RESEARCH ON THE CONSTRUCTION AND FUNCTION OF THE ROAD VEHICLES SUSPENSION SYSTEMS

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ABSTRACT: *This paper presents researches on the construction and function of road vehicle suspension systems, types of suspension used and methods and means of verification and testing. Suspension systems are designed to achieve an elastic connection between the frame or the car body and the running system (bridge or directly on the wheel axle), protecting against shocks, vibrations, thus contributing to the comfort, the degree of manoeuvrability and stability. The comfort, the degree of manoeuvrability and stability are indicators commonly used in the assessment of a road vehicle.*

KEY WORDS: suspension systems, motor vehicles, construction types, testing, checking.

1. THEORETICAL CONSIDERATIONS

1.1. Generalities regarding the suspension system

The vehicle suspension system is the mechanism that serves to connect the car body with the wheels of the car. It has the ability to transmit to the road surface all forces acting on the car. However, the suspension system is preventing the forces coming from the rolling area to affect handling, performances, but also comfort of the vehicle suspending the car body at a relatively small distance above the road surface and keeping it at a constant level. The machine body is thus protected from the effects of the shocks caused by road conditions.

The role of the car suspension is to link elastic between the frame or the car body and bridges, or directly with the car wheels. Suspension transforms the shocks in oscillations with amplitude and frequency endurable by passengers and dampens oscillations, avoiding resonance. It also has the role to protect loading and component organs against shocks, racking and damaging oscillations caused by road bumps.

The suspension system evenly transmits the forces (weight) acting on the vehicle to the road surface (the road) and at the same time it isolates it from the forces arising from the road surface, thus improving its comfort and handling.

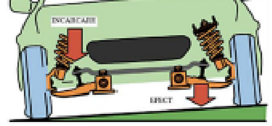


Fig.1

An important aspect is that in any of the following situations: braking, accelerating or cornering, the system suspension must retain firmness while maintaining all the tyres in contact with the ground, Figure 1.

1.2 The technical control during traffic

Traffic control service performed by specialized RAR is envisaged:

- State, fixing: bumpers, rocker arms, springs, stabilizer bars, cushions, spring bolts, bearing plates;
- Sealing: bumpers, air bags;
- Fixing state game: suspension arm bolt (axle carrier), rocker arms.
- Symmetry

1.3 The components parts, required conditions and classification

The suspension of a car is composed of:

- Elastic elements (springs) which is the actually suspension;
- Guiding devices, joints, catches;
- Bushings;
- Shock absorbers and stabilizers.

The elastic elements serve to decrease the dynamic load resulting from the wheel passage for the road irregularities. Simultaneously, the elastic elements makes the car body oscillations to be bearable by passengers and not damage the goods that are transported. The elastic suspension elements are leaf springs, coil springs, torsion bars and hydro-pneumatic spring elements. Springs and stabilizer base are those that maintain a correct position of the car while supporting its weight.

The guiding elements transmit longitudinal and transversal components of the interaction and also the moments of these forces, causing the wheels kinematics towards the frame or roadside.

Bushings are the pieces responsible with the car noiseless by isolating the habitat from the running noise.

Joints and fasteners connect the car and the road leading the traction and keeping the wheels in a correct position relative to the body.

Damping elements together with the friction between spring leaves dampens the oscillations of the car body and its wheels. The functions of the three main elements of the suspension can be performed by one and the same element or of different elements. Damper role is to ensure that a good contact with the road surface vibration by attenuating the effect of the vibration wheels and of the car body because of the road.

More-stabilizing elements are designed to reduce the turning angle of the car. In some cases, the car suspension contains additional elements - stabilizers, which serve to reduce the lateral inclinations of the vehicle when veering.

The proper functioning of these components of the suspension system largely determines the comfort of the car, thus increasing the driving enjoyment. The dividing suspension systems is quite simple, they can be independent or rigid.

The main conditions that must be met by the suspension of the car:

- The appropriate elastic characteristic to ensure a satisfactory degree of comfort;
- The transmission of the longitudinal and transverse forces from the wheels to the frame and of the reactive moments (when there are no special devices provided), simple construction and strength, minimum weight;
- Proper sustainability of the suspension elements, the amortization of the body and wheel vibrations;
- Ensuring correct steering kinematics without allowing the oscillation of the wheels;

The classification of automotive suspensions- is made by the bridge type and by the feature of the elastic elements.

- By bridge type: suspensions wheeled dependent and suspensions wheeled independent
- Depending on the type of elastic characteristic: suspensions of linear elastic properties and suspensions of non-linear elastic characteristic. The elastic characteristic of the suspension is a change in strain (arrow) / the elastic member with the load F that produces this arrow.

1.4 The elements of the elastic suspension

The elastic suspension elements found in automobiles are leaf springs, coil springs, torsion bars, and hydro-pneumatic spring elements. Whatever type of spring (air cushion, leaf spring, coil spring) or torsion bar, they only support the vehicle weight while maintaining proper height between the body and the road. The arch absorbs and stores the energy from the movement body to the road surface.

Spring-damper tandem

Once the energy from motion is stored in the spring compression, it will try to release stored energy by extension. This phenomenon would produce body movements which would destabilize the vehicle, making the driving extremely unsafe and uncomfortable. To prevent these effects, a damper is installed in the system. The main role of the damper is to control spring movement. This control keeps the wheels in contact with the road surface, stabilizes the vehicle body and provides a comfortable fit.

Leaf springs

The components of a leaf spring are shown in figure 2 main leaf spring is bent in the form of mesh heads for which the bronze bushing or rubber rings through which binds to the suspension of the car. The other sheets are called leaf side and are tightened with central bolt main sheet. Clamps do not make it possible to move the leaf spring from each other. Springs with two main sheets also meet, whose eye of the first principal leaf is doubled by the second principal leaf.

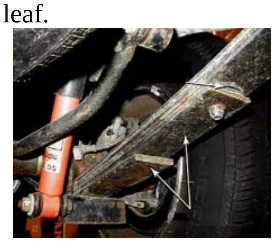


Fig.2

To reduce the tensions that arise in the main leaf, the leaf springs are executed with different radiuses of curvature, growing smaller, and to their compression a pre-tension of the main leaf, which will decrease its radius of curvature. The friction between the springs leaves contribute to the damping of the car oscillation. The friction between sheets being high, the spring is too stiff and to increase its flexibility in installation, the sheets are coated with graphite grease. The attachment of the spring framework can be longitudinal or transverse.

Suspension with semi-elliptical leaf springs arranged longitudinally.

In Figure 3 is the rear suspension of a road car with leaf springs arranged longitudinally. The arch leaf is disposed longitudinally to the frame.

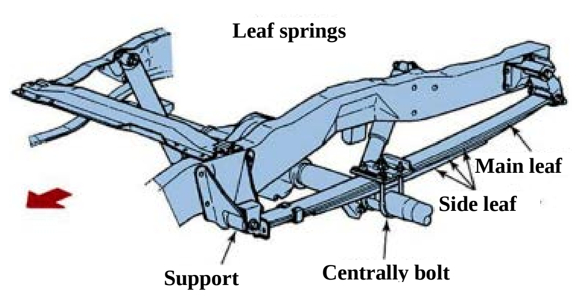


Fig.3

The front spring is connected to the pin by means of a hinge, and back through the earring. To limit the spring travel the rubber pad is provided. One end of the spring is attached by a hinge pin (to transmit traction and braking forces to the frame) and the other earring by allowing spring to deform under load action (by bending the arc, the distance between the centres meshes changes) . The damping of the oscillation is provided by the hydraulic telescopic double acting shock absorbers.

The suspension with semi-elliptical leaf springs arranged longitudinally with nonlinear characteristic

The suspension with leaf springs with linear characteristic, Figure 4, is used especially in the rear axle of trucks. An appropriate suspension where the truck is loaded it will be too rigid to the empty truck. Additional spring suspension corresponds in each case.

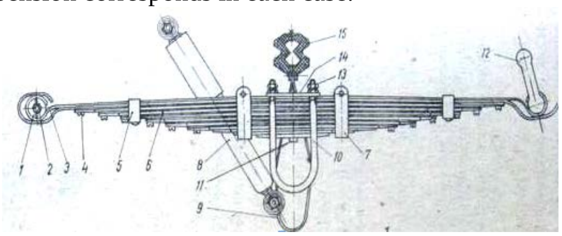


Fig.4 The suspension with leaf spring

Longitudinal semi-elliptical springs arranged longitudinal:
1 - Washer; 2 - nut bolt; 5 - Main sheet; 4 - Fixing screws spacers (plastic) of the sheet; 5 and 7 - flanges; 6 - Leaf spring; 8 - Hydraulic telescopic dampers; 9 - Strap limiters; 10 - Mounting brackets; 11 - Central bolt; 12 - Shackle; 13 - Nut; 14 - Plate; 15 - Rubber buffer.

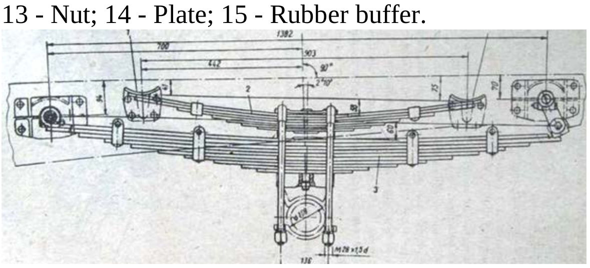


Fig.5 Rear suspension with additional spring

Figure 5 presents the rear suspension with additional spring that is used for trucks. It consists of the main spring which works on small and medium loads. At high loads, the secondary spring starts operating too, which rests on the frame supports. One advantage of the suspension with leaf springs is that in addition to the vertical forces, it takes over the horizontal forces as well.

Coiled springs

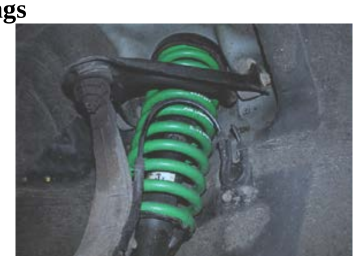


Fig.6

The coiled springs, figure 6, is made of steel bars wrapped by a propeller. In this type of spring, friction does not occur, as a result, the suspension with these kind of springs requires the use of powerful dampers. Also, these springs take only tasks that work along their axis and therefore to a suspension of such arches, guidance devices are provided.

The coiled spring is about 2.5 times easier and less bulky than the spring sheet. These springs are mainly used in independent suspensions.

Torsion bar springs

The suspensions that use torsion bars as elastic element have begun to be utilized in an increasingly large number of cars and some buses, Figure 7.

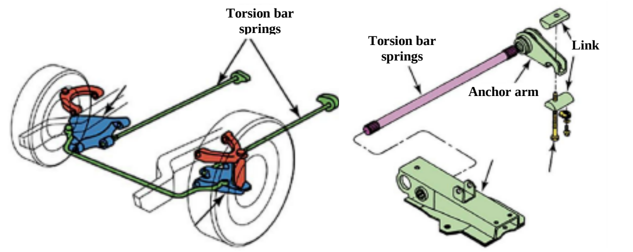


Fig.7

The torsion bar spring is formed by a circular or rectangular bar; more bars of circular cross section; overlapping blades. Torsion bars are fixed to one end of the arm, and the other one to the car body. They are arranged transversely but can also be arranged longitudinally. The advantages of torsion bars are: low consumption of metal and the possibility of adjusting the position of the suspension. A disadvantage of the torsion bar suspension is that it presents more difficult technical conditions of manufacturing.

Pneumatic spring elements

To the air suspension springs, the metal springs are replaced with resilient metal components. The suspension with elastic pneumatic elements has the following advantages: a parabolic characteristic to the linear characteristic of the metal springs, which makes it possible to reduce the area for the game suspension and thus be possible lowering of the centre of mass; allows automatic adjustment of the car body level above the ground depending on load and road conditions.

1.5 The dampers

For the rapid damping oscillations, in modern automotive suspension, hydraulic dampers are mounted hydraulic Figure 8. The dampers can be used on both axles of the vehicle or the front axle only, solution met especially to auto-trucks.

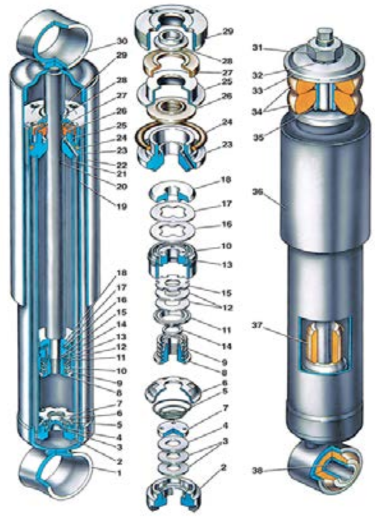


Fig.8 The construction of the damper

1 – The lower head; 2 The compression piston body; 3- The discs of the compression piston ; 4- The upper disc of the compression piston; 5- The spring compression piston; 6- The hemisphere compression piston; 7- The rigid disc of the compression piston; 8 - The nuts expansion valve; 9- The expansion valve spring; 10-The damper piston; 11- The retaining disc of the expansion valve; 12 – The expansion piston discs ; 13- The piston segment; 14- The expansion piston of the disc nut and washer systems; 15 -The upper disc piston; 16-The valve communication disc 17- The communication valve spring ; 18- The disc stop; 19 - Tank; 20 - Rod; 21-Cylinder; 22-Tube tank; 23- The guiding bushing of the rod; 24- The jointing ring of the tank; 25-The sealing disc system; 26- Jointing element ; 27 – The ring safety saddle; 28- Circlip; 29- The nut tank; 30- The higher head ; 31- The retaining nut of the upper head; 32-Groiver; 33- The disc of the fixing cushion of the damper ; 34- The cushion (buffer); 35- The bushing; 36- Tube; 37- Damping rod; 38-The fixing bushing of the rubber mounting lower head.

The working principle of the hydraulic damper is based on the transformation of mechanical energy into thermal energy oscillation, to the forced crossing of a particular lich from one damper room to another, through a calibrated orifice. Most dampers are double acting, working in both directions, that is, to the approaching wheels they have low resistance; to the remoteness of the body wheels they have a higher resistance.

The most common car dampers are the ones with telescopic form, classified into single-pipe and two-pipe, and which in turn can be of several types. The most used types are the two-pipe dumpers, which, compared to the single-pipe, have a smaller length and a bigger working.

The two-pipe telescopic damper

In Figure 9 is the schematic diagram of the two-pipe telescopic hydraulic damper. The upper head which is fixed to the piston rod, is joined to the suspension of the vehicle, and the lower head tube integral with the tank tube on the unsprang side. The inner tube (the working cylinder) is filled with special damping fluid.

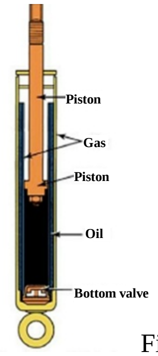


Fig.9

In the course of expansion, the liquid from the top of the piston is compressed and sent through the expansion valve to the bottom. The volume generated by the piston at the bottom is greater than the volume of liquid pushed down, with the volume of the rod coming out of the tube. The gap is filled with liquid compensation chamber (the space between the tube and the inner tube tank) coming through the intake valve due to the depression created in the piston and the air cushion in the upper room clearing.

In the compression stroke, the liquid under the piston passes through the communication valve in the top of the tube. A part of the liquid (equal to the volume introduced into the tube stem) passes through the compression valve in the compensation chamber. The tube serves for the protection of the piston rod and the sealing ring to the tightening of the damper.

If the speed of the oscillations increases, the fluid pressure increases, exceeding the star-shaped spring pressurising force of the compression valve and the valve disks move down, resulting in a greater transition section (which results in a decrease of the damping force by a critical speed). This is very important for the operation of the vehicle in cold weather when the viscosity of the liquid increases; its crossing through the gauged hole is done much harder, leading to an increased pressure in the cylinder and the valve compression starts working by downloading the suspension and the damper of overstraining.

The telescopic absorber-pipe damper

In comparison to the two-pipe, this has at external equal diameter, a greater piston diameter, being easier and having a better cooling. After the gas pressure from the compensation room , the single-pipe damper can low pressure; high pressure (hydro).

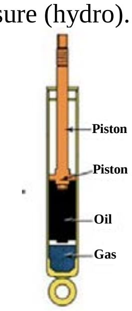


Fig.10

In Figure 10 is shown the hydro pneumatic single-pipe damper. In the compensation chamber, nitrogen under pressure of about 2.5 N / mm 2 is introduced. The air cushion is separated from the damping fluid through the floating piston. The compensation volume due to its decrease at the compression stroke is obtained by compression of the gas cushion and by the movement of the upper floating piston.

To the expansion stroke, the generated volume is occupied by the gas that expands by moving the floating piston down. The holes and discharge valves are mounted in the piston. Due to the elasticity of the compensation, the damper also serves as additional elastic element.

Adjustable telescopic dampers

The vehicles move on different roads with certain speeds and a certain degree of loading. Changing the above parameters during vehicle use for keeping the conditions of comfort and stability, it is necessary that the damper characteristics are modified. Changing the damping characteristic can be achieved by: modifying the holes; changing the open pressure of the valves; changing the pre compression of the valve springs.

Changing the damper characteristic can be controlled by the driver via a button on the dashboard (electromagnetic control). There are some dampers with automatically adjustment of the characteristic depending on the load that acts on the suspension and road bumps.

For example, the Peugeot 407 vehicle, provides 9 different settings to adjust the degree of damping. Adapting the degree of damping to the driving conditions (road subsidence) and to the charge status of the car, is made with four motion sensors placed on each wheel. These sensors provide information to the electronic control of the suspension.

1.6 Stabilizers

Due to the action of the centrifugal force on a veering car, they tilt sideways, thus decreasing its stability. Stabilizers serve to limit the tilting without increasing the suspension stiffness.

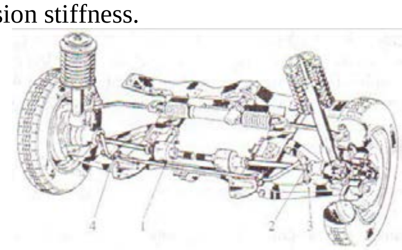


Fig.11

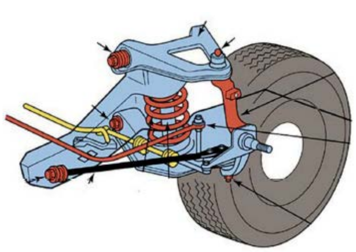


Fig.12

With the help of the stabilizer, it can be reduced the lateral inclination of the body by 20-30% without changing the characteristics of the suspension.

2. CONSTRUCTIVE TYPES OF SUSPENSIONS USED IN VEHICLES

2.1. Suspensions with dependent wheels

Suspension systems with rigid axle

They are characterized by a rigid connection between the left and right wheels and the lifting or lowering of a wheel, Figure 13 caused by unevenness in the track, causes the change of position for the other wheel.

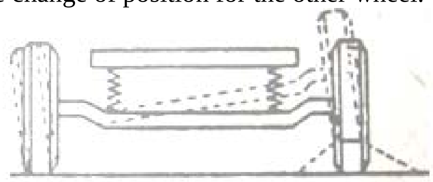


Fig.13

Advantages: low-cost, lifetime

Disadvantages: imprecise direction, bigger imperfect contact between the wheel and the road.

In many cases, the suspension of the vehicles with rigid axle uses spring leaves springs arranged longitudinally, due to simple construction.

The suspension with semi-elliptical leaf springs arranged longitudinally.

The arch sheet is disposed longitudinally to the frame. One end of the spring is attached by a hinge pin (to transmit traction and braking forces to the frame) and the other, through the earring by allowing the spring to deform under the load action (by bending the arc, the distance between the centres of the eye principal sheet is amended). The damping of the oscillation is provided by hydraulic telescopic dampers with double acting.

Dependent suspension with coil springs.

Because the coil springs take only vertical loads, the bridge is provided with arms for the horizontal forces withstanding.

Traditional suspension

In this configuration, the damper is not a structural part of the suspension system. This means that if it were broken or missing, it is still possible that the car can be driven up to the first service to be repaired. In this case the position of the wheel (on the upper and lower arm) and the height chassis and the road (on the bow) will remain the same. At the traditional system of suspension the damper and spring are always mounted separately. The damper suspension system used is called traditional damper. The most common solution for fixing the damper are:

Type socket / socket - Type bush / spindle - type threaded rod / pole - pole Type / U Type support

2.2. Suspensions with independent wheels

Independent suspension systems

The wheeled independent suspension predominates on the front wheels, but lately has spread to all four wheels, Figure 14. To the independent suspension, it is missing a direct link between the car wheels and the position change does not affect the other wheel. In this type of configuration chassis the fixing of the wheels through an articulated system allows each wheel to get up and down by one, independently of the other. This type of suspension system is more efficient than rigid deck, being able to provide more stability by maintaining a firm contact between road surface and wheels. In Figure 14 the rear suspension of a car fitted with springs twist transverse bar is presented. Wheels oscillate in the longitudinal plane of the vehicle, being connected by the front twisting springs through the swing arms.

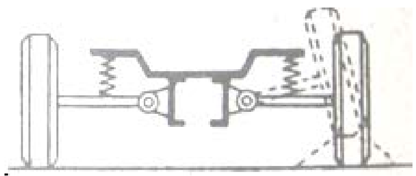


Fig.14

The suspension is provided by two hydraulic telescopic dampers - double acting – having at the interior a shock buffer expansion, for limiting the lift.

Advantages: better improved contact between the wheel and road, highly comfort.

Disadvantages: higher cost, more complex constructive solution depending on how the suspension behaves.

Due to the advantages it presents, the suspension with independent wheels wheeled independent suspension is widespread. The independent suspension compared to dependent suspension, presents the following benefits: Improving comfort by reducing unsprang mass; better road holding as wheel movements do not influence each other; the decrease of the rolling oscillation of the and the increase stability of the car. Two types of front suspension systems are widely used in vehicles today: MacPherson strut suspension and short/long arm suspension (SLA).

Short / long (SLA) suspension arm

Each SLA part consists of two control arm attached to the frame at one end and spindle to the other, Figure 15. The arms pivoting on the spindle ball joints and on rubber bushings at the frame.

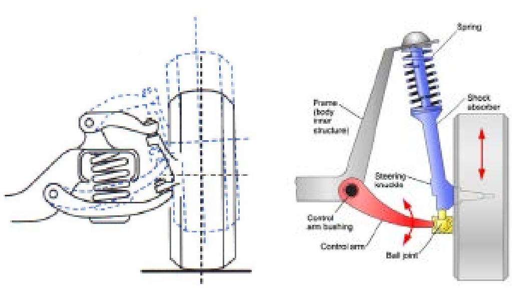


Fig.15

A variety of spring arrangements may be used, a coil spring placed between the two arms is the most common, but in the spring may be mounted on the upper control arm or a torsion bar can be attached to the lower rocker arm. Using a shorter arm allows the track to remain constant to the road surface during compression spring, the elimination of the friction tires slide that could occur in the case he arms were the same length. A conventional steering system is commonly used to this suspension, which may also be referred to as a conventional suspension.

MacPherson suspension

The MacPherson suspension, Figure 16, combines a coil spring and a shock absorber in one unit on each side. The beam is attached to the body in upper and a lower rocker arm by a ball joint at the bottom. The other end of the control arm attaches to the frame and the pivots on the rubber bushings. The spindle is rigidly mounted to the beam. This suspension is lighter and smaller than SLA design, and can be found on smaller vehicles with rack and pinion steering. This suspension is commonly used on front wheel drive cars.

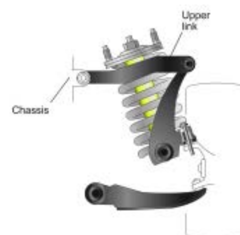


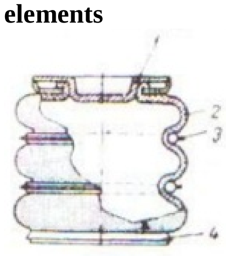
Fig.16

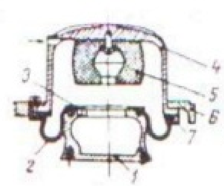
• **The multilink suspension**, Figure 17, is a variation of MacPherson type and are popular both front and rear to the performance-oriented small cars. This design uses the upper arm or the link attached to the chassis to add stability.

Fig.17

• Another variation of MacPherson suspension is modified MacPherson suspension, which mounted the coil spring on the lower control arm. This arrangement was used on the front and rear independent suspension.

2.3 The suspension with elastic pneumatic spring elements





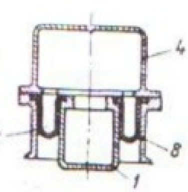


Fig.18 Fig.19 Fig.20

In figure 18 is represented the resilient pneumatic in the shape of bellows. It consists of a membrane of rubberized nylon fabric 2, having between each floor a steel ring 3, which limits the radial deformations. At the ends, the elastic member is provided with valves 1 and 4 by means of which it is fixed to the suspended or non-suspended part or the vehicle.

Another type of elastic pneumatic element is the diaphragm type or wit bellows, Figure 19 and 20, with one floor. It consists basically of a cylinder 4, linked to the suspended part and a valve (piston) 7, connected to the non-suspended part. These parts are joined by a membrane or diaphragm 2, which is wound and carried on the valve depending on the position of the cylinder relative to the valve. Unlike leaf springs, the pneumatic resilient element cannot currently take only vertical forces.

The rigid axle suspension systems means that the wheels are mounted opposite each other by a rigid bar. In this way, when on one side of the body, the distance between the wheel and body car changes, the same distance on the opposite side change as much, but in the opposite direction. In the configuration with independent suspension, the wheels are fixed to the chassis by an articulated system that allows one to get up and down independently of the other. This system provides better stability, increased comfort and firmer contact between the wheels and the road.

2.4 Active, semi-active, passive, reactive suspension

Active suspension

The active suspension system has the ability to adjust the operating parameters continuously according to the road conditions. The system constantly monitors various parameters and adjusts them by itself. The active suspension system has a computer to control each wheel when, in what direction, the distance and how fast to move. The computer makes these decisions through a network of sensors that measure for example, the machine speed, lateral acceleration and longitudinal acceleration forces on each wheel. After the computer sends the command wheel to get the ideal in the situation.

Continuous adjustment of the operating parameters dependent on the roadway is possible due to the active suspension. Thus, due to this type of system it is possible to continuously monitor and automatically adjust their parameters. This is possible thanks to a computer whose role is to control each wheel to time, the direction, distance and speed with which you must move. Setting parameters is possible because of sensors that measure certain values of longitudinal and lateral acceleration, the force on each wheel acceleration and speed of the moving car. After collecting this information through a sensor network, the computer begins sending the command to optimize the wheels depending on the situation. The luxury and performance vehicles have active suspension systems. Height and comfort features are actively controlled by the computer:

• Use hydraulic cylinders (RAM) instead of conventional shock absorbers. The sensors on each ram sends signals to the computer, which can extend or withdraw rams by varying the fluid pressure.

• The system can react within milliseconds to changes in traffic conditions such as sudden braking or cornering short, uneven; the pressure is provided by a hydraulic pump driven by the engine.

• When a wheel encounters a bump, the sensor signals to the computer which immediately releases the pressure with a control valve. The pressure may be issued immediately or slowly, depending on the road surface. Any bump computer increases the pressure in the tire causing the damper to follow the road surface.

Semi-active suspension

The main characteristic of the semi active suspension is the ability to continually change the damping coefficient, making damper harder or softer depending on road conditions. This is done by connecting the electronic control unit of 4 dampers with adjustable damping coefficient. Sometimes the solution outside tandem with a traditional bow, these dampers can be combined / paired with different solutions for automatic adjustment of ground clearance and type Hydro pneumatic systems, Hydrolastic or Hydra gas. The main advantages of semi-active suspension are:

1. Adjustable road clearance, optimized for comfort and handling
2. The possibility to adjust the strength of the suspension
3. Suspension will automatically adjust depending on road conditions
4. Related dimensions to traditional suspension systems

The road condition is a very important factor in the proper functioning of the suspension system. The semi-active suspensions have the ability to permanently change the shock absorber damping coefficient and hardness depending on road conditions and of course on driving style. This type of suspension involves four adjustable dampers connecting the electronics unit. These dampers can be combined with various control systems as the ones e Hydrolastic, Hydro gas or hydro pneumatic types. When these technologies are not available, you can choose to use a traditional bow to achieve tandem. Semi-active suspensions have quite a few advantages, for example the ability to adjust the strength of the suspension of the car, automatically adjusting the suspension depending on the condition of the tread, the road clearance optimizer soil for better manoeuvrability and dimensions similar to those of the conventional suspensions.

Passive suspension

Under this name we include all conventional suspension systems / traditional. Their main feature is that once installed on the car, the suspension parameters (hardness, ground clearance) cannot be controlled from outside. All springs and traditional dampers are considered elements of passive suspension.

All traditional / conventional suspension systems fall into this category. Such suspension involves the impossibility of controlling from the outside the suspension parameters once installed on the car. This is why this term has been adopted in order that the hardness and ground clearance become uncontrollable at some level. The dampers and the conventional springs enter in the frame of passive suspension.

Reactive suspension

This includes conventional suspension systems. When there is a road hump, implicitly appears the movement of the wheel which causes suspension compression or extension in response to the external factors. Similarly, the movement of the suspension is determined by other manoeuvres such as braking or steering. This helps the car body to lean forward, backwards or sideways. Within the category of the reaction between the suspension system and the type of suspended soil which can control the ground clearance depending on such factors as the aerodynamic forces and weight of the machine. This type of suspension may also react to the internal loads such as the lateral successfully counteracting the effects. An example of a reactive-passive is RSF Kinetic system from Tenneco that facilitates equal loading weight distribution between the wheels via a passive interconnection, simplifying design parameters and some constructive solutions such as controlling the lateral balance by changing the strength of a suspension at the level of a single wheel .

2.5 Electronically controlled suspension systems

Suspensions are products that can change the loading and the comfort of the vehicle with very fast characteristics, either automatically or on demand. These systems vary greatly among manufacturers and models lines. Some luxury models or high performance have electronic control of the dampers. These systems vary the pressure of the shock with the help of a valve according to the conditions, as determined by a control module with inputs from a variety of sensors. Control module activates the motors or solenoids which change the size of the valve openings. Module can be used with input from multiple sensors, including:

- height sensors situated on the frame near the wheel;
- position sensor of the throttle valve
- vehicle speed sensor; brake and door sensors
- the direction sensor detects the rotational angle of the steering wheel and the speed

Suspension system with electronic and fluid damper control

The system uses magneto rheological fluid dampers (MR) instead of changing the valve position. This fluid is a synthetic oil containing suspended iron particles suspended. The dampers or bars contain a liquid which, when energized, act on the iron particles giving the fluid a greater uniformity for a greater damping action. The damper can be changed variably and instantly.

2.6 The body of the controlling and controlled decks

a) Rear suspension

There are many models of rear suspension, Figure 21, many of which are variations on the SLA, MacPherson, multi-link, or light trucks, a solid axle with leaf springs. Some rear suspension can use a guide rod to prevent lateral movement of the rear axle.

Fig.21

The destination of the rear axle motors

The motor bridge is designed to transmit the engine torque from the longitudinal transmission and vertical forces from the vehicle body, to the motor wheels. Also through the motor bridge is transmitted to the frame the tensile forces, the braking forces, the reactive moment and the braking moment which occur while driving the vehicle. The rear axle is composed of the main transmission, differential, drive shafts, final drive, and crankcase.

The conditions imposed on the rear axle.

The rear axle must meet the requirements: small dimensions as to achieve a bigger ground guard; has a quieter power supply; the maintenance should be as simple as possible; to provide lasting operation.

The classification of the rear axle. In terms of constructive, the rear bridges divide in: rigid axle; articulated axles, rigid bridges are used in trucks, cars, and the articulated ones in some cars.

The rear axle casing is designed to transmit the vertical load from the frame to the wheels and simultaneously to transmit the forces to the wheels on the car or truck. Carter must ensure a proper function of the organs mounted inside. The rear axle casing must be strong, rigid, to have auto weight and to allow easier installation and removal of the transmission organs.

Constructive types of casings - from the constructive point of view the rear axle crankcases can be: removable, non-removable, figure 22.

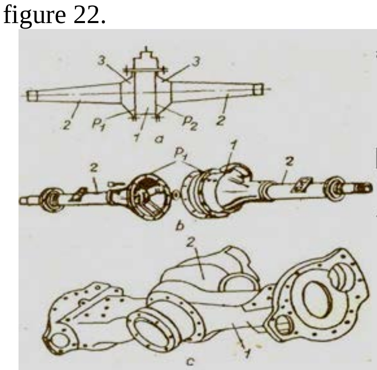


Fig.22 Constructive types of casings

The removable rear deck crankcase with 2 separate plans, Figure 22a. In this solution to the central part of the crankcase 1, tubes 2 are fixed in which there are planetary shafts. The pumps have welded at their inner ends the conical cover 3 which is fixed with screws to the central part resulting the separate planes P1 and P2.

The removable rear deck crankcase with 1 separate plan, Figure 22b. The removable casing with one separate plan P1 is composed from the central crankcase P1 and fallopian 2. The crankcase is obtained by moulding steel and the fallopian 2are executed from pipe and pressed in the central casing where there are joined by welding or riveting.

Figure 22c the engine crankcase motor bridge of a truck. It is a non-removable crank formed of a central portion 2 where the crankcase of the main transmission and the differential are mounted; and from a beam profile 1 L equipped with pipes that protects the planetary shafts.

The removable crankcase removable have the disadvantage that in order to reach the differential a rear axle must be removed completely. Non-removable rear axle casing can be made by moulding, welding, etc. The removable crankcases obtained by casting are stiff but they have a heavier load and those obtained by welding are mild and less rigid.

b) Guiding devices

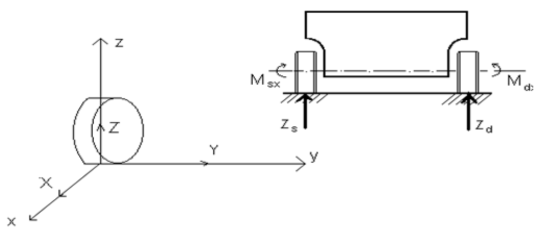


Fig.23 The forces due to the interaction between the wheels and road and their moments

Guiding devices transmit horizontal components of the forces between the wheels and the road, and the moments of these forces on the body, determining the movement of the character wheel relative to the vehicle body and to the road.

In Figure 23 shows the interaction forces between the wheels and the road and the moments of these forces.

Vertical forces Z and moments Mx are transmitted to the body through the elastic suspension. The damping elements are designed to dampen the oscillations which appear by avoiding the resonance phenomenon.

3. TESTING, CHECKING AND PRACTICAL MEASUREMENTS

General aspects

The technical condition of the suspension influences a largely comfort, road safety and vehicle endurance overall. The status parameters that would characterize the overall condition of the suspension, such as noise, shocks, and wheels oscillations have multiple connections with other parts of the vehicle, this not being characteristic only to the suspension that is the suspension diagnosis is made only on elements.

The diagnostic parameters of the suspension can be divided into four groups:
- Geometric and of state - are determined visually or by simple measurements
- Jointing - is determined visually or by simple measurements
- Elasticity - characterizes the springs' state and steering stabilizers
- Dynamic (of oscillation) - give clues particularly to the functioning dampers

Check springs

In addition to visual inspection which aims to discover the external defects, the spring is subjected to a test that aims to establish elasticity by determining its characteristic, i.e. to the variation of its effective length depending on load, the length being taken as a diagnostic parameter. If the line spring rate is below the standard characteristic, the spring must be replaced. In accordance with the standards, the comparison with the limit data is made in two situations: nominal load and no load, at the compression and at the rebound.

Check dampers

The separate checking of the dampers cannot be achieved only by removing them from the car. The method does not allow a fast diagnosis, but leads to the precise determination of the state of the organ. The method essentially relies on effective feature of the damper setting and its interpretation in terms of form and maximum values of the stresses exerted compression and rebound. This feature is a chart in which are entered the necessary efforts to move the rod in relation with the damper body in the two races. The test equipment is the eccentric rod type with variables which allow installation of different lengths or racing dampers. The machine has a recording device of the damper characteristic. The curve obtained is compared with a standard feature. A first criterion for assessing the technical condition of the damper is the actual maximum values of the technical state of the compression effort Pe and rebound on Pr. If they come out of the limit values , the damper is faulty. The deviations of the characteristic form from the standard feature provides important information about the nature of the fault.

Testing the dampers without dismantling them from the vehicle is made by raising the oscillation characteristic of the body, with the help of a roller, Figure 24.

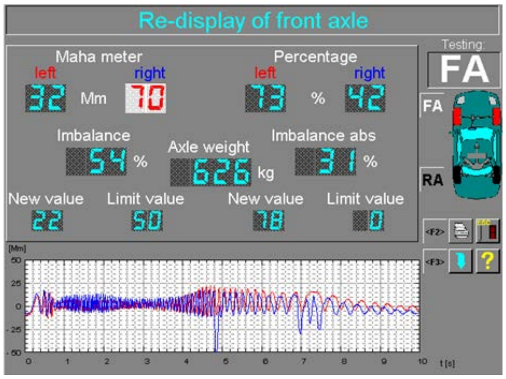


Fig.24

The shape of these features depends on the modulus of elasticity and damping coefficient, sizes affecting and resonant frequency at which the maximum amplitude values. The resonance occurs at lower frequency, where the amplitude is greatly influenced by the degree of damping. The damping ratio is high so the damper is better, therefore, the amplitude of the vehicle body, as the ones from the wheel are small, without this factor, it influences the frequency of the resonance significant. Therefore, it is sufficient to measure the maximum amplitude change caused by wheel speed and compare it with the allowable amount in order to appreciate the quality damper.

3.1 Methods and means of verification and testing of the suspension

MAINTENANCE SUSPENSION

Maintaining metal spring suspension consists of: visual inspection of the technical condition of the springs; the clamping of the joints springs; control of the damper attachment; the control of the density dampers; grease works (pins, earrings, spring supports, sliding plates). Maintaining pneumatic elastic elements consists in the daily control of the density and of the component position on the assemblage place.

Maximum permissible difference for the pressure of various pneumatic spring elements is 0.2 bar. Each year, the air spring elements have to be removed for water removal and impurities deposited on the bottom of the piston. It is recommended that this operation be performed after the cold season. The buses equipped with pneumatic spring elements require adjusting the body level from the ground. The correct position of the body from the ground level is given by the correctors of the suspension.

Annually, pneumatic spring elements must be removed to remove water and impurities taken on bottom of the piston and this operation should be performed after the cold season.

DEFECTS IN THE OPERATION OF SUSPENSION

The breaking of the main leaf spring. The causes that lead to the main leaf spring break are material fatigue, the unevenly distributed load, shocks of uneven path, shock made because of the unevenness of the lane, briskly startings and brakings. The failure can occur both at the front and the rear springs, near the spring eye or hole in front of the central clamping bolt. When the main leaf spring breaks, the car tilts side-draw the fault occurred. The driving of the car becomes more difficult because the body can rub on the tire surface. The troubleshooting can be done only at a repair shop. Along the way temporary fixes are made by supporting the broken end in the arch support and the cross linking axle to the frame so that it does not move towards the framework.

The breaking of the secondary leaf spring. Apart from the grounds listed in the main leaf breaking, the malfunction may occur due to the following factors: failure to replace defective sheet, weakening the spring clips, improper maintenance. Remediation is performed only in the repair shop.

The breaking of the central bolt spring. This failure is due to vehicle operation with spring clamps clamped. The fault elimination is done at the repair shop.

The wear or breakage of the flange fillet or bolt spring. Occurs due to the following causes: breaking secondary leaf spring bracket loosening, breaking the main leaf spring. The elimination of the fault is made at the repair shop.

Breaking or weakening of the coil springs. The causes that produce these defects are similar to those of the leaf spring breakage. The permanent elimination of the fault is done at the repair shop by changing the spring.

Along the way you can insert a metal disk between the broken parties and their binding

The failure of the dampers. The most common failures dampers refer to: leaking, clogging the connecting channels, the damage of the valves or springs. The elimination of the fault is done at the repair shop to which the car will travel at a speed related to the road bumps.

The suspension vibrates or makes noise.

Occurs due to the following main reasons: improper installation of dampers; the deformation of the frame; malfunctioning of dampers; weakening strut support; earrings, central bolt, bracket wear. While in the movement the clamping is done and at the repair shop the defect dampers and the damaged clamps are replaced.

THE REPAIR OF THE SUSPENSION

The arch leaf may show the following defects that shall be removed as follows:

• The elastic characteristic change is checked by means of a control leaf springs. The arch is reconditioned through re springing the leaves, followed by the appropriate heat treatment;

• The elastic changing characteristics is check with the help of a lamer spring controlled device, the spring is reconditioned through the re springing of the leaves, followed by the appropiate heat treatment;

• The main leaf or another leaf of the broken or fractured spring component is replaced;

• The central bolt thread is broken or damaged –it is replaced;

• Cracked or broken mounting lugs – they are replaced

The spring earring may have the following defects that shall be removed as follows:

• The worn bushing is replaced with a new one drilled on nominal size;

• The boring of the used spring bolt is reconditioned through load welding, followed by milling and drilling at nominal rate;

• The support of the used in length is reconditioned through sleeve milling and utilizing the compensating disks at mounting;

• The damaged inner lateral surface of the fork earring is refurbished through milling and using compensating washers to mount; if wear exceeds a certain limit, the used surface will load with solder, and it is milled at nominal rate;

- • The hole for the used clamping bolt is refurbished through the increase of the hole.
- • The reduced elastic cutting width is refurbished by milling the opening to the initial size and the restoring of the bore circularity.

The spring bolt may have the following defects that shall be removed as follows:

- • the used work surface is reconditioned through hard chroming and by grinding the nominal rate;
- • The damaged thread for the oiler support is refurbishes by welding charge, drilling and by re tapping to the initial size.

The adjustment of the bearing

Adjusting the hub bearings aims to eliminate play. Below, Figure 25 is an example of adjusting the wheel bearing to the two decks, front and back.

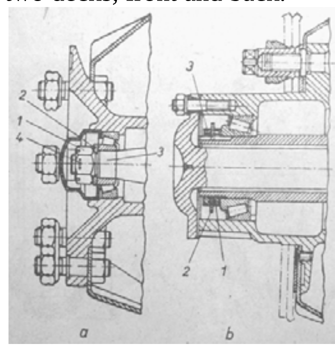


Fig.25

The front wheel bearings are usually adjusted using a castellated nut 1 (provided with cotter pin 4) and washer 2 (Figure 25a) mounted on the end of the spindle knuckle 3.

In the case of the rear axle wheel bearings, the adjustment is made, generally, with the help of the inner nut 1, the safety washer 2 and the outer nut 3 (fig.25b).

3.2 PRACTICAL MEASUREMENTS

The measurements of the suspension system was made in a motor service within one week (April 2014). The values collected are shown in Table 1:

Table 1

	FRONT AXLE			REAR AXLE			LEGAL VALUE	STATUS
	←	→	Δ	→	→	Δ		
M1 vehicle; Dacia Logan MCV								
Frequency of resonance	15Hz	20Hz	5	19	19	0		
The difference of the ground adherence		51%			2%		**<= 30%**	**NOK**
The wheel weight	430 kg	337kg		350kg	297kg			
The axle weight			767kg			647kg		
M1 vehicle; Clio Symbol								
Frequency of resonance	17Hz	17Hz	0	19	18	1		
The difference of the ground adherence		5%			48%		**<= 30%**	**NOK**
The wheel weight	390kg	355kg		261kg	200kg			
The axle weight			745kg			461kg		
M1 vehicle; VW Golf								
Frequency of resonance	16Hz	18Hz	2	20	19	1		
The difference of the ground adherence		30%			5%		**<= 30%**	**OK**
The wheel weight	517kg	389kg		343kg	300kg			
The axle weight			906kg			643kg		
M1 vehicle; Renault Laguna 3								
Frequency of resonance	14Hz	14Hz	0	16	16	1		
The difference of the ground adherence		3%			19%		**<= 30%**	**OK**
The wheel weight	554kg	511kg		332kg	279kg			
The axle weight			1065kg			611kg		
M1 vehicle; Ford Fiesta								
Frequency of resonance	15Hz	15Hz	0	17	19	2		
The difference of the ground adherence		13%			11%		**<= 30%**	**OK**
The wheel weight	374kg	321kg		271kg	202kg			
The axle weight			695kg			473kg		
M1 vehicle; VW Pol0								
Frequency of resonance	17Hz	17Hz	0	19	18	1		
The difference of the ground adherence		3%			6%		**<= 30%**	**OK**
The wheel weight	403kg	358kg		282kg	221kg			
The axle weight			761kg			503kg		
M1 vehicle; Mercedes ML								
Frequency of resonance	17Hz	16Hz	1	16	15	1		
The difference of the ground adherence		16%			2%		**<= 30%**	**OK**
The wheel weight	667kg	592kg		559kg	484kg			
The axle weight			1259kg			1043kg		

Table 1 Continued

M1 vehicle; Renault Fluence								
Frequency of resonance	15Hz	14Hz	1	16	15	1		
The difference of the ground adherence	6%			7%			**<= 30%**	**OK**
The wheel weight	464kg	413kg		300kg	255kg			
The axle weight			877kg			555kg		
M1 vehicle; VW Passat								
Frequency of resonance	14Hz	14Hz	0	16	16	0		
The difference of the ground adherence	5%			7%			**<= 30%**	**OK**
The wheel weight	437kg	418kg		337kg	250kg			
The axle weight			855kg			587kg		

Figures 26 and 27 present the sheet with measurements of a Logan MCV suspension system illustrated at position 1 in Table 1

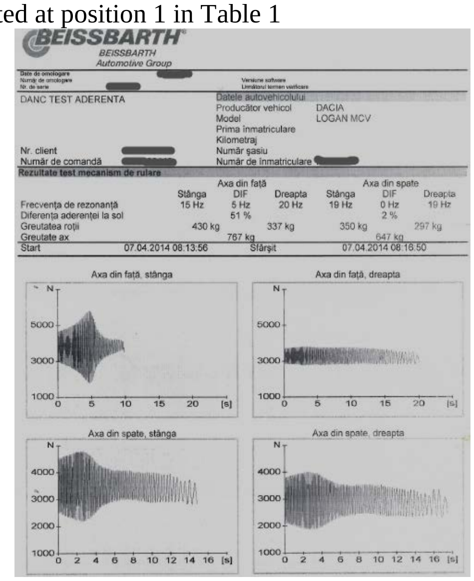


Fig.26

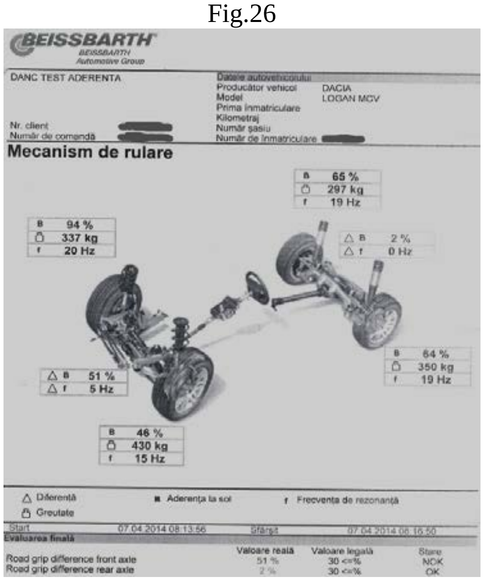


Fig.27

4. CONCLUSIONS

How to detect the problems of suspension?

Many drivers do not realize that running with serious problems at the suspension system is particularly dangerous. Anytime, one of the suspension components, Figure 28, can break at a power turn, and the consequences can be dramatic in some cases because the car is virtually uncontrollable. It is important how vehicle users check themselves whether the suspension system of the car works properly.

First, it is essential to determine the role of suspension. Thus, besides the ride comfort provided through shock damper taken from the road, the suspension system decisively influences the decisively the road ability, thus the safety driving. We must know that especially worn dampers can cause loss of control when veering or on windy conditions. In practice it was also found that the risk of aquaplaning and braking distance increases considerably with the assessment of the wear of the damper degree. It is recommended that after a turnover of about 60,000 km to replace the dampers because the longer the wear progresses, their performance decreases. However, it has to be taken into account the life of the shock damper is influenced decisively by the driving conditions, if the machine is mostly used on dirt roads, the dampers need to be changed sooner.

Fig.28

To assess by ourselves the state of operation of the suspension system it is recommended that periodically the car body be pressed into the damper areas. If after this process it is found that the car leans too far and fast in one direction or another, it means that the either the spring or the damper are loose. Other clues may be loud noises while driving or the apparition of shocks when rolling on uneven surfaces. And if during a comparing visual inspection of the wheels on the same axle suspension, a difference is noticed on the vehicle height (slope), the diagnosis is obvious.

Another important recommendation is to change a pair of dampers and springs, with all other components of the suspension bridge. It is good to know that the solution of changing a single damper from the bridge generates naturally a decrease of its lifespan. Even if replacing one damper is a more economical solution, the car will be unnatural and extremely dangerous at runtime. The used damper should be replaced with new ones of controlled origin. It is well known that the market offers many counterfeit parts, poor quality and may jeopardize safety. And if after this inspection relative empirical there are still doubts on the degree of wear of the suspension system, then it requires a thorough technical inspection from a specialized service.

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