MOTORCYCLE ENGINEERING—8

REAR SPRINGING

Part Two — Detail design of the moving parts and their bearings

by PHIL IRVING

IN discussing the general effect upon frame design of pivoting fork suspension, the first part of this article stressed the importance of eliminating flexure in the region of the bearing-mounting. It is clear that the best way of doing so is to design the centre section with this primary object in view, rather than to utilize a composite structure which depends on several components bolted together; at the same time, provision can be made for carrying the overhung weight of the crew.

In many of the early designs, such as the Bentley and Draper type (Fig. 1), the rear springs were mounted under the saddle in a nearly horizontal position, which is quite a good arrangement in one way because the forward thrust from the springs is acting in opposition to the rearward thrust in the top tube created by the rake of the forks, so that the tendency towards "lozenging" of the centre section is reduced, at least under static conditions.

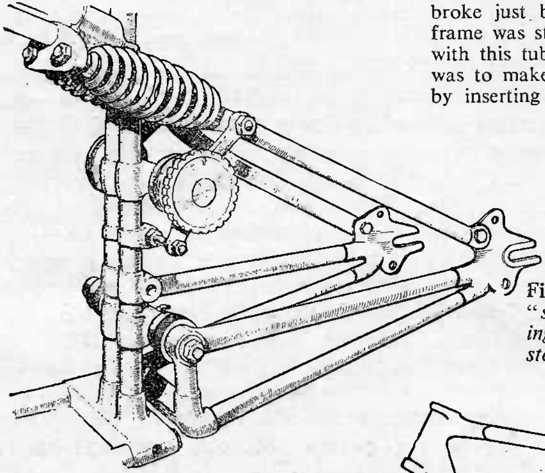


Fig. 1 *The Bentley and Draper rear springing system, incorporating friction damping. The two pivot bearings were independent (see Fig. 4).*

One of the first significant examples of a frame conceived from the beginning as a rear-sprung structure, instead of being merely a rigid frame with springing added, was the one designed in 1928 by P. C. Vincent, which incorporated a patented triangulated rear fork of great strength. It was illustrated in the sixth article of this series (October 8 issue, page 446).

In side elevation, this frame comprised three triangles, the front and rear ones being rigid and the centre one, by virtue of the pivot and springs, elastic. It will be seen that all dynamic loads on the pivot bearing were transmitted directly to the main frame tubes and, as the whole structure was 11 in. wide, the chain pull was not overhung from the bearings. At the front the design was not so happy because, as originally made, the front down-tube supplied more fore-and-aft rigidity than the top tube and the duplex side tubes, due partly to the closeness of these three higher tubes at the points where they joined the head and partly to the way in which the side tubes left the head at a wide included angle. As a result the front tube broke just below the weld; but since the frame was still complete as a structure even with this tube broken, the simplest solution was to make an artificial break in the tube by inserting a tongue-and-slot joint with a horizontal pin through it, so that the tube acted as a tension stay to support the power unit with enough lateral strength to prevent it oscillating laterally.

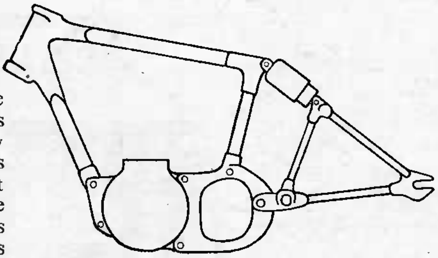


Fig. 2 *(Below) In the Vincent "springer" of 1932, the swinging fork pivot was housed in a stout casting surrounding the gearbox.*

A still better solution—that finally adopted—was to discard this frame altogether in favour of a simple tubular edition (Fig. 2), with the bearing contained in a robust casting surrounding the gearbox and bolted to engine plates of such vertical height that the whole unit was very rigid in itself, as well as being lighter than the earlier design.

The difficulty with any design which has the springs located under the saddle nose is that of accommodating a pillion passenger (or a rider in the accepted racing attitude) other than by seating the passenger on a violently oscillating mudguard. There are only two alternatives—to build a structure which is cantilevered out from the centre section and may or may not incorporate the mudguard, or to design a seat-frame hinged at the front and supported at the rear by stays from the forks.

The first solution is the cleaner mechanically, but has two disadvantages. First, the overhung length is unavoidably great due to the far-forward location of the spring abutments, which in turn entails a liability for the tail-section to oscillate laterally. Secondly, the effect of the passenger's overhung weight on the springs is very great, causing them to compress much more than normally and leaving less available movement before the limit of travel is met. To realize how serious this effect may be, it should be appreciated that the weight on the rear end of a 380-lb. machine with an eight-stone rider is 250 lb.

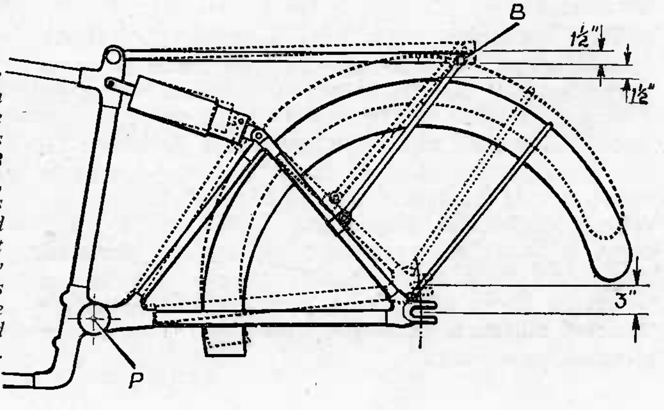
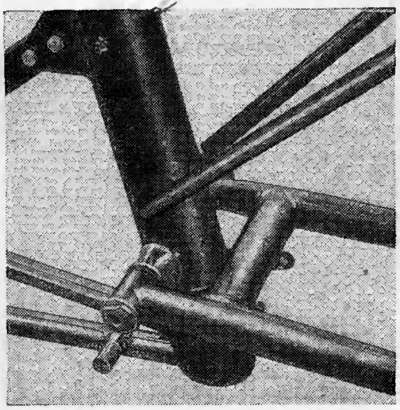
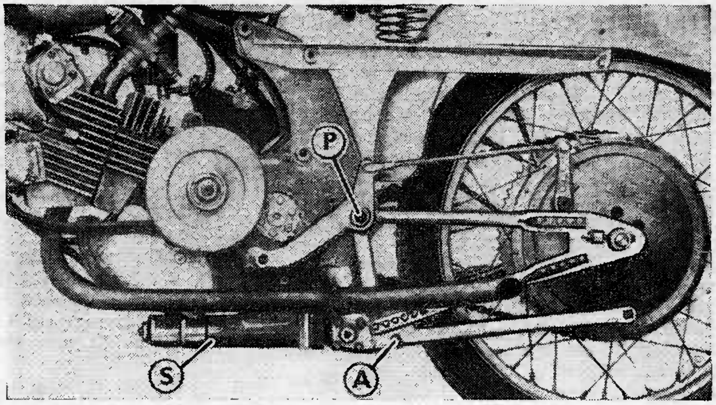


Fig 3. *The principle of the hinged pillion seat. By locating the lower seat stay pivots nearer to the line PB than the wheel axle, seat movement is reduced as compared with axle movement — in this case, by two to one. There is 1½ in. of clearance between seat and guard at normal load.*



(Left) A large cross-tube close behind the 3½-in. down-tube gives great torsional rigidity to the swinging fork of this Reynolds frame.

(Right) Sprung rear end of the 1947 250 c.c. Guzzi twin. A swinging fork with triangulated side members, joined at P and A, and pivoting at P, was controlled by a horizontal spring unit S below the engine.



in round figures, whereas with a crew of two 14-stoners the weight increases to 500 lb.

This variation, of course, is bound to occur whatever sort of springing is used and necessitates some action to meet it—such as using springs of variable length or strength, or altering the mechanical leverage of the springing system—and successful solutions along these lines are found on many machines built recently.

The method of using a hinged pillion seat is interesting more as an exercise in mechanics than for its practical application, since it is no longer used. The scheme (illustrated in Fig. 3) is to pin-joint a seat-base to the saddle-lug and support its rear end by jointed stays rising from the fork tubes, the whole arrangement forming a deformable quadrilateral. If the stays were pivoted near the rear axle, the end of the seat would rise at wheel speed and thus be virtually unsprung, but by placing the stay-pivots nearer to the line P-B the movement is reduced, although clearance must then be provided between the seat and the guard. If, as a compromise, the movement at the top of the stays is arranged to be 1½ in. when the wheel rises 3 in., the rear end will be semi-sprung without being raised too high, yet at the same time the increase in weight on the springs will be only about 30% of what it would be if the seat were attached directly to the centre-section. Therefore the effect of the additional weight can be borne by the same set of springs without much more liability to bottoming, although the comfort provided is not of such a high order as if the seat were fully sprung.

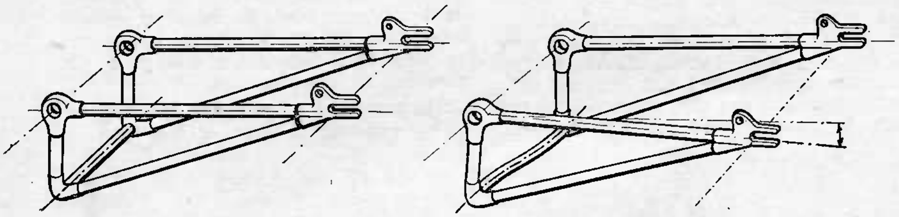


Fig. 4 *How the cross-member of a built-up swinging fork will bend as well as twist if located at some distance from a pair of independent bearings.*

Swinging forks produced about 30 years ago were, in the main, built to resemble the rear stays which they replaced, but lacked rigidity because the triangles at each side were not interconnected with sufficient care. In one design, used by several makes, each fork-leg was composed of a shallow triangle joined by a cross-member which did not surround the bearing, but lay several inches below, the two corners in which the bearing bushes were housed being, in effect, free (Fig. 4). When a twisting moment was applied to the rear axle, the cross-member was placed in bending as well as in torsion, instead of in pure torsion as it would have been if it had surrounded the pivot. Transverse loads also tended to distort the whole structure, and it was in consequence not very successful. The stays which transmitted loads to the springs added a little strength, but with a degree of complication not commensurate with their effectiveness.

A less complicated and more effective method is to join the two side-triangles rigidly together at the upper and lower front corners, making one of the connections the housing for the pivot-bearing. Ideally, excluding this short cross-member there should be six tubes forming a pyramid of immense rigidity, but the substitution of a well-designed lug at the apex, although it has to be wide enough to clear the mudguard, gives results which are almost as good. "Apex" in this context means the corner not occupied by the pivot; it could be located either above the pivot or below it, as in some Guzzi designs. The Guzzi arrangement permitted the springs to be mounted horizontally below the power unit, keeping the weight low and leaving more free space for the oil tank. However it is laid out in detail, the essence of this scheme is to provide rigid junctions at both front corners of the two triangles.

It is axiomatic that in any suspension system the unsprung weight should be kept to the minimum. Although the triangulated rear fork is not too bad in this respect, because the heavy parts are close to the pivot and therefore do not move at any great speed, it is not so good as the plain fork consisting of two legs and a cross-member, which has now become almost universal. When the springs are attached to the axle-lugs, the fork legs are relieved of weight-carrying stresses and their whole duty is to maintain wheel alignment.

Under both transverse and twisting loads, the side-tubes of the fork are subjected to almost pure bending stresses, which increase in intensity towards the bearing. Ideally, therefore, they should be tapered tubes, though parallel tubes are often employed. The difference in weight is only a matter of ounces, while the raw material cost of the parallel tube is very much less; also it becomes possible to do away with cast or forged axle-lugs by flattening the tubes locally and slotting them to accommodate the axle.

If the cross-member is co-axial with the pivot-bearing—i.e., consists either of a tube surrounding it or a solid spindle passing through the centre—twisting moments on the rear axle subject it to pure torsion, while lateral loads subject it to bending stresses which are most intense at the junction-points; the shorter the fork, the less do these loads become.

Stiffening the Fork

In the case of shaft drive, the cross-member can be located just clear of the tyre, but with chain drive it may not be possible to get as close as this without making the distance between the gearbox centre and the pivot so great that undesirable chain-tension variations are set up. Also, the design of the main frame may be such that it is not convenient to make the cross-member and the pivot co-axial, in which event the former has to be moved towards the wheel and thereby becomes subject to bending as well as torsion under the influence of axle-twisting loads. It must therefore be stronger for the same degree of stiffness as that furnished by the co-axial design—a point which evidently is not always appreciated. A very good example of the way it should be done is the Reynolds frame illustrated, which has a large cross-tube located behind the 3½-in. down-tube, affording a structure of great strength and simplicity.

Another method, used on the racing Velocettes which first demonstrated the value of a well-engineered plain fork, is to clamp two separate fork-blades to a solid spindle, splined at each end to provide a positive mechanical resistance to movement. This entails some very accurate machining, as the slightest error in angular location of the splines on the shaft or in the lugs would have a magnified effect at the fork-ends.

(Continued overleaf)

Rear Springing - - - *Continued*

An easier scheme (Fig. 5) is to cut two Woodruff keyways dead in line in the spindle and mill each lug with a slot which cuts into the metal on the far side of the bore, thus forming a keyway and, in the same machining operation, providing a gap to permit the lug to be clamped to the spindle. Of course, each keyway must also be very accurately located in relation to its opposite number and the keys *must* be a tight fit in the keyways. This form of construction lends itself to adoption if the frame has a single down-tube, as the spindle, which should be case-hardened, can then oscillate in bronze bushes housed in a wide, substantial lug and assembly becomes a simple matter.

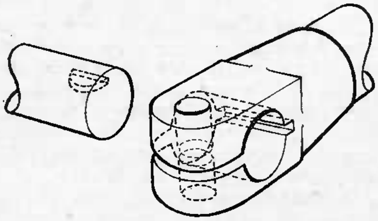


Fig. 5 *Arm of a swinging fork keyed to the spindle (see text above).*

This is, however, still rather an expensive solution and is heavier than a welded-up fork with a cross-tube surrounding the bearing. The latter layout fits in very well with a full duplex frame, because the inner member of the bearing can be mounted directly on the two vertical tubes below the saddle, as exemplified in the "Featherbed" Norton frame. These tubes are very widely spaced, so they afford good support to the fork-bearing, but as the loads are applied approximately midway along the tubes they are locally stiffened by gusset-plates, to provide a good depth of section in the plane of major stress.

This frame, which has been eminently successful ever since its introduction in 1950, deserves special mention. In its original form (illustrated in the sixth article of this series, page 446) it was constructed from two tubes, each bent to a four-sided shape and with the forward ends crossed just before they arrived at the head-lug. As the corner bends were of several inches radius there was not much likelihood of undesirable stress concentrations, but looked at in side elevation it did not appear to be unduly strong at the point where the tubes crossed along a common horizontal axis. The engine, which fitted between the tubes both above and below, was stayed to a cross-member joining the tank-rails just behind the main tubes' cross-over point, and there was another stay running upwards to the top of the steering-head; in effect these two stays formed a triangle which resisted fore-and-aft loads in the column. In later editions of the frame, built for production models, an additional sheet-steel gusset is employed to join the head-tube to the down-tubes, thus providing much greater inherent strength in this region. The drawing on this page shows the 1960 version.

The half-litre racing M.V. utilizes a similar type of frame. Reference has been made in an earlier article to the clever way in which transmission stresses have been absorbed in this model by passing the pivot spindle through a lug cast on the rear of the power-unit and also through the rear down-tubes. The primary transmission stresses are, of course, all internal to the unit and have no effect on the frame, but the large block bulk of the engine poses a problem in assembling and dismantling. This has been solved by making the duplex tubes detachable, with long spigots at each end, but it is doubtful whether such an arrangement would have provided sufficient rigidity had the pivot-bearing design been less effective. In the 350 c.c. model, although the power-unit is the same size, the loop tubes are integral but the single top tube is removable. Great care has been taken with the end-attachments of this vital member; additional branch-tubes enable it to be attached with three close-fitting bolts at each end.

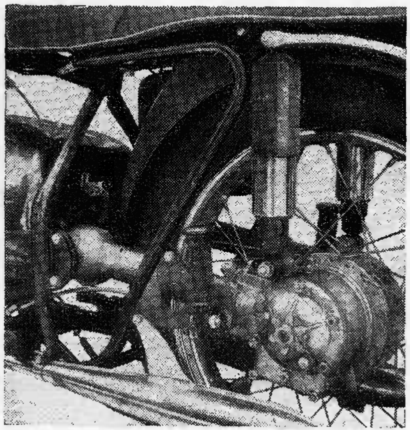
On the small shaft-driven Velocette machines, which have duplex tubes below the saddle, an interesting rear fork is employed. This takes the form of a one-piece casting made of strong aluminium alloy with the propeller shaft and universal joint enclosed in one leg; the section uniting the sides is co-axial with the pivot-bearings, which are spaced very widely apart and attached to the duplex down-tubes. As, for other reasons, these tubes are bowed outwards to a considerable extent and would therefore flex under fore-and-aft loads, they are connected locally to the rear end of the power unit. The whole structure is rigid and the bearings are quite lightly loaded.

As far as the pivot bearings themselves are concerned, it is important that they should last for a long time without developing wear, otherwise a progressive deterioration would occur, unnoticed by the rider, perhaps, until it became so bad that he found himself in difficulties in an emergency.

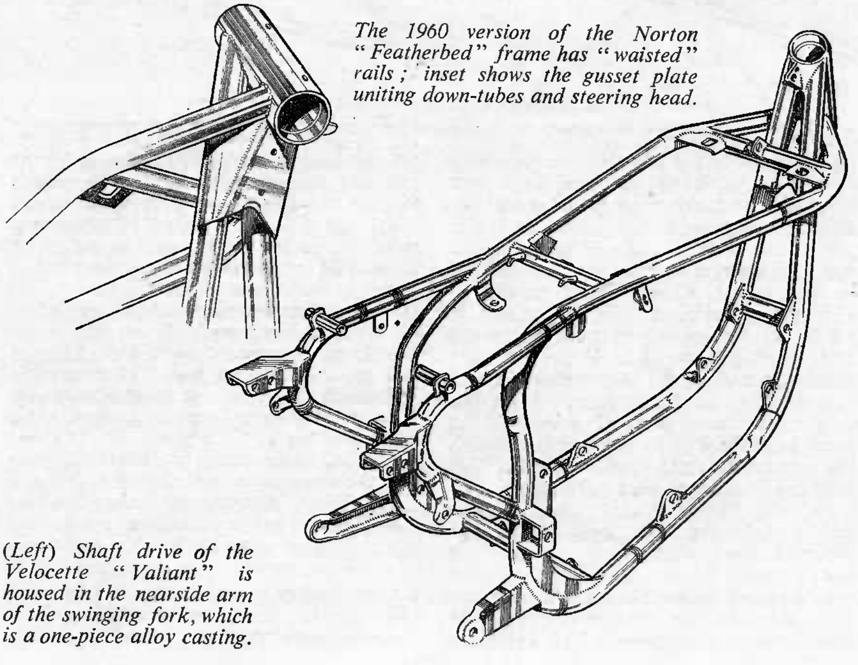
Rubber bushes of the Silentbloc type, in which the radial thickness of rubber is quite small, are satisfactory, especially if they are widely spaced, but thick-walled, soft bushes of the kind frequently fitted to car suspension systems are not good and can be definitely bad if they are only three or four inches apart with the chain-line overhung on one side. Tapered roller bearings, being adjustable, can be set up very accurately with a slight pre-load and will run for almost the life of the machine without attention provided they are grease-packed and adequate precautions are taken to exclude water and grit, but they are expensive and occupy more space than plain bearings.

Needle roller bearings are quite suitable, but provision must be made for resisting side-thrust. Bronze bushes are probably the cheapest and lightest solution, so long as the rider remembers to lubricate them, although with the advent of molybdenum disulphide lubricants greasing intervals of 10,000 miles or more become a distinct possibility. Porous-bronze, oil-impregnated bushes are also suitable, provided that they are not too heavily loaded; but even with these provision should be made for periodic lubrication and, of course, great care should be taken to exclude dust and water by the provision of adequate seals.

The properties of springing and damping units will be discussed next week.



(Left) Shaft drive of the Velocette "Valiant" is housed in the nearside arm of the swinging fork, which is a one-piece alloy casting.



The 1960 version of the Norton "Featherbed" frame has "waisted" rails; inset shows the gusset plate uniting down-tubes and steering head.