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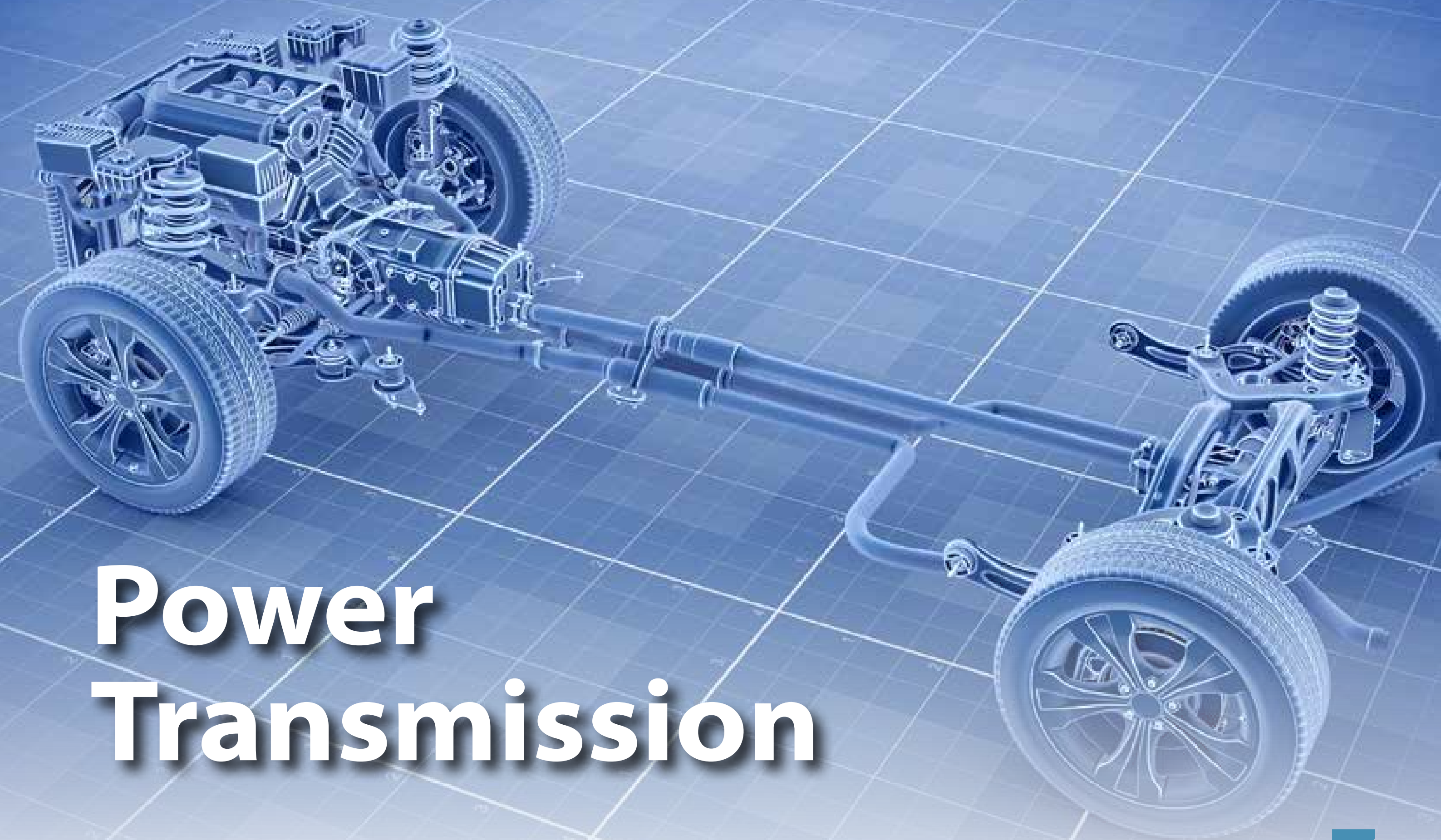
Eure!TechFLASH

THE UP-TO-DATE TECHNICAL INSIGHT IN AUTOMOTIVE TECHNOLOGY & INNOVATIONS

EDITION 21



Power Transmission

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INTRODUCTION

The determining factor for the creation of the car was, as strange as it may seem, the creation of the transmission system. The connecting of stationary internal combustion engines with the structures of already existing horse-drawn carriages only needed the invention of a system capable of transmitting the force and movement from its source, the engine, to the wheels. However, this was no easy task, and it gave rise to the development of an entire mechanical system that, after years of study and evolution, is capable of transmitting, interrupting and converting the force in order to adapt it to the driving needs of vehicles over the ground's variable surface.

Today, the design of the transmission system is a key factor in the performance, consumption and dynamic quality of cars. Its study and development are as necessary as that of the engine itself. An exceptional engine is of little use if its potential cannot be fully transmitted to the wheels and converted into motion.

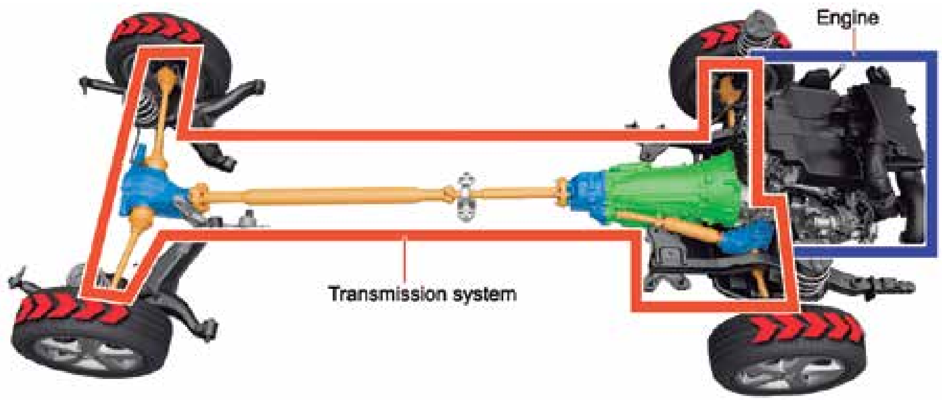
This article describes the origin of the transmission system, the physical phenomena related to force transmission in vehicles, as well as the various components that form the system responsible for this task, with special emphasis on the clutch system.

EVOLUTION OF THE TRANSMISSION SYSTEM

The transmission system in cars is responsible for transmitting and converting the rotary force developed by the engine to the wheels, so that the wheels rotate to drive the vehicle.

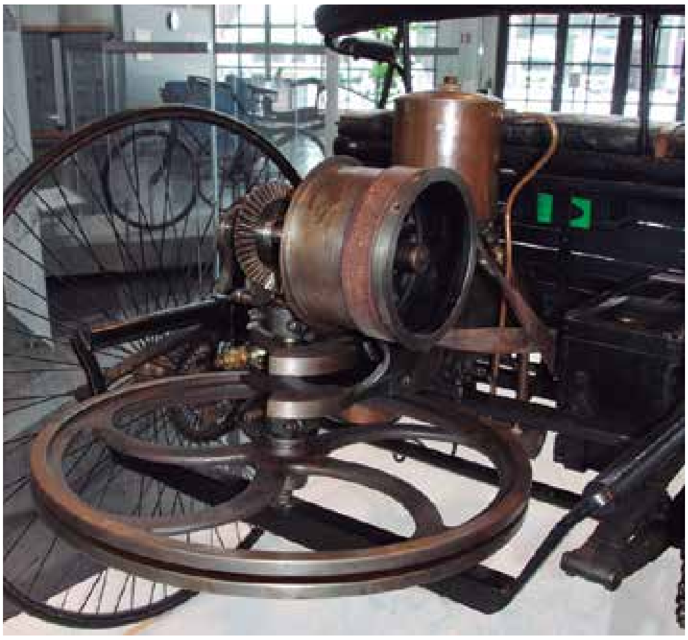
Historically, it was the development of the transmission system that was the determining factor for the creation of the first cars with an internal combustion engine. In contrast to steam locomotives and even the first electric vehicles whose drive sources allowed direct drive systems, the internal combustion engines developed at the end of the 19th century had numerous disadvantages to their adaptation to mobility against one real advantage, liquid fuel.

The tricky starting process of primitive combustion engines restricted their practical application, especially when stopping the vehicle without stopping the engine. The "high" minimum speeds of crankshaft rotation to achieve a minimally regular performance required progressive coupling when setting off.



In 1886 Carl Benz and Gottlieb Daimler both developed, a few kilometres from each other, motorised vehicles that would define the birth of the concept today known as the car, whose primitive idea as a self-propelled carriage is attributed to Leonardo Da Vinci in 1495.

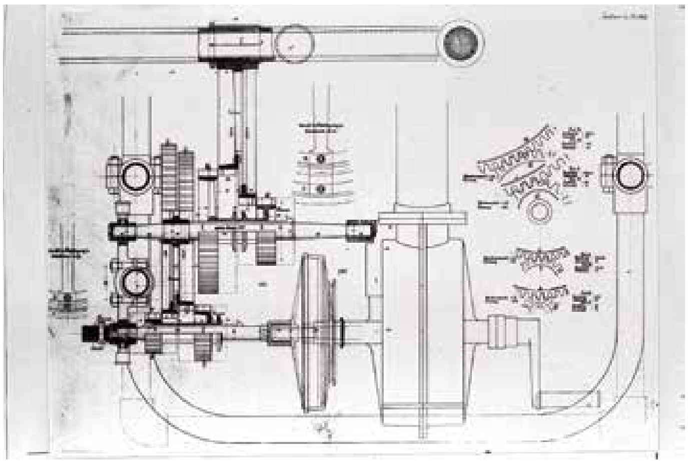
On 29 January 1886 Carl Benz obtained German patent number 37435 for the first car. This was a tricycle design with a tubular chassis propelled by a horizontally arranged single-cylinder 954 cc engine with a stated power of 2/3 hp at 250 rpm. Transmission was by an uncouplable leather belt (primitive clutch system), single speed and rigid drive shaft.



In the summer of the same year, Gottlieb Daimler presented his first self-propelled vehicle with four wheels and two transmission speeds, the first gearbox concept. This was an open horse-drawn carriage with an Otto cycle engine with a single piston coupled in the vertical central position with dual-ratio transmission provided independently by means of two leather belts that were tensioned and transmitted the force alternately.

Both vehicles had a rigid drive shaft that compromised their ability to turn as they rotated the rear wheels at the same speed. However, the double wheel on a pivoting rigid shaft gave a certain advantage in this aspect to the Daimler carriage.

In 1889, the first car marketed by the Daimler-Maybach company was driven by a V-twin cylinder engine and incorporated a four-speed gearbox, the first gearbox. The idea was Wilhelm Maybach's, the technical director of the company.



Henry Ford's Quadricycle, introduced in 1896, incorporated the drive shaft with differential mechanism, thus solving the resistance to turning problems.

In 1903, Jacobus and Hendrik-Jan Spijker's 60 hp Spyker revolutionised the technical automotive scenario at global level with three innovations. The first six cylinder engine, the first vehicle with brakes on four wheels as well as the first four-wheel drive system. The enormous power obtained from the 8.8 L in-line engine was continuously transmitted to the wheels with a three-differential system, one per axle plus a central differential.

In barely 20 years, the bases for drive systems were established, and these have not stopped evolving mechanically in order to transmit higher powers, in an increasingly comfortable, quick and effective way. Modern drive systems with electronic control allow movement even on slippery surfaces, and they are the result of more than a century of development forged in competition. These systems contribute considerably to improving the dynamics and safety of vehicles.

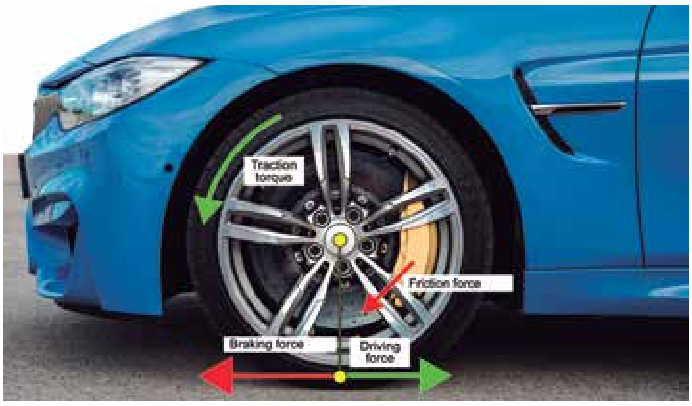
KINEMATIC CHAIN

Kinematics is a branch of physics that involves the study of motion irrespective of how it is produced. The set of elements that transmit the same motion is called a kinematic chain. The kinematic chain of automotive vehicles is made up of different components that transmit the motion from the engine to the wheels.

The engine and its internal components are not considered part of the kinematic transmission chain itself, as they are the point of origin of the force that must be transmitted. This force, in the case of internal combustion engines, is delivered as a torque and speed of rotation, both of which are variable. Bearing in mind that the crankshaft is a connecting element for the forces transmitted by the engine conrods and the first rotating element, the study of the car's kinematic chain covers the components whose function is to transmit the rotation from the crankshaft output to the wheels, where the torque is again converted into a force, tangential to the wheel, with the aim of driving the vehicle.

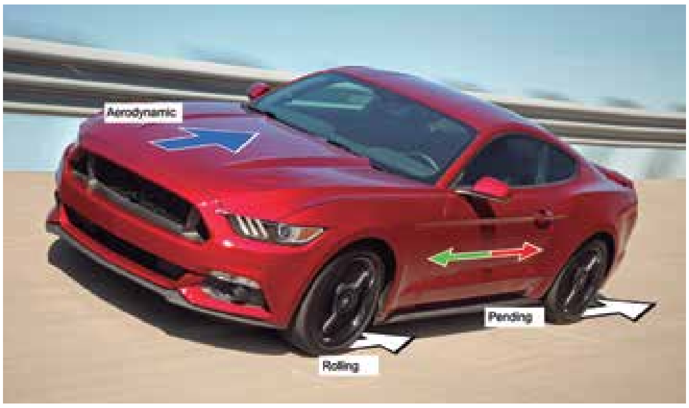
For the vehicle to be driven and consequently its movement to be possible, two necessary physical conditions must be met.

First condition



The torque transmitted to the wheels must be converted into a tractive and/or thrust force. The capacity to convert the torque into a driving force basically depends on the number and size of the wheels that convert the torque into a linear force, the contact surface of the tyres with the road, the weight supported by each wheel and the coefficient of grip of the tyre on the ground.

Second condition

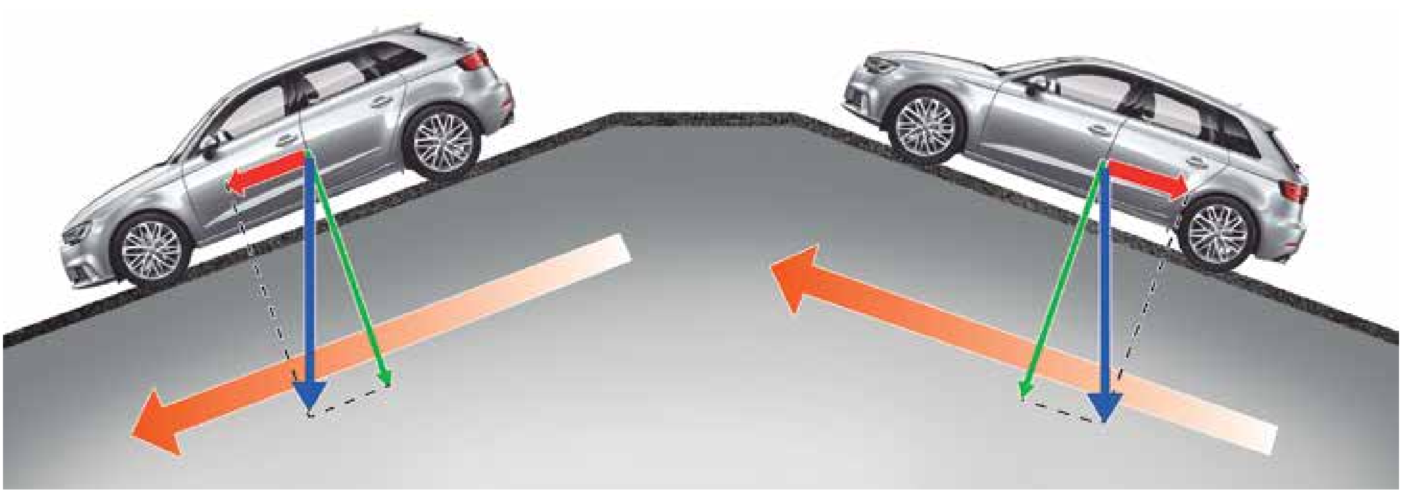


The sum of the thrust/tractive forces developed by the wheels of the vehicle must be greater than the sum of the forces that act in the opposite direction, which have different origins and are variable in many cases.

- **Rolling resistance:** Due to the load that is supported by the wheels, the tyres exert pressure on the ground. This pressure means that the tyre does not rest on a point but over a more or less large surface area, the footprint that creates friction with the ground, and therefore, resistance. This resistance depends on the depth of the footprint that a tyre leaves on the ground, the weight on that wheel and the rolling resistance coefficient. In turn, the rolling resistance coefficient varies depending on the nature and condition of the ground itself.

- **Slope resistance:** The inclination of the ground and the weight of the vehicle can provide a force that opposes or aids movement. The magnitude and direction of this force depends on the angle and nature of the slope (uphill or downhill), the mass of the vehicle and the force of gravity, which, as it is practically constant over the entire earth's surface, we can leave out.

- **Air resistance:** The air occupies all the space on Planet Earth that is not occupied by solid or liquid elements, or other gases, so any element that changes its position must be moved through the mass of air and must, therefore, displace this gas. The work carried out for this requires a force that is resistant to or opposes that which generates the motion of the object that is being moved. In automotive vehicles, the air resistance force depends on 5 factors:
  - The speed of movement
  - The front surface area of the vehicle and its volume
  - The air density
  - The aerodynamic coefficient
  - The speed and direction of the atmospheric air



TORQUE CONVERSION

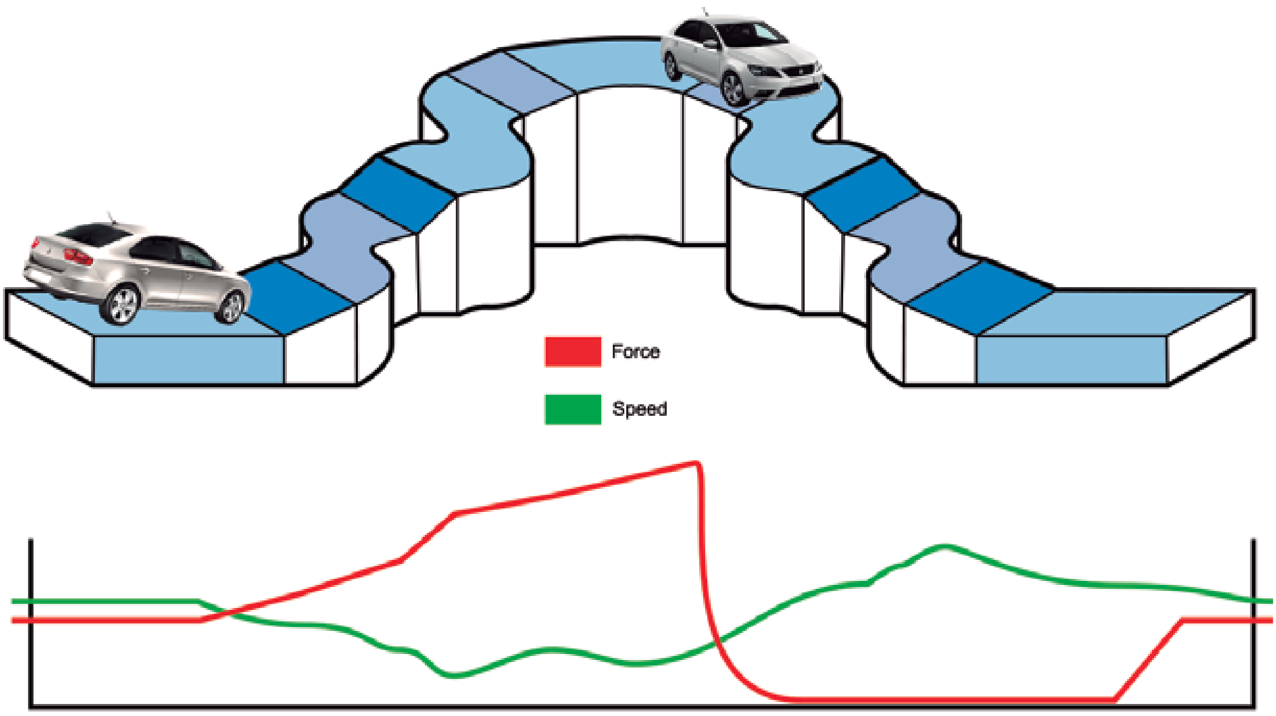
The irregularity of the ground's surface and the heavy weight of vehicles means that the torque necessary at the driving wheels to start a vehicle moving is very variable, and on occasions much higher than the generated force and even the maximum that the motor can generate. Moreover, internal combustion engines generate a very variable rotary force (engine torque) which depends on the working speed, which in turn depends on numerous factors that affect the filling of the cylinders and the development of combustion.

Overcoming these constraints all the time would involve the use of engines capable of developing a very large torque indeed with their corresponding high weight, greater fuel consumption etc. or the conversion of the torque produced by the engine into a rotary force better transmitted to the wheels.

To perform this function, one or more elements are incorporated into the transmission system which, in addition to transmission, modify the torque and, consequently, the speed of rotation.

The driver of the vehicle, for their part, can modulate the percentage of engine torque developed by regulating the amount of fuel provided to the combustion cycle, which under real conditions translates into the control of the engine's torque and speed of rotation. Equally, the necessary torque conversion must be selected for adapting the driving force of the vehicle to its movement conditions.

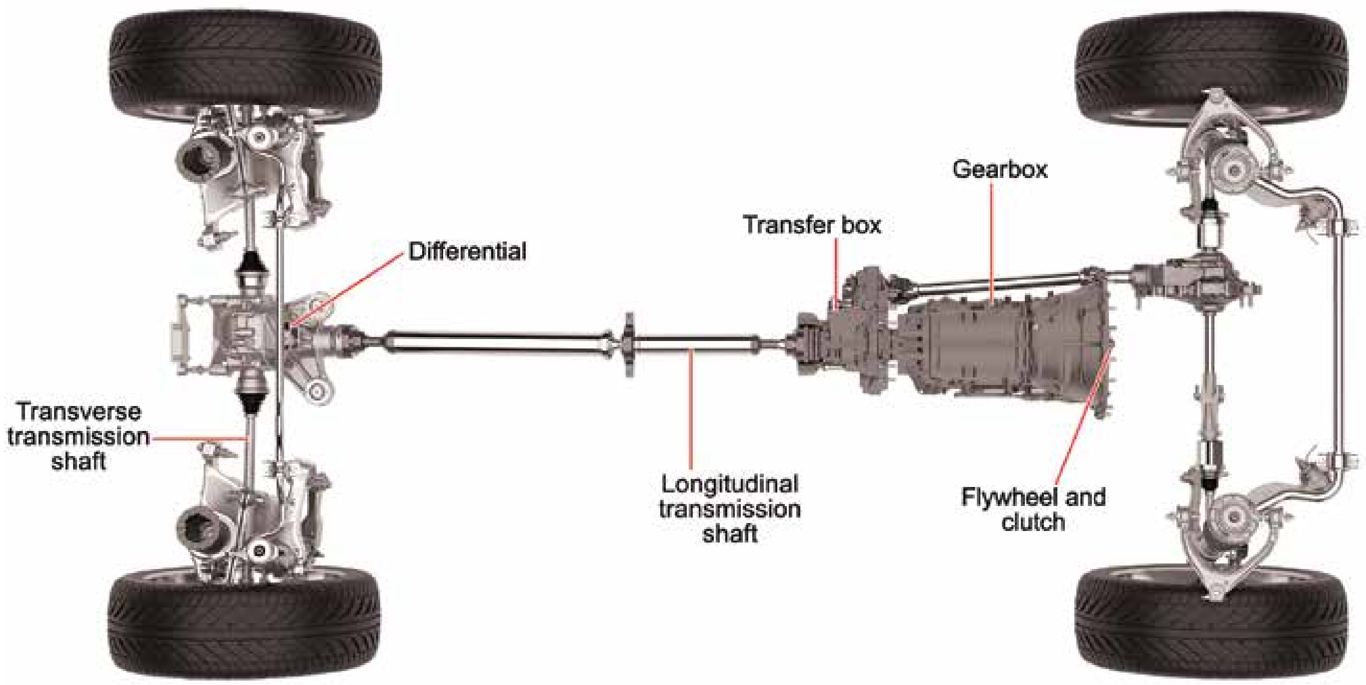
In this way, the force and speed of the vehicle is controlled by selecting the torque conversion ratio that is always higher than that instantaneously necessary in order to ensure the engine continues rotating and the capability to increase it. Otherwise, the engine would be incapable of continuing to run or it would reduce its rotation speed progressively until it comes to a complete stop.



STRUCTURE OF THE TRANSMISSION SYSTEM

The car's transmission system must be adapted to the intrinsic characteristics of the vehicle as a whole and its use, as well as the engine's performance. Its inadvertent evolution has notably contributed to the improvement of the dynamic conditions of cars and their safety, an increase in performance and areas of use and the reduction of fuel consumption. In turn, the constant increase of engine power and torque has determined the adaptation of the transmission to the new requirements.

Its structuring and arrangement in the vehicle vary depending on the position and number of drive wheels and type of vehicle. Nevertheless, the majority of transmission systems are made up of more or less of the same components:



- **The flywheel:** This is a rotating inertial mass joined to the engine's crankshaft whose main function is to homogenise the transmitted speed of rotation and engine torque.
- **The clutch:** This couples and uncouples the rotary motion of the engine to the drive system in order to be able to start to move or stop the vehicle.
- **The gearbox**: Its purpose is to convert the engine torque so that the torque and speed transmitted to the wheels is appropriate for the conditions of use of the vehicle at all times.
- **The differential:** Its function is to equalise the rotary force between the two wheels on the same axle that are describing different paths and, therefore, rotate at a different speed.
- **The transmission shafts:** These elements transmit force and rotation speed between components that may or may not vary their position. Their work involves compensating the angle and distance variation due to the vehicle's suspension travel, transmitting the torque and speed of rotation without changing them.
- **The transfer case:** In vehicles with four-wheel drive, it duplicates the rotation movement output after the gearbox in order to send the movement to both axles of the vehicle simultaneously.
- **The reduction gearbox:** This operates as an additional torque multiplication mechanism on all gearbox speeds. Used mainly on all-terrain vehicles to overcome steep gradients at slow speed.

FLYWHEEL

When the piston is in the engine's TDC position, the conrod-crank pin is in a straight line, and it does not produce a turning moment on the crankshaft. A moment later, as the piston descends, the conrod forms a certain angle and the thrust force acts on the crank pin to drive the crankshaft, and there is now a turning moment. The delivery of force is clearly irregular and the function of the flywheel is to smooth this delivery.

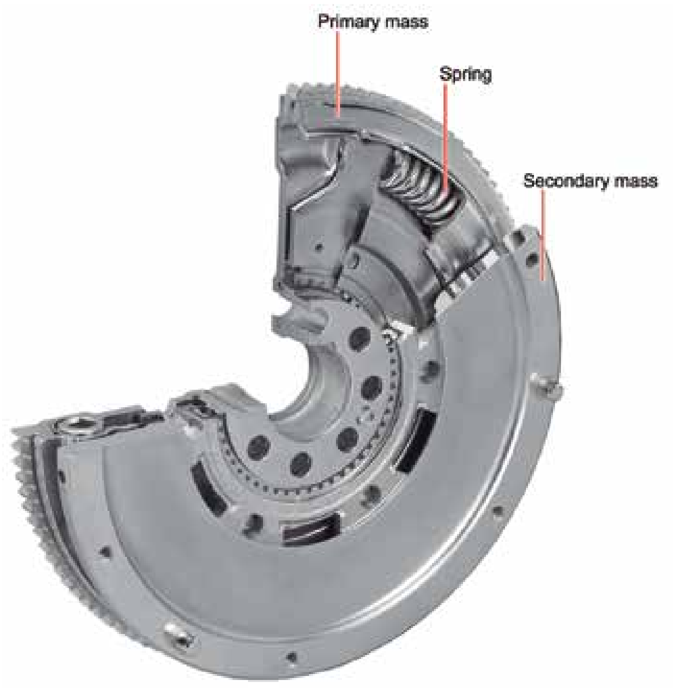
This device is a heavy disc installed on the crankshaft on the opposite end to the pulley. It is capable of storing the kinetic energy of the engine impulses and returning it when there is no energy input, which smooths the dynamic operation of the engine.

Nevertheless, its use has certain disadvantages, as a very heavy flywheel applies torsion forces to the crankshaft, principally during the work pulses of the cylinder furthest from it. A very heavy flywheel with high inertia also makes quick changes of the rotation speed difficult, therefore the response capability during acceleration can be reduced. Consequently, the design of the characteristics of this component should be specified according to the type of engine for which it is intended and its use.

The flywheel also serves to support the clutch, which connects and disconnects the engine to the transmission at the will of the driver. Also, an outer gear ring joined to the flywheel engages with the starter motor pinion as required. In addition, a ring gear or phonic wheel can be incorporated for the rpm and crankshaft position sensor. References for the timing and ignition settings are etched on the outermost part of the front face.

It is normally manufactured in spheroidal graphite cast-iron or in steel, and must be individually balanced and together with the crankshaft and clutch.

For lower vibration transmission to the vehicle components that receive the engine force, the dual mass flywheel is used. It is constructed as two independent masses connected elastically by means of springs. The first rotates together with the crankshaft and the second moves with the rest of the kinematic chain (clutch, gearbox, etc.). During the most intense turning moments (increasing torque), the springs are compressed and store kinetic energy and, as the intensity reduces, they recover their form and deliver the energy again. In addition, in some cases, friction systems are used between both masses to smooth the reaction of the assembly.



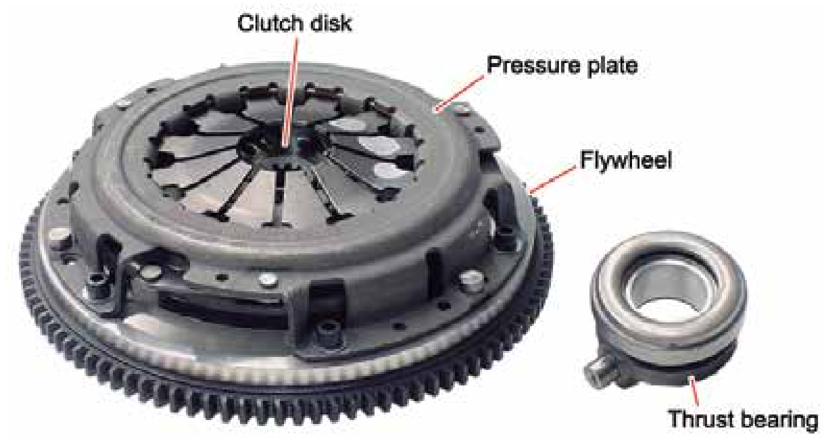
THE CLUTCH

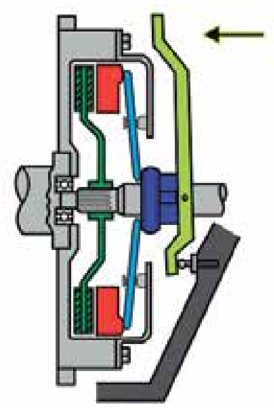
The clutch mechanism is responsible for interrupting the transmission of the engine rotation to the gearbox, so that the vehicle can stop completely but the engine can continue to run. When it is engaged, it must transmit the engine torque to the transmission system in a way that makes moving off smooth and progressive. Lastly, it must be capable of quickly stopping the transmission of the engines motion and rotary force to the gearbox, in order to allow the gears of the different speed or gear ratios to be engaged without effort.

The diaphragm spring clutch

The diaphragm spring clutch combines in a single element the components responsible for maintaining the clutch disc pressed against the flywheel. In a compact assembly called the diaphragm spring clutch, are located the pressure plate, the diaphragm spring and the outer housing that is bolted to the flywheel.

The pressure plate is bolted by its outer casing and presses the disc between it and the flywheel, so that the disc is under pressure and the system is engaged. By means of a bearing that is displaced axially on a guide collar, the spring feet of the diaphragm are pressed on the inside, which, on tilting on the support studs of the external housing, deforms releasing the pressure plate. If there is no pressure, the clutch disc slides along the gearbox input shaft splines and interrupts the transmission of force and the system is disengaged.





The circular and nearly flat construction of the diaphragm spring makes it insensitive to the rpm and centrifugal force, at the same time allowing for a light simple and compact design. The considerable distance between the point of application of the force for disengaging the clutch and the support or reaction point, allows the manufacture of very strong springs which also require a very low actuating force.

Currently, nearly all passenger vehicles with a friction clutch use clutch systems with one or more discs pressing against the flywheel by means of diaphragm springs.

The components and functions of the clutch assembly are the following:

- Flywheel
- Clutch disk
- Torsion damper
- Clutch pressure plate
- Clutch thrust bearing and fork
- Clutch control

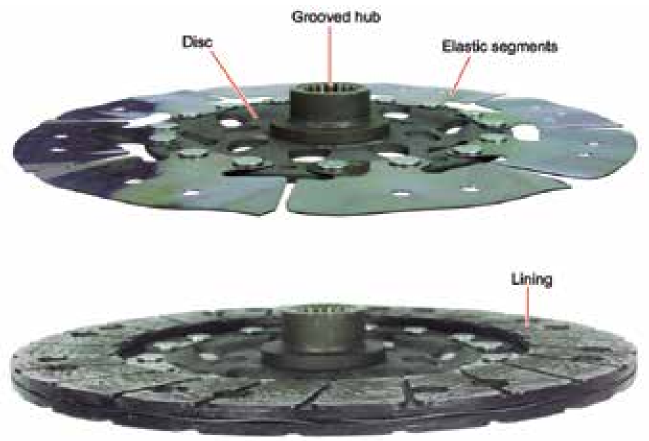
Flywheel

As seen previously, the flywheel can be rigid or dual mass and forms part of the clutch mechanism as it is one of its friction surfaces. Normally it is manufactured in cast steel and later undergoes the corresponding machining, turning and balancing operations. Its dimensions, volume and surface area depend on the inertial weight that they must have and the friction surface necessary to transmit the engine torque. Its heat dispersion capacity and dimensional stability must also be considered. In high-performance clutches and competition engines in which the inertial weight of the flywheel is reduced as much as possible (aluminium, titanium, etc.), the friction surface for the clutch is manufactured as an additional element bolted or riveted to it.

Clutch disk

The clutch disc is located between the flywheel and the pressure plate. Its work consists of transmitting the force that it receives from the flywheel and pressure plate on its outer part to the primary shaft of the gearbox by means of the machined grooves on its inner diameter. The clutch disc is made up of a steel disc mounted on a grooved hub that is moved axially over the gearbox input shaft, during the engaging and disengaging phases.

The friction linings or coatings are riveted to the discs with the heads embedded, and in the majority of cases over intermediate elastic segments. The elastic segments act as a spacer spring between both friction linings, so that the increase of the friction, and consequently, the engaging of the clutch is more easily regulated and more progressive. Depending on requirements, the elastic segments are fitted on the clutch bearing disc or externally riveted around the outside of it. There are three types of friction linings in different materials depending on needs and applications:



- **Continuous:** The circular contact surface of this type of lining is completely smooth and works equally as a friction area. Not currently used due to its irregular and vibratory dragging start.
- **Continuous segmented:** This has a continuous lining structure with its surface radially grooved, so that it is divided into different, independent friction working units. The grooves provide a certain flexibility to the linings, which, combined with the force of the elastic segments, ensures that the clutch engages progressively.
- **Discontinuous:** The friction material is fitted in the form of independent pads riveted at a certain distance from each other on the clutch disc. Sometimes, the disc supporting body is reduced in order to decrease its weight and make the structure flexible. They are normally used on competition clutch discs when gear changes are made at high speed, for which the weight of the disc and its inertia are essential features.

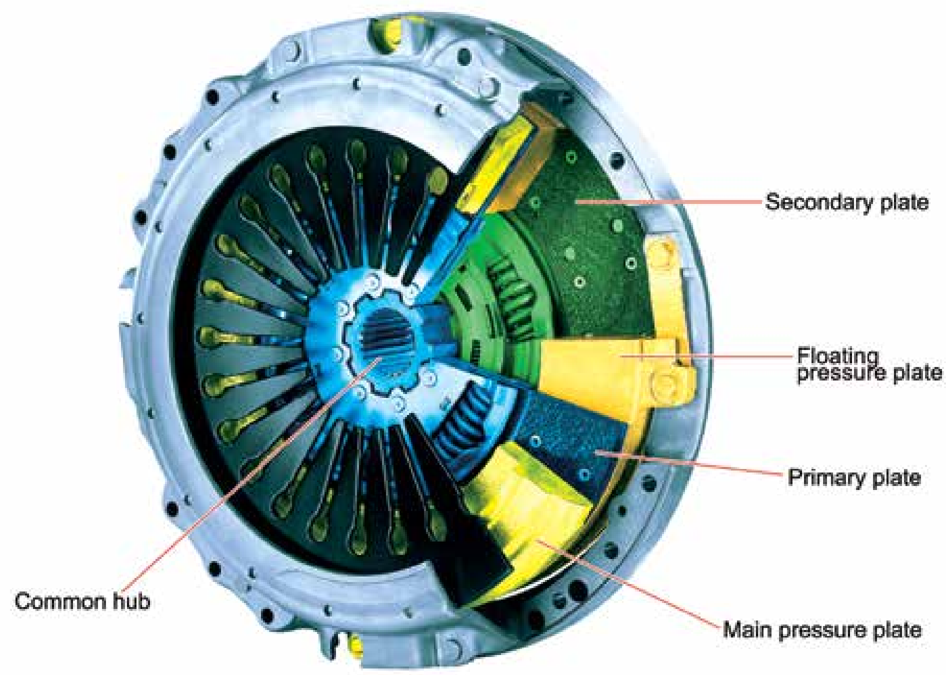
The clutch linings can be manufactured with the following materials:


Organic-metal material Organic-aramid material Kevlar material Carbon ceramic material

- **Organic material:** This is the most used material due to its uniform and smooth torque transmission. Its wear is moderate, it withstands the pressure very well and has adequate thermal behaviour. It is made up of interwoven metal fibres (iron, copper or brass) compacted with aramid, cellulose, glass fibre and resin. It is a brownish or dark grey colour with metallic sparkle.

- **Kevlar (Poly-paraphenylene terephthalamide):** Ideal because of its high resistance to traction and shearing, its thermal behaviour is a drawback, its friction coefficient varying considerably with temperature. It wears slowly, which prolongs the periods of surface adaptation. It is usually used in vehicles with a high-performance sequential or automated gearbox in which electronics limit the slipping and temperature of the clutch.

- **Carbon ceramic material**: Ceramic materials are very resistant to high temperatures and transmit high levels of engine torque, therefore they are ideal for very powerful and competition vehicles. Their coefficient of friction is very high, which compromises their progressiveness in the transmission of torque, therefore they are combined with different soft metals to form composites. The rigidity intrinsic to ceramic material also makes the use of intermediate elastic segments difficult, which results in an abrupt response that is difficult to modulate. For these reasons, it is usually fitted on discontinuous linings and flexible discs. They are usually coppery or greyish brown depending on the metals used in their manufacture.



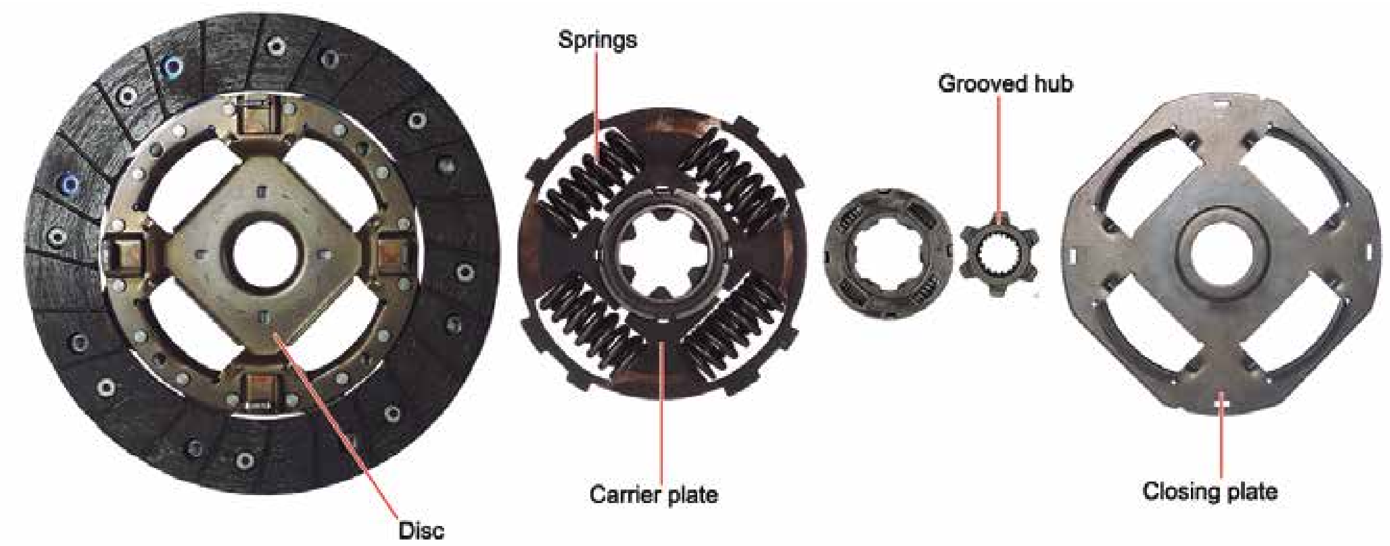
Currently, the manufacture of high-performance clutch linings is moving towards mixing various cast metals together under pressure (sintered metal), in order to achieve a balanced clutch response at different temperatures.

In order to transmit high torque levels with a low or moderate clutch actuation force, dry multi-plate clutch systems are manufactured that increase the friction surface area and maintain a moderate and even small disc diameter. The pressure exerted by the diaphragm spring is applied over a greater contact surface area by adding one or more discs and intermediate floating pressure plates, which results in the force transmission capability increasing considerably for the same diameter.

Torsion damper

Before the introduction of dual mass flywheels, the regulating function of the torque and speed of rotation between the engine and the gearbox was carried out by the clutch disc with a torsion damper, a system that is still very much used in many vehicles.

The variation of the engine's torque and speed of rotation is compensated by the work of several springs that store energy by compressing when there is maximum torque, and return when there is lower transmission force. The metal clutch disc is divided into two halves, the inner and outer, which together with the cover and the springs form the torsion damper. The inner carrier half is joined to the grooved hub that rests on the springs on one side, while the outer half acts as a support for the friction linings and drives the inner half against the face opposite the springs. The outer carrier plate and its opposing closing plate rotate together joined by pins, the springs and the inner drive plate are housed inside.

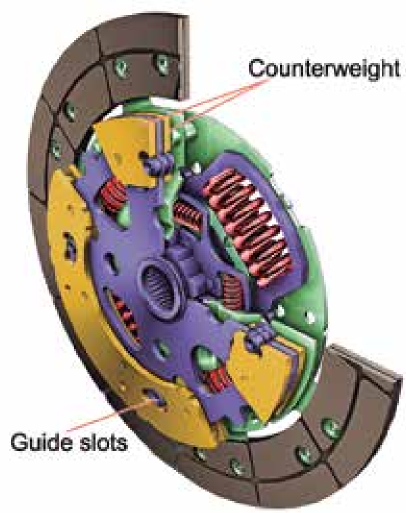


To achieve damping with different drag torques and frequency, combinations of concentric springs are used.

The maximum travel of the springs and the angular absorption variation are limited by the space available along the intermediate perimeter of the clutch disc. For this reason, in recent times, active clutch discs have been developed with pendular counterweights similar to those used in the flywheels.

The central structure of the clutch disc incorporates an additional drive disc where the pendular counterweights are installed. These are guided in their movement by the slots and reduce the variation of force mainly transmitted at low rpm.

The weight of the clutch disc raises its inertia, which is a drawback for speed changes and gear selection, due to the inertial drag that the disc causes on the gearbox input shaft.



Clutch pressure plate

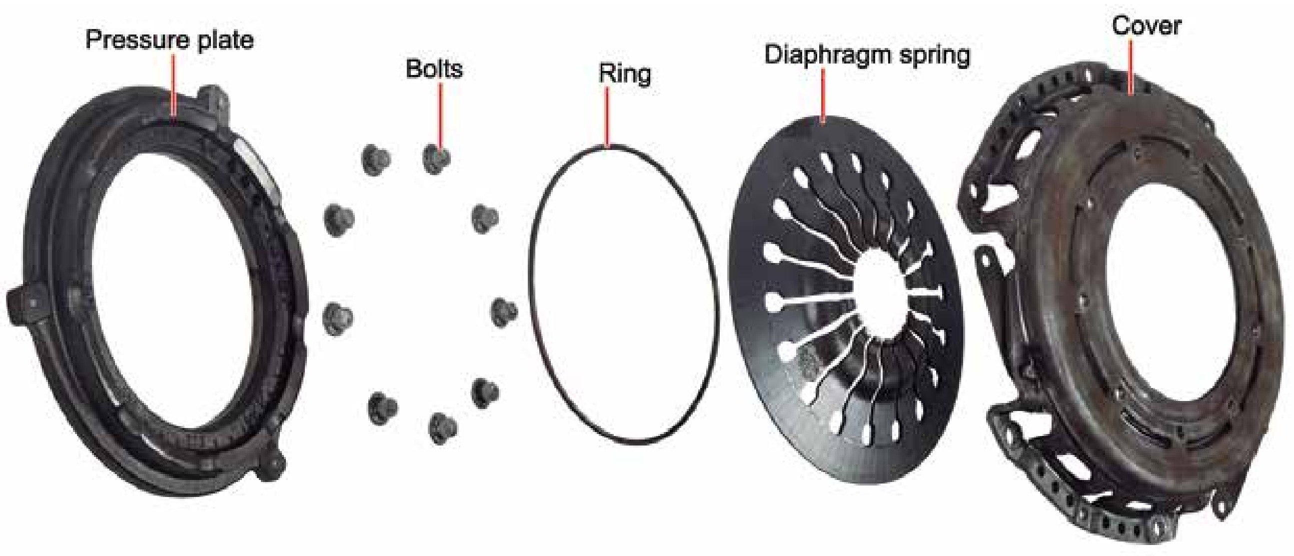
The pressure plate is the component responsible for applying the pressure on the friction linings in order to modulate the torque transmitted to the gearbox input shaft, from 100% transmitted when engaged, to 0% force transmission when the pedal is pressed.

The pressure plate is made up of:

- The **cover or support**, manufactured in pressure stamped steel plate which incorporates, on its outer part, the holes for its fixing to the flywheel by means of bolts and the openings for its correct centring.

- The **diaphragm spring** is manufactured in steel plate pressed to give it a conical shape, the spring is fixed to the cover at its pivot point by means of studs and a pressure ring. Although there are clutches with a free pressure plate guided by channels, the most usual is that it is joined to the cover by flat steel leaf springs riveted at their ends to both elements. The metal of the spring's inner pins distributes the actuating force uniformly over the area close to the diaphragm support on the housing, and the spring, due to its flexibility, tilts on the fixing studs and deforms. The conicity of the diaphragm reduces, releasing the pressure plate, which causes the friction surfaces to come apart as it withdraws.

- The clutch **pressure plate** is manufactured in tempered cast steel and its purpose is to uniformly distribute the pressure exerted by the diaphragm spring on the friction surface of the disc. It is also responsible for cooling, together with the flywheel, the clutch disc by transmitting its heat to the air by contact.

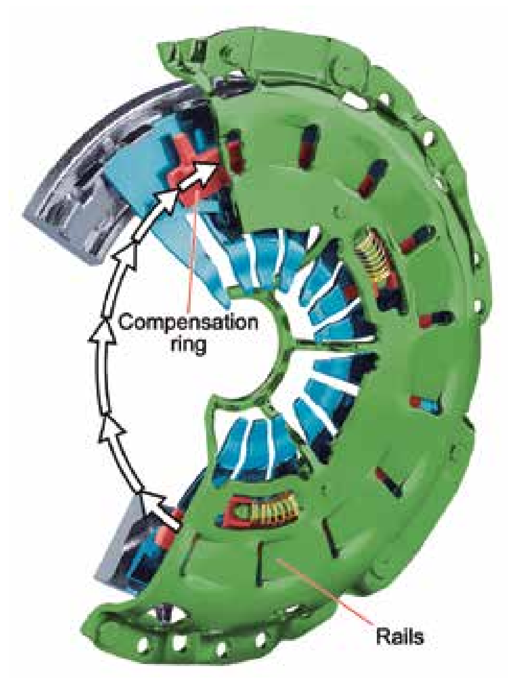


Depending on the relative position between the input point, support and output of the diaphragm spring force, pressure plates are classified as push or pull. Push pressure plates have the diaphragm pivot point between the pressure input and output, while on the pull type, the input point is internal, the pivot point is external and the pressure output is located between the two. The conicity of the diaphragm is reversed on both springs. The pull pressure plates are used on very stiff diaphragm clutches as they have a longer actuating lever arm for the same assembly diameter.

Self-adjusting clutch pressure plate

The progressive wear of friction linings due to friction and the loss of flexibility of the elastic segments causes variation in the thickness of the clutch disc, and with it the respective positions of the pressure plate and the diaphragm spring. The variation of the diaphragm spring position reduces its force and varies the clutch engaging point with respect to the actuating pedal travel, which, in turn, alters the feel and force required for its actuation. This behaviour makes it necessary to readjust the actuating mechanism several times during the useful life of the clutch system.

Self-adjusting clutch pressure plates were created to overcome this disadvantage by correcting the disc wear by means of a ring placed between the diaphragm spring and its support point on the outer housing. The angular displacement of the adjustment ring on the housing support ramps, caused by the force of the compensation springs, increases the separation between both and thus compensates for the lost travel due to disc wear. The mechanism self adjusts progressively as the force of the diaphragm spring reduces especially when the flexing of the diaphragm changes rapidly. The self-adjusting nature of the system requires it to be assembled with the diaphragm spring compressed and the adjustment system blocked. The first disengaging action unblocks the compensation springs and activates the self-adjustment system.



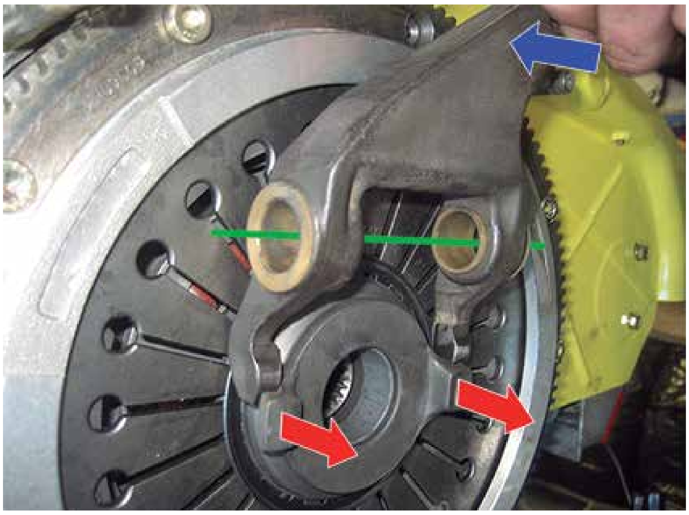
Clutch thrust bearing and fork

Thrust bearing

The thrust bearing or release bearing is responsible for transmitting the actuating force made by the driver to the diaphragm spring to disengage the clutch. It is a ball bearing that is displaced over an interior guide sleeve (collar). The outer bearing race (fixed) receives the linear movement from a fork which, on pivoting about a shaft or support point, causes its displacement. The force and direction of the displacement is transmitted by the balls to the bearing's inner race, which when coming into contact with the diaphragm pins, rotates at the same speed.

For pull pressure plates, the actuation direction for disengaging, and therefore the work of the bearing, must be push, although the system is practically the same. The moving race of the bearing incorporates a conical sleeve that is inserted into the diaphragm at pressure, so that when the outer bearing race is pulled by the fork, the force is transmitted to the cone inserted in the diaphragm spring, pulling it.

The thrust bearing is displaced on a hub or guide collar that encircles the gearbox input shaft. The guide collar keeps the thrust bearing centred during its displacement so that it rests flat and centred on the diaphragm spring feet and moves fully linearly, distributing the force equally over the diaphragm spring.



Clutch fork

The fork is the component responsible for moving the thrust bearing on the guide collar. The fork receives the movement from outside the clutch housing and translates it to the inside, altering its travel and force. There are direct and reverse forks, depending on whether they apply the force in the same direction as they receive it or in the reverse direction. The majority of modern vehicles use direct forks, as their force multiplication capacity is much greater. Reverse forks have a smaller lever arm as the pivot shaft is in the middle, requiring a greater actuating force.

Clutch control

The clutch actuation system is responsible for transmitting the force and movement made by the driver on the control pedal to the thrust bearing. To be practical and for the engaging or disengaging to be progressive and capable of regulation, the thrust bearing travel must be proportional to that of the actuating pedal, the force, however, usually increases. The clutch control can be:

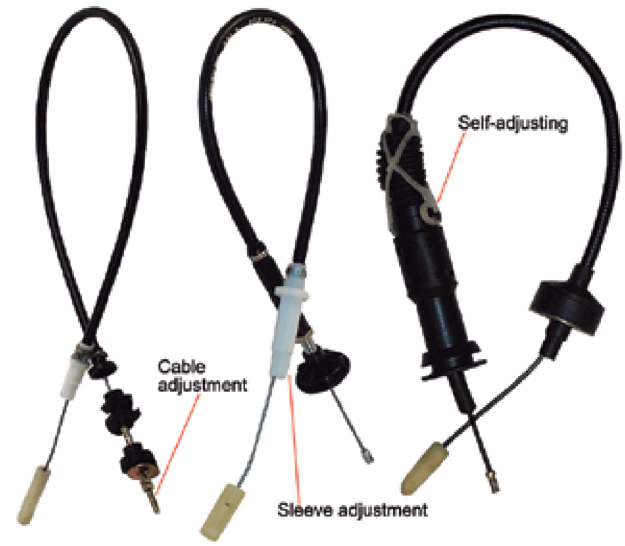
- Mechanical
- Mixed
- Hydraulic

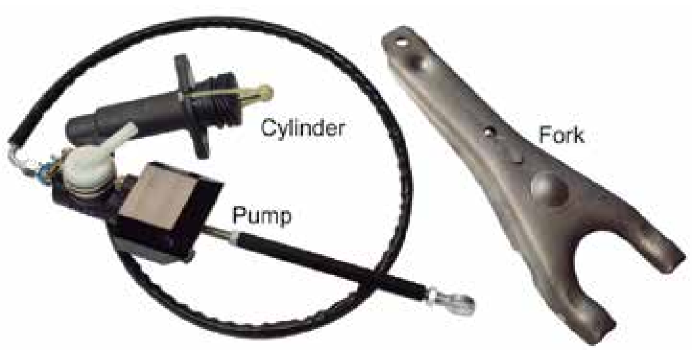
Mechanical control

The first control systems were made up of a set of levers and connecting rods on pivot points that connected the clutch pedal to the clutch fork. The force and travel transmission by means of levers was very reliable and rigid, but it was not very practical as regards flexibility in mounting the gearbox in the vehicle. Subsequently, steel cables with a flexible cover were the most used system for many years for actuating the clutch, as this system solved the rigidity problem of its predecessors.

The mechanical cable systems evolved considerably with the incorporation of low friction coatings, reverse twisted double sleeves and even automatic tensioning mechanisms (wear compensation), either by lengthening the sleeve or by cable recovery on the pedal.

In spite of being a reliable system, the cable control involves certain design limitations, due to the inflexible routing of the cable (very large radii of curvature), need for space in the pedal area (straight cable routing), and very little or no force amplification capacity.





Mixed control

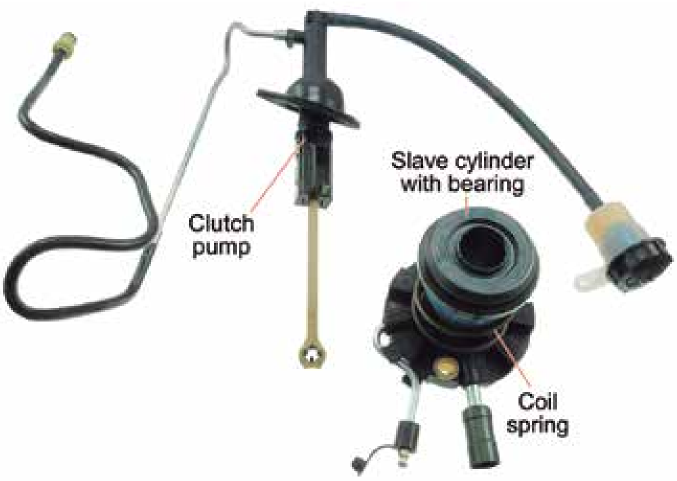
Increasingly stiff diaphragm springs led to the design of hydraulic clutch actuation systems, many of them with force amplification. The actuating cable is replaced by a master cylinder, hydraulic lines and a slave cylinder in hydraulic control systems.

The clutch master cylinder (pump) receives the clutch pedal force which generates hydraulic pressure that transmits the movement to the movable piston of the slave cylinder. The force and movement of the slave piston is transmitted by means of a rod to the clutch fork, the final mechanical element.

Hydraulic control

The fully hydraulic clutch control system eliminates the clutch fork, and combines the slave cylinder and clutch thrust bearing in a single component. The slave cylinder surrounds the primary input shaft of the gearbox, which considerably increases the slave piston diameter and its area, thus increasing the force. To keep the thrust bearing in contact with the clutch pressure plate and prevent dead working travel (with no force) of the clutch cylinder, a coil spring is usually incorporated inside.

Generally, the system shares a fluid reservoir with the braking system due to its proximity, although there are systems with an independent reservoir and different fluid specifications. The presence of the coil spring and the usual combination with self-adjusting pressure plates, means readjustment due to wear of the system is unnecessary. The hydraulic nature of the control system automatically compensates for wear.



CLUTCH DIAGNOSTICS

The diagnostics and checking of the clutch system operation must consider its three main functions and the force required for its actuation.

Full transmission of engine torque

At rest, the system must be capable of transmitting the maximum engine torque in any gear and movement condition of the vehicle. To check this, the engine should be accelerated from its maximum torque speed up to maximum power speed in high gears and on uphill terrain. At the moment when the forces opposing the movement are greater than the force generated by the engine, the engine will cease to increase its speed although the engine is at maximum output.

If at any time the engine accelerates without producing the mechanically related speed increase and without the wheels losing traction on the road surface, it means that the clutch disc is slipping. This phenomenon may be due to excess wear of the disc and reduction of the pressure plate spring force due to normal use, or due to incorrect operation or adjustment of the control system.

In mechanical control systems, the pedal travel and clutch engaging point must be checked and readjusted if necessary. In hydraulic control systems, check the rapid pressure drop in the circuit on releasing the pedal. To do this, repeatedly press the pedal in a short space of time and open the bleeder after releasing the pedal to make sure there is no pressure.

The accumulation of excess residual pressure in the hydraulic control system is noticeable especially after releasing the pedal quickly during gear changes and limits slipping to a few seconds, and the phenomenon does not reoccur until a new pedal actuation cycle. It may be due to residual pressure valves/pulsation dampers in poor condition or flexible hydraulic lines that are blocked or partially blocked.

When the control/actuation system is ruled out, the clutch assembly must be replaced, while ensuring that there are no liquids or oils on the friction surfaces from the engine or gearbox, in which case they must be repaired.

No or minimal transmission of engine torque

With the pedal completely pressed down or at more than 70% of its travel, there must be no force transmission to the gearbox, so all the gears can be engaged without difficulty.

To find the point at which no torque is transmitted, start driving the vehicle in first gear with the parking brake partially on and slowly press the clutch until you feel the vehicle braking. If necessary, adjust the actuating mechanism if possible.

In the same way, in mechanical or mixed control systems, check the rectilinear and linear movement of the external end of the fork and its travel in line with the pedal. Lastly, in mixed and hydraulic control systems, bleed the hydraulic system and check the correct functioning of the clutch master cylinder and slave cylinder and the generation of pressure.

Once the above checks are passed, the non-interruption of the force transmission can only be due to the pressure plate/disc/thrust bearing mechanism, which must be dismantled, checked and replaced.

Progressiveness and regulation

The clutch must engage progressively and proportionally to the intermediate travel of the pedal in order to start the vehicle moving comfortably and smoothly. To check this, it is recommended to very slowly engage the vehicle in a high gear with the parking brake applied or the foot brake pressed down. You should notice the progressive braking of the engine with continuous pulling, with no physically or audibly perceptible judder or vibrations.

With the vehicle on a steep uphill slope, starting off must be continuous, progressive and without disturbance. Non-uniform work or clutch judder may be due to the deformation of the disc, pressure plate or to the support of the clutch bearing being offset on the diaphragm spring, which means it must be dismantled and visually inspected.

The support marks of the thrust bearing on the diaphragm feet must be clear and centred on it, and of a thickness equivalent to or less than the front surface area of the bearing. Larger diameter marks are indicators of the incorrect movement of the thrust bearing due to deformation/wear of the guide collar, play in the bearing itself or defective transmission of force/movement by the fork.

As they are an integral part of the system, the integrity and correct condition of the various support or pivot points of the clutch fork, the guide collar and the bearing should be checked after disassembly. Sometimes, the flywheel incorporates a bearing for centring the primary shaft. A visual check should be performed to make sure that it is in good condition and operates smoothly.`

Actuating force

The force required for disengaging must also be checked. Due to ageing or frequent heating (steel), the diaphragm spring hardness may increase, which, although it does not cause the malfunctioning or slipping of the clutch, does require a greater disengaging force, and subjects the actuating mechanism to excess forces.

As a consequence, the wear of the support points is accelerated giving rise to play and maladjustment that can lead to operating problems and faults. In an extreme case, the hardening of the diaphragm can even cause a deformation and/or breakage of the clutch fork and recurrent faults in the hydraulic system or actuating cable.

REPAIR AND REPLACEMENT

Currently, the repair of the clutch system is limited to the replacement of the actuation system components or the clutch assembly due to wear or fault.

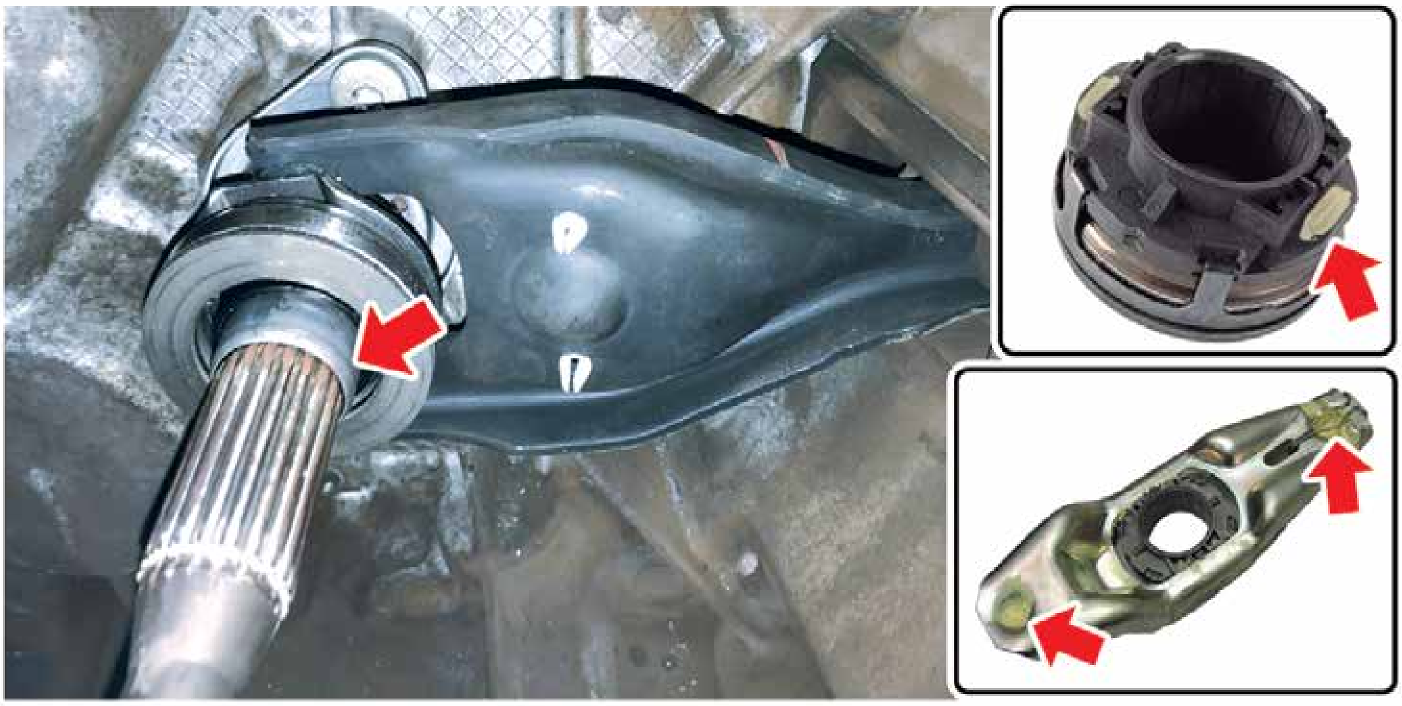
The replacement of the clutch disc linings, although possible, is not now cost-effective as its wear is limited and in line with the other clutch components under conditions of normal use. The surface of the pressure plate, the diaphragm spring and its support points or studs, the thrust bearing and even the flywheel itself, like the disc, show signs of wear. Therefore, in case of repair, it is advisable to replace the entire clutch assembly in order to guarantee the result.

Moreover, currently the supply of separate components is very limited and even non-existent, and spare parts manufacturers sell repair kits that include the disc, the pressure plate and the thrust bearing as one assembly and, in some cases, include the flywheel, clutch fork and/or slave cylinder.

Nevertheless, and even when replacing the whole clutch unit, special attention should be paid to the condition and wear and working marks of the various components during the disassembly process. The old parts are, in many cases, indicators of the causes of the faults and should therefore be inspected.

The condition and colouration of the friction surfaces are a clear indicator of heating/slipping of the clutch, and its cause should be determined. The presence of oil, whether it is from the engine or gearbox, or coolant must also be considered. Likewise, special attention should be paid to the wear of the support or pivot points, and the condition of the guide collar. If necessary, replace or repair.

Check the wear of the gearbox input shaft splines and that they match the clutch disc to be fitted. The new clutch disc must slide on the splines with no difficulty but without side play. Excessive wear and consequently free movement of the disc can cause vibration and noise when disengaging.



Properly clean and lubricate the support contact points on the fork, the fork on the thrust bearing, the bearing on the guide collar and the disc grooves. The specific grease usually supplied with the clutch kit is highly adhesive and moisture repellent. It is sufficient to distribute half the content of the packet on the shaft splines and the disc grooves. Move the disc along the shaft three or four times and remove the excess quantity. Distribute the remaining grease between the different contact points.

Generally, the clutch disc is asymmetrical between its faces, thus it has a correct assembly position. The assembly position is usually indicated on the disc during its manufacture in different languages depending on the manufacturer or country of manufacture, the attached table indicates the most common markings.

Gearbox side	**Flywheel side**
GB side	Fw Side
Getriebeseite	Schwungrad Seite
Trans side	Engine Side
PP	Motor Side
T/M Side	Cote Volant
Lato cambio	F/W

During assembly, the clutch disc must be fitted perfectly centred on the flywheel before tightening the pressure plate. In order to do this, the centring sleeve – in many cases supplied with the clutch kit – or a universal alignment device should be used.

The pressure plate must be tightened on the flywheel progressively, in a circle or crosswise, in several consecutive stages in order to prevent damage or deforming the disc or the pressure plate itself, and the tightening torques recommended by the manufacturer should be observed.

Special mention should be given to the fitting of self-adjusting pressure plates. Due to their operating characteristics, they should be fitted in a blocked mechanism/zero wear compensation position and with the disc free of pressure. Not doing so could damage the adjustment mechanism or cause the initial setting to be incorrect and, therefore, the malfunctioning of the clutch. For this reason, many manufacturers supply pressure plates blocked in the service position, and the blocking element must simply be removed after fitting the pressure plate on the flywheel.

In case of disassembling without replacement or fitting a new unblocked self-adjustable pressure plate, the specific tool must be used that is required for compressing the diaphragm spring to withdraw it and block the wear compensating mechanism.

TECHNICAL NOTES

This section describes the most common faults related to the transmission system, especially the flywheel and clutch. Depending on the manufacturer and the different models, the number of faults occurring over the years may vary.

These faults are selected from the online platform: www.einavts.com. This platform has a series of sections that specify: make, model, line, system affected, and subsystem, which can be selected independently depending on the desired search.

VW

VW POLO (6R_) 1.4 TDI (CUSA)	
Symptoms	Engine does not start intermittently. Rattling or knocking noise on starting. Rattling or knocking noise with the engine idling. Engine stops when the clutch pedal is pressed while moving at low speed. The vehicle displays one or several of the above symptoms. NOTE: This newsletter only affects those vehicles that are within a specific chassis number range.
Cause	Defect in the dual mass flywheel. Due to the consecutive stops and starts of the engine as a consequence of the Start & Stop system, strong vibrations occur due to resonance of the dual mass flywheel causing the free play angle of the flywheel to increase.
Solution	Repair procedure: • Confirm that one or more of the symptoms mentioned in the symptom field of this technical note occur. • Replace the dual mass flywheel with a single mass version. • Re-programme the engine control unit with updated software.

FORD

TRANSIT Van (FA_ _) 2.4 TDdi (D4FA), (FA_ _) 2.4 TDE (DOFA), (FA_ _) 2.4 TDE (FXFA); TRANSIT Bus (FD_ _, FB_ _, FS_ _, FZ_ _, FC_ 2.4 TDCi (H9FA), (FD_ _, FB_ _, FS_ _, FZ_ _, FC_ 2.4 TDdi (D2FE)	
Symptoms	Clutch disc wear smell inside the cabin. Proper operation of the gearbox clutch. The clutch may or may not slip.
Cause	Accumulation of dirt inside the gearbox due to wear in the clutch mechanism, as long as it is confirmed that the clutch is operating properly.
Solution	Repair procedure: • Check that the clutch is not slipping by conducting an excess weight check; for example with a trailer. • Thoroughly clean the inside of the housing and the gearbox clutch area if the check confirms that the clutch is not slipping. • If the clutch slips during the check: • Replace the clutch release bearing with a modified version. • Replace the dual mass flywheel with a modified version. • Replace the clutch disc assembly and the pressure plate with a modified version.

MERCEDES-BENZ

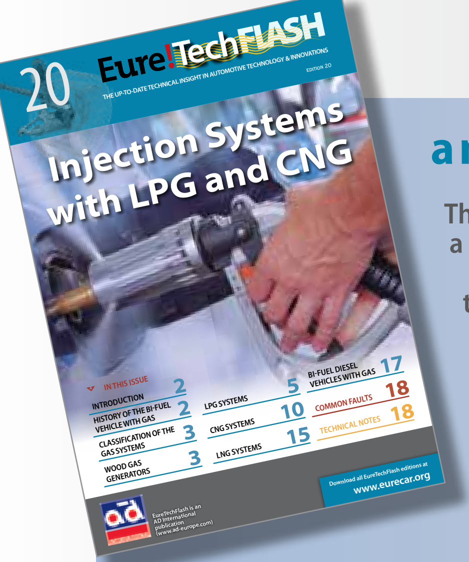
CLASS A (W168) A 140 (168.031; 168.131) (M 166.960), (W168) A 160 (168.033; 168.133) (M 166.960), (W168) A 160 CDI (168.006) (OM 668.940)	
Symptoms	Improper operation of the clutch. The clutch disc does not separate and/or gear changes are deficient. NOTE: This technical note only affects those vehicles that are within a specific chassis number range and are equipped with an automatic clutch system.
Cause	Defect in the clutch plate. This remains stuck due to the evaporation of the resin in the clutch disc material itself.
Solution	Replace the clutch mechanism with a new modified version.

SEAT

ALTEA (5P1), CORDOBA (6L2), LEON (1P1), TOLEDO III (5P2)	
Symptoms	Screeching noise in the gearbox area on pressing the clutch pedal. NOTE: This technical note only affects those vehicles within a specific chassis number range that are equipped with one of the following gearbox models: MQ200 (0AF, 02T) and MQ250 (0A4, 02S, 02R).
Cause	There is deterioration due to corrosion or premature wear on the support pivot of the clutch release lever and the clutch release lever itself.
Solution	Repair procedure: Replace the support pivot for the clutch release lever with a modified version. • Apply a lubricant to the new support pivot. • Replace the clutch release lever with a new version. • Lubricate the clutch system elements and the clutch pump.

PEUGEOT

PEUGEOT 1007 (KM_)	
Symptoms	The clutch slips when accelerating in any gear. NOTE: This newsletter only affects vehicles equipped with a manual gearbox.
Cause	Possible causes: • Defective clutch actuation system. • Defective clutch mechanism.
Solution	Repair procedure: • Check the condition of the clutch actuation system. • Replace the defective components of the clutch actuation system. • Conduct a clutch slip test using the hand brake and engaging a high gear and checking if the engine stalls. • Check the condition of the clutch mechanism if the engine does not stall during the previous test. • Replace the clutch mechanism with a new one. NOTE: Do not replace the flywheel when the clutch slips if overheating markings are present, consult with your normal repair centre.



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