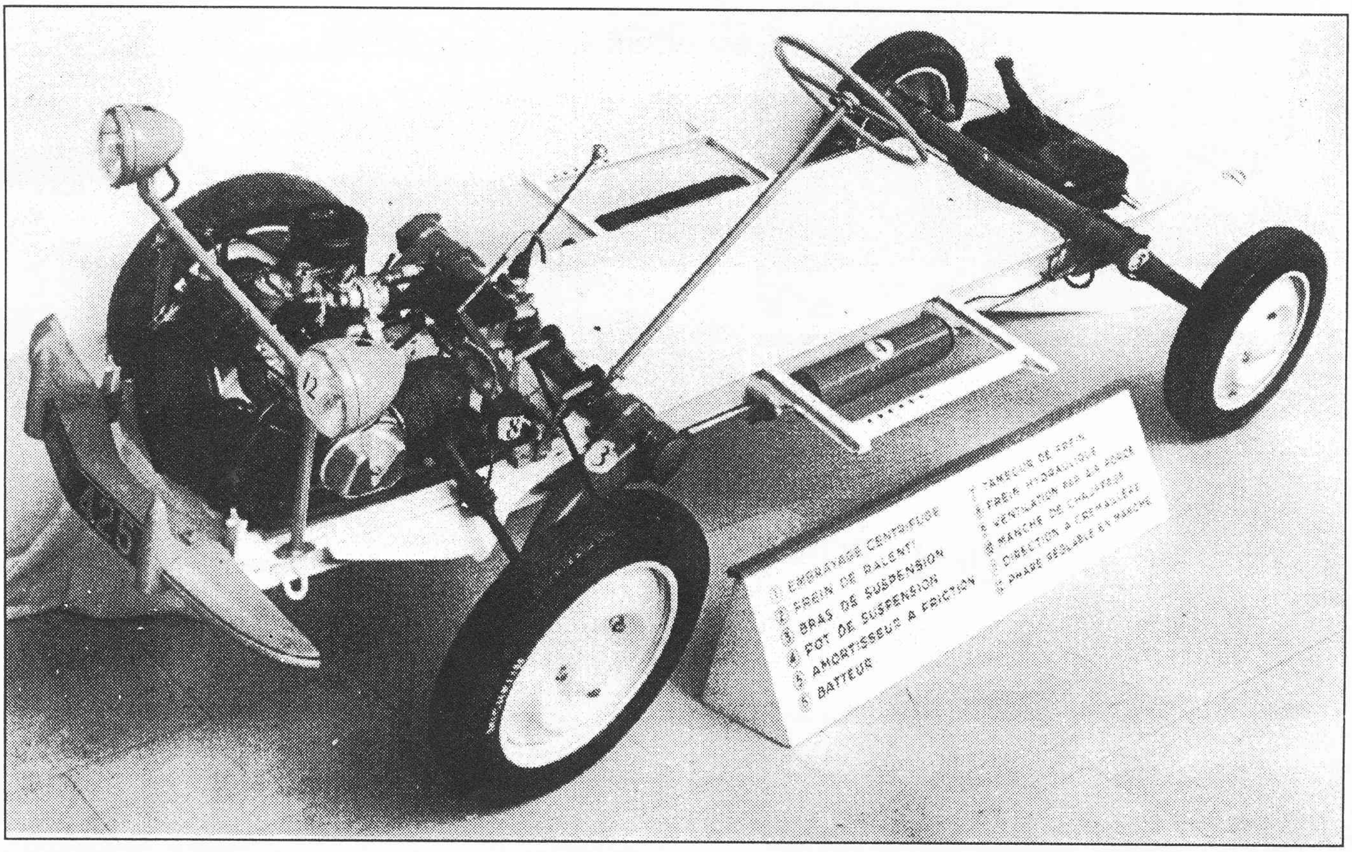
SUSPENSIONS THAT THINK

COMPILED BY PETER FITZGERALD



All modern active or adaptive suspensions says Geoffrey Howard are driven by control systems which react, process information, then operate fast responding systems.

It has always been the suspension engineer's unreachable goal to maintain simultaneously the highest standards of ride handling and body attitude control, under all conditions. The problems are huge and complex, but they stem, broadly speaking from the wide operating range created by the many possible combinations of road surface, speed and vehicle load. And as the relative weight of unsprung masses increases with reduced vehicle size, the problem is especially acute in smaller cars and growing more so.

Conventional suspension systems must always be designed as a compromise. Even with the aid of self levelling and interconnections between the wheels, any system that is soft enough to provide a very comfortable ride cannot also provide the stiff location a vehicles body needs to ensure the best possible handling. At the heart of the issue is the often overlooked but fundamental fact that ride is a measure of the suspension's ability to handle vertical forces at ground level, while handling and attitude control are influenced mostly by horizontal forces acting on the centre of gravity and by ground level couples or moments.

The dynamic performance of car suspension systems has progressively improved over the years, as the science of wheel control has developed hand in glove with more advanced analysis techniques and refinement of the basic kinematics. The design of wheel geometry, springing media, location members, damping elements, insulating bushes and tyre characteristics can today achieve standards that are way beyond those even envisaged through complicated hydraulic systems 20 or 25 years ago.

The fundamental difference between an active and a passive suspension is that active systems provide independent treatment of the road induced (bump) forces from the body inertia (cornering) forces. In simple terms, that means you can have a car with very compliant bump-absorption behaviour, which is so stiff in resisting roll, drive and squat, that the body stays more or less flat whatever you do.

While pure active suspensions are system-driven, it can be argued that there are some "less active" or "reactive" suspensions that are road-driven, and there are several examples where some of the performance of active systems can be simulated by internal processing of the direct road inputs. The two examples which come immediately to mind are the Citroën 2CV, which has interconnected mechanical springs, and the ill-fated Morris 1100, the first car to use Alex Moulton's Hydrolastic suspension.

Hydrolastic was one of the neatest and most underexploited reactive suspensions ever conceived. It was first patented in 1955 and launched commercially in 1962 in the Morris 1100. Although it worked very well in its original form, it suffered from long term durability problems in service and never made a successful transition to the mini, and on large models.

Hydrolastic was road-driven by the load inputs from the wheels and totally controlled from within the system itself. It had some very clever features that effectively simulated an active system.

The integrated Hyrdrolastic system did four specific things: It absorbed vertical shock forces, it dampened the subsequent rebound motion without fade, it dissipated the energy of the induced motion and it fed front inputs to the rear in proportion to the vertical wheel velocity.

If the same spring is shared each side between front and rear suspension (as on the first 1936 conception of Citroën's people' car, later developed into the 2CV) any pitching moment caused by deflection of the front suspension is countered by an equal and opposite moment at the rear, cancelling disturbance.

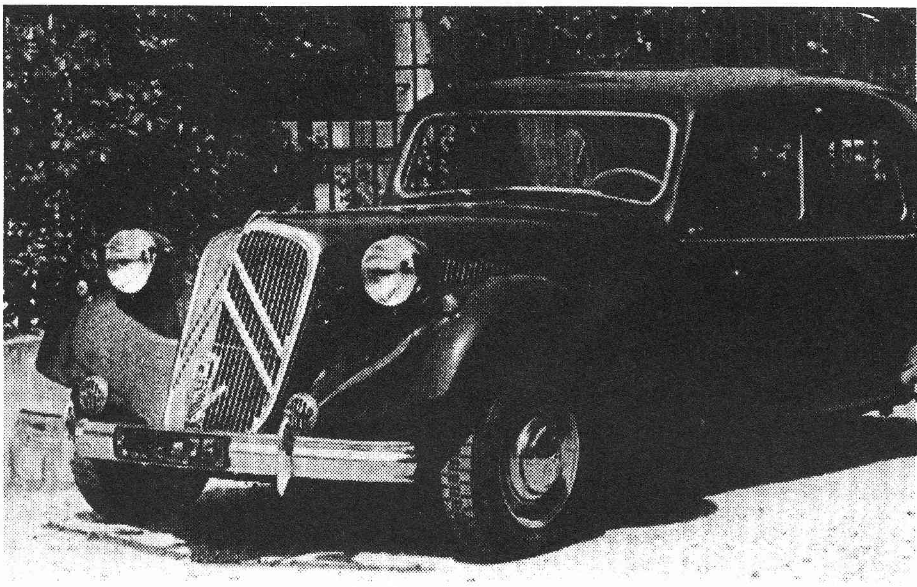
The problems start because the centre of gravity is never on the line joining front and rear suspension pivots so it causes additional moments usually described as dynamic weight transfer. These are totally freely mounted linked springs so the interconnection must be compromised some what to reduce the excessive squat and dive that would otherwise cause the car to hit its bump stops at the rear when moving off and at the front under braking.

Yet the advantages of interconnection endowed by the Morris 1100 with a most amazing ride and handling balance for a 1962 car of its class. Sadly, the considerable potential of the system was never fully developed.

The story at Citroën was much happier. Their adventurous hydropneumatic suspension, first introduced in 1953 on the rear of the Big Six Traction Avant, was carried over to the front and rear of the new DS 19 in 1955. It did not use interconnection other than to provide self levelling under load, however, and was only "adaptive' in static terms under the influence of pressurised hydraulic controls which changed the spring rates and damping to provide a near contant ride frequency.

It probably stimulated Alex Moulton into filing his Hydrolastic patent and led directly to the design of many other hydropneumatic systems, notably from Mercedes Benz for the 600 in 1964 and later S Class models, and from a German component supplier called Langen AG of Dusseldorf in 1965.

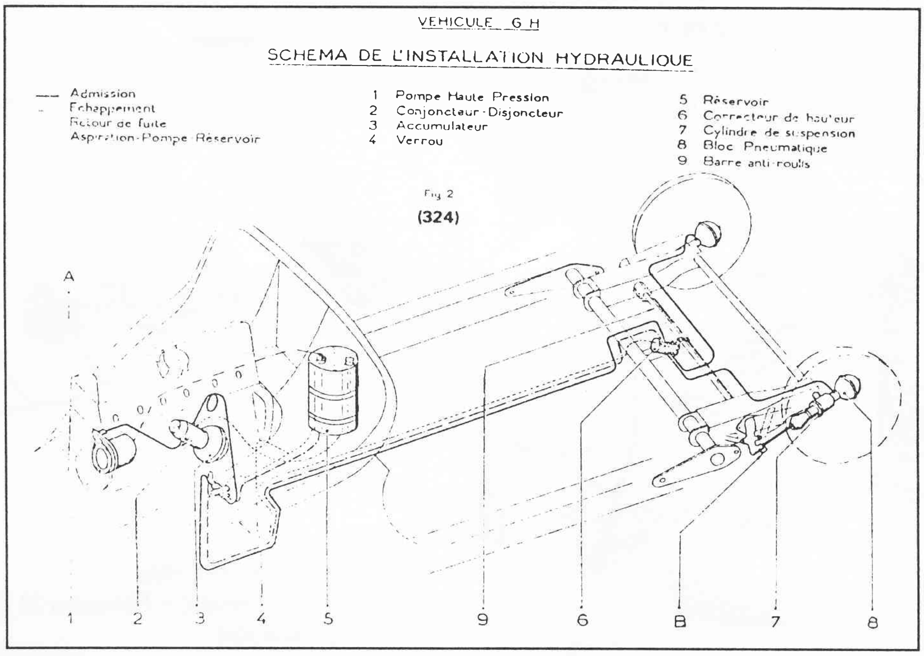
Non-adaptive but self levelling air suspension dates back even further, to Firestone experiments in the 1930's which eventually resulted in air springs being fitted to Greyhound buses in 1952. Air suspension was also adopted by Cadillac in 1957 but dropped only three years later.

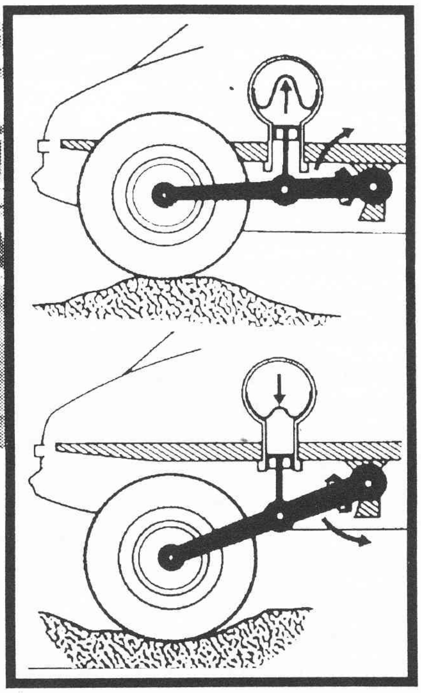


The system used by Citroën (and Langen) employs speriodal shaped steel containers in which a rubber bag filled with nitrogen under pressure is compressed by the action of a working fluid (mineral oil). Various valves in the system control the flow and pressure of the fluid to provide a constant ride height regardless of load. They also provide damping of the wheel movements and a variable rate for the springs caused by changes to the effective area of the convoluted rubber diaphragm separating the fluid from the gas.

But the Citroën system is actually prevented from responding to rapid changes in wheel position in the way Hydrolastic can. The Langen system, on the other hand extended Citroën principles further towards true active suspension theory, by interconnecting the hydraulic line front and rear. Unlike Hydrolastic, the connections were made diagonally and both front and rear spring units were mounted at the rear.

The advantages of this approach was that although the stiffness of the springs roll was less that in a non-diagonal connection, the diagonal pitching moments were resisted better. Langen spent several years developing their system for production and fitted prototype units to several cars, including a Morris 1100, a





Ford Taunus 12M, a Citroën DS19 and a Mercedes Benz 220S. But it wasn't adopted as original equipement.

The first truly active suspension, stabilised to eliminate pitch and roll, was developed by Automotive Products in the early 1970's,. A prototype Rover 3500 P6 was used for some very convincing demonstrations at the time and a similar system was fitted to a Ford Granada research vehicle for assessment in 1974. I was an extension of the Langen principles used in conjunction with a primary main system, several motion sensors and a very fast acting, high capacity hydraulic pump. Unlike the Citroën system, where time delays are built in to prevent fast reactions.

The early Automotive Products systems generated self levelling under inertia loads to provide virtually zero roll and zero pitch.

But the system operated by generating a displacement error that was then corrected, and it took time to respond. It was a two edged sword which killed off the concept before production.

Lotus effectively removed all of these constraints in their active system by replacing the spring and damper units with irreversible double acting hydraulic actuators.

The first test car was an Esprit, followed by a Lotus 92 formula one car. Both used the most advanced suspension control ever tested, based on precision signal conditioning units designed by the electronics boffins at Cranfield who used digital control of analogue inputs to maintain hydraulic pressure, tailor the dynamic attitude of the car at speed and monitor the health of the system at all times.

The result on the Esprit, as the systems were developed was dramatic. Control of body motion over bumps and complete absence of roll or pitch in transient manoeuvres provided security and precision which made a quantum leap from even todays high standard at Lotus

Citroën in 1993...the XM

Citroën was the first manufacturer to apply active suspension technology to mass production car - the XM. Called Hydractive, the XM suspension was described by one British magazine as the finest suspension yet made.

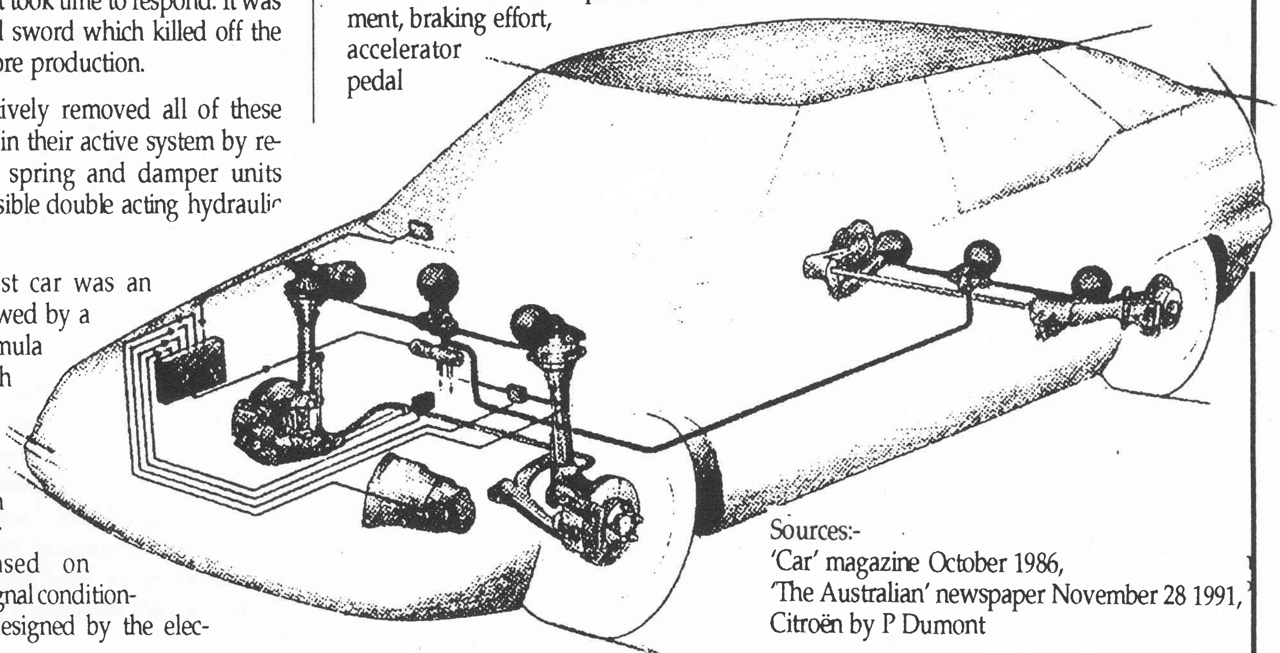
Other suspensions simply react to road irregularities, but the Hydractive systems deals with them through the use of sensors and a powerful processor.

Sensors monitor vehicle speed, body movement, braking effort, accelerator pedal movement and steering input and this information is used to select the appropriate suspension setting.

What makes the Citroën system different to many other semi-active ride systems, which control only the shock absorbers, is that it also controls the springs.

The change from soft setting for cruising or coping with bumps to a hard one for high speed cornering or an emergency situation is made in just five hundredths of a second.

Driving into a pothole, the system senses the front wheel dropping and can adjust the suspension before the rear wheel hits the hole.



Sources:-
'Car' magazine October 1986,
'The Australian' newspaper November 28 1991,
Citroën by P Dumont