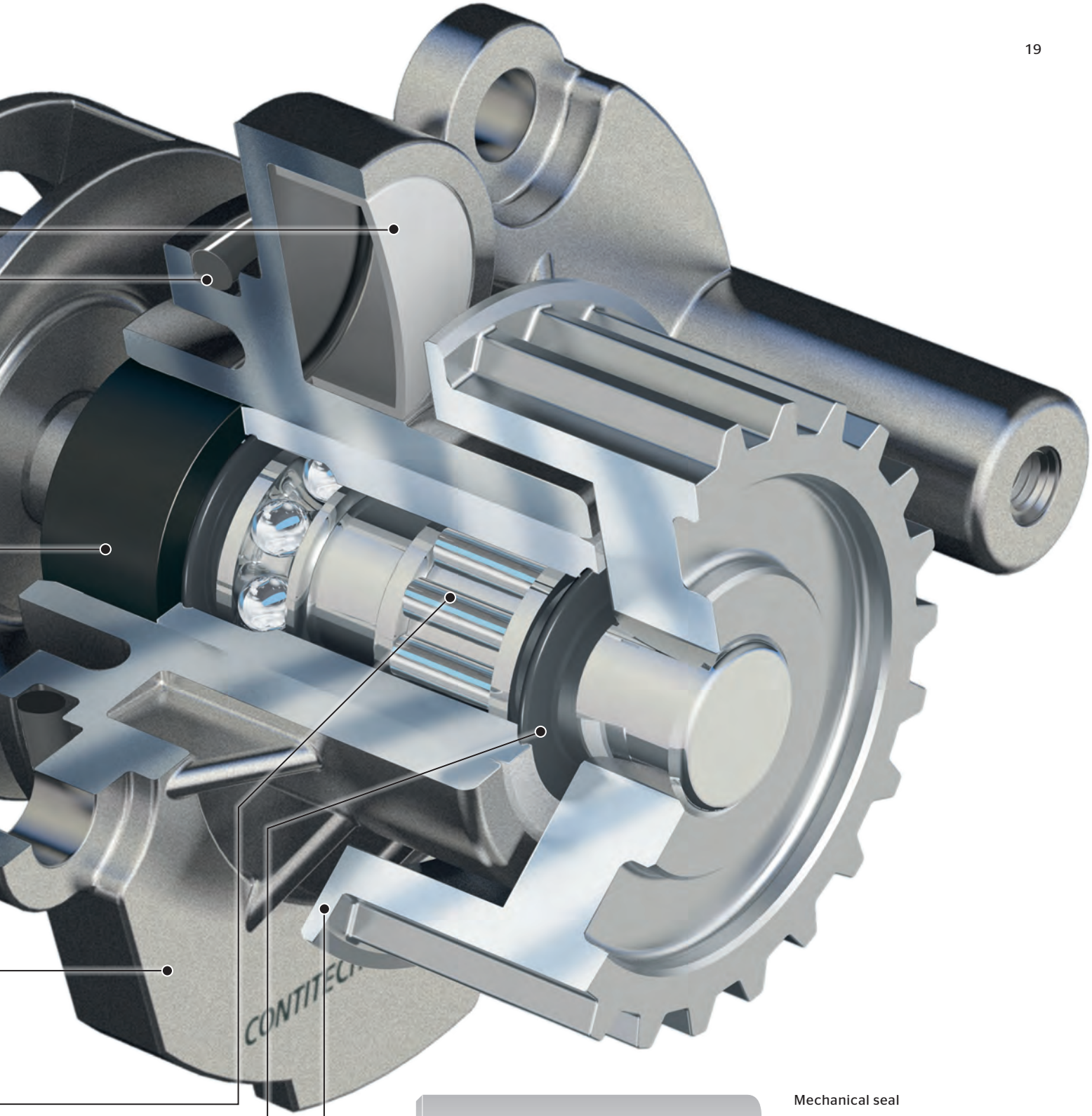
Comprises the pump shaft and two bearings: either with 2 ball bearings or, as shown, with one roller bearing and one ball bearing. The bearing absorbs the forces resulting from the belt tension.

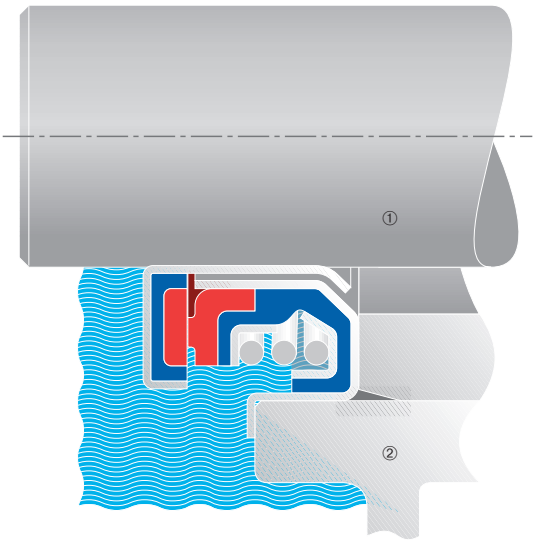
Shaft seals

Protect the antifriction bearings against the ingress of dirt and moisture and prevent the escape of bearing lubricant.

Belt pulley

To drive the pump. Smooth or toothed for timing belts, ribbed for multi V-belt. They are made of sintered metal or plastic.





Mechanical seal

The seal gap between the two rings (red) is just a few micrometers wide and can be destroyed by dirt particles in the cooling medium.

The two rings are embedded in a secondary seal (blue) and are pressed together by a coil spring.

① shaft, ② housing

Coolant

A blend of water (distilled or demineralized) and ethylene glycol forms the basis of the coolant. Ethylene glycol lowers the freezing point while at the same time raising the boiling point of the blend, which enables more heat to be dissipated. With a ratio of 1:1 in the blend and at atmospheric pressure the freezing point is approx. -35°C and the boiling point approx. 108°C.

Many different materials are used within the cooling circuit and can cause corrosion when they are in contact with each other. In addition to its function as a "heat dissipator", the coolant is also intended to protect against this electrochemical effect and be compatible with different materials. This protective function is achieved by the addition of antioxidizing substances (known as inhibitors) which also reduce deposits and foaming.

Organic, inorganic and mixed inhibitors can be used, though these are often incompatible with each other. Under no circumstances, therefore, may different coolants be mixed with each other. Colorings used by the manufacturers indicate the presence of different inhibitors. The vehicle manufacturers specify the coolant quality to be used.

Play safe

> If the water pump is driven by the timing belt, we recommend changing the water pump at the same time as the tensioning pulleys and idlers as a precaution every time you change the timing belt.

> Empty the cooling circuit completely and flush it thoroughly with water (use a system cleaner if hazing is visible). You can find instructions here: www.contitech.de/wapu-fit

> Do not reuse drained coolant but dispose of it in accordance with regulations.

> Clean the seal surfaces carefully and gently (use sealant removal spray, if necessary).

> Only use a sealant if no seal or gasket is present. Use the sealant sparingly. Observe the curing time, if applicable, before filling the cooling system. Moisten the O-ring with silicone oil before fitting.

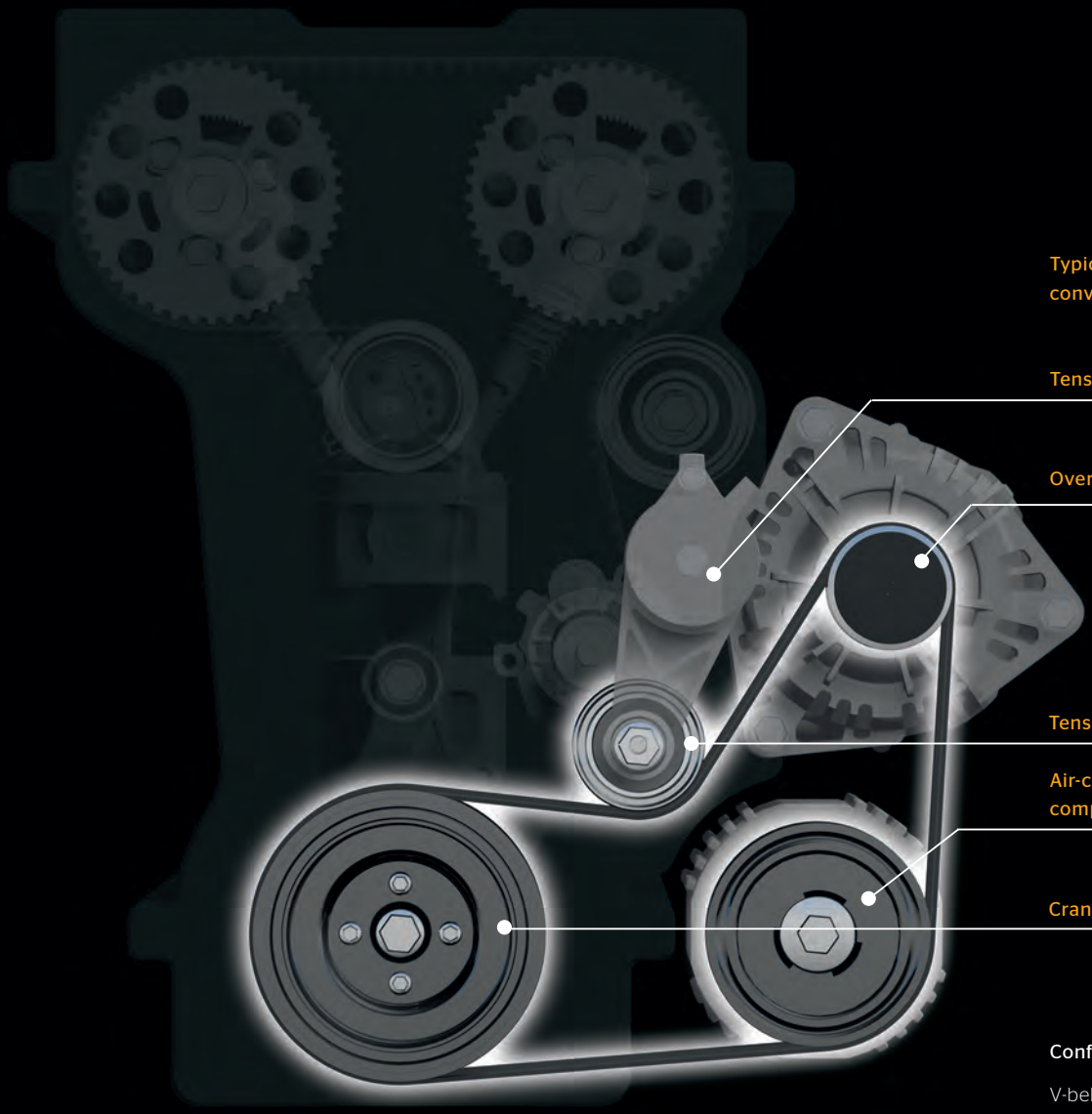
> Bleed the cooling system in accordance with the manufacturer's specifications.

Typical fault pattern

Cause	Solution
Leaks from pump bearing ① Slight condensate trace on housing (bore) or trap ② Water used instead of coolant ③ Impurities or foreign objects in coolant circuit ④ Application of excessive sealant has destroyed mechanical seal, sealant adhering to mechanical shaft seal ⑤ Seal and sealant used	① Nature of design means that tiny amounts of coolant escape at mechanical shaft seal. This does not constitute a leak ② Use coolant specified by vehicle manufacturer, change water pump ③ Thoroughly flush cooling system with system cleaner and refill. Remove foreign objects, if necessary. Change water pump ④ Thoroughly flush cooling system with system cleaner and refill. Change water pump. Only use sealant if no seal is present ⑤ Under no circumstances may additional sealant be applied to seals. Change water pump.
Leaks on seal surfaces ① Water pump or seal not correctly seated ② Seal surfaces insufficiently cleaned ③ Unevenly applied sealant	① Check pump for correct design, thoroughly clean seat surfaces, temporarily secure paper seals on housing ② Clean seal surfaces thoroughly and carefully, using sealant remover, if necessary ③ Apply sealant thinly and evenly
Corrosion ① Wrong coolant used ② Water used instead of coolant or incorrect mixing ratio	① ② Change water pump, flush cooling system thoroughly with system cleaner and refill using coolant specified by manufacturer
Bearing and bearing shaft are severely worn ① Bearing overloaded as a result of defective fan clutch ② Bearing overloaded as a result of incorrect timing belt tension ③ Ingress of coolant into bearing as a result of leaky mechanical shaft seal	① Change water pump and fan clutch ② Always set timing belt tension correctly ③ Remedy cause of coolant ingress (see: Leaks from pump bearing), change water pump
Deformed or detached impeller vanes ① Foreign objects in coolant circuit ② Bearing damage on pump shaft causes imbalance and contact with engine housing	① ② Remove foreign objects (vane fragments) from circuit, flush circuit carefully, change water pump correctly, refill system with coolant specified by manufacturer
Damaged drive pulley ① Damaged or detached flanges as a result of misalignment. Belt not running centrally on pulleys, pressing constantly against flanges	① Check and correct balance of belt drive, ensure water pump is correctly seated on engine
Noise ① Air bubbles in coolant circuit still	① Bleed cooling system correctly
Overheating ① Movement of coolant inadequate as a result of air remaining in pump chamber	① Bleed cooling system correctly

V-belts and multi V-belts

V-belts and multi V-belts transmit the rotary motion of the crankshaft to ancillary components via belt pulleys. They are used wherever synchronous rotary motion is not required or not wanted, e.g. for the alternator, the water pump, the hydraulic pump, the power steering, the air-conditioning compressor or the fan.



Configuration example

V-belt and multi V-belt drives come in many different variants.

Function

V-belts and multi V-belts work as friction-fit drive elements, using the static friction between the belt and the belt pulley to transmit power.

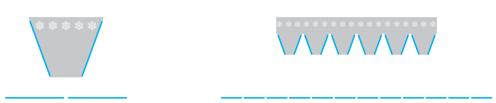
V-belts have a trapezoidal cross-section and run in a wedge-shaped groove in the belt pulley. They enable one or two components to be driven. They can transmit substantially higher torques than flat belts for the same space requirement. Because of the friction on the belt flanks (friction-fit) the loads acting on the bearings are lower. If multiple components have to be driven at the same time, a belt drive with multiple V-belts is required.

Multi V-belts are a further development of the V-belt with multiple longitudinal ribs. Power is transmitted via the static friction between the flanks of the individual ribs and the grooved belt pulley. Multi V-belts therefore have a greater friction surface area than V-belts and allow higher torques to be transmitted. Drives with reverse flexing and small deflection diameters are possible because of the more flexible structure. One belt can drive multiple components at the same time and is therefore ideal for the requirements of a compact engine design.

Elastic multi V-belts are mounted with pretension and do not require a tensioner.

Comparison of belt types

	V-belts	Multi V-belts	Elastic multi V-belts
Deflection with reverse flexing	–	++	++
Small deflection diameter	o	++	++
Double-sided component drive	–	++	++
Efficiency	+	++	+
Installed size	o	++	++
Pretension generation	Adjustment of component position	Tensioner	Belt
Fitting	Without special tool(s)	Without special tool(s)	Only with special tool(s)
Contact surface area in relation to cross-section	Relatively small	Relatively large	Relatively large



Handling

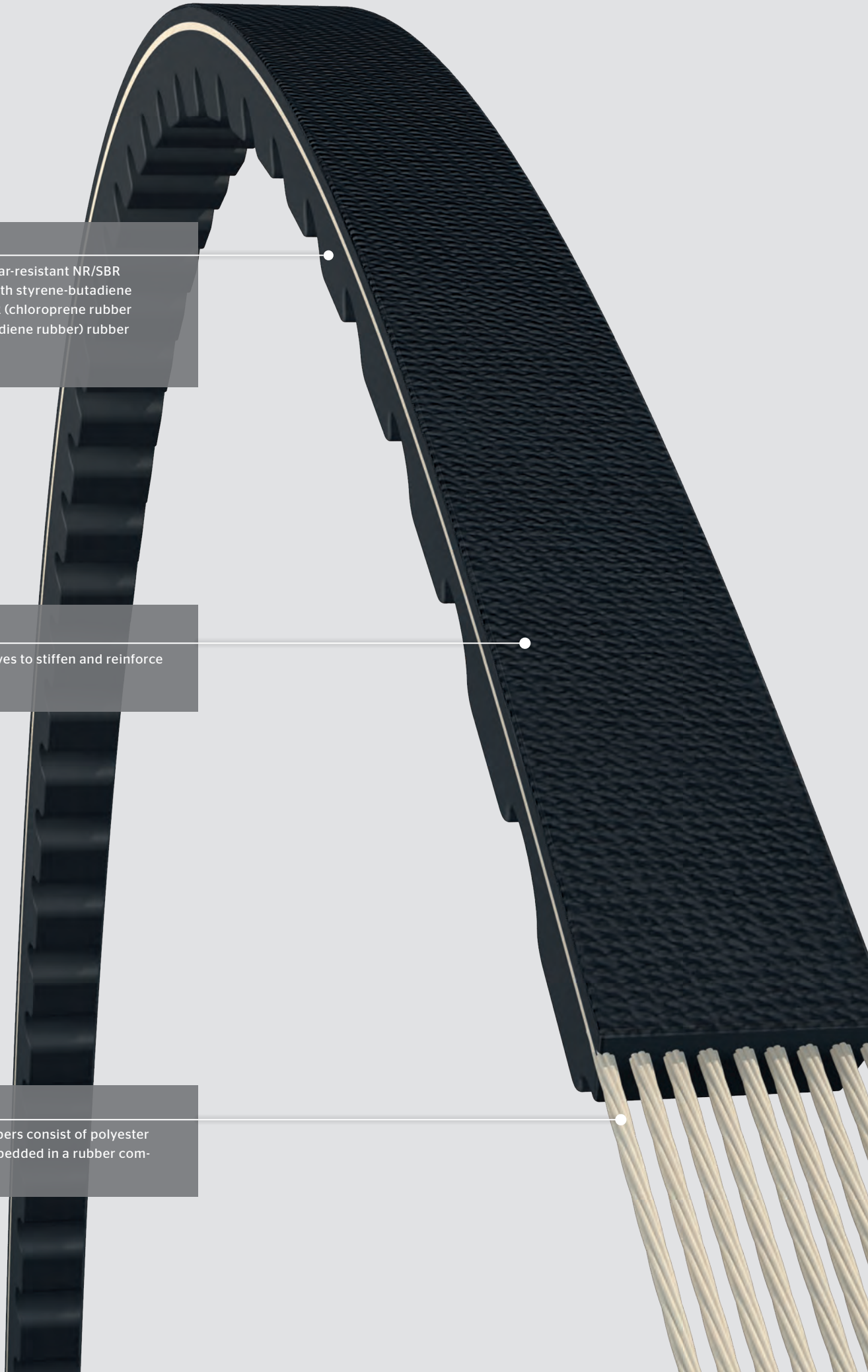
V-belts and multi V-belts are high-performance components which are required to work reliably over a long service life under extreme operating conditions. Correct handling of the belts is very important to avoid damaging them before use.

Storage

- Cool (15–25°C) and dry.
- No direct exposure to sunlight and heat.
- Not near highly flammable, aggressive media, lubricants and acids.
- Maximum of 5 years.

Fitting

- Follow automaker's fitting instructions.
- Use specified special tools. Never use force, e.g. with a tire lever or similar, when fitting the belt around the pulleys.
- If necessary, set the manufacturer-specified belt tension using a tension tester.
- Protect the belt against the effects of oil (including oil mist) and other service fluids such as coolant, fuel and brake fluid. Do not use any sprays or chemicals to reduce belt noise.



Elastomer body

It consists of a wear-resistant NR/SBR (natural rubber with styrene-butadiene rubber) or CR/SBR (chloroprene rubber with styrene-butadiene rubber) rubber compound.

Fabric backing

The fabric ply serves to stiffen and reinforce the belt.

Tension members

The tension members consist of polyester fibers and are embedded in a rubber compound.

V-belts

V-belts are made up of three main components:

> Elastomer body
> Tension members
> Fabric backing

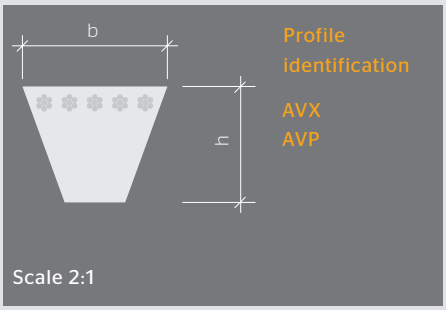
The design depth means that their reverse flexibility is poor. They are therefore unsuitable for deflection and can only drive components with their inside.

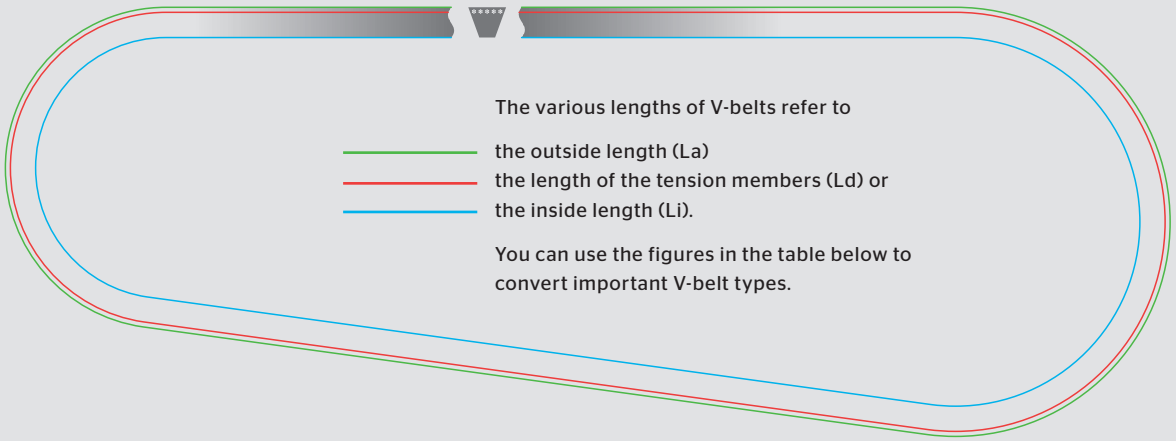
To transmit large torques, multiple V-belts can be used in parallel (in sets) to enlarge the frictional surface area. They have to have exactly the same length and always be changed as a set to ensure that the pretension is identical and the belts are loaded equally.

Profiles

V-belts have a trapezoidal cross-section. They vary – depending on the application – in their length, the exact dimensions of the cross-section and their design. Narrow-section V-belts are wrapped with a fabric ply; raw-edge V-belts dispense with this.

If V-belts are compressed by pulley diameters which are too small or as a result of deflection, this results in increased heat build-up and premature wear. With raw-edge V-belts, therefore, the inside can be toothed to permit smaller deflection diameters. Asymmetric toothing enables noise generation to be reduced.





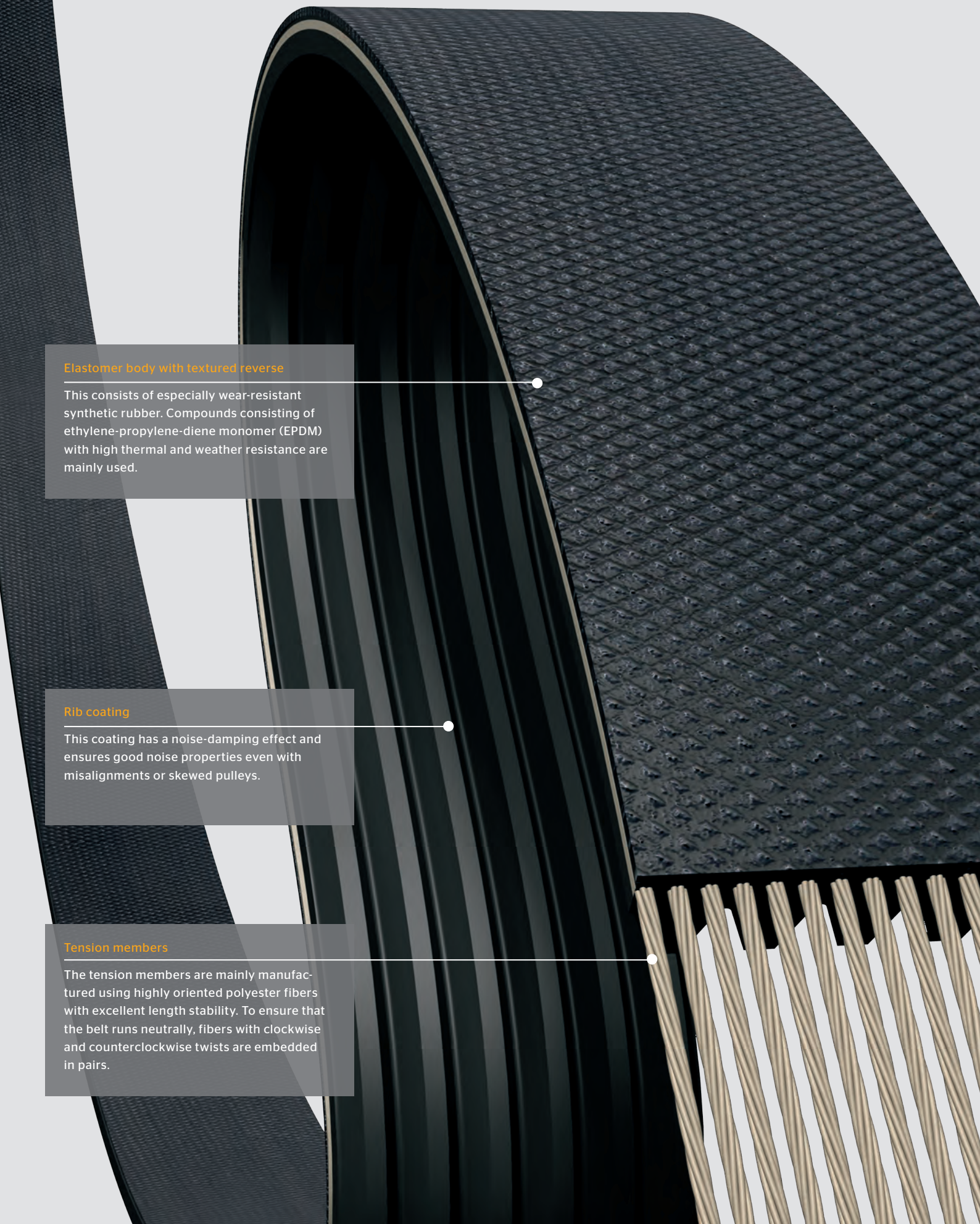
The various lengths of V-belts refer to

the outside length (La)
the length of the tension members (Ld) or
the inside length (Li).

You can use the figures in the table below to convert important V-belt types.

Profile designation	Top belt width (b = rated width)	Effective width	Bottom belt width	Belt height (h)				
AVX10	10	8,5	4,5	8	La = Ld + 13	La = Li + 51	Li = Ld – 38	Li = La – 51
AVX13	13	11,0	6,8	9	La = Ld + 18	La = Li + 57	Li = Ld – 39	Li = La – 57
AVX17	17	14,0	7,3	13	La = Ld + 22	La = Li + 82	Li = Ld – 60	Li = La – 82

All figures in mm



Elastomer body with textured reverse

This consists of especially wear-resistant synthetic rubber. Compounds consisting of ethylene-propylene-diene monomer (EPDM) with high thermal and weather resistance are mainly used.

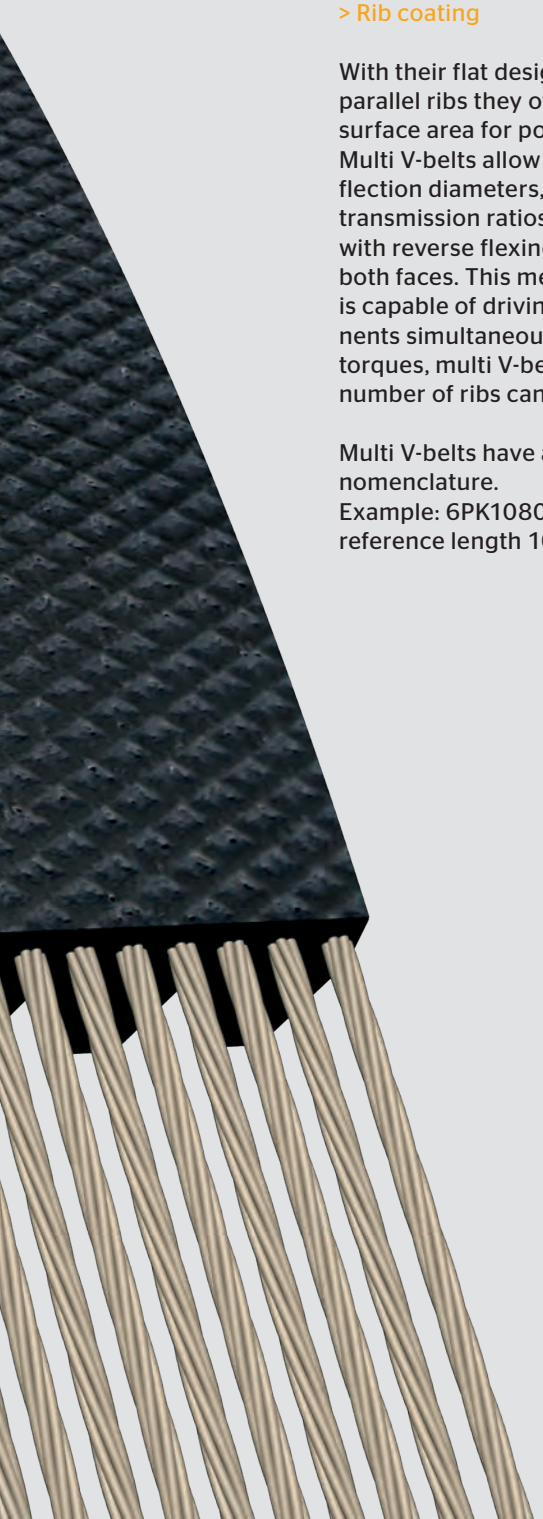
Rib coating

This coating has a noise-damping effect and ensures good noise properties even with misalignments or skewed pulleys.

Tension members

The tension members are mainly manufactured using highly oriented polyester fibers with excellent length stability. To ensure that the belt runs neutrally, fibers with clockwise and counterclockwise twists are embedded in pairs.

Multi V-belts



Multi V-belts are made up of three main components:

> Elastomer body with textured reverse
> Tension members
> Rib coating

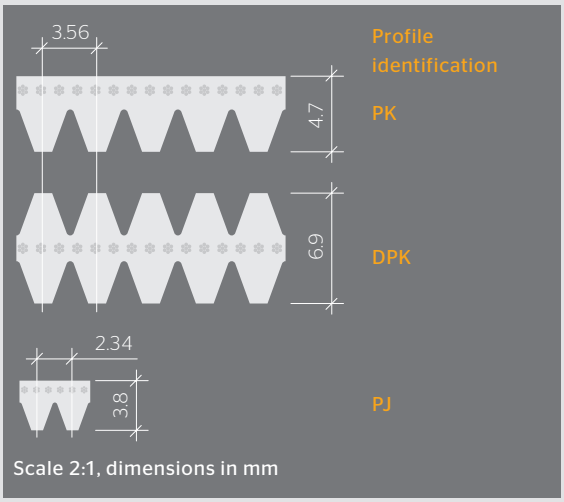
With their flat design featuring multiple parallel ribs they offer a large friction surface area for power transmission. Multi V-belts allow relatively small deflection diameters, resulting in high transmission ratios. They can be used with reverse flexing and can drive with both faces. This means a multi V-belt is capable of driving multiple components simultaneously. To transmit high torques, multi V-belts with a larger number of ribs can simply be used.

Multi V-belts have a self-explanatory nomenclature.
Example: 6PK1080 (6 ribs, PK profile, reference length 1080 mm)

Even with high levels of wear, high-quality EPDM multi V-belts often exhibit little in the way of classic wear characteristics. With these types, therefore, the degree of wear must be verified using a profile gauge (e.g. ContiTech Belt Wear Tester).

Profiles

Only a small number of different profiles are used with multi V-belts. The length and number of ribs (i.e. the width) vary, depending on the application.



Scale 2:1, dimensions in mm

Elastomer body with textured reverse

This consists of especially wear-resistant synthetic rubber. Compounds consisting of ethylene-propylene-diene monomer (EPDM) with high thermal and weather resistance are mainly used.

Rib coating

This coating has a noise-damping effect and ensures good noise properties even with mis-alignments or skewed pulleys.

Tension members

The tension members are made of elastic polyamide fibers. To ensure that the belt runs neutrally, fibers with clockwise and counter-clockwise twists are embedded in pairs.

Elastic multi V-belts

Elastic multi V-belts are made up of three main components:

> Elastomer body with textured reverse
> Tension members
> Rib coating

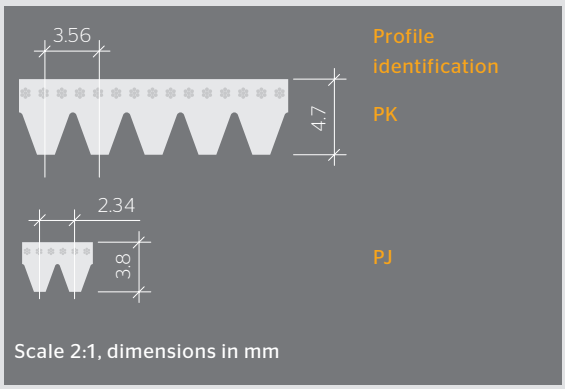
Elastic multi V-belts are fitted with an initial pretension which they maintain largely independently because of their elasticity. It is very difficult to distinguish them visually from normal multi V-belts.

They are used in the lower and medium power ranges if fixed centers are present. Since they maintain their tension over their entire lifetime, the drive requires no tensioner.

Elastic and classic multi V-belts are not interchangeable. If an elastic multi V-belts is factory-fitted, it may also only be replaced by another elastic multi V-belts.

Profiles

Elastic multi V-belts are used in PK and PJ profiles.



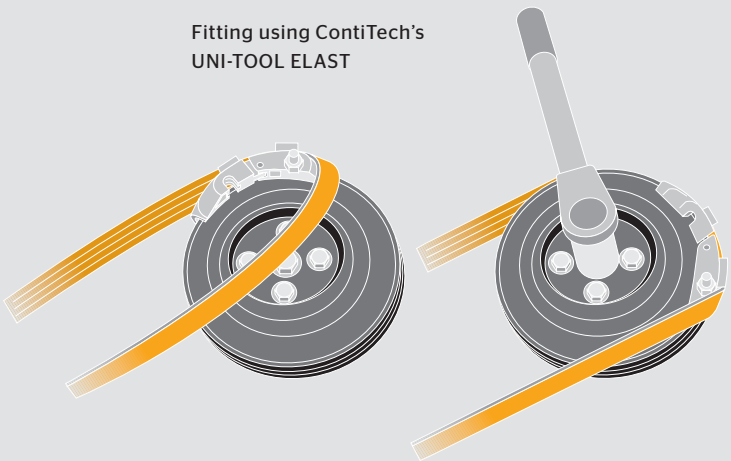
Scale 2:1, dimensions in mm

Elastic multi V-belts can be labeled with two lengths:
1. The production length and
2. The (larger) operational length of the tensioned belt when fitted.

The nomenclature of elastic belts varies from manufacturer to manufacturer. ContiTech belts are labeled on the back with the operational length, followed by the production length in parentheses.
Example: 6PK1019 (1004) ELAST

Special tools are generally required to ensure no damage is caused during fitting. Both multi-use tools and disposable solutions (often supplied with the belt) are available.

Fitting using ContiTech's UNI-TOOL ELAST



Maintenance and replacement

V-belts and multi V-belts are subject to constant flexing and are directly exposed to ambient influences such as dust, dirt and large temperature differentials in the engine compartment. They therefore age and wear and should be changed after running for 120,000 km.

V-belts are normally tensioned by means of the components' adjustable/movable shafts. A tensioning pulley is used only in exceptional cases. Multi V-belts, by contrast, usually operate in combination with tensioning pulleys and idlers because of their great length involving wraps around several ancillary components. Elastic multi V-belts do not use a tensioner. They generally have to be fitted using a special tool.

Play safe

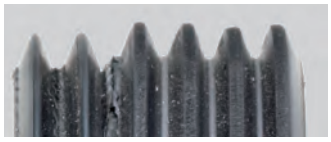
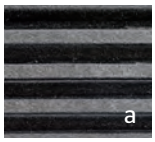
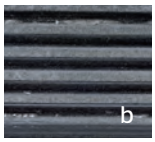
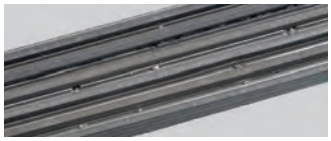
> Only fit belts that have been correctly stored and are not out-of-date.

> Only use belts of the right profile and length. A number of different V-belt lengths are cited (La, Ld or Li).

> Elastic and classic multi V-belts are not interchangeable. An elastic multi V-belt may only be replaced by another elastic V-belt.

> When fitting, follow the automaker's instructions and the handling tips on p.23.

> Always use the specified special tools.

Problem	Typical fault pattern
Pronounced wear of ribs or flanks	
Uneven rib wear	
Edge formation on ribs (a) and abrasive material in ribs (b)	 
Rib material cracks and breaks off	 
Damage to ribs	
Detached ribs	
Tension member torn out of belt back or flank	
Damage to back	
Belt failure caused by chemical effect of service materials	
Hardened, polished flanks	

Cause	Solution
① Pulleys, idlers or ancillary units defective or tight ② Belt pulleys not aligned ③ High level of slip ④ Pulley profile worn ⑤ Severe belt vibrations	① Change defective parts and belt ② Align pulleys and idlers and change if necessary. Change belt ③ Check belt length, change belt, set correct tension ④ Change pulleys and belt ⑤ Check OAP, TVD and tensioner and change, if necessary. Change belt
① Belt pulleys not aligned ② Severe belt vibrations	① Align misaligned pulleys and idlers or change, if necessary. Change belt ② Check OAP, TVD and tensioner and change, if necessary. Change belt
① Belt pulleys not aligned ② OAP or TVD defective ③ Belt was laterally offset when mounting on ribbed pulleys	① Check drive, align misaligned pulleys and idlers or change, if necessary. Change belt ② Check function of OAP, TVD and tensioner, change if necessary. Change belt ③ Change belt, ensure belt is correctly seated
① Belt tension too low or too high ② Lifetime exceeded ③ Belt gets too hot	① Change belt, set correct tension ② Change belt ③ Remedy cause (e.g. engine temperature too high, check fan function, tight ancillary components), change belt
① Foreign objects in belt drive	① Check all components for damage, clean or change, if necessary; change belt, remove foreign objects
① Alignment fault as a result of offset mounting of belt on ribbed pulleys ② Belt pulleys not aligned ③ As a result of severe vibration belt jumps to offset position ④ Foreign objects (small stones) in belt pulley	① Change belt, ensure correct positioning of belt ② Align misaligned pulleys and idlers or change, if necessary. Change belt ③ Check function of OAP, TVD and tensioner, change if necessary. Change belt ④ Remove foreign objects, change belt pulley, if necessary. Change belt
① Alignment fault as a result of offset mounting of belt on ribbed pulleys ② Belt runs against solid edge at side ③ Pretension too high	① Change belt, ensure correct positioning of belt ② Check belt can run unhindered, align misaligned pulleys and idlers and change, if necessary. Change belt ③ Change belt, set correct tension
① Reverse idler defective or tight ② Idler outer ring damaged by foreign objects ③ Idler outer ring forms edge because of wear	① Change reverse idler, change belt ② Check drive for foreign objects, change idler, change belt ③ Change idler, change belt
① Bubbling of elastomer compound and decomposition of vulcanization	① Rectify leaks in engine or engine compartment (e.g. escape of oil, fuel, coolant etc.), clean pulleys, change belt
① Incorrect pretension ② Incorrect set composition with V-belts ③ Incorrect flank angle with V-belts	① Change belt, set correct tension ② Always change a complete belt set ③ Change belt, ensure that correct belt is used

Multi V-belt drive components

As drivers' comfort expectations rise, the power demand of the ancillary components also rises. Absorbing torsional vibrations has therefore taken on great importance in multi V-belt drives. These vibrations are caused by the braking and acceleration of the crankshaft as a result of the engine's cycles and ignition sequence. They are transmitted to all the ancillary components by the belt drive and can result in vibration, noise and component failure.

Torsional vibration dampers

Belt pulleys often (or generally, in the case of diesel engines) come in the form of torsional vibration dampers (TVD). Their elastomer elements absorb vibrations and help to extend belt and component lifetimes. Torsional vibration damper isolators (TVDi) also eliminate cyclic irregularities in the crankshaft.

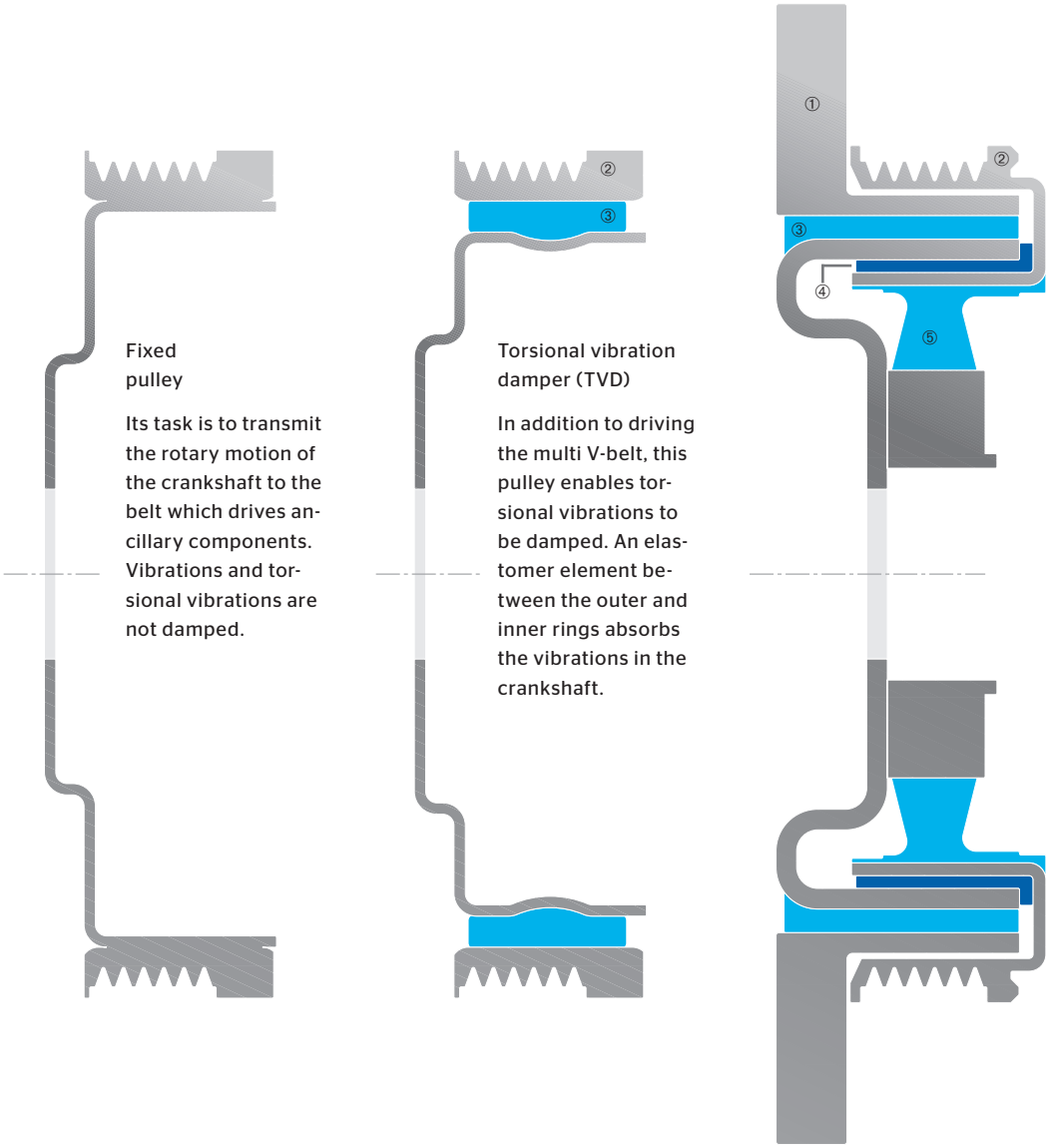
Maintenance and replacement

The elastomer elements of torsional vibration dampers tend to harden as a result of the constant mechanical stresses and ambient conditions in the engine compartment. Pieces tend to crack and break off over time; in extreme cases the outer part separates from the inner ring. They are put under particular stress by engines which are frequently left idling (e.g. taxis) or have been modified by chip tuning.

A defective damper is indicated by a chattering multi V-belt, jerky movement of the tensioner, increased engine noise and vibrations. The belt, tensioner and other components in the drive wear faster as a result. In the worst-case scenario the crankshaft can snap.

The condition of the torsional vibration damper therefore has to be checked at every major service or every 60,000 km. When conducting a visual inspection of the crankshaft pulley (which involves removing it), it is important to check for cracks, detachment, broken-off parts and deformation of the elastomer track. Some pulleys are equipped with indicators in slots which show the degree of wear.

Torsional vibration dampers are matched to the particular engine and therefore cannot be retrofitted.



Fixed pulley

Its task is to transmit the rotary motion of the crankshaft to the belt which drives ancillary components. Vibrations and torsional vibrations are not damped.

Torsional vibration damper (TVD)

In addition to driving the multi V-belt, this pulley enables torsional vibrations to be damped. An elastomer element between the outer and inner rings absorbs the vibrations in the crankshaft.

Torsional vibration damper isolator (TVDi)

Designed with the aim of minimizing the vibrations in the belt drive by damping torsional vibrations and also isolating the belt drive from the crankshaft. This is done by a second elastic rubber/metal connection which absorbs the torsional vibrations and does not transmit them to the outer ring. The torsional vibrations are damped by a sliding bearing. A rotating flywheel stabilizes the belt drive.

① Flywheel
② Pulley
③ Damping elastomer track
④ Sliding bearing
⑤ Coupling elastomer track

Idlers and guide pulleys

The position of the driven belt pulleys normally requires the belt to be guided by means of idlers and/or guide pulleys.

Further reasons for their use:
- To increase the arc of contact. This is mainly necessary with small pulley diameters in order to transmit large outputs (e.g. alternator)
- To steady sections in the drive which tend to produce unwelcome vibrations (e.g. with large belt run lengths; see graphic on p.15)

Design
- Outer ring made of steel or plastic (polyamide), smooth or grooved
- Single- or double-row deep groove ball bearing with enlarged grease reservoir
- Fitted with a plastic dust cap to protect against dirt and dust since ancillary drives do not have a cover. A new dust cap must be used if a component is removed.

Tensioners

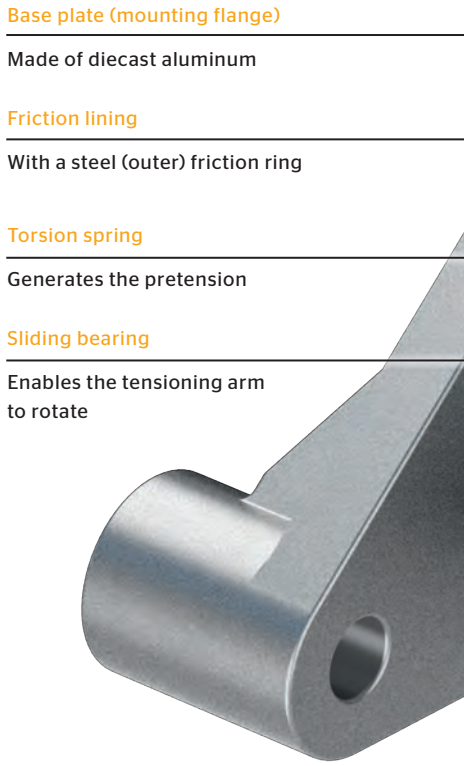
The belt tension in the drive should be high enough to transmit power reliably while subjecting the mechanical components to minimal wear. It is the task of the tensioner to ensure this optimum level.

It compensates for changes caused by
- temperature differentials
- wear
- belt stretch

and minimizes belt slip and vibrations.

Elastic multi V-belts maintain their tension automatically and are operated without a tensioner.

Mechanically damped belt tensioner
Various designs of mechanical, friction-damped tensioners are in widespread use. The tensioning pulley is mounted at the end of a lever arm and deflects the belt by means of an integral torsion spring. The pretension generated in this way can be kept almost constant under various operating conditions. A friction layer between the baseplate and lever mechanically damps any lever movement, thereby reducing the vibrations in the drive. The pretension and damping are matched independently of each other to the relevant application.



Tensioning damper system
Hydraulic tensioning systems are also used in the event of very high dynamic loads. In these, the tensioning pulley is mounted on a lever arm whose movement is damped by a hydraulic cylinder. A compression spring in the hydraulic cylinder generates the pretension. Thanks to their asymmetric damping they offer excellent damping properties even at low pretension loads. Their design corresponds to that of the tensioning damper system used for tensioning timing belts, see the graphic on p.17.

! Play safe

> Protect pulleys, idlers and tensioners against service fluids such as oil, brake fluid, coolant, fuel and other chemicals.

> It is essential to avoid damaging the (ribbed) contact surface.

> When mounting TVD pulleys on the crankshaft, use new expansion bolts and the correct tightening torque.

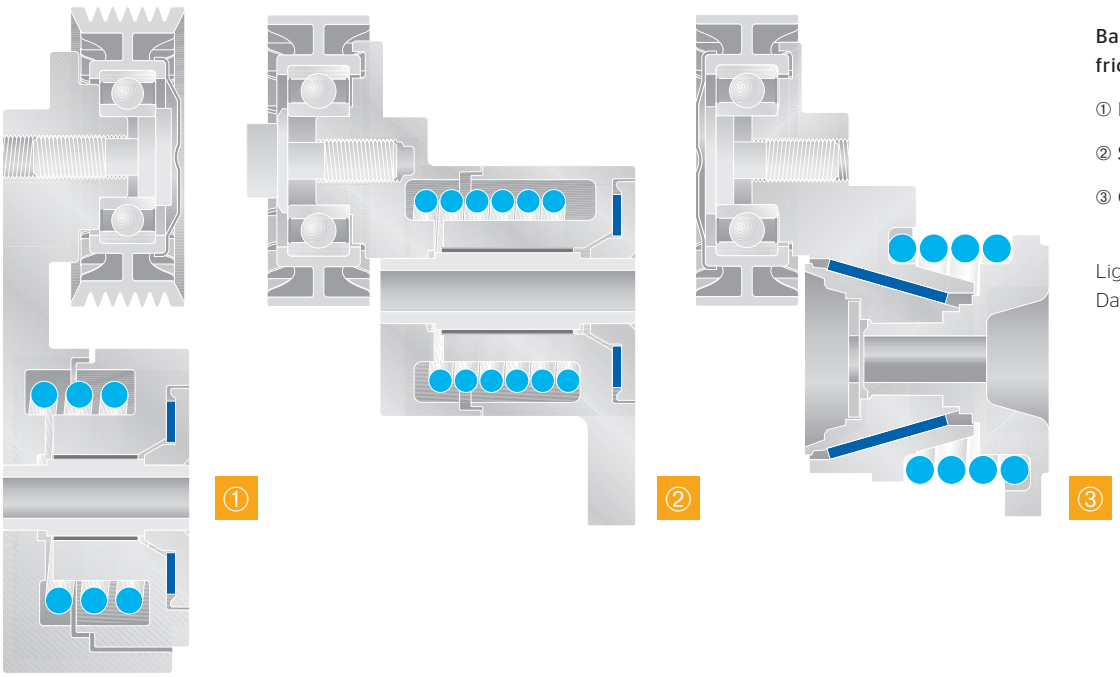
> Always use the specified special tools.

Tensioning pulley

With a single-row bearing

Tensioning arm

Made of diecast aluminum



Basic forms of mechanical, friction-damped tensioners:

① Long-arm tensioner

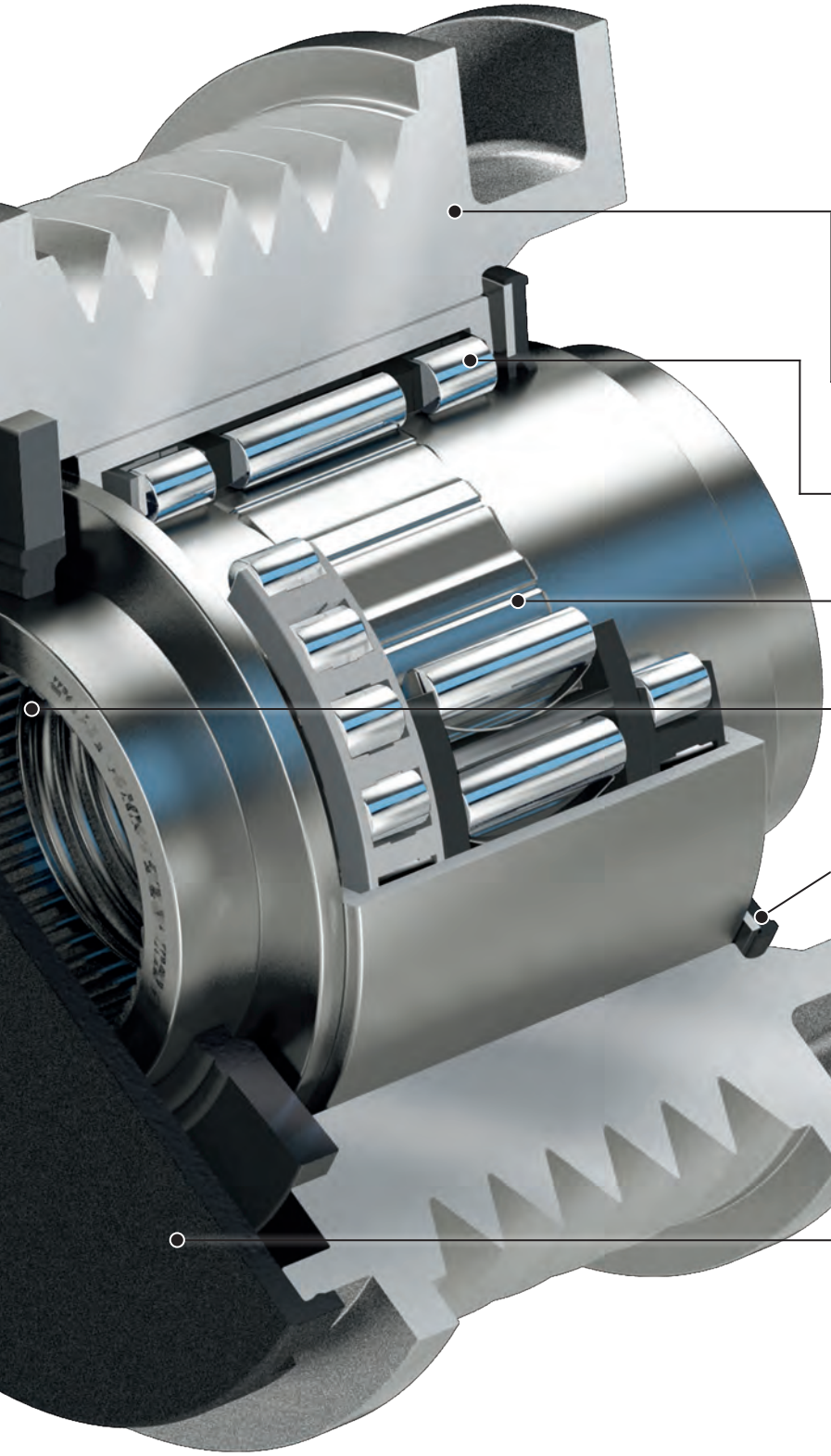
② Short-arm tensioner

③ Cone-shaped tensioner

Light blue: torsion spring
Dark blue: friction layer

Overrunning alternator pulleys

The alternator is the drive component with the greatest inertia and a large transmission ratio. It therefore has a major effect on the whole drive. The continually increasing demand for electrical power is resulting in more powerful alternators which generally have a greater mass and reinforce this effect.



Overrunning alternator pulley
OAP

Outer ring

With profile for multi V-belt, corrosion-protected

Roller bearing

Support bearing for low-wear freewheel function

Freewheel unit

Inner sleeve with ramp profile, pinch rollers

Inner ring with serrations

The inner ring is screwed to the alternator shaft via a fine thread. The serrations are provided to enable the tool to engage the inner ring when fitting/removing.

Double-sided lip seal

To protect against dirt ingress

Dust cap

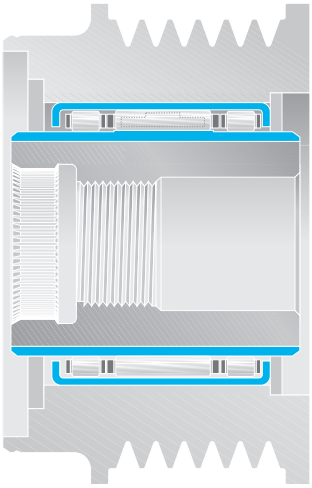
Covers the front of the pulley and protects against the ingress of dirt and spray.

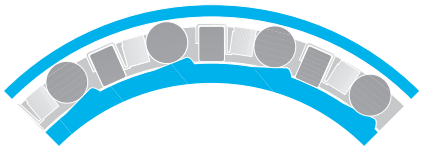
An overrunning pulley is used on the alternator in order to reduce the effect of the alternator mass on the belt drive. It interrupts power transmission as soon as the speed of the secondary side exceeds that of the primary side. The alternator shaft can therefore rotate faster than the belt pulley. This compensates for cyclic irregularities. Furthermore, the alternator can "coast down" if the speed is suddenly reduced (gear change).

This function is easy to check once the component has been removed. The inner ring of the overrunning pulley must turn when rotated in the alternator's running direction and must be locked in the opposite direction. In the case of the OAD, a significantly increasing spring force must be felt in the opposite direction.

Overrunning pulleys
- improve the smoothness and noise properties of the belt drive
- minimize belt vibrations and slip
- extend the lifetime of the belt and tensioner.

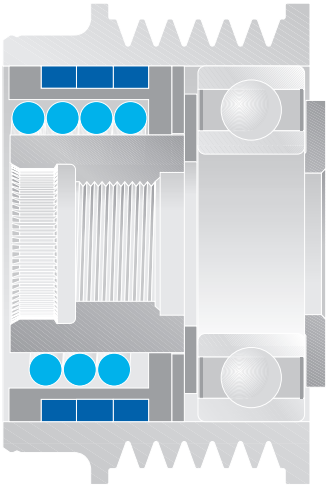
Belt vibrations, belt chatter, premature wear of the belt and tensioner, whistling/squealing noises and severe tensioner wear are signs of a defective overrunning pulley.





Overrunning alternator pulley (OAP)

As a result of the overrunning pulley (pinch roller freewheel – blue) the inner ring can only be turned in the alternator's running direction. Because of the ramp profile on the inner ring the middle row of rollers (pinch rollers) locks the opposite direction.



Overrunning alternator decoupler (OAD)

The OAD also decouples the multi V-belt drive from the alternator by means of an integrated spring damper system (blue). This torsion-damped overrunning unit enables better absorption of vibrations. The torsion spring absorbs the cyclic irregularities in the crankshaft and thus ensures a "soft" alternator drive. At the same time, the design takes the form of a wrap spring clutch to generate the freewheel function.

Play safe

> It is essential to avoid damage to the outer ring.

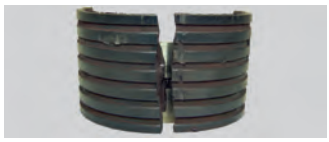
> Check the pulley function at every belt change.

> Fit a new dust cap every time a pulley is removed (the pulley may only be operated with a dust cap fitted).

> Always use the specified special tools.

Appendix

Fault patterns for idlers, tensioners and pulleys

Problem	Typical fault pattern	Cause
End stop worn, stop lug broken		① Tensioning pulley wrongly adjusted (e.g. tensioned in wrong direction) ② Tension too low or too high ③ Tensioning pulley oil-fouled (failure of damping friction element)
Front plate broken		① Wrong tightening torque when securing pulley ② Washer was not used when securing pulley
Idler is oily and soiled, spring may be broken	 	① Leaks from engine result in ingress of service fluid into tensioning system. Lubricating effect of fluid means that friction element no longer performs its damping function. End stops of tensioning pulley are damaged
Outer ring broken		① Foreign objects in belt drive ② Pulley damaged before or during fitting
Tensioner snapped off		① Multi V-belt vibrating badly ② Lifetime exceeded ③ Damper fastening screw tightened to wrong torque
Overheated roller (color change of bearing metal)		① Pulley overheated as a result of friction caused by slip of the belt ② Pulley has seized mechanically (e.g. as a result of touching the belt cover or protruding edges on the engine)
Oil leak at seal gaiter of hydraulic tensioner		① Gaiter torn
Wear marks on flange of pulley		① Pulley not correctly aligned in belt drive ② Increased bearing play in pulley because of wear
45° cracks in decoupler track of TVDi		① Damage as a result of extreme idling load, e.g. taxi ② Lifetime exceeded ③ Overload, e.g. as a result of chip tuning

Solution

① Fit new tensioning pulley and adjust in accordance with manufacturer's specification. Change belt
② Fit new tensioning pulley and set correct tension
③ Rectify cause of leak, change pulley and belt

① Fit new pulley and use correct tightening torque
② Fit new pulley with washer and use correct tightening torque

① Rectify cause of leak, change pulley and belt

① Remove foreign objects, check all components for damage and change if necessary
② Change pulley and fit correctly

① Check function of OAP and TVD and change if necessary
②③ Fit new tensioning damper and apply correct tightening torque

① Rectify cause of slipping belt (e.g. seized water pump, seized pulley), change pulleys and belt, apply correct tension
② Change pulley and belt, check that pulley can rotate freely (e.g. positioning timing belt guard correctly)
Note correct rotational direction when tensioning

① Ensure correct fitting without damaging gaiter

① Adjust misaligned pulley or change if necessary. Ensure correct pulley is used and counterhold is correctly positioned, change belt
② Change pulley and belt

①② Change belt pulley correctly

③ Restore engine power to factory level. Change belt pulley correctly

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