Essay on Car Suspension for Shock Elimination.

First Prize won by W. L. Murrell.
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The modern motor vehicle is unreliable practically in only one respect—that of tyres.

The pneumatic tyre, besides giving trouble when least expected, is a very large item in damaging expenditure. Hence we need a substitute for it even at increased first cost of suspension fittings, and there is the possibility of making the vibration very much less at the same time.

Our necessity is the mother of a large number of inventions which claim to be more or less perfect methods of suspension, which, in some cases, do away with the necessity of pneumatic tyres altogether.

Any form of suspension should be—

(a) Efficient in shock absorbing.

Consider the angle of inclination to the vertical of the ordinary cycle or motor cycle front forks. It is about 25 deg. (fig. 1), and is designed thus in order to be approximately in line with the direction of the shock from the road.

The direction, of course, varies with the roughness of the road and the diameter of the wheel; but bicycles travel the same roads as any motor vehicle and there is little difference in the diameters of the respective wheels, so we assume that the shock from the road for any motor vehicle is inclined to the vertical at 25 deg.

We may consider this shock (R) (fig. 2) as the resultant of two—i. one horizontal and equal to Rs in 25 deg. (H); ii. one vertical and equal to R as 25 deg. (V). Or ratio of shocks \( \frac{H}{V} = \tan 25 \text{ deg.} = .466 \).

Now a thoroughly efficient suspension must be capable of absorbing both components, for while it is the passenger who feels the vertical shock, it is the man who pays the tyre bill who knows the horizontal shock.

(b) Simple.

That is to say the working parts must be few (and hence the cost of manufacture low) and with no complications or inaccessible parts. They should be light (for every pound weight tells in running expenses); but as light only as is compatible with durability.
(c) A good damper.
The shock having been absorbed, the oscillations should be quickly damped.

(d) Capable of easy fitting to any vehicle.

We might differentiate three types of motor vehicle—

1. The commercial goods carrier—both light and heavy.
2. Runabout and touring cars.
3. The motor cycle and tri-cars.

1. The front suspension for both heavy and light vehicles.

This almost invariably consists of the single semi-elliptical spring with a link (fig. 1).

For the back suspension we have several alternatives in the light vehicle, but for the heavy type the usual form is a reversal end for end of the front spring (fig 2). Or the link may be replaced by a block B (fig. 3) with undercut groove bolted to the frame, and a sliding block (shaded) to which the spring is fixed.

The single semi-elliptic with two links (fig. 4) is common in chain driven lorries.

Suppose in the normal position, with load on, the links are vertical—Fig. 5 shown by LM and NO dotted. Fig. 5 shows the chain with tension T and spur wheel for the drive. The sudden application of the clutch will pull the whole wheel and spring to the forward position a a a. I denoting the position of the central portion of the spring. It is evident that the stress in the spring is increased, its ends being lowered while its centre is at constant level. There must be "an equal and opposite reaction," and so the body of the car must be raised.

In this way the tyre doesn't bear the whole brunt of the application. Hence this system has an advantage over that shown in fig. 2 (single link).

On the other hand, if when running, we get a bad road shock, the horizontal component forces the wheel and spring backwards into the position bbb shown. Although this is absorbed partly by again raising the body and thus doing work, it is evident that it puts a sudden extra tension T on the chain which is transmitted to the engine as a shock, and this is bad.

The light commercial back suspension.

In fig. 6, AB is a lever arm bolted to the sleeve of back axle covering A and hinged at B to a half link C. D is a pin pore in the bend of the link and by two plates, supports the spring S (semi-elliptical) hinged to the pin FF.

S is a plate fixing the spring to the body of the vehicle. A is constrained to move in a certain path by means of radius bars suitably placed.
Suppose the bars are arranged so as $A$ moves with $X$ as centre, and let $AA'$ be the normal displacement on ordinary roads (fig. 8).

Then if \( \frac{x}{y} = \tan 25 \text{ deg.} = .46 \). This would be an excellent arrangement. But the axle cover is subjected to dangerous torque, which must of course be taken up by the torque rod. Also if the torque rod moves, there will be a movement of the differential gear which will transmit the shock to the engine.

2. Runabout and touring cars.

The front is suspended by the single semi-elliptical spring with single link (see fig. 1), while the back suspension is frequently of the type known as the quarter elliptical—a recent type (see fig. 10).

Many of the good cars adopt this type of suspension in spite of the fact that it almost totally neglects the horizontal component of the shock.

Cheaper cars dispense with the four side springs, and have a single semi-elliptical spring at each end (fig. 11). This form is also suspicious, for there is no resilience whatever for the horizontal shock.

Lately there have appeared several unique suspensions.

(a) (fig. 12).

A is the back axle, to the cover of which is attached a radius-bar $AB$, and a link $C$, hinged to a quarter elliptical spring $D$, which, being attached to a lever arm $F$, is pivoted to the frame at $E$.

$a$ is the front axle (fixed), and to it two rigid columns $b$ and $c$ are fixed. $C$ carries two parallel arms pivoted at $e$ and $d$ on $C$, and at $g$ and $f$ on the frame—giving a vertical and backward movement. The column $b$ is hinged at the top to carry the spring $h$, which is fixed rigidly to the lever arm $m$ and pivoted to the frame at $l$.

$G$ and $n$ are rods hinged to $F$ and $m$ and have end plates $H$ and $O$, which move back and forth under the restricting action of springs in a box. The ends of the springs are fixed to the plates and to the ends of the box.

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If a moves upward under shock it partly compresses the spring h, and acting through m, compresses the pair of springs n o, and pulls or extends the spring OH. Upward movement of A has the same effect on HC and OH, and so the shock is absorbed.

Since the radius bar AB is short, there will be a considerable back horizontal movement x for a given vertical movement y; and here again, if for the ordinary oscillation \( x = \frac{46}{y} \), we have ideal conditions (see fig. 13).

Again, since the two rods eg and df are normally horizontal, any shock will be capable of analysis both vertically and horizontally, and the fixed axle does not rotate in the slightest degree (fig. 14).

It would perhaps be an improvement to make the radius bar AB and the parallel bars shorter than they are at present, and put in a link between b and the front spring h to allow of this horizontal movement.

(b) (fig. 15).

In this suspension the whole body is slung entirely between the axles.

The spring is fixed at A and held in the forging B, bolted to the frame and carrying C and D, two ball and socket joints for the parallel bars CE and DF. EF is an arm fixed to the front axle or back axle cover (the suspension is reversed on the back), and the spring is hinged to the axle at C, and the frame at A.

In the front position the parallel bars have a forward slope down in the back, a backward slope down (fig. 16).

For the front this is faulty, for it is evident that an upward movement due to shock entails a forward movement of the front axle, instead of a backward movement. But the bars CE and DF are in practice so long as to have practically no horizontal component of the movement at all.

There is a new feature embodied in this design. Compare with ordinary suspension (fig. 17).

Let K,K' be the centres of gravity of the two vehicles; L, L' = points of application of resultant loads due to chassis fittings. M,M' = axles.

Suppose both axles receive an upward movement, M Mm and M' M'm' respectively (fig. 18). Then, assuming the vehicle to oscillate about its centre of mass, in the first case movement of L is only L Ll, while in the second case L L' is moved through L' L''.

That is to say the body oscillates less in the first case. To procure the large wheel base shown in fig. 16, the ordinary car frame would need to be increased through the length of one semi-elliptical spring (say 3 feet), which is no small matter.
(c) (fig. 19).
Front suspension. The fixed axle A is fitted with a vertical pillar B, at the top of which is hinged an arm CD. EF is a plate bolted to the frame and carrying the two quarter elliptical springs GH and HI bolted together and pivoted to the plate at H. IL is a link. These springs are about 2 feet long, and somewhat stiff.

Since the spring GH is only hinged to fixed axle at G, it is necessary to keep the axle steady by means of the pillar B and arm CD.

Now suppose the axle gets an upward shock. CD must remain the same length, that is to say the "fixed" axle rotates through a small angle, which may mean erratic working of the steering gear. The only alternative is for CD to buckle under the compression caused by C'B' remaining vertical (fig. 20).

Back Suspension. (fig. 21.)
The axle covering a is hinged to the bottom spring b, which is in turn bolted to the upper spring f, the two being pivoted at C to the plate de, and thus fixed to the frame. f is fixed to the frame by gh.

These springs are especially long—about 3ft. 6in., and give a very large oscillation which, probably owing to friction between the plates of the spring, is damped remarkably quickly.

It is also claimed for this spring that it automatically adjusts its stiffness—for with increase of load the point of contact X of the springs will move backward, thus giving less leverage for the upward thrust on a, i.e., less oscillation or greater stiffness.

But it will be noticed there is no allowance made for the horizontal shock.

(d) (figs. 22, 23, 24).
A is the back axle cover and carries a small table B at either end (one end only shown here). B is hinged at C to a bar CE. H is a roller mounted on B, while the flat bar DF is capable of sliding back and forth beneath the roller and is hinged to F. The arm EF is pivoted to the frame at G.

The axle and table are kept down by the spring (helical) SS pushing down on the roller.

At its other end the spring is clamped to the end K of the lever arm LK. At L the arm is keyed to a shaft M, which bears in the frame QR of the car and carries a spurwheel N keyed to it. By fitting a handle on to the square head P we may turn the worm O and rotate N, thus getting a greater or less tension or strain in the helical spring.

This form has the advantage that the arm CE may swivel up and down, thus giving a certain amount of horizontal motion, but the whole apparatus is too cumbersome and occupies the valuable space generally used for the petrol tanks.
There is this great thing to be said in favour of it. It would only be the work of a few seconds to adjust the tension of the spring to an amount, found by practice to be the best for the load the car is about to carry.

The front suspension is of the ordinary type.

(e) (fig. 25).

This is a back suspension.

The axle cover is placed under B and has an upward reaction. The semi-elliptical spring ABC is fixed to the body at A and hinged on to a link at C. At the bottom of the link there is a bolt DE on which rests another bolt GF connecting two frames FH and GI. These frames are slotted to allow of a vertical movement of a bolt PO, and at the bottom are joined together by a plate L on which rests a cylindrical casting M fitting into another N, there being a spring (helical) between the tops of M and N.

Also the spring SRQ is hinged to the top of N by means of the bolt OP.

The portion R of SRQ is bolted to the frame, and at S there is a repetition of the apparatus with another side semi-elliptical spring.

This system has the advantage of comparative lightness. It, however, neglects the horizontal shock.

It is to be found fitted to one of the most luxurious types of limousine body, so it evidently has advantages which are not at once apparent.

(f) fig. 26).

A back suspension.

The back axle cover is placed under A of the semi-elliptical spring BAC, which is hinged to the frame at B and to a link CD at C.

The link CD supports a plate EF in which are two springs EH and FG. H and G are flat heads forged on to the extremities of the forks of the steel bar ML. The springs EH and GF are fixed so as to take both compression and tension. LM is clamped to the body.

The disadvantages and advantages are the same as for the foregoing.

An arrangement of helical springs shown in figure 28 is calculated to make the ordinary semi-elliptical spring more effective.

The heavy bronze plate L is cast with an elliptical boss G, which is drilled to allow two arms EE and FF of the inverted U, to pass through it. In the bend of the U is a bolt with collars. The lower extremity of both EE and FF is bolted to another plate M.

The helical spring is placed between L and M.
A pair of these is shown to the left, connected by the bolt CD, which passes through the bosses and another AB.

The bottom spring is fastened to AB, and the top to CD, as shown in fig. 29.

There are several different patterns of this spring, but they all amount to the same thing.

It is said that this spring absorbs the short rapid shocks which result from running over loose pieces of metal, the friction of the ordinary elliptical spring being too great to allow it to absorb a rapid shock.

Also the arrangement does away with the necessity for a link, and further is easily fitted to any car with the ordinary suspension.

Quite recently an entirely new idea has been carried out. It aims at making the spokes of the wheel take up the shock.

Figure 30 represents the hub and spokes cast in one piece. The spokes are bored out down their length as shown, into the hollow centre of the hub H. The valves V allow of air passing from the hubs to the spokes only.

Figure 31 represents the hollow piston, with two piston rings. This is fitted into the bored spokes as shown in fig. 33.

Figure 32 indicates the "floating rim" R and "segmental pathway" W. W is a wave-shaped bar placed within the rim and fastened to it.

The positions of the piston heads against the curves of R is shown in fig. 33.

The system is kept literally intact by two plates XX attached to the hub (fig. 34), and two more YY attached to the rim. These serve also to keep the dirt out.

Consider bottom spoke—it is evident that when the shock comes, it drives the rim up, thus driving the piston further into the spoke. But this closes the valve, and so the air is compressed in the spoke, thus giving a certain amount of resilience.

Consider the top spoke when the shock comes. The rim will rise above the spoke, i.e., will "float"; now, if the piston were attached to the rim, it would move outwards, open the valve and suck more air in from the hub. This would tend to make up for any loss of air through leakage when compression comes. But the piston is not attached to the rim. Hence it will be necessary to make H air tight, and compress air into it, and the pressure of this air will raise the valve when in the up position. But the pressure in H will have to be maintained. This will institute a bother.

The great advantage is that solid rubber tyres or even steel may be used.

Consider the effect of sudden application of the clutch. In fig. 25, let S represent the position of a spoke and P that of its piston in the hollow of a segment of pathway. If the
drive is in the direction indicated by A, then the tendency for the wheel to lag behind is indicated in direction by B.

This causes the spokes to move relatively to the rim, i.e., the piston head must traverse the pathway. This causes a compression.

Hence the whole brunt of the sudden application is not taken by the tyres; the compression of the air absorbs a large amount of the shock, and this is a factor to be considered.

Further than this, the horizontal shock is catered for just as much as the vertical one.

As a set off against this, the weight of each wheel must be very considerable, and in this respect there is room for improvement.

3. Motor cycle side car. (fig. 36.)

ABC represents the side spring of an ordinary side car. The body of the car is slung at A and B, while the axle of the wheel is beneath C. The way in which the respective parts of the spring are used, is to be noticed.

The resultant of A and B is a load D downward in about the position shown. In the ordinary car D falls well to the left of C, when for ideal conditions, it should be in line with C for vertical shocks. For this reason many side cars have a tendency to tilt forward when running and the effect is increased by the vibration, due to road shocks.

Tricars.

The tricar is used almost exclusively in commerce for transport of small and comparatively light packages. The front pair of wheels is generally suspended as in fig. 11, while the back has frequently no suspension at all.

In concluding, it is to be noticed how few of the types of suspension described, can truly claim to a total analysis of the road shock—analysis into both horizontal and vertical components.

Again, it remains to be seen whether any type of suspension will ever obviate the necessity for pneumatic tyres; for the short rapid oscillation resulting from a run over loose metal with solid tyres is a problem, the difficulty of which is only equal in magnitude to the simplicity of the fact that loose metal simply embeds itself in the dents it causes in the pneumatic tyre, causing little or no vibrating at all.
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