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Кафедра иностранных языков по техническим специальностям

AUTOMOBILE

Suspension and Drive
Exhaust Flow
Servicing the Car

СБОРНИК ТЕСТОВ ПО ЧТЕНИЮ НА АНГЛИЙСКОМ ЯЗЫКЕ

для студентов специальности
1 – 37 01 06 «Техническая эксплуатация автомобилей»
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Сборник текстов по чтению на английском языке предназначается для студентов специальности 1 - 37 01 06 «Техническая эксплуатация автомобилей» заочной формы обучения.

Цель пособия – совершенствование навыков чтения и понимания аутентичной научно-технической литературы по изучаемой специальности, расширение вокабуляра специальной лексики, развитие умений восприятия и оценки получаемой информации.

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UNIT I. TYPES OF SUSPENSION AND DRIVE

1. General characteristics of wheel suspensions

The suspension of modern vehicles need to satisfy a number of requirements whose aims partly conflict because of different operating conditions loaded/unloaded, acceleration/braking, level/uneven road, straight running/cornering). The forces and moments that operate in the wheel contact area must be directed into the body. The kingpin offset and disturbing force lever arm in the case of the longitudinal forces, the castor offset in the case of the lateral forces, and the radial load moment arm in the case of the vertical forces are important elements whose effects interact as a result of, for example, the angle of the steering axis.

Sufficient vertical spring travel, possibly combined with the horizontal movement of the wheel away from an uneven area of the road (kinematic wheel) is required for reasons of ride comfort. The recession suspension should also be compliant for the purpose of reducing the rolling stiffness of the tyres and short-stroke movements in a longitudinal direction resulting from the road surface (longitudinal compliance), but without affecting the development of lateral wheel forces and hence steering precision, for which the most rigid wheel suspension is required. This requirement is undermined as a result of the necessary flexibility that results from disturbing wheel movements generated by longitudinal forces arising from driving and braking operations.

For the purpose of ensuring the optimum handling characteristics of the vehicle in a steady state as well as a transient state, the wheels must be in a defined position with respect to the road surface for the purpose of generating the necessary lateral forces. The build-up and size of the lateral wheel forces are determined by specific toe-in and camber changes of the wheels depending on the jounce and movement of the body as a result of the axle kinematics (roll steer) and operative forces (compliance steer). This makes it possible for specific operating conditions such as load and traction to be taken into consideration. By establishing the relevant geometry and kinematics of the axle, it is also possible to prevent the undesirable diving or lifting of the body during braking or accelerating and to ensure that the vehicle does not exhibit any tendency to over-steer and displays predictable transition behaviour for the driver.

Other requirements are:
• independent movement of each of the wheels on an axle (not guaranteed in the case of rigid axles);
• small, unsprung masses of the suspension in order to keep wheel load fluctuation as low as possible (important for driving safety);
• the introduction of wheel forces into the body in a manner favourable to the flow of forces;
• the necessary room and expenditure for construction purposes, bearing in mind the necessary tolerances with regard to geometry and stability;
• ease of use;
• behaviour with regard to the passive safety of passengers and other road users;
• costs.

The requirements with regard to the steerability of an axle and the possible transmission of driving torque essentially determine the design of the axis. Vehicle suspensions can be divided into rigid axles (with a rigid connection of the wheels to an axle), independent wheel suspensions in which the wheels are suspended independently of each other, and semi-rigid axles, a form of axle that combines the characteristics of rigid axles and independent wheel suspensions.

On all rigid axles, the axle beam casing also moves over the entire spring travel. Consequently, the space that has to be provided above this reduces the boot at the rear and makes it more difficult to house the spare wheel. At the front, the axle casing would be located under the engine, and to achieve sufficient jounce travel the engine would have to be raised or moved further back. For this reason, rigid front axles are found only on commercial vehicles and four-wheel drive, general-purpose passenger cars.

With regard to independent wheel suspensions, it should be noted that the design possibilities with regard to the satisfaction of the above requirements and the need to find a design which is suitable for the load paths, increase with the number of wheel control elements (links) with a corresponding increase in their planes of articulation. In particular, independent wheel suspensions include:
• longitudinal link and semi-trailing arm axles, which require hardly any overhead room and consequently permit a wide luggage space with a level floor, but which can have considerable diagonal springing;
• wheel controlling suspension and shock-absorber struts, which certainly occupy much space in terms of height, but which require little space at the side and in the middle of the vehicle (can be used for the engine or axle drive) and determine the steering angle (then also called McPherson suspension struts),
• double wishbone suspensions);
• multi-link suspensions, which can have up to five guide links per wheel and which offer the greatest design scope with regard to the geometric definition of the kingpin offset, pneumatic trail, kinematic behaviour with regard to toe-in, camber and track changes, braking/starting torque behaviour and elastokine-

matic properties. In the case of twist-beam axles, both sides of the wheels are connected by means of a flexurally rigid, but torsionally flexible beam. On the whole, these axles save a great deal of space and are cheap, but offer limited potential for the achievement of kinematic and elastokinematic balance because of the functional duality of the function in the components and require the existence of adequate clearance in the region of the connecting beam. They are mainly used as a form of rear wheel suspension in front-wheel drive vehicles up to the middle class and, occasionally, the upper middle class, for example, the Audi A6, and some high-capacity cars.

2. Independent wheel suspensions

2.1. Requirements

The chassis of a passenger car must be able to handle the engine power installed. Ever-improving acceleration, higher peak and cornering speeds, and deceleration lead to significantly increased requirements for safer chassis. Independent wheel suspensions follow this trend. Their main advantages are:

- little space requirement;
- a kinematic and/or elastokinematic toe-in change, tending towards understeering is possible;
- easier steerability with existing drive;
- low weight;
- no mutual wheel influence.

The last two characteristics are important for good road-holding, especially on bends with an uneven road surface. Transverse arms and trailing arms ensure the desired kinematic behaviour of the rebounding and jouncing wheels and also transfer the wheel loadings to the body. Lateral forces also generate a moment which, with unfavourable link arrangement, has the disadvantage of reinforcing the roll of the body during cornering. The suspension control arms require bushes that yield under load and can also influence the springing. This effect is either rein-forced by twisting the rubber parts in the bearing elements, or the friction increases due to the parts rubbing together, and the driving comfort decreases. The wheels incline with the body. The wheel on the outside of the bend, which has to absorb most of the lateral force, goes into a positive camber and the inner wheel into a negative camber, which reduces the lateral grip of the tyres. To avoid this, the kinematic change of camber needs to be adjusted to take account of this behaviour and the body roll in the bend should be kept as small as possible. This can be achieved with harder springs, additional anti-roll bars or a body roll centre located high up in the vehicle.

2.2. Double wishbone suspensions

The last two characteristics above are most easily achieved using a double wish-bone suspension. This consists of two transverse links (control arms) either side of the vehicle, which are mounted to rotate on the frame, suspension subframe or body and, in the case of the front axle, are connected on the outside to the steering knuckle or swivel heads via ball joints. The greater the effective distance c between the transverse links, the smaller the forces in the suspension control arms and their mountings become, i.e. component deformation is smaller and wheel control more precise.

The main advantages of the double wishbone suspension are its kinematic possibilities. The positions of the suspension control arms relative to one another – in other words the size of the angles ά and β – can determine both the height of the body roll centre and the pitch pole (angles ά and β). Moreover, the different wishbone lengths can influence the angle movements of the compressing and rebounding wheels, i.e. the change of camber and, irrespective of this, to a certain extent also the track width change. With shorter upper suspension control arms the compressing wheels go into negative camber and the rebounding wheels into positive. This counteracts the change of camber caused by the roll pitch of the body. The vehicle pitch pole O is located behind the wheels on the front axle and in front of the wheels on the rear axle. If O_r can be located over the wheel centre, it produces not only a better anti-dive mechanism, but also reduces the squat on the driven rear axles (or lift on the front axles). These are also the reasons why the double wishbone suspension is used as the rear axle on more and more passenger cars, irrespective of the type of drive, and why it is progressively replacing the semi-trailing link axle.

2.3. McPherson struts and strut dampers

The McPherson strut is a further development of double wishbone suspension. The upper transverse link is replaced by a pivot point on the wheel house panel, which takes the end of the piston rod and the coil spring. Forces from all directions are concentrated at this point and these cause bending stress in the piston rod. To avoid detrimental elastic camber and caster changes, the normal rod diameter of 11 mm (in the shock absorber) must be increased to at least 18 mm. With a piston diameter of usually 30 mm or 32 mm the damper works on the twin-tube system and can be non-pressurized or pressurized.

The main advantage of the McPherson strut is that all the parts providing the suspension and wheel control can be combined into one assembly. This includes:

- the spring seat to take the underside of the coil spring;
- the auxiliary spring or a bump stop;
- the rebound-travel stop;
- the underslung anti-roll bar;
- the steering knuckle. The steering knuckle can be welded, brazed or bolted firmly to the outer tube.

Further advantages are:

• lower forces in the body-side mounting points E and D due to a large effective distance c;
• short distance b between points G and N;
• long spring travel;
• three bearing positions no longer needed;
• better design options on the front crumple zone;
• space at the side permitting a wide engine compartment; which
• makes it easy to fit transverse engines.

Nowadays, design measures have ensured that the advantages are not outweighed by the inevitable disadvantages on the front axle. These disadvantages are:
• less favourable kinematic characteristics;
• introduction of forces and vibrations into the inner wheel house panel and therefore into a relatively elastic area of the front end of the vehicle;
• it is more difficult to insulate against road noise – an upper strut mount is necessary, which should be as decoupled as possible;
• the friction between piston rod and guide impairs the springing effect; it can be reduced by shortening distance b;
• in the case of high-mounted rack and pinion steering, long tie rods and, consequently, more expensive steering systems are required; in addition, there is the unfavourable introduction of tie-rod forces in the middle of the shock-absorbing strut plus additional steering elasticity;
• greater sensitivity of the front axle to tyre imbalance and radial run-out;
• greater clearance height requirement;
• sometimes the space between the tyres and the damping element is very limited. This final constraint, however, is only important on front-wheel drive vehicles as it may cause problems with fitting snow chains. On non-driven wheels, at most the lack of space prevents wider tyres being fitted. If such tyres are absolutely necessary, disc-type wheels with a smaller wheel offset e are needed and these lead to a detrimentally larger positive or smaller negative kingpin offset at vents wider tyres being fitted. If such tyres are absolutely necessary, disc-type wheels with a smaller wheel offset e are needed and these lead to a detrimentally larger positive or smaller negative kingpin offset at ground ro.

McPherson struts have become widely used as front axles, but they are also fitted as the rear suspension on front-wheel drive vehicles (e.g. Ford Mondeo sedan). The vehicle tail, which has been raised for aerodynamic reasons, allows a larger bearing span between the piston rod guide and piston. On the rear axle:
• the upper strut mount is no longer necessary, as no steering movements occur;
• longer cross-members, which reach almost to the vehicle centre, can be used, producing better camber and track width change and a body roll centre that sinks less under load;

• the outer points of the braces can be drawn a long way into the wheel to achieve a shorter distance b;
• the boot can be dropped and, in the case of damper struts, also widened;
• however, rubber stiffness and the corresponding distance of the braces on the hub carriers are needed to ensure that there is no unintentional elastic self-steer;

2.4. Rear axle trailing-arm suspension

This suspension – also known as a crank axle – consists of a control arm lying longitudinally in the driving direction and mounted to rotate on a suspension sub-frame or on the body on both sides of the vehicle. The control arm has to withstand forces in all directions, and is therefore highly subject to bending and torsional stress. Moreover, no camber and toe-in changes are caused by vertical and lateral forces.

The trailing-arm axle is relatively simple and is popular on front-wheel drive vehicles. It offers the advantage that the car body floor pan can be flat and the fuel tank and/or spare wheel can be positioned between the suspension control arms. If the pivot axes lie parallel to the floor, the bump and rebound-travel wheels undergo no track width, camber or toe-in change, and the wheel base simply shortens slightly. If torsion springs are applied, the length of the control arm can be used to influence the progressivity of the springing to achieve better vibration behaviour under load. The control arm pivots also provide the radius-arm axis O; i.e. during braking the tail end is drawn down at this point.

The tendency to oversteer as a result of the deformation of the link (arm) when subject to a lateral force, the roll centre at floor level, the extremely small possibility of a kinematic and elastokinematic effect on the position of the wheels and the inclination of the wheels during cornering consistent with the inclination of the body outwards (unwanted positive camber) are disadvantages.

2.5. Semi-trailing-arm rear axles

This is a special type of trailing-arm axle, which is fitted mainly in rear-wheel and four-wheel drive passenger cars, but which is also found on front-wheel drive vehicles. Seen from the top, the control arm axis of rotation EG is diagonally positioned at an angle $\alpha = 10°$ to $25°$, and from the rear an angle $\beta \leq 5°$ can still be achieved. When the wheels bump and rebound-travel they cause spatial movement, so the drive shafts need two joints per side with angular mobility and length compensation. The horizontal and vertical angles determine the roll steer properties.

When the control arm is a certain length, the following kinematic characteristics can be positively affected by angles α and β:

- height of the roll centre;
- position of the radius-arm axis;
- change of camber;
- toe-in change;

Camber and toe-in changes increase the bigger the angles α and β: semi-trailing axles have an elastokinematic tendency to oversteering.

2.6. Multi-link suspension

A form of multi-link suspension was first developed by Mercedes-Benz in 1982 for the 190 series. Driven and non-driven multi-link front and rear suspensions have since been used.

Up to five links are used to control wheel forces and torque depending on the geometry, kinematics, elastokinematics and force application of the axle. As the arrangement of links is almost a matter of choice depending on the amount of available space, there is extraordinarily wide scope for design. In addition to the known benefits of independent wheel suspensions, with the relevant configuration the front and rear systems also offer the following advantages:

- free and independent establishment of the kingpin offset, disturbing force and torque developed by the radial load.
- considerable opportunities for balancing the pitching movements of vehicles during braking and acceleration (up to more than 100% anti-dive, anti-lift and anti-squat possible).
- advantageous wheel control with regard to toe-in, camber and track width behaviour from the point of view of tyre force build-up, and tyre wear as a function of jounce with almost free definition of the roll centre and hence a very good possibility of balancing the self-steering properties.
- wide scope for design with regard to elastokinematic compensation from the point of view of (a) specific elastokinematic toe-in changes under lateral and longitudinal forces and (b) longitudinal elasticity with a view to riding comfort (high running wheel comfort) with accurate wheel control.

As a result of the more open design, the wheel forces can be optimally controlled, i.e. without superposition, and introduced into the bodywork in an advantageous way with wide distances between the supports. The disadvantages are:

- increased expenditure as a result of the high number of links and bearings;
- higher production and assembly costs;
- the possibility of kinematic overcorrection of the axle resulting in necessary deformation of the bearings during vertical or longitudinal movements;
- greater sensitivity to wear of the link bearings;
- high requirements with regard to the observation of tolerances relating to geometry and rigidity.

3. Rigid and semi-rigid crank axles

3.1. Rigid axles

Rigid axles can have a whole series of disadvantages that are a consideration in passenger cars, but which can be accepted in commercial vehicles:

- mutual wheel influence.
- the space requirement above the beam corresponding to the spring bump travel.
- limited potential for kinematic and elastokinematic fine-tuning.
- weight – if the differential is located in the axle casing, it produces a tendency for wheel hop to occur on bumpy roads.
- the wheel load changes during traction and (particularly on twin tyres) there is a poor support base b_{Sp} for the body, which can only be improved following costly design work.

The effective distance b_{Sp} of the springs is generally less than the tracking width b_r, so the projected spring rate c_φ is lower. The springs, and/or suspension dampers, for this reason should be mounted as far apart as possible.

The centrifugal force acting on the body's centre of gravity during cornering increases the roll pitch where there is a rigid axle.

Thanks to highly developed suspension parts and the appropriate design of the springing and damping, it has been possible to improve the behaviour of rigid drive axles. Nevertheless, they are no longer found in standard-design passenger cars, but only on four-wheel drive and special all-terrain vehicles.

Because of its weight, the driven rigid axle is outperformed on uneven roads (and especially on bends) by independent wheel suspension, although the deficiency in road-holding can be partly overcome with pressurized monotube dampers. These are more expensive, but on the compressive stroke, the valve characteristic can be set to be harder without a perceptible loss of comfort. With this, a responsive damping force is already opposing the compressing wheels. This is the simplest and perhaps the most economic way of overcoming the main disadvantage of rigid axles.

In contrast to standard-design vehicles, the use of the rigid rear axle in front-wheel drive vehicles has advantages rather than disadvantages. The rigid rear axle weighs no more than a comparable independent wheel suspension and also gives the option of raising the body roll centre. Further advantages, including those for driven axles, are:

- they are simple and economical to manufacture;
- there are no changes to track width, toe-in and camber on full bump/rebound-travel, thus giving
- low tyre wear and sure-footed road holding;
- there is no change to wheel camber when the body rolls during cornering,therefore there is constant lateral force transmission of tyres;
- the absorption of lateral force moment $M_y = F_{tx}\, h_{ro,r}$ by a transverse link, which can be placed at almost any height;

• optimal force transfer due to large spring track width bsp
• the lateral force compliance steering can be tuned towards under- or over-steering.

There are many options for attaching a rigid axle rear suspension beneath the body or chassis frame. Longitudinal leaf springs are often used as a single suspension control arm, which is both supporting and springing at the same time, as these can absorb forces in all three directions as well as drive-off and braking moments. This economical type of rear suspension also has the advantage that the load area on lorries and the body of passenger cars can be supported in two places at the back: at the level of the rear seat and under the boot. This reduces the stress on the rear end of the car body when the boot is heavily laden, and also the stress on the lorry frame under full load.

The longitudinal leaf springs can be fitted inclined, with the advantage that during cornering the rigid rear axle (viewed from above) is at a small angle to the vehicle longitudinal axis. To be precise, the side of the wheel base on the outside of the bend shortens somewhat, while the side on the inside of the bend lengthens by the same amount. The rear axle steers into the bend and, in other words, it is forced to self-steer towards 'roll-understeering'. This measure can, of course, have an adverse effect when the vehicle is travelling on bad roads, but it does prevent the standard passenger car's tendency to oversteer when cornering. Even driven rigid axles exhibit – more or less irrespective of the type of suspension – a tendency towards the load alteration (torque steering) effect, but not to the same extent as semi-trailing link suspensions.

On front-wheel drive vehicles, the wheels of the trailing axle can take on a negative camber. This improves the lateral grip somewhat, but does not promote perfect tyre wear. This is also possible on the compound crank suspension (a suspension-type halfway between a rigid axle and independent wheel suspension) which, up to now, has been fitted only on front-wheel drive vehicles.

3.2. Semi-rigid crank axles

The compound crank suspension could be described as the new rear axle design of the 1970s and it is still used in today's small and medium-sized front-wheel drive vehicles. It consists of two trailing arms that are welded to a twistable cross-member and fixed to the body via trailing links. This member absorbs all vertical and lateral force moments and, because of its offset to the wheel centre, must be less torsionally stiff and function simultaneously as an anti-roll bar. The axle has numerous advantages and is therefore found on a number of passenger cars which have come onto the market. From an installation point of view:
• the whole axle is easy to assemble and dismantle;
• it needs little space;
• a spring damper unit or the shock absorber and springs are easy to fit;

• no need for any control arms and rods; and thus
• only few components to handle.

From a suspension point of view:

• there is a favourable wheel to spring damper ratio;
• there are only two bearing points O_l and O_{rs}, which hardly affect the springing
• low weight of the unsprung masses; and
• the cross-member can also function as an anti-roll bar.

From a kinematic point of view:

• there is negligible toe-in and track width change on reciprocal and parallel springing;
• there is a low change of camber under lateral forces;
• there is low load-dependent body roll understeering of the whole axle; and
• good radius-arm axis locations O_l and O_{rs}, which reduce tail-lift during braking.

The disadvantages are:

• a tendency to lateral force oversteer due to control arm deformation;
• torsion and shear stress in the cross-member;
• high stress in the weld seams; which means
• the permissible rear axle load is limited in terms of strength;
• the limited kinematic and elastokinematic opportunities for determining the wheel position;
• the establishment of the position of the instantaneous centre by means of the axle kinematics and rigidity of the twist-beam axle;
• the mutual effect on the wheel;
• the difficult decoupling of the vibration and noise caused by the road surface;
• the considerable need for stability of the bodywork in the region of those points on the front bearings at which complex, superposed forces have to be transmitted.

4. Front-mounted engine, rear-mounted drive

In passenger cars and estate cars, the engine is approximately in the centre of the front axle and the rear wheels are driven. To put more weight on the rear axle and obtain a more balanced weight distribution, Alfa Romeo, Porsche (928, 968 models) and Volvo integrated the manual transmission with the differential. This is also the case with the Chevrolet Corvette sports car). With the exception of light commercial vehicles, all lorries have the engine at the front or centrally between the front and rear axles together with rear-wheel drive vehicles. The long load area gives hardly any other option. Articulated lorries, where a major part of the trailer weight – the trailer hitch load – is carried over the rear wheels, have the same configuration. On buses, however, the passengers are spread evenly throughout the whole interior of the vehicle, which is why there are models with front, central and rear engines.

4.1. Advantages and disadvantages of the front-mounted engine, rear-mounted drive design

The standard design has a series of advantages on passenger cars and estate cars:

•there is hardly any restriction on engine length, making it particularly suitable for more powerful vehicles (in other words for engines with 8–12 cylinders).

• there is low load on the engine mounting, as only the maximum engine torque times the conversion of the lowest gear without differential transmission has to be absorbed;

• insulation of engine noise is relatively easy;

• under full load most of the vehicle mass is on the driven rear axle (important for estate cars and trailers;

• a long exhaust system with good silencing and catalytic converter configuration.

• good front crumple zone, together with the 'submarining' power plant unit, i.e. one that goes underneath the floor panel during frontal collision;

• simple and varied front axle designs are possible irrespective of drive forces;

• more even tyre wear thanks to function distribution of steering/drive;

• uncomplicated gear shift mechanism;

• optimum gearbox efficiency in direct gear because no force-transmitting bevel gear is in action;

• sufficient space for housing the steering system in the case of a recirculating ball steering gear;

• good cooling because the engine and radiator are at the front; a power-saving fan can be fitted;

• effective heating due to short hot-air and water paths.

The following disadvantages mean that, in recent years, only a few saloon cars under 2 l engine displacement have been launched internationally using this design, and performance cars also featured the front-mounted design:

• unstable straight-running ability, which can be fully corrected by special front suspension geometry settings, appropriate rear axle design and suitable tyres;

• the driven rear axle is slightly loaded when there are only two persons in the vehicle, leading to poor traction behaviour in wet and wintry road conditions – linked to the risk of the rear wheels spinning, particularly when tight bends are being negotiated at speed. This can be improved by setting the unladen axle load distribution at 50%/50% which, however, is not always possible. It can be prevented by means of drive-slip control.

• a tendency towards the torque steer effect and, therefore,

• complex rear independent wheel suspension with chassis subframe, differential gear case and axle drive causing;

• restrictions in boot size;
• the need for a propshaft between the manual gearbox and differential and, therefore
• a tunnel in the floor pan is inevitable, plus an unfavourable interior to vehicle – length ratio.

4.2. Non-driven front axles

The standard design for passenger cars that have come onto the market in recent years have McPherson struts on the front axle, as well as double wish-bone or multi-link suspensions. The latter type of suspension is becoming more and more popular because of its low friction levels and kinematic advantages. Even some light commercial vehicles have McPherson struts or double wishbone axles. However, like almost all medium-sized and heavy commercial vehicles, most have rigid front axles. In order to be able to situate the engine lower, the axle subframe has to be offset downwards.

The front wheels are steerable; to control the steering knuckle on double wishbone suspensions, there are two ball joints that allow mobility in all directions, defined by full bump/rebound-travel of the wheels and the steering angle. The wishbone, which accepts the spring, must be carried on a supporting joint in order to be able to transmit the vertical forces. A regular ball joint transferring longitudinal and lateral forces is generally sufficient for the second suspension control arm. The greater the distance between the two joint points, the lower the forces in the components. The base on McPherson struts is better because it is even longer.

The coil spring is offset at an angle to reduce the friction between piston rod and the rod guide. The lower guiding joint performs the same function as on double wishbones, whereas point E is fixed in the shock tower, which is welded to the wheel house panel. As the wheels reach full bump, piston rod moves in the cylinder tube (which sits in the carrier or outer tube) and when there is a steering angle the rod and spring turn in an upper strut mount, which insulates noise, and is located at point E.

Wheel controlling damper struts do not require such a complex mount. The piston rod turns easily in the damping cylinder. Only the rod needs noise insulation. The coil spring sits separately on the lower control arm, which must be joined to the steering knuckle via a supporting joint. The damper is lighter than a shock-absorbing strut and allows a greater bearing span across the damping cylinder, permits a wider, flatter engine compartment (which is more streamlined) and is easier to repair. However, it is likely to be more costly and offsetting the spring from the damper may cause slip-stick problems with a loss of ride comfort.

In the case of front-wheel drive vehicles, there may be a problem in the lack of space between the spring and the drive axle.

4.3. Driven rear axles

Because of their cost advantages, robustness and ease of repair rigid axles are fitted in practically all commercial and off-road vehicles in combination with leaf springs, coil springs or air springing. They are no longer found in saloons and coupes. In spite of the advantages the weight of the axle is noticeable on this type of vehicle.

For independent suspension, the semi-trailing arm axle is used as independent wheel suspension in passenger and light commercial vehicles. This suspension has a chassis subframe to which the differential is either fixed or, to a limited degree, elastically joined to give additional noise and vibration insulation. The springs sit on the suspension control arms. This gives a flat, more spacious boot, but with the disadvantage that the forces in all components become higher.

Because of its ride and handling advantages, more and more passenger cars have double wishbone suspension rear axles or so-called multi-link axles.

Most independent wheel suspensions have an easy-to-assemble chassis subframe for better wheel control and noise insulation. However, all configurations (regardless of the design) require drive shafts with length compensation. This is carried out by the sliding CV (constant velocity) joints fitted both at the wheel and the differential.

5. Rear and mid-engine drive

The rear-mounted power plant consists of the engine and the differential and manual gearbox in one assembly unit, and it drives the rear wheels. The power plant can sit behind the axle (rear-mounted engine) or in front of it (central engine). This configuration makes it impossible to have a rear seat as the engine occupies this space. The resulting two-seater is only suitable as a sports or rally car.

The disadvantages of rear and central engine drive on passenger cars are:

- moderate straight running abilities (caster offset at ground angles of up to 8° are factory set);
- sensitivity to side winds;
- indifferent cornering behaviour at the stability limit (central engine);
- oversteering behaviour on bends (rear-mounted engine);
- difficult to steer on ice because of low weight on the front wheels;
- uneven tyre wear front to rear (high rear axle load);
- the engine mounting must absorb the engine moment times the total gear ratio;
- the exhaust system is difficult to design because of short paths;
- the engine noise suppression is problematic;
- complex gear shift mechanism;
- long water paths with front radiators,

• high radiator performance requirement because of forced air cooling, the electric fan can only be used on the front radiator; the heating system has long paths for hot water or warm air;
• the fuel tank is difficult to house in safe zones;
• the boot size is very limited.

In the case of vehicles with a short wheel base and high centre of gravity with the engine on or behind the rear axle, there is a danger that the vehicle will over-turn if it is rolling backwards down a steep slope and the parking brake, which acts upon the rear axle, is suddenly applied. As a result of the logical further development of the kinematics and elastokinematics of the axles, Porsche have succeeded in improving straight running as well as cornering in the steady state (vehicles now understeer slightly up to high lateral accelerations) and transient state as well as when subject to torque steer effects. Even in the case of the Boxsters (with mid-engine, since 1996) and 911 (water-cooled since 1997), Porsche are adhering to rear-wheel drive (whereas the VW Transporter has not been built since 1991) and, in so doing, obtain the following benefits:
• very agile handling properties as a result of the small yawing moment;
• very good drive-off and climbing capacity, almost irrespective of load;
• a short power flow because the engine, gearbox and differential form one compact unit;
• light steering due to low front axle load;
• good braking force distribution;
• simple front axle design;
• easy engine dismantling (only on rear engine);
• no tunnel or only a small tunnel in the floor pan;
• a small overhang to the front is possible.

6. Front-wheel drive

The engine, differential and gearbox form one unit, which can sit in front of, over, or behind the front axle. The design is very compact and, unlike the standard design, means that the vehicle can either be around 100 – 300 mm shorter, or the space for passengers and luggage can be larger. These are probably the main reasons why, worldwide, more and more car manufacturers have gone over to this design. In recent years only a few saloons of up to 2 l capacity without front-wheel drive have come onto the market. Nowadays, front-wheel drive vehicles are manufactured with V6 and V8 engines and performances in excess of 150 kW.

However, this type of drive is not suitable for commercial vehicles as the rear wheels are highly loaded and the front wheels only slightly. Nevertheless, some light commercial vehicle manufacturers accept this disadvantage so they can lower the load area and offer more space or better loading conditions. The propshafts necessary on standard passenger cars would not allow this.

6.1. Engine mounted longitudinally 'North–South' in front of the axle

In-line or V engines mounted in front of the axle – regardless of the wheelbase – give a high front axle load, whereby the vehicle centre of gravity is pushed a long way forwards. Good handling in side winds and good traction, especially in the winter, confirm the merits of a high front axle load, whereas the heavy steering from standing (which can be rectified by power-assisted steering), distinct understeering during cornering and poor braking force distribution would be evidence against it.

This type of design, as opposed to transverse mounting, is preferred in the larger saloons as it allows for relatively large in-line engines. The first vehicles of this type were the Audi 80 and 100. Inclining the in-line engine and placing the radiator beside it means the front overhang length can be reduced. Automatic gearboxes need more space because of the torque converter. This space is readily available with a longitudinally mounted engine.

A disadvantage of longitudinal engines is the unfavourable position of the steering gear: this should be situated over the gearbox. Depending on the axle design, this results in long tie rods with spring strut (McPherson) front axles.

6.2. Transverse engine mounted in front of the axle

In spite of the advantage of the short front overhang, only limited space is available between the front wheel housings. This restriction means that engines larger than an in-line four cylinder or V6 cannot be fitted in a medium-sized passenger car. Transverse, asymmetric mounting of the engine and gearbox may also cause some performance problems. The unequal length of the drive shafts affects the steering. During acceleration the vehicle rises and the drive shafts take on different angular positions, causing uneven moments around the steering axes. The difference between these moments to the left and to the right causes unintentional steering movements resulting in a noticeable pull to one side; drive shafts of equal length are therefore desirable. This also prevents different drilling angles in the drive shaft causing timing differences in drive torque build-up.

The large articulation angle of the short axle shaft can also limit the spring travel of the wheel. To eliminate the adverse effect of unequal length shafts, passenger cars with more powerful engines have an additional bearing next to the engine and an intermediate shaft, the ends of which take one of the two sliding CV joints with angular mobility. Moreover, 'flexing vibration' of the long drive shaft can occur in the main driving range. Its natural frequency can be shifted by clamping on a suppression weight.

6.3. Advantages and disadvantages of front-wheel drive

Regardless of the engine position, front-wheel drive has numerous advantages:

- there is load on the steered and driven wheels;
- good road-holding, especially on wet roads and in wintry conditions – the car is pulled and not pushed;
- good drive-off and sufficient climbing capacity with only few people in the vehicle;
- tendency to understeer in cornering;
- insensitive to side wind;
- although the front axle is loaded due to the weight of the drive unit, the steering is not necessarily heavier (in comparison with standard cars) during driving;
- axle adjustment values are required only to a limited degree for steering alignment;
- simple rear axle design (e.g. compound crank or rigid axles – possible);
- long wheelbase making high ride comfort possible;
- short power flow because the engine, gearbox and differential form a compact unit;
- good engine cooling (radiator in front), and an electric fan can be fitted;
- effective heating due to short paths;
- smooth car floor pan;
- exhaust system with long path (important on cars with catalytic converters);
- a large boot with a favourable crumple zone for rear end crash.

The disadvantages are:

- under full load, poorer drive-off capacity on wet and icy roads and on inclines;
- with powerful engines, increasing influence on steering;
- engine length limited by available space;
- with high front axle load, high steering ratio or power steering is necessary;
- with high located, dash-panel mounted rack and pinion steering, centre take-off tie rods become necessary or significant kinematic toe-in change practically inevitable;
- geometrical difficult project definition of a favourable interference force lever arm and a favourable steering roll radius (scrub radius);
- engine gearbox unit renders more difficult the arrangement of the steering package;
- the power plant mounting has to absorb the engine moment times the total gear ratio;
- it is difficult to design the power plant mounting – booming noises, resonant frequencies in conjunction with the suspension, tip in and let off torque effects etc., need to be suppressed;
- with soft mountings, wavy road surfaces excite the power plant to natural frequency oscillation (so-called 'front end shake');

• there is bending stress on the exhaust system from the power plant movements during drive-off and braking (with the engine);
• there is a complex front axle, so inner drive shafts need a sliding CV joint;
• the turning and track circle is restricted due to the limited bending angle (up to 50°) of the drive joints;
• high sensitivity in the case of tyre imbalance and non-uniformity on the front wheels;
• higher tyre wear in front, because the highly loaded front wheels are both steered and driven;
•poor braking force distribution (about 75% to the front and 25% to the rear);
• complex gear shift mechanism which can also be influenced by power plant movements.

The disadvantage of the decreased climbing performance on wet roads and those with packed snow can be compensated with a drive slip control (ASR) or by shifting the weight to the front axle. On the XM models, Citroen moved the rear axle a long way to the rear resulting in an axle load distribution of about 65% to the front and 35% to the back. The greater the load on the front wheels, the more the car tends to understeer, causing adverse steering angles and heavy steering, which makes power steering mandatory.

6.4. Driven front axles

The following are fitted as front axles on passenger cars, estate cars and light commercial vehicles:
• double wishbone suspensions;
• multi-link axles;
• McPherson struts, and (only in very few cases);
• damper struts.

On double wishbone suspensions the drive shafts require free passage in those places where the coil springs are normally located on the lower suspension. This means that the springs must be placed higher up with the disadvantage that (as on McPherson struts) vertical forces are introduced a long way up on the wheel house panel. It is better to leave the springs on the lower suspension control arms and to attach these to the stiffer body area where the upper control arms are fixed. Shock absorbers and springs can be positioned behind the drive shafts or sit on split braces, which grip round the shafts and are jointed to the lower suspension control arms. The axle is flatter and the front end (bonnet contour) can be positioned further down. The upper suspension control arms are relatively short and have mountings that are wide apart. This increases the width of the engine compartment and the spring shock absorber unit can also be taken through the suspension control arms; however, sufficient clearance to the axle shaft is a prerequisite. Due to the slight track width change, the change of camber becomes favourable. Furthermore, the inclination of the control arms provides an advantageous radius arm axis position and anti-dive when braking.

Most front-wheel drives coming on to the market today have McPherson struts. It was a long time after their use in standard design cars that McPherson struts were used at the front axle on front-wheel drive vehicles. The drive shaft requires passage under the damping part. This can lead to a shortening of the effective distance $\ell - o$, which is important for the axle, with the result that larger transverse forces $F_{Y,C}$ and $F_{Y,K}$ occur on the piston and rod guide and therefore increase friction.

On front-wheel drive vehicles there is little space available to fit rack and pinion steering. If the vehicle has spring dampers or damper struts, and if the steering gear is housed with short outer take-off tie rods, a toe-in change is almost inevitable. A high steering system can readily be attached to the dash panel, but a centre take-off is then necessary and the steering system becomes more expensive. Moreover, the steering force applied to the strut is approximately halfway between mountings E and G. The inevitable, greater yield in the transverse direction increases the steering loss angle and makes the steering less responsive and imprecise.

6.5. Non-driven rear axles

If rear axles are not driven, use can frequently be made of more simple designs of suspension such as twist-beam or rigid.

6.5.1. Twist-beam suspension

There are only two load paths available on each side of the wheel in the case of twist-beam axles. As a result of their design (superposed forces in the links, only two load paths), they suffer as a result of the conflicting aims of longitudinal springing – which is necessary for reasons of comfort – and high axle rigidity – which is required for reasons of driving precision and stability. This is particularly noticeable with the loss of comfort resulting from bumpy road surfaces. If the guide bearings of the axle are pivoted, the superposition of longitudinal and lateral forces should particularly be taken into consideration. As a result of the design, twist-beam suspensions exhibit unwanted oversteer when subject to lateral forces as a result of deformation of the swinging arms. In order to reduce the tendency to oversteer, large guide bearings which, as 'toe-in correcting' bearings, permit lateral movements of the whole axle body towards understeer when subject to a lateral force are provided. As the introduction of longitudinal and lateral forces into the body solely occurs by means of the guide bearings, it must be ensured that the structure of the bodywork is very rigid in these places.

6.5.2. Rigid axle

Non-driven rigid axles can be lighter than comparable independent wheel suspensions. Their advantages outweigh the disadvantages because of the almost non-variable track and camber values during drive. An inexpensive yet effective design can be described in the following way:
• axle casing in steel tubing;
• suspension on single leaf springs.

The lateral and longitudinal wheel control characteristics are sufficient for passenger cars in the medium to small vehicle range and delivery vehicles. The Resultant hard springing is acceptable and may even be necessary because of the load to be moved. The wheel bearing can be simple on such axles. Faster, more comfortable vehicles, on the other hand, require coil springs and, for precise axle control, trailing links and a good central guide or Panhard rod. This is generally positioned behind the axle.

6.5.3. Independent wheel suspension

An independent wheel suspension is not necessarily better than a rigid axle in terms of handling properties. The wheels may incline with the body and the lateral grip characteristics of the tyres decrease, and there are hardly any advantages in terms of weight. This suspension usually needs just as much space as a compound crank axle.

Among the various types, McPherson struts, semi-trailing or trailing link axles and – having grown in popularity for some years now – double wishbone suspensions, mostly as so-called multi-link axles are all used. The latter are currently the best solution, due to:
• kinematic characteristics;
• elastokinematic behaviour;
• space requirements;
• axle weight;
• the possibility of being able to retrofit the differential on four-wheel drive

7. Four-wheel drive

In four-wheel drives, either all the wheels of a passenger car or commercial vehicle are continuously – in other words permanently – driven, or one of the two axles is always linked to the engine and the other can be selected manually or automatically. This is made possible by what is known as the 'centre differential lock'. If a middle differential is used to distribute the driving torque between the front and rear axles, the torque distribution can be established on the basis of the axle–load ratios, the design philosophy of the vehicle and the desired handling characteristics. That is why Audi choose a 50%:50% distribution for the V8 Quattro and Mercedes-Benz choose a 50%:50% distribution for M class off-road vehicles, whereas Mercedes-Benz transmits only 35% of the torque to the front axle and as much as

65% to the rear axle in vehicles belonging to the E class. This section deals with the most current four-wheel drive designs. In spite of the advantages of four-wheel drive, suitable tyres should be fitted in winter.

7.1. Advantages and disadvantages

In summary, the advantages of passenger cars with permanent four-wheel drive over those with only one driven axle are the following:

- better traction on surfaces in all road conditions, especially in wet and wintry weather;
- an increase in the drive-off and climbing capacity regardless of load;
- better acceleration in low gear, especially with high engine performance;
- reduced sensitivity to side wind;
- stability reserves when driving on slush and compacted snow tracks;
- better aquaplaning behaviour;
- particularly suitable for towing trailers;
- balanced axle load distribution;
- reduced torque steer effect;
- even tyre wear.

According to EU Directive 70/156/EWG, a 'towed trailer load' of 1.5 times the permissible total weight has been possible for multi-purpose passenger vehicles (four-wheel passenger vehicles) since 1994. However, the system-dependent, obvious disadvantages given below should not be ignored:

- acquisition costs;
- around 6% to 10% higher kerb weight of the vehicle;
- generally somewhat lower maximum speed;
- 5% to 10% increased fuel consumption;
- in some systems, limited or no opportunity for using controlled brake gearing, for instance for anti-locking or ESP systems;
- not always clear comering behaviour;
- smaller boot compared with front-wheel drive vehicles.

Predictability of self-steering properties even in variable driving situations, traction, toe-in stability and deceleration behaviour when braking, manoeuvrability, behaviour when reversing and interaction with wheel control systems are the principal characteristics of the vehicle movement dynamics which are taken into consideration for an assessment of four-wheel drive systems.

To transmit the available engine torque to all four wheels, interaxle differentials (such as cone, planet or Torsen differentials), which are manually or automatically lockable, or clutches (such as sprag, multi-disc or visco clutches) must be installed on the propshaft between the front and rear axles. Differentials must be present on both drive axles. However, on roads with different coefficients of friction on the left and right wheels, known as μ-split', and with traditional diferentials, each driven axle can, at most, transmit double the propulsion force of the wheels running on the side with the lower coefficient of friction (μ-low).

Higher driving forces can be achieved with an 'axle differential lock' or controlled wheel brake gearing which creates the need for 'artificial' torque on the spinning wheel. Differential-locking can only be 100% effective on the rear axle as, at the front, there would no longer be problem-free steering control. The lock partially or completely stops equalization of the number of revolutions between the left and right wheel of the respective axle and prevents wheelspin on the µ-low-side.

In passenger cars, automatic locking differentials are used between front and rear axles. These can operate mechanically (multi-disc limited slip differentials, Torsen differential or based on fluid friction (visco lock) and produce a locking degree of usually 25% to 40%. Higher values severely impede cornering due to the tensions in the power train. Nevertheless, up to 80% locking action can be found in motor sport.

The locking action of uncontrolled or slip-dependent differential locks necessitates increased expenditure with the use of brake-power control systems (ABS, ESP). Thus in the case of the visco lock, a free-wheel clutch is required that is engaged during reversing. Here the advantage of controlled differentials (Haldex clutch, automatically controlled locking differential) becomes apparent: They can be used to maximum effect in any operating conditions and with any brake-power control system, because the locking action is produced by an electronically controlled, hydraulically activated multi-disc clutch.

Traditional differential locks are increasingly being replaced because of the use of wheel control systems in both front- and rear-wheel drive as well as four-wheel drive vehicles. In these systems, the wheel speed is measured, usually with the use of ABS sensors. If the speed of a wheel is established, this wheel is retarded by means of the wheel braking device. In the case of the differential, this corresponds to the build-up of torque on the side of the spinning wheel and it can now transmit torque at the higher coefficient of friction up to the adhesion limit of the wheel. Volkswagen AG calls this system electronic differential lock, as front-wheel drive forces which correspond to those of a driven axle with differential lock and 100% locking action, and which can even be exceeded in intelligent (slip-controlled) systems, such wheel gearing systems produce. The system can ensure that the driving torque that is to be applied to the side with the retarded wheel is equal to the torque on the side with the higher coefficient of friction. This 'lost torque' must be generated by the transmission, on the one hand, and retarded by the wheel brake, on the other, so that loss of engine power and heating of the wheel brakes are produced. The braking temperatures are calculated on the basis of the braking torque and period of application of the brakes. If the temperatures calculated exceed the permissible limits, application of the brakes is discontinued during the front-wheel drive phase until a calculated cooling of the system has taken place; the transmission then corresponds to that found in a conventional vehicle.

Another possibility for maximum utilization of grip is afforded by traction control systems in which engine power is reduced by means of the throttle, injection and ignition point so that the spinning wheels work in the region of lower slip and consequently higher adhesion. Both systems are used together, even without four-wheel drive. In models of the E and M class with an electronic traction system (ETS), Mercedes-Benz uses electronic locks instead of mechanical differential locks.

7.2. Four-wheel drive vehicles with overdrive

In four-wheel drive vehicles with overdrive the middle differential is not used. The engine torque is distributed to all four wheels by means of a clutch on the propshaft, as required. The clutch can be engaged manually, or automatically in response to slip. With the use of sprag clutches, which are usually engaged manually, the torque is transmitted in a fixed ratio between the front and rear axles; multi-disc or visco clutches permit variable torque distribution. As these systems have essential similarities with permanent four-wheel drive varieties.

With sprag-clutch engaged transmissions, the design complexity, and there-fore the costs, are lower than on permanent drive. Usually there is no rear axle differential lock, which is important on extremely slippery roads; while this results in price and weight advantages, it does lead to disadvantages in the traction.

Front-wheel drive is suitable as a basic version and the longitudinal engine has advantages here. With the transverse engine, the force from the manual gearbox is transmitted via a bevel gear and a divided propshaft, to the rear axle with a differential. There is relatively little additional complexity compared with the front-wheel drive design, even if, on the Fiat Panda (Trecking 4 x 4), there is a weight increase of about 11% (90 kg), not least because of the heavy, driven, rigid axle. It is possible to select rear-wheel drive during a journey using a shift lever that is attached to the prop-shaft tunnel.

Manual selection on the Subaru Justy operates pneumatically at the touch of a button (even while travelling). This vehicle has independent rear-wheel suspension and weighs only 6% more than the basic vehicle with front-wheel drive. Traction is always improved considerably if the driver recognizes the need in time and switches the engine force onto all four wheels. In critical situations, this usually happens too late, and the abrupt change in drive behaviour becomes an additional disadvantage.

Conversely, if the driver forgets to switch to single axle drive on a dry road, tensions occur in the power train during cornering, as the front wheels travel larger arcs than the back ones. The tighter the bend, the greater the stress on the power train and the greater the tendency to unwanted tyre slip.

A further problem is the braking stability of these vehicles. If the front axle locks on a wet or wintry road during braking, the rear one is taken with it due to the rigid power train. All four wheels lock simultaneously and the car goes into an uncontrollable skid.

7.3. Manual selection four-wheel drive on commercial and all-terrain vehicles

The basis for this type of vehicle is the standard design which, because of the larger ground clearance necessary in off-road vehicles, has more space available between the engine and front axle differential and between the cargo area and the rear axle. The design details for this type of vehicle are:

- a central power take-off gear with manual selection for the front axle, plus a larger ratio off-road gear, which can be engaged if desired;
- three propshafts;
- complex accommodation of the drive joints if there is a rigid front axle.

7.4. Permanent four-wheel drive; basic passenger car with front-wheel drive

All four wheels are constantly driven; this can be achieved between the front and rear axle with different design principles:

- a bevel centre differential with or without manual lock selection;
- a Torsen centre differential with moment distribution, based on the traction requirement;
- a planet gear central differential with fixed moment distribution and additional visco clutch, which automatically takes over the locking function when a difference in the number of revolutions occurs or a magnetic clutch (which is electronically controlled;
- electronically controlled multi-disc clutches (Haldex clutch);
- a visco clutch in the propshaft power train, which selects the initially undriven axle depending on the tyre slip.

Here too, the front-wheel drive passenger car is suitable as a basic vehicle. In 1979, Audi was the first company to bring out a car with permanent four-wheel drive, the Quattro, and today vehicles with this type of drive are available throughout the entire Audi range. On a longitudinally mounted engine, a Torsen centre differential distributes the moment according to the traction requirement. The four-wheel drive increases the weight by around 100 kg.

VW used a visco clutch in the power train (without centre differential) for the first time on the Transporter and then subsequently used it in the Golf syncro. The clutch has the advantage of the engine moment distribution being dependent on the tyre slip. If the slip on the front wheels, which are otherwise driven at the higher moment, increases on a wet or frozen surface or off-road, more drive is applied to the rear wheels. No action on the part of the driver is either necessary or possible. The transverse engine makes a bevel gear in front of the split propshaft necessary. The visco clutch sits in the rear differential casing and there is also an overrunning clutch, which ensures that the rear wheels are automatically disengaged from the drive, on overrun, to guarantee proper braking behaviour. This type of drive is fully ABS compatible. When reverse is engaged, a sliding sleeve is moved, which bridges the overrunning clutch to make it possible to drive backwards.

When selecting their rear axle design, manufacturers choose different paths. Audi fits a double wishbone suspension in the A4 and A6 Quattro, Honda uses the requisite centre differential on the double wishbone standard suspension in the Civic Shuttle 4WD.

7.5. Permanent four-wheel drive, basic standard design passenger car

Giving a standard design car four-wheel drive requires larger modifications, greater design complexity and makes the drive less efficient. A power take-off gear is equired, from which a short propshaft transmits the engine moment to the front differential. The lateral offset must be bridged, for example, with a toothed chain. The ground clearance must not be affected and so changes in the engine oil pan are indispensable if the axle drive is to be accommodated.

The power take-off gear contains a planet gear centre differential which facilitates a variable force distribution (based on the internal ratio); 36% of the drive moment normally goes to the front and 64% to the rear axle. A multi-disc clutch can also be installed that can lock the differential electromagnetically up to 100%, depending on the torque requirement (front to rear axle). Moreover, there is a further electrohydraulically controlled lock differential in the rear axle which is also up to 100% effective.

The two differentials with variable degrees of lock offer decisive advantages:

• to reach optimal driving stability, they distribute the engine moments during overrun and traction according to the wheel slip on the drive axles;

• they allow maximum traction without loss of driving stability. The locks are open during normal driving. By including the front axle differential, they make it possible to equalize the number of revolutions between all wheels, so tight bends can be negotiated without stress in the power train and parking presents no problems. If the car is moved with locked differentials and the driver is forced to apply the brakes, the locks are released in a fraction of a second. The system is therefore fully ABS compatible.

In its four-wheel drive vehicles of the E class, Mercedes-Benz uses a transfer gear with central differential situated on the gearbox outlet and a front axle gear integrated into the engine-oil pan. The (fixed) driving torque distribution is 35%:65%. Instead of traditional differential locks, the wheel brakes are activated on the spinning wheels as in off-road vehicles of the M class. This system permits maximum flexibility, its effect not only corresponds to differential locks on front and rear axles as well as on the central differential, but also makes it possible for other functions such as ABS and electronic yaw control (ESP) to be integrated without any problem. Design complexity – and thus cost – is considerable.

Present-day development of four-wheeled vehicles shows the increasing use of slip-controlled clutches (visco and Haldex clutches) for the transmission of torque instead of an interaxle differential and the importance of electronic brake application systems which are used instead of lockable differential gears. Modern four-wheel varieties operate without functional restrictions with antilocking, slip and driving stabilization systems.

UNIT II. EXHAUST FLOW IN AN AUTOMOBILE

The engine is like an air pump; the more air that is allowed to flow through it, the more horsepower that you get out of it. In other words, if you have a free-flowing air intake and exhaust system in your average vehicle, you'll get more horsepower because of the efficient flow of air into and out of the engine. Fuel requires air to burn and thus to produce energy. The more air that is available for combustion will also improve efficiency otherwise known as gas mileage.

The purpose of this project is to research on the present common air flow systems in today's automobiles, particularly cars. This will be too general and cover too wide of a topic, as a car also uses air for various other mechanical purposes. So I will focus my project on the exhaust gas flow in a naturally aspirated fuel injected vehicles. Thus, I will not cover turbos, superchargers and nitrous oxide systems (which are forced inductions and are a substantial topic alone). And since some other students are doing projects on the engine itself, I will not spend too much time on how the air undergoes combustion in the engine. In short, my whole project will be divided into 4 sections:

Hopefully after the review of this project the reader will get a better understanding of how an exhaust system works in a vehicle and how power and efficiency can be unleashed with some modifications. This project is in no way suggestive for getting a car prepped for illegal street racing.

1. Relation between performance and air flow

Components that influence airflow *into* the engine are the: air filter, intake air piping, mass air sensor (if applicable), throttle body or carburetor, intake manifold, camshaft, intake port and valve of cylinder heads, turbo's compression, section, and supercharger (if applicable).

Components that influence airflow *out of* the engine are: the exhaust valve and exhaust ports of the cylinder heads, camshafts, exhaust manifolds, turbo's turbine (if applicable), exhaust tubing, catalytic converters, muffler.

When these components are modified to increase flow *out of* the engine, pumping losses are reduced. Pumping losses refer to the amount of horsepower (HP) used to push the exhaust gases out of the cylinders on the engine's exhaust stroke. Since less HP is used to get the exhaust out of the engine, more horsepower is available at the flywheel. An added benefit of reducing pumping losses is that fuel mileage will also increase.

No matter how much additional air is forced into the engine, no additional HP will be made unless additional fuel is also added. The energy that makes HP in an engine comes from the combustion of the fuel, not only the air. In general, every two HP produced requires one pound of fuel per hour. When modifications are performed that increase airflow into the engine, more air is available for the combustion of fuel. The combustion of the additional fuel is what translates into additional HP.

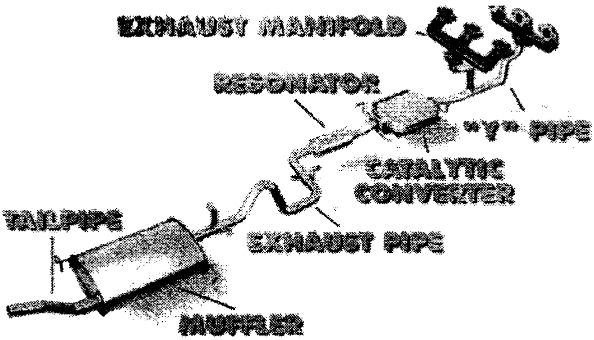
Air flow is not just influenced by the size (area) of the paths it takes into and out of the engine. It is also influenced by the speed at which it moves.

Specific Port Flow (cubic meter/sec) = Flow Velocity (m/s) x Average Path Area (m^2)

Whenever an engine modification increases the average area of the air-flow paths into and out of an engine, there is a chance the velocity of the flow will decrease. Most of the time the factor of velocity decrease is very small compared to the area increased, so flow is generally increased. If modifications are taken too far, the velocity will decrease more than the area increases, so flow is adversely affected (example - four inch exhaust system on a 1.6 liter engine).

The following section we will analyze the components of an exhaust system in a car and how air flows from the engine to the outside environment.

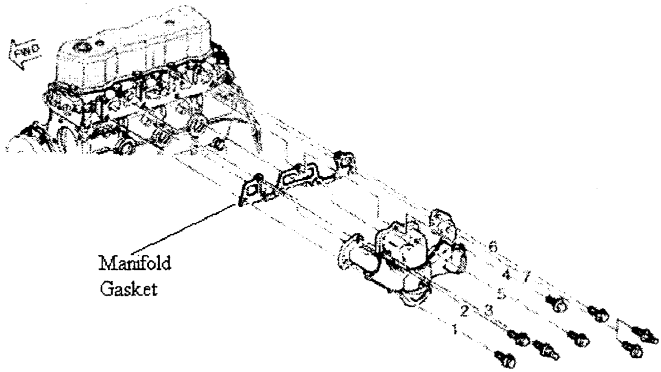
2. Analysis of the exhaust system in an average car



The above is a diagram of the major components of an exhaust system in a car. Exhaust system components are designed for a specific engine. The pipe diameter, component length, catalytic converter size, muffler size, and exhaust manifold design are engineered to provide proper exhaust flow, silencing, and emission levels on a particular engine. Further on, we shall learn about In this section the function and specifics of each component.

2.1 The exhaust manifold

The exhaust manifold is a pipe that conducts the exhaust gases from the combustion chambers to the exhaust pipe. Many exhaust manifolds are made from cast iron or nodular iron. Some are made from stainless steel or heavy-gauge steel. The exhaust manifold contains an exhaust port for each exhaust port in the cylinder head, and a flat machined surface on this manifold fits against a matching surface on the exhaust port area in the cylinder head. Some exhaust manifolds have a gasket between the manifold and the cylinder head, as can be seen in the diagram below:

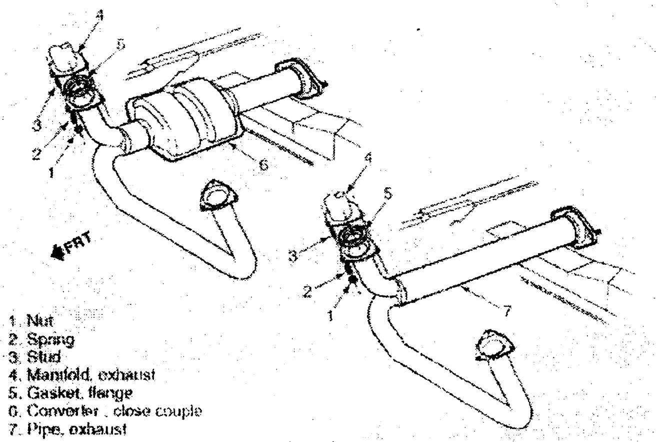


Exhaust manifold and gasket on an in-line engine

Gaskets are meant to prevent leakage of air/gases between the manifold and cylinder heads. The gaskets are usually made out of copper, asbestos-type material, or paper. In other applications, the machined surface fits directly against the matching surface on the cylinder head. The exhaust passages from each port in the manifold join into a common single passage before they reach the manifold flange. An exhaust pipe is connected to the exhaust manifold flange. On a V-type engine an exhaust manifold is bolted to each cylinder head.

2.2. The exhaust pipe (in-line) / "Y" pipe (v-type)

The exhaust pipe is connected from the exhaust manifold to the catalytic converter. On in-line engines the exhaust pipe is a single pipe, but on V-type engines the exhaust pipe is connected to each manifold flange, and these two pipes are connected into a single pipe under the rear of the engine. This single "Y" pipe is then attached to the catalytic converter. Exhaust pipes may be made from stainless steel or zinc-plated steel, and some exhaust pipes are double-walled. In some exhaust systems, an intermediate pipe is connected between the exhaust pipe and the catalytic converter. Some have a heavy tapered steel or steel composition sealing washer positioned between the exhaust pipe flange and the exhaust manifold flange. Other exhaust pipes have a tapered end that fits against a ball-shaped surface on the exhaust manifold flange. Bolts or studs and nuts retain the exhaust pipe to the exhaust manifold, as shown in the diagram below.



Some V-type engines have dual exhaust systems with separate exhaust pipes and exhaust systems connected to each exhaust manifold.

2.3. The catalytic converter

Three major automotive pollutants are carbon monoxide (CO), unburned hydrocarbons (HC), and oxides of nitrogen (NOx). When air and gasoline are mixed and burned in the combustion chambers, the by-products of combustion are carbon, carbon dioxide (CO2), CO, and water vapor. Gasoline is a hydrocarbon fuel containing hydrogen and carbon. Since the combustion process in the cylinders is never 100% complete, some unburned HC are left over in the exhaust. Some HC emissions occur from evaporative sources, such as gasoline tanks and carburetors.

Oxides of nitrogen (NOx) are caused by high cylinder temperature. Nitrogen and oxygen are both present in air. If the combustion chamber temperatures are above 1,371 degrees Celsius, some of the oxygen and nitrogen combine to form NOx. In the presence of sunlight, HC and NOx join to form smog.

Catalytic converters may be pellet-type or monolithic-type. A pellet-type converter contains a bed made from hundreds of small beads, and the exhaust gas passes over this bed (see Fig 1). In a monolithic-type converter, the exhaust gas passes through a honeycomb ceramic block (Fig 2). The converter beads, or ceramic block, are coated with a thin coating of platinum, palladium, or rhodium, and mounted in a stainless steel container. An oxidation catalyst changes HC and CO to CO_2 and water vapor (H_20). The oxidation catalyst may be referred to as a two-way catalytic converter (Fig 3).

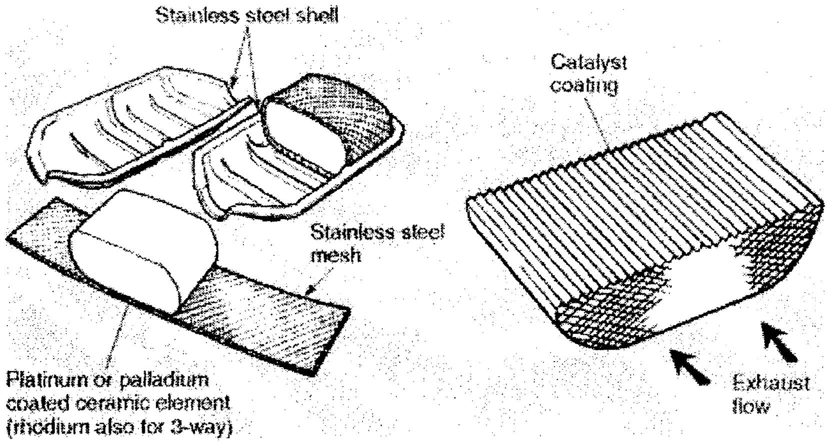


Fig 1: *Pellet-type catalytic converter*

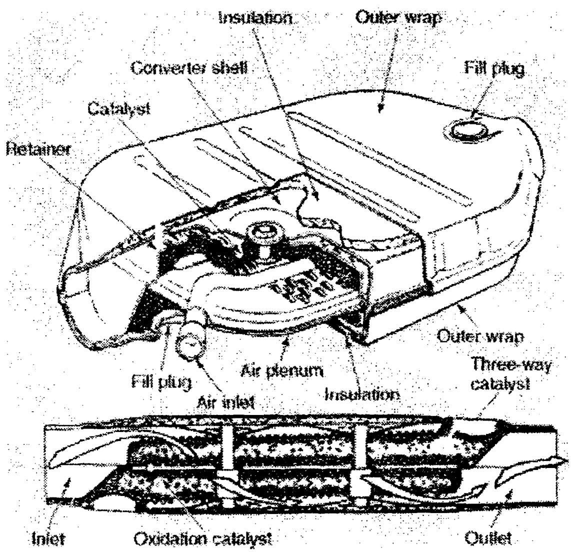


Fig 2: *Monolithic-type catalytic converter*

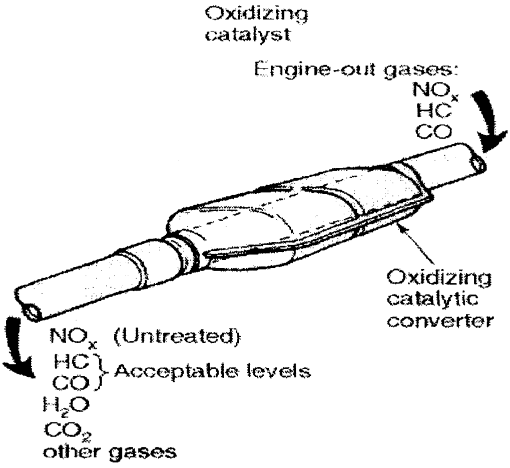


Fig 3: *Oxidation catalyst changed HC and CO to CO_2*

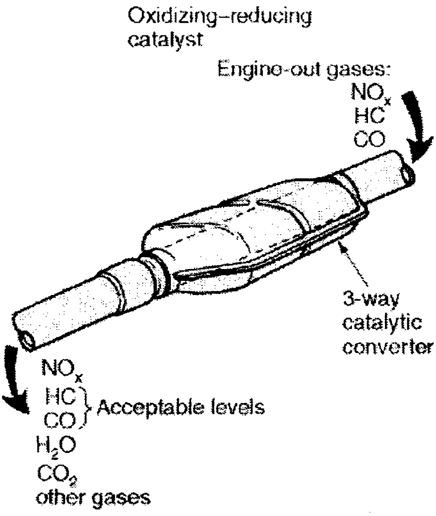


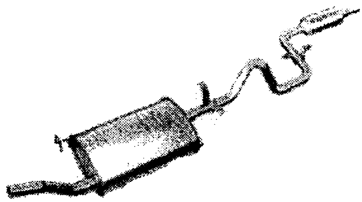
Fig 4: *Three-way catalytic converter operation*

In a three-way catalytic converter, the converter is positioned in front of the oxidation catalyst. A three-way catalytic converter reduces NOx emissions as well as CO and HC. The three-way catalyst reduces NOx into nitrogen and oxygen (Fig 4).

Some catalytic converters contain a thermo-sensor that illuminates a light on the instrument panel if the converter begins to overheat. Unleaded gasoline must be used in engines with catalytic converters. If leaded gasoline is used, the lead in the gasoline coats the catalyst and makes it ineffective. Under this condition, tail pipe emissions become very high. An engine that is improperly tuned would also cause severe overheating of the catalytic converter. Examples of improper tuning would be a rich air-fuel mixture or cylinder misfiring.

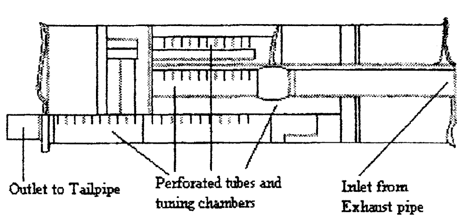
Many catalytic converters have an air hose connected from the belt-driven air pump to the oxidation catalyst. This converter must have a supply of oxygen to operate efficiently. On some engines, a mini-catalytic converter is built into the exhaust manifold or bolted to the manifold flange.

2.4. The resonator, muffler, and tailpipe



Since the resonator and muffler perform basically the same functions, I decided to write about them under one heading. Firstly, the main function of the muffler is to reduce the sound of the engine's outcoming exhaust gases through the exhaust pipes to a minimal level. Since the muffler cannot reduce the noise of the engine by itself, some (if not most) exhaust systems also have a resonator between the catalytic converter and the muffler. Resonators are basically the second muffler, and are usually the "straight through" type.

The muffler quiets the noise of the exhaust by "muffling" the sound waves created by the opening and closing of the exhaust valves. When an exhaust valve opens, it discharges the burned gases at high pressures into the exhaust pipe, which is at low pressure. This type of action creates sound waves that travel through the flowing gas, moving much faster than the gas itself (up to 1400 mph = 625.8m/s), that the resonator and muffler must silence. It generally does this by converting the sound wave energy into heat by passing the exhaust gas and its accompanying wave pattern, through perforated tubes and tuning chambers. Passing into perforations and reflectors within the chamber forces the sound waves to dissipate their energy.



The above described and pictured muffler design is the most common type, the reverse-flow design, which changes the direction of exhaust flow inside the muffler. Exhaust gases are directed to the third chamber, forced forward to the first chamber, from where they travel the length of the muffler and are exhausted into the tailpipe.

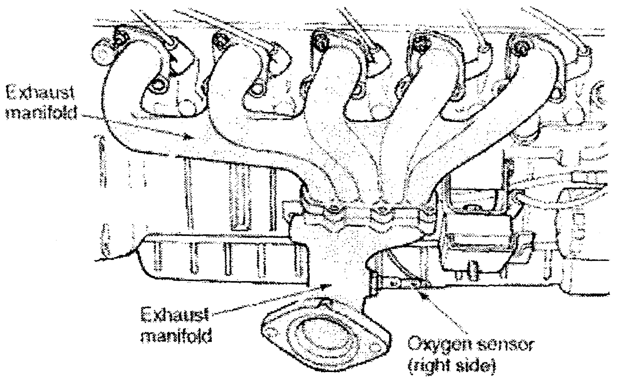
Some mufflers are a straight through design in which the exhaust passes through a single perforated pipe into a outside chamber packed with metal, fiberglass, packed glass, or other sound absorbing (or insulating) material. As the exhaust gases expand from the perforated inner pipe into the outer chamber, they come in contact with the insulator and escape to the atmosphere under constant pressure. Because of this, the expanding chamber tends to equalize or spread the pressure peaks throughout the exhaust from each individual cylinder of the engine. This type of muffler is thus freer flowing and designed for the purpose of reducing back pressure and, consequently, makes slightly more noise.

The tail pipe basically carries the flow of exhaust from the muffler to the rear of the vehicle. Some vehicles have an integral resonator in the tail pipe. Like the resonator mentioned earlier, this resonator is similar to a small muffler, and it provides additional exhaust silencing. In some exhaust systems, the resonator is clamped into the tail pipe. Tail pipes have many different bends to fit around the chassis and driveline components. In general, all exhaust systems components must be positioned away from the chassis and driveline to prevent rattling. The tail pipe usually extends under the rear bumper, and the end of this pipe is cut at an angle to deflect the exhaust downward.

3. Methods on how to improve efficiency and power

After the above discussion of the components in an automotive exhaust system, it is obvious that the principle of the engine as a pump is not being utilized to the fullest. Air is not allowed to flow too freely because of restrictions in the form of the catalytic converter, the resonator, and the muffler. However, these components are necessary by regulations to maintain safe exhaust gas emissions and minimal sound levels (noise suppression). Also, in part, it takes time and money to design an excellent performing and free flowing exhaust system; something that car manufacturers just can't afford to waste resources on. This is where aftermarket companies come in to create cost effective options for performance minded car owners. Of course, a free flowing exhaust would be expected to make more noise than a normal one. But a good manufactured system has a deep throaty tone, while yielding increases in horse power and also passing emission tests. I will now go through some of the modifications of the exhaust system that would "unleash" some horsepower and efficiency, while still being street-legal.

3.1. Replacing the exhaust manifold with a tuned header



A header is a different type of manifold; it is made of separate equal-length cylindrical tubes with smooth curves in it for improving the flow of exhaust.

Each time a power stroke occurs and an exhaust valve opens, a positive pressure occurs in the exhaust manifold. A negative pressure occurs in the exhaust manifolds between the positive pressure pulses, especially at lower engine speeds. Some exhaust headers are tuned so the exhaust pulses enter the exhaust manifold between the exhaust pulses from other cylinders, preventing interference between the exhaust pulses. If the exhaust pressure pulses interfere with each other, the exhaust flow is slowed, causing a decrease in volumetric efficiency (and thus decrease in horsepower). Proper exhaust manifold/header tuning actually creates a vacuum, which helps to draw exhaust out of the cylinders and improve volumetric efficiency, resulting in an increase in horsepower.

3.2. Dual exhaust systems

For engines with the "V" type configurations, it would be more efficient to use a dual exhaust system than the "Y" pipe. In other words, two pipes (instead of one) connect the exhaust manifold/header to two catalytic converters, two resonators, and two mufflers. Thereby each manifold will have their own resonators, catalytic converters, exhaust pipes, mufflers, and tailpipes. The advantage of a dual exhaust system is that the engine exhausts air and gases more freely, thereby lowering the back pressure, which is inherent in an exhaust system. With a dual exhaust system, a sizable increase in engine horsepower can be obtained because the "breathing" capacity of the engine is improved, leaving less exhaust gases in the engine at the end of each exhaust stroke. This, in turn, leaves more room for an extra intake of the air-fuel mixture. The disadvantage of a dual exhaust system is that it would be costly due to the additional components. No doubt the addition of another exhaust system adds more weight to the car, but the increase in horsepower is substantial enough to outweigh the horsepower losses through additional weight.

3.3. Removing the resonator

The resonator does not function also as emissions control device, so removing it and putting a straight pipe connecting the catalytic converter and the exhaust pipe will not cause the car to fail emissions test. Instead, some horsepower can be realized and not to mention the loudness of the exhaust. However, with a tuned muffler, the sound can be toned down to a deep throaty sound that is not irritable.

Upgrading to Larger Pipe Diameter

The factory exhaust pipes have diameters around 1.5" to 2" (some 2.25" for newer larger engine cars). Increasing the diameter of the piping will also increase the average path/cross-sectional area that the air can pass with a minute decrease in velocity. As mentioned before, if the diameter (and hence cross-sectional area) of the pipe is increased too much, the velocity of the air flow will decrease more than the area increases, so flow would be adversely affected and power would be lost.

So, depending on the size of the engine, the optimal size pipe to upgrade to varies from 2" to 2.5". On average, a naturally aspirated 2.5 liter engine would suffice with 2.25" exhaust piping from the catalytic converter back to the muffler inlet.

3.4 Upgrading to larger pipe diameter

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3.5. Mandrel bent versus crush bent piping

Another way to upgrade the exhaust piping from the catalytic converter back to the muffler is to have the exhaust piping mandrel (heat) bent instead of the conventional crush bending. As the name suggests, mandrel bends are achieved through the heating of the piping before bending whereas crush bent just literally mean that the piping is bent entirely by force. However, the main difference between mandrel bent and crush bent piping is the ease of flow. Mandrel piping keeps the pipe at a constant cross-sectional area throughout a bend which makes exhaust flow easier. On the other hand, crush bending deforms the pipe at the bend(s), which can restrict the exhaust flow. The disadvantage of mandrel bending is that it is relatively expensive, because of the costs involved in operating a mandrel bending heat machine. A popular alternative is to get piping with larger diameter and then have it crush bent. This way, it kind of evens out the differences in air flow ease, especially if that particular exhaust pipe configuration has a lot of bends and 90 degree bends.

3.6. Straight through versus reverse flow mufflers

Having a optimally free flowing exhaust all the way from the manifold would not do much good if the restrictive stock muffler is still used. The inlet and outlet diameters of the pipe in the muffler should also be as large as feasible, so as to allow free flow of exhaust gases. A straight through muffler would be preferred to a reverse flow muffler mainly because the process of air redirection in the reverse flow muffler is too restrictive. A straight through muffler design would allow exhaust gases to be expedited out as efficiently as possible, although the muffling abilities would not be as efficient as that of the reverse flow design. Therefore it will be inevitable that the exhaust will sound louder than before, but as mentioned before a couple of times, an aftermarket straight through muffler uses noise suppressing material that tones down the sound to that of one that's deep and throaty and not irritating. However, as will be discussed in the next section, a new generation of mufflers may be able to tackle this.

4. The future development of exhaust system

These days, you can't think of exhaust system as just some crude plumbing hung on as an afterthought to pipe away air, heat, and to keep those decibels down. It's become an integral part of the powertrain and under-car architecture critical to performance, fuel efficiency, and emissions reduction. There has already been development of low or zero emission vehicles already in the recent auto shows by major automobile manufacturers like Honda (Natural Gas vehicle) and Ford (Electric car). An oncoming development is the Electronic Muffler.

As an executive with Walker, one of the major muffler makers involved in developing the concept puts it: "After the introduction of the catalytic converter in 1975, this is probably the most revolutionary technology that's happened to exhaust systems in the entire history of the automobile."

While the idea is surprising, the basic principle isn't hard to grasp. From a microphone and a crankshaft speed/position sensor, the computer receives input on the pattern of pressure waves (that's what sound is, after all) the engine is emitting at its tail pipe. This data is processed using patented algorithms, which produce mirror-image pulses that are sent to speakers mounted near the exhaust outlet, creating contra-waves that cancel out the noise. In other words, the sensors trap the waveform signature of the engine, and the speakers generate anti-noise waves 180 degrees out of phase with the gas waves. This destructive interference idea is sort of like fighting fire with fire. The sound waves collide, wiping each other out. It doesn't just mask the noise, it actually removes sound energy from the environment, and from the law of conservation of energy where the energy has to turn up someplace, all that is left is low-level heat.

Although electronic mufflers are not widely used (if ever) at present, they may be installed on vehicles in the near future. In 1989, a joint Electronic Muffler System development program was started and the University of Michigan's Delphi study predicts that 20% of the cars produced in North America will have electronic mufflers by the turn of the century.

Well, if the electronic mufflers are really as effective as they claim to be and they were available now, we could build a perfect exhaust system using the setup described earlier with the addition of an electronic muffler then the problem of loud exhaust wouldn't exist. But then again, by the time the electronic muffler is out in the market, technology might have other improvements of the exhaust system and we will again try to match components to produce more horsepower and attain better gas mileage (efficiency).

In conclusion, let's go back to the basic analogy of the engine as a pump; the more air that can flow freely, the more horsepower that can be optimally achieved from the engine. This research paper has only dealt with how to get air OUT of the engine. It is important to note that the INFLOW of air also influences the output performance of the engine. As a matter of fact, we need the inflow of air before the outflow process starts. In brief, the inflow of air can be modified by removing the intake resonator, or even removing the entire airbox and installing a pipe with a cone-shaped filter at the end. There are many other ways to improve air inflow, but I shall not discuss about them as it would be outside he scope of this paper if I'm primarily interested in the outflow of exhaust gases.

It is also important to note that "horsepower" is a unit of energy over time. So the more energy it requires to do something, the less power you will get out of it. In other words, it is because motorcycles are lighter than cars that they can achieve similar if not higher horsepower. That is why race cars are stripped of the interior, air conditioning, and any other unnecessary weight. This way, there will be less weight to move, meaning less energy required and thus more power produced. That is why automotive engineers are trying to use materials of lighter weight, like plastics and carbon fiber.

UNIT III. SERVICING THE CAR

This article outlines basic problems, but it is not meant to be a do-it-yourself repair guide for resolving all possible no-start scenarios. If your mechanical experience is limited, this information may be helpful as preparation for dealing with a repair shop.

With today's computer controlled cars, the possibility of a vehicle not starting when you turn the key is less likely then ever before. But it does happen, and when it does, it would help if you knew some basic tests and procedures that could allow you to determine the cause and often fix the problem yourself instead of relying on your local repair shop to bail you out.

The first step is to narrow down the cause of the no-start.

Let's go over the process of starting the car, so you have a better understanding of what is going on when you turn the key: Here is what happens on a properly running car:

- You sit behind the wheel and insert the ignition key into the switch.
- You then turn the key to the spring loaded start position. When you do that, the ignition switch engages the starter by connecting the battery to the electric starter motor which, in turn cranks the engine over. This can be easily heard and is referred to as cranking the engine over.
- The next thing you will hear is the engine running, which is your signal to release the key.
- At that point, the engine is running and you are ready to place the transmission selector in Drive and be on your way.

A number of things can go wrong during the starting process. The following should help you distinguish exactly where the problem is occurring in order to determine what needs to be done to resolve the situation and get on your way.

1. Key will not turn

This can happen for a couple of reasons: the most obvious is that you are using a key not meant for that car or you have a worn out key. If you have a spare, try that one. A very common problem can occur when you park with the wheels turned all the way to one side and remove the key. When you try to turn the key to start, there is too much pressure on the steering lock to allow the key to turn. To correct this, force the steering wheel, first in one

2. Engine does not crank

When you turn the key to start, you may hear a single click or nothing at all, or you may hear a rapid series of clicks, like a woodpecker, or you may hear the cranking sound, but it goes very slowly. The most common cause for any of these is either a weak or dead battery, or a dirty or corroded connection to the battery. Before you go any further, turn your interior light on, then try to start the car.

If the interior light is bright when you turn it on and doesn't change when you turn the key to start, the battery is probably ok. This condition can be caused by the following: (this list is sorted from most likely to least likely):

- You do not have the transmission selector in park or neutral on an automatic transmission vehicle or there is a problem with the neutral safety switch. Try starting again with the transmission selector in Neutral.
- You are not depressing the clutch pedal all the way down on a standard transmission vehicle or there is a problem with the clutch pedal switch.
- There is a problem with the ignition switch or connecting wiring.
- There is a problem with the starter motor or starter solenoid.

3. Engine cranks normally, but it does not fire

You turn the key to start and hear the starter motor crank the engine, but when you release the key, the cranking stops and there is silence. This means that the battery and starting motor are working properly, but the engine is not firing. If you continue cranking the engine over in this way, the battery will eventually run down and will need to be recharged, but the battery and starter are not the cause of your problem.

There are a number of causes for this type of no-start condition, the most common being that you are simply out of gas. Assuming that you have fuel in the tank, you will need to go through a series of tests to determine what is causing the problem. The testing procedure requires that you use specialized equipment in order to determine the problem area. There are three main tests in order to get you pointed in the right direction. You will need to test for Spark, Fuel and Compression, in that order. As soon as you see a problem in one of those areas, that is where you will need to concentrate your efforts.

4. Spark

An easy way to test for spark is with an inexpensive spark tester. This is a device that is readily available at most auto supply stores. You use it by simply holding it next to a spark plug wire. If you see the neon lamp flashing while someone cranks the engine, then you have spark and should move on to checking for fuel. If there is no spark, or a very weak spark, you will have to do a series of methodical tests that vary depending on the type of vehicle. You will need a repair manual for your car in order to get the correct diagnostic procedures.

5. Fuel

First step here is to listen for the fuel pump running inside the gas tank. When you turn the key to run, you should easily hear the pump come on, run for a few seconds to build fuel pressure, then turn off. If you do not hear it, it could mean that the fuel pump or circuitry is bad. (Fuel pump failure is a common problem on modern cars.)

Fuel injected cars are very sensitive to proper fuel pressure. If the pressure is off, even by a few pounds, it will cause noticeable performance problems, or a no-start condition. To check for proper fuel pressure, you will need a fuel pressure gauge that is suitable for your type of system. A fuel injected engine (found on just about every vehicle less than 20 years old) produces very high fuel pressures and requires a fuel pressure gauge that reads up to 100 pounds per square inch. This type of gauge has a threaded connector that must match the pressure tap on your fuel rail. Since you are working with a highly combustible fluid which can be quite dangerous if you do not know what you are doing, you should leave this step to a pro.

6. Compression

If you know that you have spark and fuel, the next step is to check for compression. For this, you will need a mechanic's grade compression tester that will screw into a spark plug hole. You will need to remove the spark plugs and use the compression tester to test the compression on each cylinder. If the compression is very low on all cylinders, that is a sure sign that the timing belt (or timing chain depending on the engine) has failed and will have to be replaced.

Engine runs, but car will not move when put in gear. If the engine is running, but the car won't move when you put the transmission selector in gear, follow these steps.

Automatic Transmission. If you place the selector in Drive or Reverse, but the engine just races when you step on the gas and the car does not move or moves very slowly, it means that there is a problem with the transmission or driveline. First thing to do is check the fluid level in the transmission. In most cars, you check the transmission fluid level with the engine running in Park. If the fluid level is very low, in short, you see no fluid on the dipstick, shut off the engine to avoid further damage to the transmission and call for a tow to a repair shop. In some cases, a leak can be repaired fairly easily without a large expense (assuming the transmission wasn't damaged by running with low fluid levels). If the fluid is full, there is a slight chance that the gearshift may have come disconnected, which means that you lucked out. Otherwise, you are most likely facing an expensive transmission rebuild.

Standard Shift Transmission: If you put the transmission in gear, but when you release the clutch, the car does not move or moves very slowly even though the engine is racing, it is probably time to replace the clutch. On some cars, you may be able to get by with a clutch adjustment, but if it has been slipping for a while, chances are that the friction surface of the clutch is burnt and will need to be replaced.

7. Dead battery

One of the most common no-start conditions is caused by a dead battery. This does not automatically mean that the battery is no good, it only means that the battery has lost its charge for one reason or another.

The reason for the battery in a car is to provide temporary power to start the car or to run some accessories (like lights or radio) when the car is turned off. Once the car is running, the charging system (which consists of the alternator and voltage regulator along with the interconnecting wiring) will recharge the battery and provide all necessary electrical power to the vehicle. The battery then only serves as a backup if the vehicle requires more electrical current than the charging system can provide. This can happen when there is a high demand for electrical power, for instance on a cold, rainy night when you are in a traffic jam. In this case, your lights and wipers are on, the heater fan is blowing on high, the brake lights are being activated and the alternator is not spinning fast enough to keep the power coming. You may notice the lights dimming slightly, then brighten as you step on the gas. In these cases, a battery in good condition is more than capable of taking up the slack to keep everything going.

There are a number of reasons for a battery to become discharged so that it no longer has the power to start the engine. The more common reasons for a dead battery are:

- Forgetting the headlights turned on after you park the car.
- Forgetting a reading light or courtesy light turned on. This is easy to do since most cars have a feature that delays turning off the interior lights after you leave the car, so that you don't notice that you left a light turned on.
- A corroded or loose connection between the battery and the cables attached to it.
- A defective interior or trunk lamp switch that leaves the bulb lit.
- A defective charging system that does not replenish the battery's charge.
- An old battery that has lost its ability to maintain a full charge. Batteries have a life expectancy of 3 to 5 years, after which they should be replaced preventatively even if they are working well. Batteries have to work much harder during winter months when it is cold out. Sub freezing temperatures are when batteries usually begin to show signs that they are failing.

First, some important safety information: the automotive battery requires special handling. The electrolyte inside the battery is a mixture of sulfuric acid and water. Sulfuric acid is very corrosive; if it gets on your skin it should be flushed with water immediately; if it gets in your eyes, you should immediately flush them thoroughly with water and see a doctor right away. In this situation, time is critical. If you work with batteries often, you should have a mild solution of baking soda and water on hand and flush with that. The baking soda will neutralize the acid and minimize the damage. Remember: it is more important to flush immediately. Do not take the time to make up a solution first.

Sulfuric acid will eat through clothing, so it is advisable to wear old clothing when handling batteries. It is also advisable to wear goggles and gloves while servicing the battery. When charging, the battery will emit hydrogen gas; it is therefore extremely important to keep flames and sparks away from the battery.

Because batteries emit hydrogen gas while charging, the battery case cannot be completely sealed. Years ago there was a vent cap for each cell and we had to replenish the cells with distilled water when the electrolyte evaporated. Today's batteries (maintenance free) have small vents on the side of the battery; the gases emitted have to go through baffles to escape. During this process the liquid condenses and drops back to the bottom of the battery. There's no need to replenish or add water to this type of battery.

A car battery has two terminals either on top or on one site of the battery. On top terminal batteries, one post is slightly larger than the other post. The large terminal is the positive terminal and is marked with a prominent plus sign (+). The smaller terminal is the negative terminal and is marked with a minus sign (-). On a side terminal battery, the cables are screwed to the terminals. They are also clearly marked with a + and - and are also color coded, Red for positive and Black for negative.

The negative terminal is directly connected to the metal body of the car as well as the metal engine block. This is also called the Ground. The positive terminal is insulated and goes to all the components that require power. The positive terminal must never come into contact with the body or you will cause a dangerous short circuit.

8. What to do when your battery is dead

The first thing you can do is check the battery connections. Find a pair of old gloves before you touch anything around the battery. Touching battery terminals with your hand will not give you a shock since we are dealing with only 12 to 14 volts and it would take more than that before you would feel it.

If however, you touch the battery terminal with anything metal and allow the metal to come into contact with any metal on the car, you will get a severe spark that could cause injury and possibly ignite the hydrogen gas causing an explosion. So if you plan to do this yourself, you should feel confident in your abilities and follow all the safety precautions, otherwise seek the help of a professional automotive technician.

If you still plan to do this yourself, here are some procedures to follow. Once you are protected, grab each terminal and feel if the connection is loose on the battery. Only use a small amount of pressure so you do not damage the battery post. If you notice that one of the terminals is loose, just by moving it, you may be able to establish a good enough connection to start the car.

9. Getting a jump start

There are a couple of ways to boost, or jump start a car with a dead battery. You can get a Battery Booster Box, which is readily available in stores that sell automotive parts and accessories. This is a device with a rechargeable battery in it that has two large clamps that are used to connect to the dead battery. These booster boxes are recharged by plugging them into a regular wall outlet to keep them ready for use at a moment's notice. Many of them also have an air compressor that can be used to inflate your tires, and a search light to provide emergency light on the side of the road.

The other way is to use another car and connect its good battery to the dead battery using Jumper Cables. It is important to use good quality cables when trying to boost a car with a dead battery. Using thin, cheap cables may not allow sufficient amperage through. Furthermore, they can get very hot and fail, possibly causing serious burns or even fire.

When shopping for booster cables, look for heavy cable with insulated wire that is at least 6 gauge, with 4 gauge being better (the lower the cable gauge, the thicker the wire). Make sure that the wire goes all the way through the clamp and is connected directly to the jaw. If the wire is connected only to the clamp grip, do not buy it. Good jumper cables will cost more than $20 with professional quality cables costing $30 or more. There are plenty of cables that cost as little as $5 to $10. Stay away from those.

Booster cables have one black clamp on each end of one of the wires and a colored clamp, usually red or yellow, on each end of the other cable. When connecting the cable clamps to a battery, it is imperative that you always clamp the positive clamp (Red) to the positive terminal (+) and the negative clamp (Black) to the negative terminal (-)

Batteries on newer cars are not always easily accessible, but when this is the case, they will have a battery tap somewhere in the engine compartment. The positive side will usually be clearly marked under a red plastic protective cover. The negative side may or may not be there, but you can always connect to the engine block or metal brackets that are directly attached to the engine.

10. Using another car for the jump start

Important: check the owner's manual for both cars. On some vehicles, the manufacturer does not recommend jump starting under any circumstances. Other vehicles have specific steps that must be taken before jump starting, such as removing a certain fuse before proceeding. Failure to follow these manufacturer's instructions can cause expensive damage to the vehicle electronics. If the jump start procedure in either owner's manual is different from the instructions listed below, you should follow the instructions in the owner's manual instead.

When using another car with a good battery, follow these steps:

- Get the front of the car as close as you can to the front of the disabled car, making sure that the two cars do not touch.
- Shut both cars off and open the hoods.
- Wear suitable eye protection.
- Connect the positive (+) cable (Red) clamps to the positive battery terminal on each car.
- Make absolutely sure that you are connected to the positive terminals on both batteries with the same side of the cable (the connectors on each end of the cable are the same color (usually Red or Yellow)
- Next, connect the negative (Black) clamp to the negative terminal on the good battery. There should be no sparks.
- This is important. You will NOT be connecting the remaining clamp to the battery on the disabled car.
- Find a place on the dead car to connect the other negative clamp away from the battery, either on the engine block or a metal bracket that is directly attached to the engine. You most likely will see some small sparking. If you get a big spark, either there is something not connected properly, or the battery is shorted out, in which case you should not attempt a jump start until you replace the bad battery.
- Once you have the cables connected, you can try to start the disabled car. If the only thing that was wrong was a discharged battery, the car should start up quickly.
- If the car is still hard to start, first disconnect the negative cable from the bad car, then check to make sure that there is a good solid connection at each of the remaining cable clamps, then reconnect the negative clamp on the disabled car's engine block and try again.
- If the cables begin to get hot, discontinue the boost immediately: the cables are not heavy duty enough to do the job.
- Once the disabled car is running, first remove the negative cable from the engine block of the problem car, then remove the negative cable from the other car.
- Finally, remove the positive clamps from both cars and close the hoods.
- It is a good idea to keep the problem car running until you are able to have the battery recharged, either by driving on the highway or with a battery charger.
- If you suspect that the battery did not discharge by something obvious, like forgetting the lights on, have the battery and charging system tested by someone with the proper equipment to do this, preferably a professional.

11. Under hood checks

Do you know your way around under the hood of your car? While not as critical as it used to be, checking under the hood periodically can head off problems before they become costly. Today, with self service gas stations everywhere, often the only way you will get it done is for you to do it yourself.

Start by reading your owner's manual. There will always be a section on under hood checks. Keep a pair of old gloves and a roll of paper towels in the trunk.

First, a word about safety. Read the safety warnings in your owners manual and any safety warning stickers that may be under the hood.

If the engine has been running for any length of time, there are areas under the hood that can be very hot. Except for checking transmission fluid level, all checks should be done while the engine is turned off. If the engine is running, do not put your hands near any belts or fans. If you are not comfortable with touching a hot or running engine, then just do the checks that can be done with the engine cold and turned off and have someone else do the rest.

12. Engine oil level

This is the most important under-hood check you can do. An engine cannot run without oil even for a minute without serious engine damage or total destruction! To check the oil level, make sure that the engine is turned off, then find the engine oil dipstick and remove it. With a paper towel or rag, wipe off the end of the stick and notice the markings on it. You will usually see a mark for "Full" and another mark for "Add." Check your owners manual to be sure. Push the stick back into the tube until it seats then immediately pull it out to see the oil level. You should not add oil unless the level is below the "Add" mark and NEVER add oil to bring the level above the "Full" mark. Your main concern with this check is that oil consumption is not rapidly increasing. If it is, take your car to a repair shop as soon as possible and have it checked out. It is acceptable for the oil to be dark as long as you change it at the recommended intervals. However, it should never be foamy and should never have a strong gasoline smell. If either of these conditions exist, have it checked out soon.

13. Transmission fluid

Most automatic transmissions should be checked while the engine is running. Check your owners manual to be sure. Also make sure the car is on a level surface and fully warmed up. Pull the transmission dipstick out, wipe off the end and note the markings on the end of the stick. The usual markings are "Full" and "Add 1 pint." Push the stick into the tube until it seats, then immediately pull it out to see the fluid level. Transmission fluid should be pink or red in color with the look and consistency of cherry cough syrup. If the fluid is a muddy brown or has a burnt smell, have it checked by a mechanic. As with the engine, never add fluid unless it is below the "Add" mark and never bring it above the "Full" mark. Make sure you use the correct transmission fluid for your vehicle. If you plan to add Transmission fluid yourself, you should know that fluid usually comes in quarts, but the level may not be low enough to take the full quart. Also, you will need a special funnel to get the fluid into the small tube that the dipstick came out of. Check your owners manual for the type of fluid and do not substitute anything else. Any noticeable transmission oil consumption should be checked out at a repair shop.

14. Brake fluid

The brake fluid reservoir is under the hood right in front of the steering wheel. Most cars today have a transparent reservoir so that you can see the level without opening the cover. The brake fluid level will drop slightly as the brake pads wear out. This is a normal condition and you shouldn't worry about it. If the level drops noticeably over a short period of time or goes down to about two thirds full, have your brakes checked as soon as possible. Never put anything but approved brake fluid in your brakes. Anything else can cause sudden brake failure! Keep the reservoir covered except for the amount of time you need to fill it and never leave a can of brake fluid uncovered. Brake fluid must maintain a very high boiling point .Exposure to air will cause the fluid to absorb moisture which will lower that boiling point.

15. Power steering fluid

The power steering fluid reservoir usually has a small dipstick attached to the cap. Remove the cap and check the fluid level. The level should not change more than the normal range on the stick. If you have to add fluid more than once or twice a year, then have the system checked for leaks. These systems are easily damaged if you drive while the fluid is very low. Another warning of low power steering fluid is a buzzing noise when you turn the steering wheel at slow speeds.

16. Coolant (antifreeze) level

Never open the radiator of a car that has just been running. The cooling system of a car is under high pressure with fluid that is usually hotter than boiling water. Look for the cooling system reserve tank, somewhere near the radiator. It is usually translucent white so you can see the fluid level without opening it. (Do not confuse it with the windshield washer tank). The reserve tank will have two marks on the side of it. "FULL HOT" and "FULL COLD." If the level frequently goes below "full cold" after adding fluid, you probably have a leak which should be checked as soon as possible. Today's engines are much more susceptible to damage from overheating, so do not neglect this important system.

17. Battery

Most batteries today are "maintenance free" which simply means that you can't check the water level. This doesn't mean however, that there is nothing to check. The main things to check are the top of the battery which should be clean and dry, and the terminal connections which should be clean and tight. If the top of the battery continuously becomes damp or corroded soon after cleaning, then have the charging system and battery checked by your mechanic.

18. Windshield washer solvent

Windshield washer solvent is readily available by the gallon in auto supply stores as well as supermarkets and it is cheap. It is fine to use with or without adding water but will clean better undiluted. Never dilute it during winter months to insure that it retains its antifreeze protection.

19. Belts and hoses

In most cases your mechanic can check your belts and hoses when you bring in the car for an oil change. However, if you get your oil changed by some quick lube type centers, belts and hoses may not be on their list of items to check in which case you're on your own. These checks are best done while the car is cold.

Belts are used to drive a number of components on an engine including: the water pump, power steering pump, air conditioner, alternator and an emission control pump. Some later model cars have a single "serpentine" belt that handles everything. This type of belt looks flat on one side with several ribs on the other side. You should check the ribbed side for signs of dry and cracked rubber. Serpentine belts are usually self adjusting and very durable. They should last about 30,000 miles. The other type of belt is called a "V" belt and is adjustable. There is usually more than one to an engine, sometimes three or four. Check each one for cracks and tightness and have them replaced if you find any problems. Some V belts are hard to reach but no less important so if you can't reach it to check then have your mechanic do it periodically.

Hoses should be checked visually and by feel. You are looking for dry cracked rubber, especially at the ends where they are attached. You should also check the ends for any signs of ballooning.

20. Windshield wiper blades

I think that every driver knows what it is like to drive in the rain with bad wiper blades. (I know... I'm not under the hood any more... stop being technical) Wiper blades should be changed every 6,000 to 10,000 miles. Wiper blades will tend to streak when they are dirty. Take a paper towel with some window cleaner and clean the rubber blade whenever you clean the windshield.

21. Tyres

Buy a decent tire gage and keep it in the car. Improper tire pressure can affect tire wear as well as ride and handling. You should always check your tires when they are cold. Use the manufacturers recommended tire pressures. Tire pressure tends to rise as you drive due to heat build-up. Manufacturers have this in mind when they set the recommended cold pressures so do not let air out when the tire gets hot. Check the tire again when it cools off and you will find that the pressure is back to where it was. Tire pressure will change with the seasons, so in winter months make sure they are not under inflated. Remember, always check them when they are cold.

22. Oil change

One of the few maintenance items that automobile manufacturers have not found a way to eliminate Regular oil changes are the best way to ensure longer engine life. If you frequently take short trips where the car doesn't always completely warm up, then oil changes are even more important because acid and moisture buildup does not have a chance to burn off. Some new engines normally run very hot and are very hard on oil. Even missing a single oil change on these cars can cause an engine to develop sludge which can cause engine damage in a car with as little as 15,000 miles on the odometer. Today's modern oils contain detergents and additives that are designed to protect against sludge formation, but if you regularly do a lot of stop and go driving, like rush hour driving, engine heat will eventually break down these additives so that they stop protecting your engine. Sludge problems are NOT covered by a new car warrantee. You could be stuck with a bill for major engine work! It happens more times than you think, usually to people who lease their car and think that they can get away with not doing proper maintenance. The best way to protect yourself is with regular oil changes and make sure that you save your receipts.

When an oil change service is referred to as an "Oil, Lube & Filter", the "lube" is a chassis lubrication where the mechanic applies grease to various steering and suspension joints under the car. Most modern cars are manufactured with sealed-for-life joints that do not have grease fittings; however if any of these parts were replaced, the new parts probably do have lubrication points and must be greased to prevent premature wear. If you have had parts replaced, make sure that the mechanic knows it or he may overlook them. Doing an oil change yourself does not require much skill, but crawling under a car and having oil drip down your sleeve is hardly worth the $10 or so that you might save. Then, you have to deal with the old oil and filter. I could think of a more productive way to spend a Saturday afternoon.

23. Washing

Environmental pollution, not to mention fallout from birds, will take its toll on your car's finish. The best way to protect the finish is to keep it clean. This is especially true during the winter months in the snow belt where salt is used to keep the roads clear. While today's cars have very durable finishes, they are susceptible to prolonged exposure to corrosives. I have seen new cars sitting in a dealers lot for two or three months that had to be refinished because the paint became etched from bird droppings. If you have retractable headlights, make sure you clean them regularly. They are often overlooked when having your car washed.

A car wash will keep your car clean with a minimum of time and effort. The brushes they use are safer on a car's finish than they used to be and many are brushless. I don't ask for wax at car washes because it may coat the windshield and cause the wipers to streak, but then I hand-wax my car twice a year. If you decide to wash the car yourself, use products that are safe for car finishes.

24. Alignment and balance

Wheel alignment and wheel balancing are two totally different things, but many people often get them confused. In a nutshell, wheel alignment consists of adjusting the angles of the wheels so that they are perpendicular to the ground and parallel to each other. The purpose of these adjustments is maximum tire life and a vehicle that tracks straight and true when driving along a straight and level road. Wheel balancing, on the other hand allows the tires and wheels to spin without causing any vibrations. This is accomplished by checking for any heavy spots on the wheel-tire combination and compensating for it by placing a measured lead weight on the opposite site of the wheel from where the heavy spot is.

The symptoms of a car that is out of alignment are:

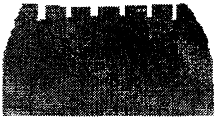
- Uneven or rapid tire wear
- Pulling or drifting away from a straight line
- Wandering on a straight level road
- Spokes of the steering wheel off to one side while driving on a straight and level road.

The symptoms of a wheel that is out of balance are:

- Vibration in the steering wheel at certain highway speeds.
- Vibration in the seat or floorboard at certain highway speeds.
- Scalloped or cupped wear pattern on the tires

25. Wheel alignment

To find out if you need an alignment, first check each tire and look for uneven wear patterns. The problem with this method, however, is that if you can see a wear pattern like the ones listed below, it may be too late to save that tire. This is why it is a good idea to have your alignment checked periodically. At each tire, take a coin and insert it in the tread at the inside, center and outside.



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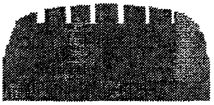
If the tread is deeper on the edges than in the center, the tire is over inflated.



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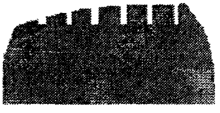
If the tread is deeper in the center than the edges, the tire is under inflated.



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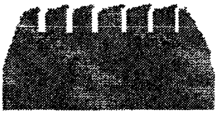
If the tread is deeper on one side than the other, have your wheel alignment checked soon.



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Run your hand back and forth across the tread, being careful not to cut yourself on any debris or exposed steel belt wire. If the tread is smooth in one direction, but jagged in the other you have what is called a "saw-tooth" wear pattern which is caused by a toe-in problem. Have the alignment checked as soon as possible as this condition causes rapid tire wear. The first two conditions do not call for a wheel alignment but the second two do. If these wear patterns are pronounced, you should replace the tires or move them to the rear before aligning the car. Ask your alignment specialist to be sure.

Another indication of an out-of-alignment condition is a car that continuously drifts or pulls to one side of the road when you let go of the wheel. A car that is hard to keep in a straight line without constant steering corrections is also a candidate. These conditions may or may not also contribute to premature tire wear. A wheel alignment cannot be done on a car with loose or worn front end parts. The technician will first check for worn parts and inform you of any problems before beginning the alignment.

The best type of wheel alignment is a four wheel alignment. Many cars today have adjustable rear alignment settings, but even for cars without adjustments in the rear, a four wheel alignment will allow the technician to identify any rear tracking problems and compensate for them with adjustments to the front.

After the wheel alignment is finished, you should drive the car on a straight and level road and check that the car goes straight and that the steering wheel is in the proper position with the spokes level. If you notice a problem, take the car back and have the technician drive it and fine-tune the alignment settings.

26. Wheel balance

Out-of-balance tires will cause a car to vibrate at certain speeds, usually between 50 and 70 mph. A tire is out of balance when one section of the tire is heavier than the others. One ounce of imbalance on a front tire is enough to cause a noticeable vibration in the steering wheel at about 60 mph. To balance a wheel, the technician will mount it on a balancing machine which spins the wheel to locate the heavier part. He will then compensate for the heavy part by attaching a lead weight on the opposite side. Many people are pleasantly surprised at how smooth their car drives after balancing all four wheels.

Most high quality tires will hold their balance fairly well and go out of balance very gradually. If you notice a vibration that wasn't there the day before, it is possible that one of the lead balancing weights fell off. If you feel the vibration mostly in the steering wheel, the problem is most likely in a front wheel. If the vibration is mostly in the seat, the problem is probably in the rear. For those of you who are very sensitive about vibrations and your shop can't seem to get that last bit of vibration out, check to see if you have locking wheel lugs. Some locking lugs are as much as 1.5 ounces heavier than the other lug nuts which translates to about 1/2 ounce at the wheel rim. Try putting a 1/2 ounce weight opposite the locking lug and see if it helps.

27. Waxing

Regular waxing will keep a car looking new for many years. A ten-year-old car that has been waxed twice a year will probably have a better shine then when it was new. It will also command a higher resale value and be easier to sell.

If rain water does not bead on the painted surfaces of your car, it's time to wax it. How often you have to wax your car is dependent on the type of wax you use and how good you want your car to look. Some of the new synthetic waxes will last more than a year. Obviously, there are two ways to get the car waxed: have it done by someone or do it yourself. If you don't mind spending about $100.00, check out an auto detailer. They will clean the entire car inside and out, cleaning and waxing the body and shampooing the interior, right down to using a toothbrush to clean the seams in the dashboard. They will deep-clean the wheels and tires and make sure they remove any wax residue around the nameplates and emblems. Check with your local car wash or look in the Yellow Pages under "Automobile Detailing".

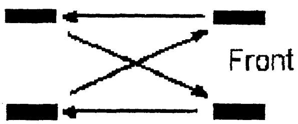
If you decide to wax the car yourself, make sure you start with a clean car and never work in direct sunlight on a hot day. Before you start, run your hand over the surface, it should feel smooth like glass. If it feels rough or gritty like there are bits of sand embedded in the paint, then you should first use a non-abrasive cleaner to clean the paint before waxing. One of the best methods that I have found uses clay to smooth the surface. Products such as Clay Magic & Meguiars Clay Detailer work beautifully with amazing results. Make sure you only use products designed for automotive finishes and follow the instructions on the container. After you finish waxing the car, you should go over the entire surface to look for wax residue, especially around trim and body seems. A tooth brush or Q-tips work well for this. If your car has black trim, try to keep the wax away from it. Some waxes may leave a chalky film on dull black trim, such as rubber and some plastics, that can be hard to remove. Look for products that are made for cleaning black trim. I found them to work well and really let the black stand out.

Before beginning the job, examine the paint closely for chips and scratches and touch them up. Touch-up paint is available at most auto supply stores for the most popular paint colors. If you can't find your color there, check with your new car dealer. If they don't have it you may have to go to an auto body supply where they can match any color you might have (for a price). I always ask for a tube of touch-up paint when I buy a new car. That tube will usually last a few years if you only use it for chips and small scratches and keep it covered. Make sure that you wipe the paint off the bottle before you put the lid back on or you will never get it off again. (I speak from experience)

28. Tyre rotation

On front wheel drive cars, it is especially important to rotate your tires periodically because the front tires wear faster than the rear. Uneven tire tread thickness, front to rear, will give you uneven braking and poor handling, especially in the rain. If you don't rotate the tires, you'll wind up replacing them two at the time, which means you'll always have uneven tread thickness. Replacing tires in a matched set of four will keep the handling and braking traction of the car balanced.

On certain cars, you may experience an additional problem when you do not rotate the tires: tire noise or humming on smooth roads. If you notice a humming noise, check the rear tires for a "saw-tooth" wear pattern on the inside and outside shoulder of the tire. You can detect this by running your hand back and forth along the edges of the tire tread. Be careful not to cut yourself on debris or exposed steel belt wire. If it feels smooth in one direction, but jagged in the other, you may have found some of your noise. This condition happens on some front wheel drive vehicles with tires that have tread blocks on the shoulder of the tire. Rotating this tire to the other side of the car should even out this type of wear and quiet down the humming. Check your owner's manual for the proper rotation method. Most front wheel drive cars require the following rotation method:

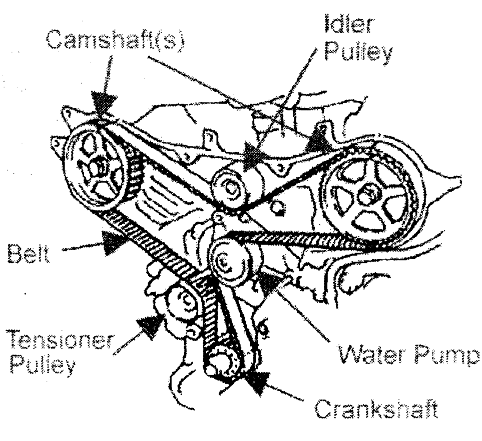


Front wheel drive tire rotation

Warning: If you have directional tires such as Goodyear Aquatreads they must never be crossed over to the other side of the car. You can tell by the fact that they will have a clearly marked arrow on the sidewall showing the direction of rotation.

29. Tune up

Prior to 1975, a tune up consisted of replacing the plugs, points and condenser; then setting the timing, adjusting the carburetor and checking or replacing the cap, rotor, wires, gas filter, PCV valve and a host of other replaceable maintenance items. Today, computerized cars with electronic ignitions eliminate the points and condenser and adjust themselves at the rate of ten times per second.



Typical V6 Timing Belt

The only items that need to be replaced on a regular basis are the spark plugs and certain filters such as the air filter, fuel filter, and some emission control filters. When the spark plugs are replaced the technician should check the ignition wires and the cap and rotor if your car has them. Some new cars are even equipped with platinum tipped spark plugs some of which last for 100,000 miles!

30. Winterizing

Corrosion inside the cooling system can cause failure of various components such as the water pump, thermostat, radiator cap and heater control valve. The best way to prevent corrosion is to flush the cooling system periodically and replace the antifreeze. If the car has more than 60,000 miles, you should also consider replacing the thermostat and radiator cap preventatively. Some modern engines cannot tolerate even a single bout of overheating without incurring serious damage like a blown head gasket. So everything you can do to prevent overheating is a plus.

31. Timing belt

Certain engines with overhead camshafts have timing belts that have a limited life span. Car makers use these belts instead f more durable chains because chains are noisier and cost more to manufacture. Your vehicle owner's manual will recommend at what mileage the timing belt must be replaced. These intervals range from every 60,000 miles to every 105,000 miles. To see what is recommended for your engine, click on the link at the bottom of this article.

The job of the timing belt is to turn the camshaft(s) at exactly 1/2 the speed of the crankshaft while maintaining a precise alignment. This means that the crankshaft will make two revolutions for every revolution of the camshaft. Engines will have at least one camshaft, or as many as four camshafts in some of the V-type engines. The camshaft causes the intake and exhaust valves to open and close in time with the pistons which move up and down in the cylinders. The valves must open and close at exactly the right time in relationship to the piston movement in order for the engine to run properly.

There are two types of engines that use timing belts. They are described as: "Interference Engines" and "Non-interference Engines" The difference lies in the proximity between the valves and the pistons. On an interference engine, if the timing belt slips even one notch, the piston can crash into an open valve causing serious engine damage by bending valves and breaking pistons. Non-interference engines will usually not self destruct, but in either case if the belt fails, the engine will immediately shut down leaving you stranded. The link at the bottom of this article will tell you which category your engine falls under.

Timing belts fail without warning and on some vehicles, are almost as hard to check as they are to change. In most cases, your only protection is to change the belt at the recommended intervals. Timing belt replacement is not a cheap job but it is far less costly than the alternative.

Some technicians may recommend that you replace the water pump during a timing belt job even if there is nothing wrong with it. This is because 90% of the labor to change the water pump has already been done with the timing belt job and some technicians consider it good insurance to replace the pump at this time. My feeling is that some water pumps can last the life of the car but many do fail and will cost big money to replace at a later date. So ask your technician what his experience is with the water pump on your model car and look at how long you plan to keep the car. This way, at least you will be making an informed roll of the dice.

32. Filters

There are a number of replaceable filters in a car. They are listed in your owners manual along with recommended replacement intervals. If you live in a dusty area or in a big city, then you should replace them more frequently. The following filters are common to most cars:

- air filter: used to filter the air going into an engine. This filter is usually easy to replace yourself.
- fuel filter: found either in the engine compartment or near the gas tank. This filter is best left to your auto mechanic to change.
- breather: works with the PCV valve to allow clean air to be drawn into the crankcase to purge moisture and acids from the engine.
- PCV valve: works with engine vacuum to draw fumes from the crankcase and burns them in the combustion chamber.
- cabin filter: on a number of late model cars since the early '90s, there is a filter in your air conditioning system that cleans the air before allowing it into the passenger compartment. These filters are usually somewhere under the dash. Your owner's manual will tell you if you have one and where it is.

Учебное издание

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AUTOMOBILE

Suspension and Drive
Exhaust Flow
Servicing the Car

СБОРНИК ТЕСТОВ ПО ЧТЕНИЮ НА АНГЛИЙСКОМ ЯЗЫКЕ

для студентов специальности
1 – 37 01 06 «Техническая эксплуатация автомобилей»
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