THE HISTORY OF COMPONENTS

This section of the journal deals with one of the metal components used in the automotive industry, recording the changes in its design. At the same time, the many ways in which the techniques and materials employed in its manufacture have developed will be described.
This approach helps to emphasize the vital role played by metal component manufacturers in developing the basic materials and working out production processes.
The article in this issue deals with springs.

Springs

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Abstract
The advent of the automobile provided many important new uses for springs. In this paper various types of springs used for the suspensions, the shock absorbers, engine valves and the clutch are presented and discussed. The most significant changes in design and manufacturing process are also considered.

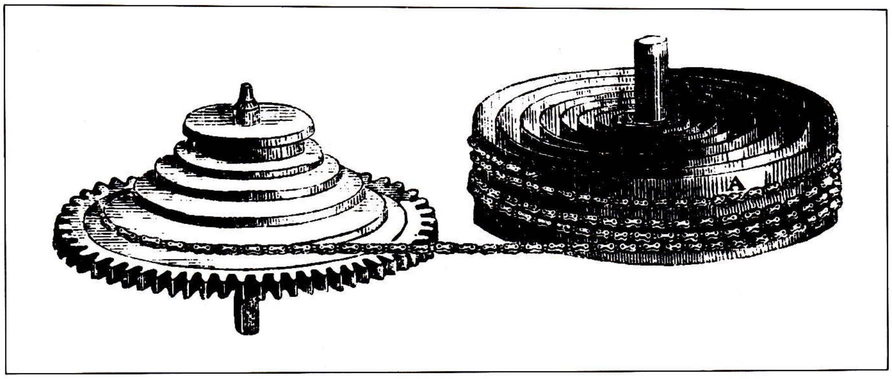
Riassunto
Con l'avvento dell'automobile le molle trovarono nuovi e importanti impieghi. In questo articolo vengono esaminati vari tipi di molle utilizzati per le sospensioni, gli ammortizzatori, le valvole del motore e la frizione. Sono anche messi in evidenza i mutamenti più significativi intervenuti in sede di progettazione e di realizzazione.

Springs are mechanisms whose distinguishing feature is their elasticity. The underlying assumption applicable to the investigation and calculation of their behaviour is that elastic deformation is proportional to the force applied. This hypothesis is known as Hooke's law and is sufficiently accurate over the elastic range of all steels used in the manufacture of springs. Permanent deformation takes place when stresses beyond the proportionality limit are applied. Temperature, the state of plastic deformation and ageing of the material are influential factors.
The bow can be cited as an initial example of a spring. This is a throwing weapon consisting of a flexible elastic part made of wood (elm, hazel, ash, cornel, yew, etc.). The nock of the arrow butt rests on a bowstring tied to each of its ends. The crossbow, ballista and catapult are based on the same principle.
The bow was in use as early as the Stone Age (Fig. 1). All the Oriental peoples were renowned archers. The English and Scots, too, were great bowmen until firearms got the upper hand.
Archery today is a noble sport that calls on the services of modern techniques for its materials andmanufacturing processes and for bows of ever greater functional efficiency. Another significant step in the history of the spring was its use as a motor in clocks and watches (Fig. 2).

Fig. 1 - A hunting scene with archers (Neolithic painting).

In 1657, Christian Huygens submitted to the States General of Holland a detailed description of a clock worked by a spiral spring instead of by the force of gravity in the form of weights. This coiled spring was made of cement steel, the only sort known at the time, and was frequently unsatisfactory owing to the presence of dross inclusions and other defects. It was also poorly uniform.
The credit for overcoming these drawbacks goes to Benjamin Huntsman of Sheffield, who first thought of using molten steel

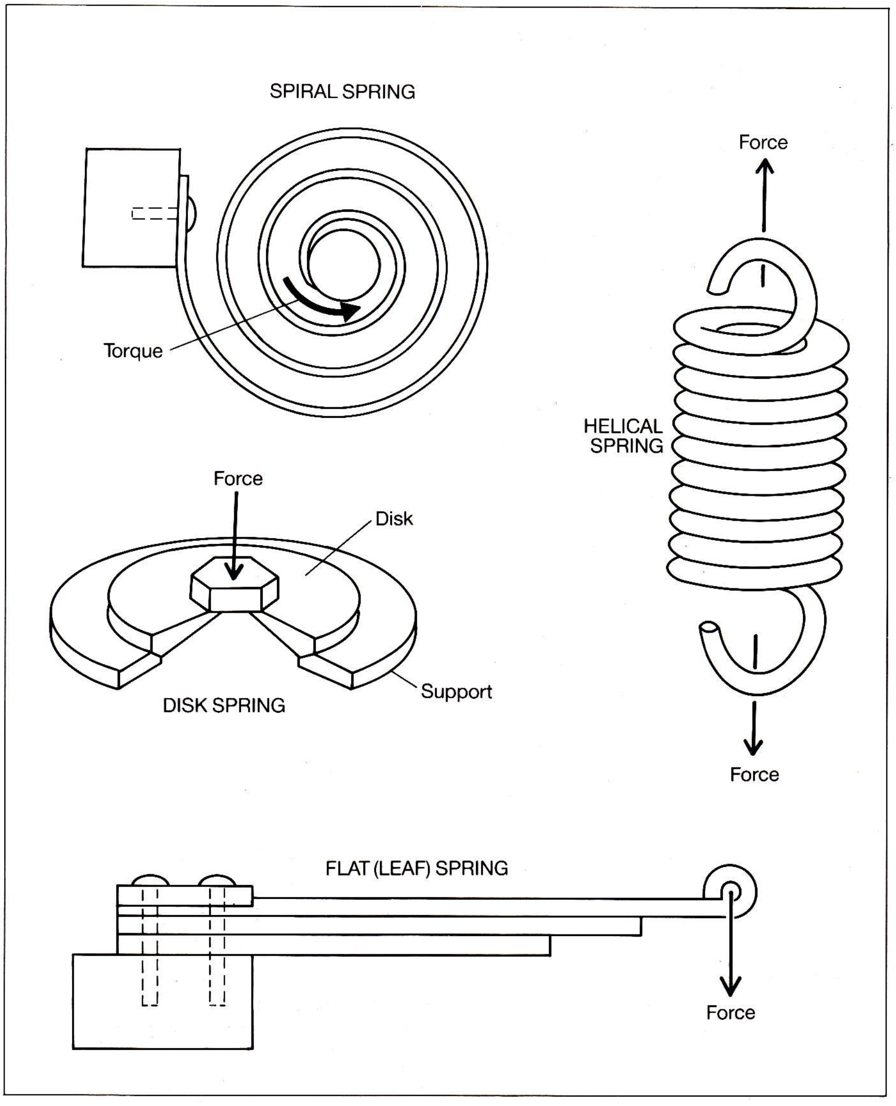
Fig. 2 - Spring used as a motor in clocks and watches.



The state of the roads, the poor grip offered by the wheels and the low speeds attained by the earliest vehicles did not demand the same degree of sophistication as was extended to their other components in the early years of this century. Indeed, the state of the art with regard to suspensions was expressed as follows by Georges Kellner, President of the Paris Coachbuilders' Association, at the International Automobilism Congress in Milan (May 1906): " For a vehicle to be well suspended and stable, it is essential for its (leaf)

instead of cement steel.
This new material — molten carbon steel — proved better than the previous kind in terms of homogeneity and purity. The fabrication process consisted of melting in a clay crucible on a coke oven a charge of small pieces of casehardened iron bars. The molten metal was then poured into cast-iron moulds. Huntsman's process remained the only one available until the middle of the nineteenth century, when new, more economical processes placed large quantities of good quality molten steel at the service of the fast developing industrial world.
The advent of the automobile provided many important new uses for springs in various forms (Fig. 3). One of the major problems with which early car manufacturers had immediately to deal was that of the suspensions (Fig. 4). Since cars were the direct descendants of horse-drawn carriages, these pioneer automakers naturally began by adopting the traditional system of springing used on coaches. This was based on two rigid axles connected to the body by means of lengthwise or crosswise leaf springs. The wheels were iron-tyred and devoid of shock absorbers as we now know them, though a certain degree of damping was provided by the rubbing together of the leaves forming the springs themselves.

Fig. 3 - Types of springs.



springs to be very long, with not too much displacement, and set as far out board as possible with respect to the vehicle, i.e. the inside of the springs should be 5-6 cm outside the chassis.
It is also indispensable for the vehicle to be suspended on the inside and not above the springs, so as to lower the centre of gravity as much as possible. The tractive effort of a car is greater, the better its suspension. What is needed, therefore, is a suspension that is all the more perfect, the faster the vehicle is expected to go.
Badly suspended vehicles bounce, are noisy and wear out quickly.
The displacement of leaf springs when the chassis is fitted with its body and accessories should be 5% of their length. In the final analysis, for a spring to be gentle its rate must be progressive, not sudden. Indeed, one only has to look at the springs of express trains, sleeping cars and dining cars, in other words, vehicles designed for high speeds, to realise that our recommendations are in fact followed to the letter".
Turning to shock-absorbers, then called anti-shock or brake-spring devices, one Truffault is said to have been the first to make them and put them to use.
In the early years of the century, the steels used for car leaf springs were the same as those employed by the railways, namely carbon steels made in an open-hearth furnace from charges of selected materials. Their strength ranged from 75 to 85 kg/mm^2 with an elongation of 16-20%. Hardening and tempering resulted in a tensile strength of 120-130 kg/mm^2 with an elongation of 7% and a yield point of 80-90 kg/mm^2.

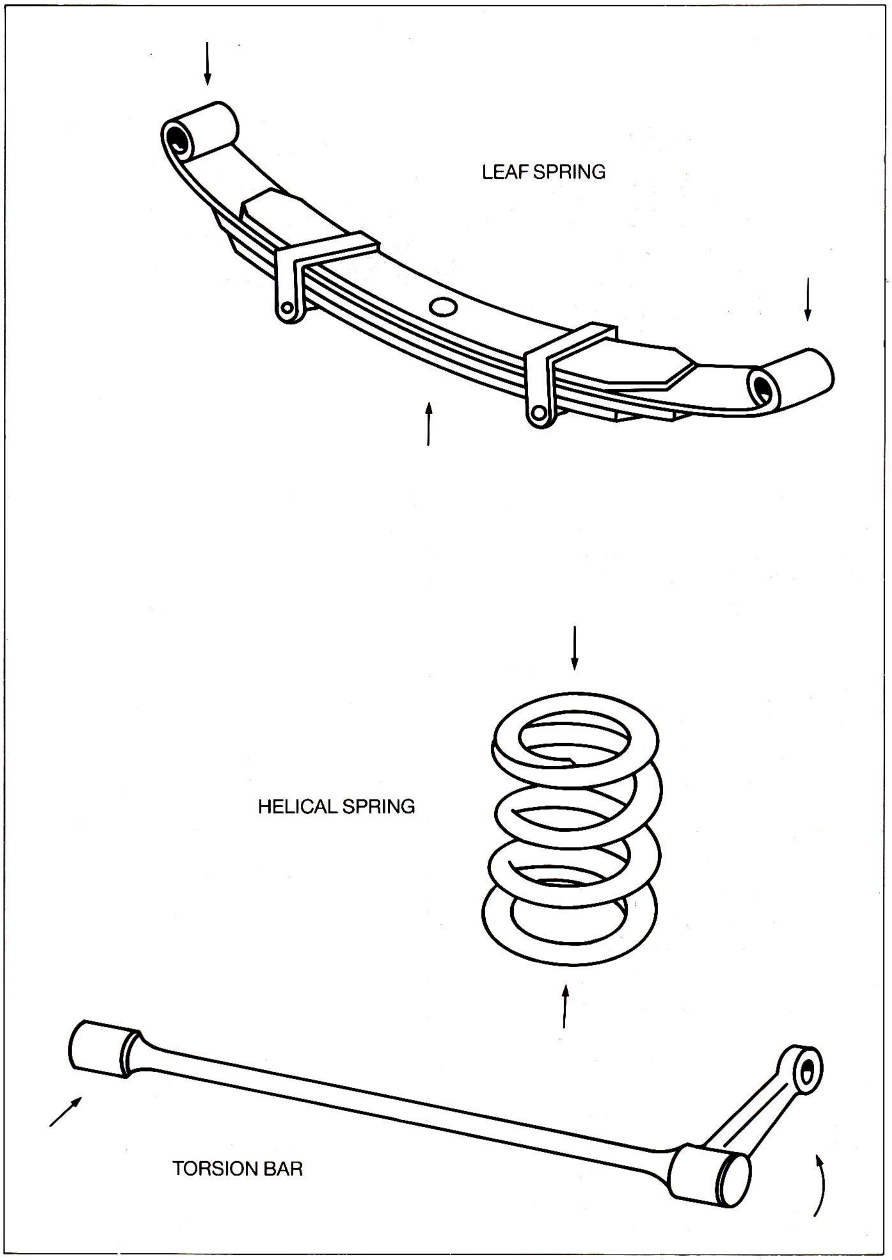
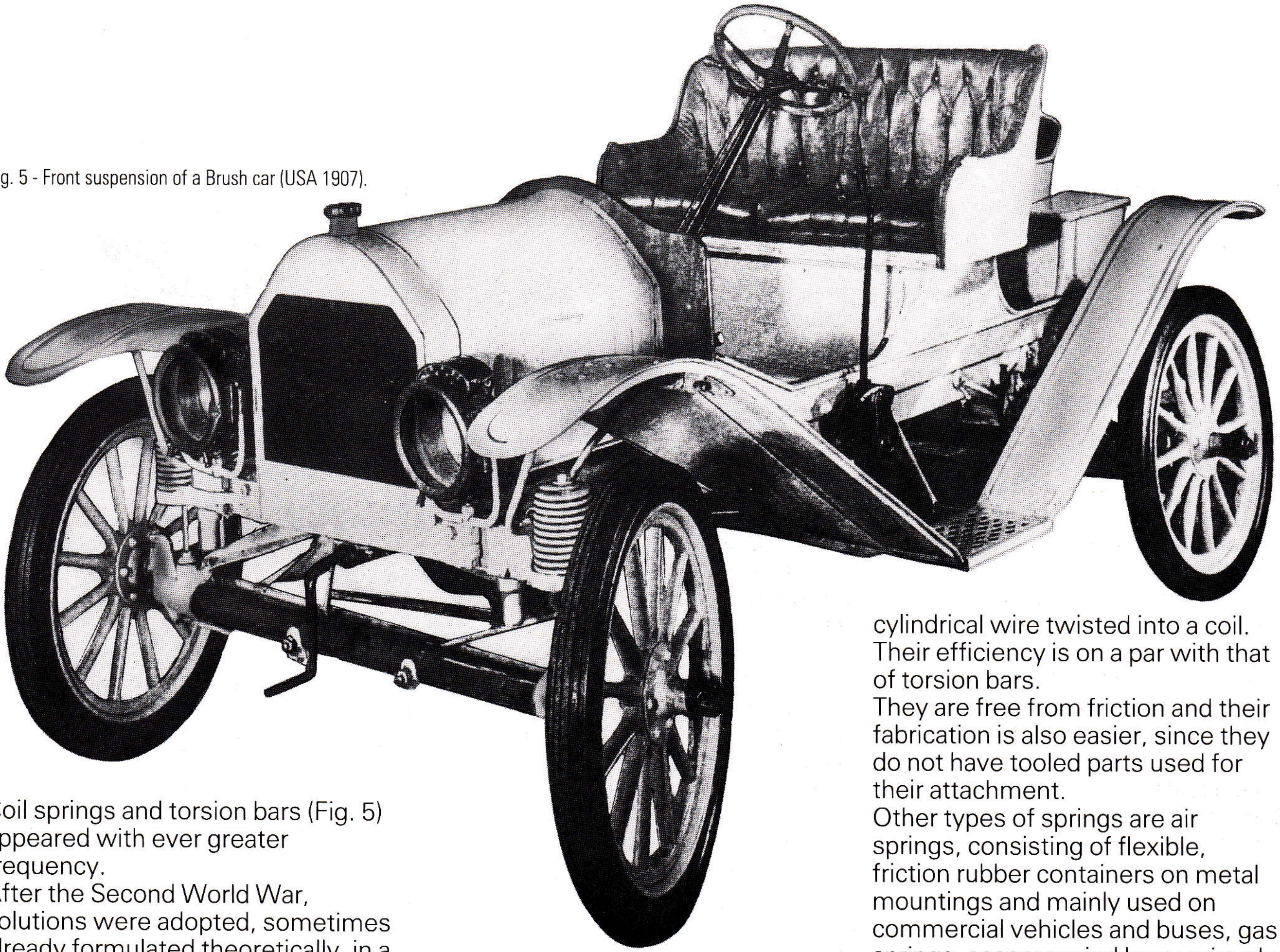


Fig. 4 - Springs for suspensions.

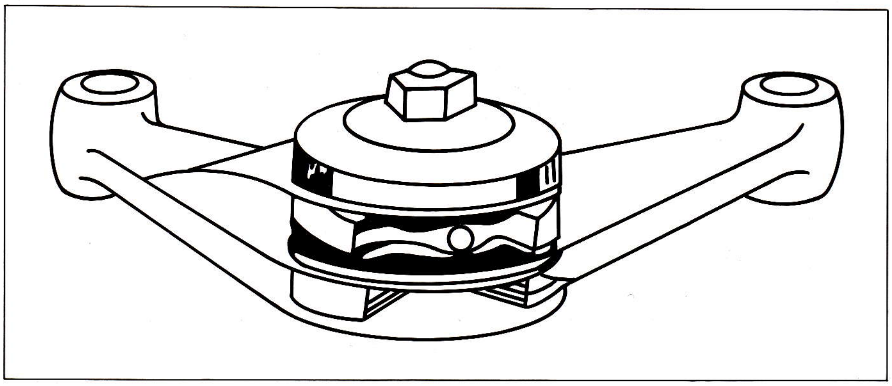
Silicon and tungsten alloyed steels were used in special cases. Later, cars were designed in a manner more in keeping with the constructional principles and performance of an engine-driven vehicle with regard to their manufacturing principles and performance. Innumerable attempts were also made to find new solutions for their suspensions.
Starting in the Twenties, a search was made for manufacturing solutions in keeping with the ever-improving performance of automobiles and to achieve good roadholding.
Suspension layouts were progressively distinguished in function of the type of vehicle (position of the engine, front or rear drive, load arrangements, etc.
For prestige vehicles and racing cars, new and more complex schemes were developed in a sophisticated search for greater comfort and better performance.

Fig. 5 - Front suspension of a Brush car (USA 1907).



Coil springs and torsion bars (Fig. 5) appeared with ever greater frequency.
After the Second World War, solutions were adopted, sometimes already formulated theoretically, in a fresh proposal adapted to high-volume production and new solutions were also sought for the same purposes.
We thus come down to today's suspensions. Together with the engine, aerodynamics, wheels, safety features and new materials, they form part of the visiting-card of every new vehicle.
Flexible devices are now composed of spring-wheel hub or by springs and a more or less complicated system of levers. Leaf springs have a number of important advantages in their favour: the sufficiently longitudinal and transverse link between the chassis and the wheel hubs, simple fabrication and the fact that breakage of a leaf does not usually result in loss of the connection between chassis and hub that is essential for safety.
On the other hand, leaf springs have one drawback, namely a by no means negligible amount of friction, depending on their state and maintenance. Moreover, their efficiency is not very high.
Torsion bars, which are cylindrical bars reinforced at their ends, do not have inherent friction and their efficiency is high. However, their use means more complicated manufacturing, while if they break the elastic reaction that ensures suspension of the corresponding wheels is immediately lost.
Coil springs work on the torsion principle and consist of a simple cylindrical wire twisted into a coil. Their efficiency is on a par with that of torsion bars.
They are free from friction and their fabrication is also easier, since they do not have tooled parts used for their attachment.
Other types of springs are air springs, consisting of flexible, friction rubber containers on metal mountings and mainly used on commercial vehicles and buses, gas springs, accompanied by a variously complicated hydraulic device, and rubber springs of different shapes with a compression and a shear action.
The way springs are mounted on a suspension varies in function of the type of connection between the chassis and the wheels, generally speaking, linked wheels (rigid transverse axles) or independent wheels.
Shock absorbers (Fig. 6) used to

Fig. 6 - A friction shock absorber.



work by friction. They have now become hydraulic as a rule. Appropriate calibration in both compression and rebound of the braking values can be used to adjust the suspensions to obtain the best driveability, as well as influencing the stability of the vehicle when travelling in a straight line or cornering. Electronically controlled dampers would seem to be the solution of the future. Introduced a few years ago in Japan, they are now being used on an ever wider scale.
The stiffness of these shock absorbers is regulated by the vehicle, either on order or automatically, in function of the speed, the extent to which the steering wheel is turned and how the driver works the accelerator and brake pedals.
Modern steels for springs have a high coefficient of elasticity and resistance to fatigue (Fig. 7). In practice, a high yield point is taken as the mark of a high limit of elasticity. There are carbon, silicon, chrome-vanadium, tungsten-chrome-vanadium and chrome-nickel alloyed steels for leaf and coil springs and torsion bars, and for heat and corrosion-resistant springs. Naturally hardened or hard drawn or hardened and tempered springs are employed, depending on their use, the chemical composition of the steel and the fabrication process. Composites (fibres + plastics) have made their appearance and would seem to have a promising future for the manufacture of leaf springs.
Engine valve springs have posed another problem that has accompanied the development of the automobile from its earliest days (Fig. 8). These are coil springs called upon to oppose the opening of the valves through vibration or the vacuum created in the cylinders.
The negative pressure in a cylinder at the end of the induction stage reaches a maximum value that determines the tension of the exhaust valve spring when it is closed.
During dynamic operation, the conditions of a spring are very different from its static characteristics.
When there is a fast reciprocating movement, the spring tends to not return to its original position until a certain time has passed. Its rate, instead of remaining constant, will be found to decrease when the load increases.
This phenomenon is all the more marked, the greater the variation between the valves opening and closing loads.
It is thus desirable to fit springs with considerable flexibility, in which the load varies little.
If this is not done, the spring will no longer offer during dynamic operation the same characteristics as in its static condition, but is subjected to rapid deterioration.
The earliest car engines ran at a maximum of 2000 rpm.
All types of good quality wire on the market could thus be used to make

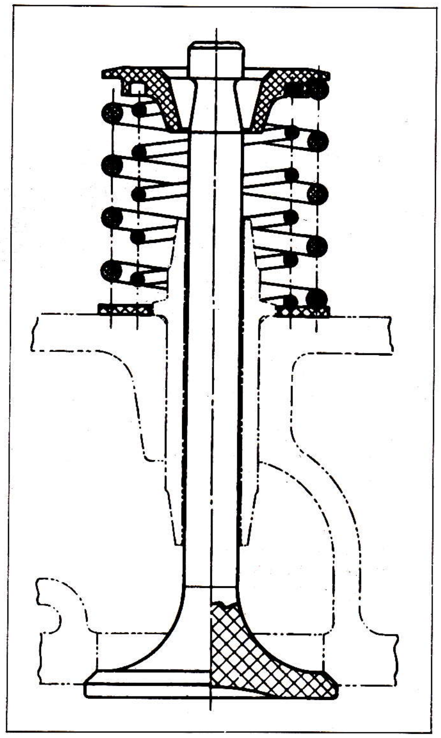
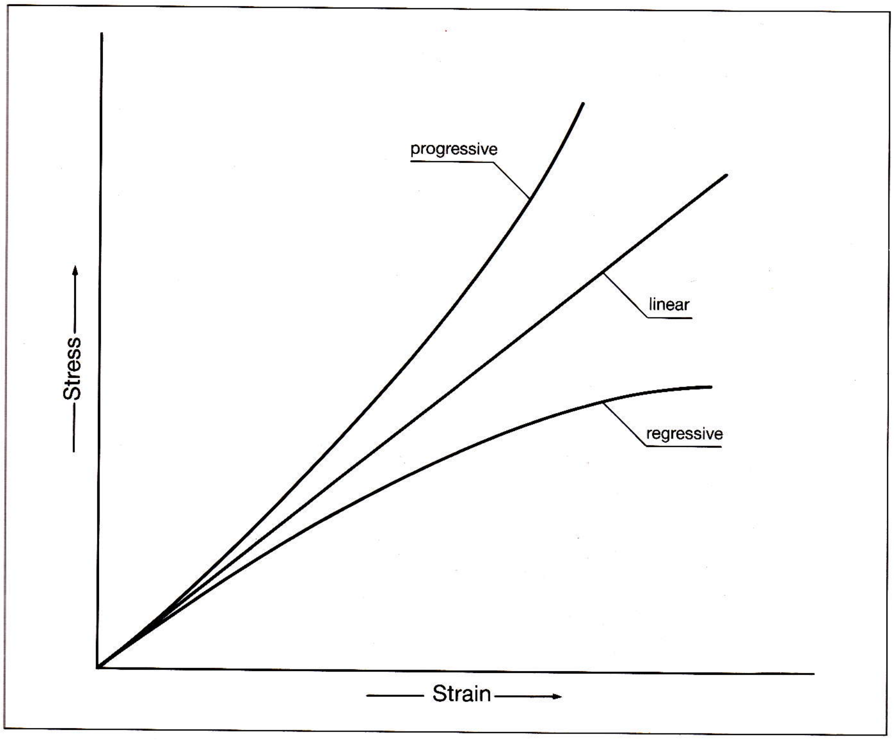


Fig. 8 - Valve springs.

Fig. 7 - Stress/strain diagram of three basic types of springs.



their valve springs.
Modern engines, however, are designed to operate at much higher speeds and their valve springs are produced from wire with special characteristics. The most powerful engines need to have a greater energy build-up. At high speeds, the inertia effect of the spring plus valve becomes much more pronounced under the influence of the valve lift and the cam profile.
Valve spring designers must do all they can to obtain the load desired without making the spring too heavy.
The force of the spring is the main factor to be taken into account. No simple and reliable rule can be offered for its calculation, however. The best method is still to start off with a standard spring and increase the force a little at a time if this is not enough. Practical testing is the only way in which the force of a valve spring can be correctly established.
High engine speeds tend to introduce dynamic stresses to add to the static stresses.
The designer usually tries to reduce these dynamic stresses to the minimum, either by adding damping coils to the spring, or by fitting separate damping springs inside the main springs.
If the stresses arising during use exceed the fatigue limit of the material, or if surface or internal defects result in local concentrations of forces, breakages due to fatigue may often occur after a vehicle has only been driven for a few hundred kilometres.
A reference should also be made to the use once made of flat springs for valves, especially on certain types of aero engines.
This sort of spring means that the valve stem can be much shorter, since its determination does not require addition of the length of the spring to the guided part.
These flat valve springs gave good results on engines running at up to 2000 rpm.
Another part of a car in which springs have a part to play is the clutch.
The earliest automakers found that the clutch posed big problems right from the start. After various more or less unsatisfactory solutions, they settled for a clutch whose operation is determined by a series of helical springs encircling the thrust plate. A system of levers compressed the springs to disengage the engine from the gearbox.
This type of clutch still has several drawbacks, such as its excessive size, the lack of uniformity in the thrust as the cylindrical helical springs require increasing force in the disengagement stage, and sensitivity to temperature changes.

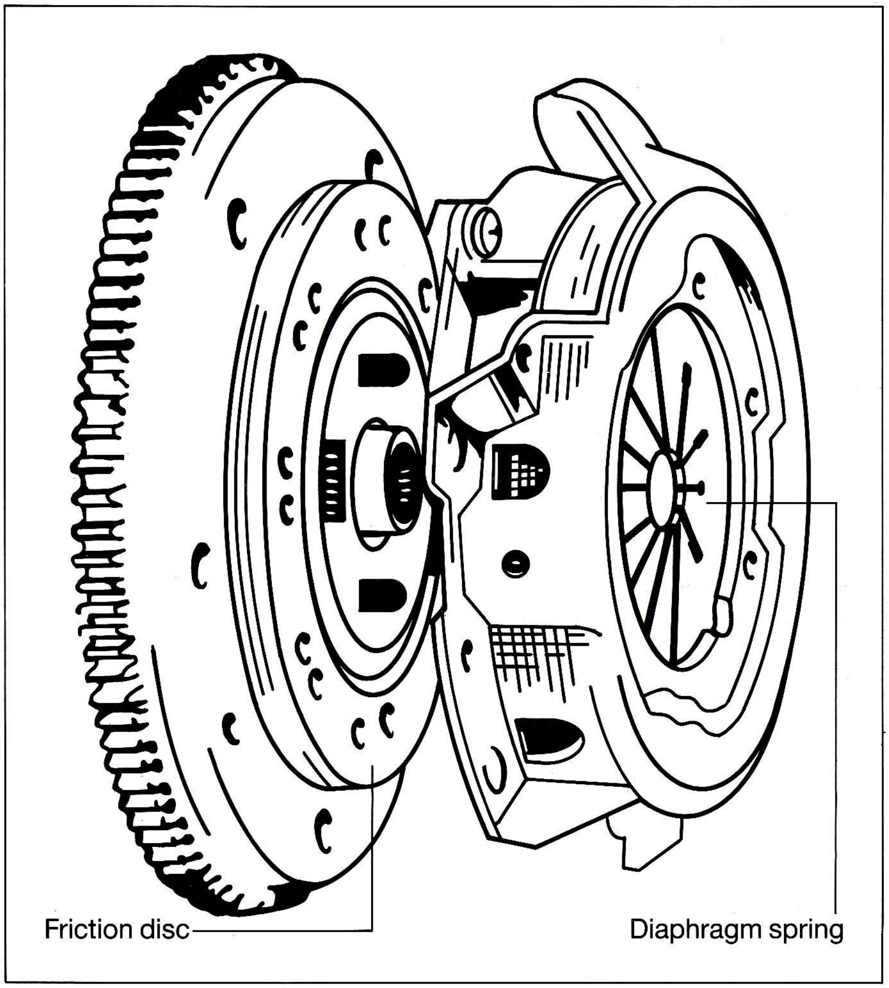


Fig. 9 - Clutch with diaphragm spring.

The diaphragm spring was introduced as an alternative around the Sixties and has since been used on a wide scale. Its advantages include elimination of the set of levers, reduction of the effort needed on the pedal during disengagement and easier maintenance (Fig. 9).
Mention should also be made of the importance of the small springs inserted in the clutch plate to ensure a soft, gradual engagement and protect other parts of the transmission from fierce shocks.
Lastly, one must not forget the springs inserted in the driver's and the passengers' seats. Here, at

least, an opinion can be formed on the functional importance of springs with no deep commitment of one's technical knowledge, nor undue strain on one's grey matter.
There are, of course, other springs fitted on motor-cars, all of them useful, though not always indispensable. Their history, however, has been less significant and need not be referred to here.

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