THE SPRINGING OF MOTOR CYCLES.

By G. H. SAVAGE.

A GREAT part of the author's experience with motor cycles was while he was with the Mechanical Transport in France, an experience which was perhaps unique, as it was the first time that the springing of motor cycles had been tested on a large scale, and he had some exceptional opportunities of seeing the springing at work and under repair, both up the line and at the base.

At different periods of his work up the line, he had attached to him for repair the machines of certain of the Signal Companies, Motor Machine Gun Batteries and R.E. Field Companies, all these being units whose machines had the maximum amount of hard work. Later on in 1917, he was sent down to the 3rd Heavy Repair Shop, where he took over the motor cycle repairing section, the work consisting of thorough overhauls of the cycles that were sent down from the line as complete casualties. The 2nd Heavy Repair Shop under Col. T. B. Browne (then Works Manager), and the 3rd Heavy Repair Shop, with Major B. H. Thomas as Works Manager, had to endeavour to make their combined output and the casualties balance. There was always a little friendly rivalry between the two Shops, and at the end the combined output of the 2nd and 3rd Heavy Repair Shops was, as far as the author can remember, over 100 solo and sidecar machines per week for re-issue.

He hopes that these experiences and deductions which are now put forward will be of some interest, and will help in solving, to some extent, the problem of motor cycle springing. He also desires to say that he is in no way interested in the motor cycle industry, and is not in consequence prejudiced in favour of any

particular design. The paper is in fact an account of some of the experiences of the Mechanical Transport, Motor Cycle Section, in France, with his own deductions therefrom.

That the problem of the springing of motor cycles is an important one there can be no doubt, and the author would go so far as to say that it is one of the most important on a motor cycle, as the severest strains that a machine has to withstand are from the road shocks. If the road shocks can be lessened, and they can be very considerably with efficient springing, the design of the motor cycle should undergo some radical changes. Designers in the past have been working on the problem of building a very nearly unsprung machine for the average rider, to withstand the road shocks when ridden at speeds up to 40 or 50 miles per hour. It is difficult to understand why they have not long ago developed front and rear springing for motor cycles, as it very much simplifies their work.

Very often it is remarked that some part of a machine has almost attained perfection, and it is difficult to see how it can be developed further. It cannot be said that the motor cycle has arrived at this stage yet, but efficient springing certainly opens up a vast field of possibilities which has hardly been touched on at present. Apart, too, from that side of the question, which only affects the manufacturer and designer, the range of the motor cycle would be in every sense much widened by good springing. At present it is no unusual thing to feel fatigued after riding, say, 60 miles over medium roads, which is in a great measure due to the shaking that the rider receives. With well sprung machines, the halt and the lame would soon be riding motor cycles, while the range would be considerably increased for the hale and hearty.

Besides the fact that the war period in France was the first time that the springing on motor cycles had been tested on a large scale, it was the first time that sprung machines had been tried against unsprung machines on exactly the same work. It is true that the springing had been tested in England, but the machines had never been subjected to the prolonged tests that they had to undergo in France, such as, in extreme cases, being ridden over corduroy roads, roads with every sort of obstacle and pothole that can be imagined, all ridden at the highest possible speed, for day after day, by riders whose instructions were to get to their destination as quickly as possible. In the more normal cases, they were ridden over roads with surfaces which in England

would be called bad indeed, but which in France were only regarded as average; ridden over these roads very often in heavy rain, with the holes filled with water, so that if a rider wished to pick his road it was next to impossible for him to do so, being ridden at night, too, very often without lights.

This, then, was the work that the average machine had to stand up to, and, granted, it was a heavy one. It was the most valuable of tests, "a test to destruction" spread over varying periods of time, thus enabling the stages of wear and fracture to be noted in sequence as far as time and war permitted. It was also a test conducted on an enormous scale, which made it more possible to be certain in the deductions made, the errors in manufacture and occasional batches of faulty material being only a small percentage of the whole.

It would, perhaps, be as well to give some of the adverse conditions worked under besides the question of road surfaces. The lack of facilities for cleaning the machines up the line, of rain, mud and dust were only to be expected. In some areas at one time chalk was the only material at hand for filling up holes and generally repairing the roads, and in the hot weather it used to lie inches thick for miles, and chalk is not a good lubricant. It impressed itself especially on the author's mind, as he was unfortunate enough to work for some time in one of these areas.

Another difficulty was due to the absence of any facilities for getting the repairs done at once. This depended to a great extent on the efficiency of the workshop the machines were attached to for repair, and in the author's experience the mobile workshops up the line had very often more work than they could cope with, and they could not, therefore, do all they wished in this respect. In the case of small repairs, it depended on the unit the machine belonged to and on the individual rider, as they undertook these themselves. It meant, in consequence, that sometimes machines were ridden somewhat longer than they should have been in an indifferent state of repair, and these difficulties especially affected the mechanical details of the springing. As the war progressed, however, they considerably improved. The quality of the riders themselves was for the most part good; they varied of course, but indifferent riders were usually kept up to scratch by their officers and non-commissioned officers, and by inspections of the machines when possible.

We now come to an important question, and that is—"Is

springing necessary as shown by experiences in France, or merely an advantage?"

That springing is an advantage will probably not be disputed; that it is a necessity, if the motor cycle is to develop the author will endeavour to show. It should be pointed out that in order to realise the value of springing, the work got out of a well sprung and a badly sprung car should be compared, also the respective costs of upkeep.

The success or failure of springing on a cycle must not be judged only by the number of broken springs, but by how the various parts which take the road shock (wheels, head lugs, frame, etc.) stand up also. The author will therefore deal with some of the mechanical failures experienced with parts other than the spring details which in his opinion were due to bad springing, and which anyway would have been greatly lessened if the springing had been better. It would be unreasonable to say that these parts should have stood up to the work without failure, as it is palpable that the machines were not designed to stand up to some of the severe tests to which they were submitted; they should, however, have stood up better than they did, although, again, war material and workmanship probably had a hand in the failures.

In a number of cases, of course, accidents and collisions, etc. were the causes of the parts breaking, but the parts mentioned below are those that failed in the vast majority of cases under more or less average riding tests. A very considerable amount of trouble was experienced with the head lugs cracking and ultimately breaking, if not changed at once; they cracked in different places on different makes of machine, and were obviously not strong enough to withstand the heavy strains put upon them. The riders of the machines were encouraged to examine the head lugs every day for cracks, and when these were not seen in time the break usually took place when the machine was travelling at a fair speed and much damage was done to the motor cycle or combination as a whole, by badly straining the frame, etc. There were, of course, cases where the failure was due to faulty work, by munition workers possibly, such as the tube holes in the head lug casting not having been bored concentric with the outside, etc.

Owing to repeated representations, one maker strengthened the head lugs on his machine by putting on extra webs, and they stood up much better; another maker, the author believes, made

his head lugs of steel in place of the usual malleable iron casting. It was disheartening work, putting in new head lugs, knowing that they would come back again broken at probably no very distant date.

It may here be asked, was it known how much running a machine had done between its overhaul and issue by the 3rd Heavy Repair Shop and its return as a casualty? The system at the 3rd Heavy Repair Shop was to number all machines when re-issued, and these numbers were looked for on all casualties coming in, so that it could be ascertained how long the machine had been out; how much running it had done could only be told approximately by looking over the machine and judging from the wear of the units. This was the procedure at a base repair shop; up the line the machines were probably seen every day. Frames were a constant source of trouble through the tubes breaking, or the frames themselves distorting and twisting; the front down tube was the weakest place, and it usually broke just below the head lug. It is possible that the heating in the process of brazing would, by annealing the tube, destroy some of the extra tensile strength of the solid drawn tube, but at the same time it was without doubt too weak. It usually broke when the machine was travelling at a fair speed, and the result was that both the top tube over the petrol tank and the middle rail bent, necessitating in most cases a replacement; any amount of damage to the machine was of course possible; the above was what usually happened.

Makers later on made these front down tubes of a heavier gauge, and they stood up to their work much better. In the author's experience, if the brazing had been well done it never broke; he remembers one consignment, though, of new machines which came to the 3rd Heavy Repair Shop. A number of these were issued, and they all came back in a few days' time with the front down tubes either broken across the pinholes, or pulled out, and it was found on examination that they had been very badly brazed up in the first place, and in consequence the whole consignment had to be rebrazed. The frames used to break in other places, but the head lugs and the front down tubes were the worst troubles. The back forks used to twist rather badly, but this cannot be put down as due primarily to bad springing.

Very important parts on the motor cycle are, of course, the front fork stem and the top and bottom bearings in the head, as

they jointly control the steering to a very great extent. The front fork stems broke very seldom in the author's experience, and stood up comparatively well. It is regretted that the same cannot be said for the ball races in the head; these were very poor, and after every 200 or 300 miles riding play developed in the head and the races had to be adjusted. When this had been done several times, it would be found that all the side play could not be taken up and new races were necessary.

Alternatively, the races cracked or pitted and balls broke or chipped, and there was also to all intents and purposes no arrangement for lubricating and greasing them as they required. Very probably this play in the head race contributed in a large measure towards the breaking of the head lugs.

At the end of this last Auto Cycle Union trial, the author had the privilege of looking over a considerable number of the machines. It was interesting but regrettable to note that a great number of them had play in the head, showing that there is still very much to be desired in the design of these bearings.

In the earlier days of the war, a great many front forks broke, usually just below the point where the first cross bar is brazed in; as time went on, the section was made larger and heavier, which was a big improvement. It might be argued that the front forks hardly come into the discussion, as on the vast majority of spring frames they are and must be still unsprung. This would not be correct, however, as on an unsprung or badly sprung machine, the shocks that the front and rear forks receive and transmit are of necessity very much greater.

Repairing wheels and scrapping them kept a small army of men busy; here again a great many were damaged through collisions, but their number was small compared with those that had failed through average running. Practically every rim that came in was badly dented, the spokes were loose and often broken, which of course did not help the rim to stand up to its work, but both were at fault, as the spokes were too light a gauge. Later on they were made heavier by some makers.

The wheel spindle bearings had to be replaced very often, and here, to be fair, it should be realised that the rain, mud and dust had a hand in shortening their lives; it must be admitted, however, that the bearings were not of sufficiently ample dimensions to withstand the vibration for long; on the sidecar machines

they stood up better, as probably these machines were not ridden so fast.

Mudguards had to be replaced very often, as they either broke, or cracked and tore away at the point where they were attached to the frame and stays; the method of attachment was usually very poor, and does not seem to have received the attention it deserves at the hands of the designer. The mudguard should be thickened up by an extra plate inside, round the set screw that attaches it to the frame. In the author's opinion the use of the back stand as a stay on the rear does not help matters.

Handle bars proved weak at times and broke, but they were good on the whole, and it is not clear that bad springing was responsible for these failures. The breakages of carriers caused a lot of trouble. Here it may be suggested that they were overloaded; there were cases, of course, when this was so, but they were exceptional, and on the new machines coming out from England, boxes which were fitted on, in addition to the carrier bags, were practically always taken off. The carriers broke everywhere, and representations were made to the makers, and later Messrs. Douglas on their 4 h.p. sidecar combination fitted a re-designed and much stronger carrier, which gave very little trouble. On some of the overhauled machines from the 3rd Heavy Repair Shop, and probably from the 2nd Heavy Repair Shop too, the carriers were strengthened by brazing on extra stays, and these proved satisfactory, but owing to pressure of work it was not possible to do this on a large scale. It was difficult to effect a satisfactory and economical repair on a broken carrier, and in consequence a great many had to be scrapped.

The carrier bags gave a lot of trouble, and the large replacement demands which were sent in gave rise to several orders from the Director of Transport urging extra care. Even with extra care though, short of not using the bags, they fell to pieces almost at once. The clip arrangement for attaching the bags to the carrier was poor, and they tore away through the excessive vibration on the rear wheel; the bags themselves, too, were not strong enough and came to pieces, although the rain must have helped considerably to deteriorate the leather. At one time some enterprising English manufacturer must have heard how the Germans were making their sandbags of paper, and he evidently decided to try cardboard for carrier bags; the author expects that he is now a disappointed man, complaining of the narrow-mindedness

of people at the head of affairs, and how they refuse to encourage "initiative." The spare parts carried in these tool bags suffered considerably unless packed in very tightly; if packed in at all loosely, the bags simply acted as tumblers. The design of these carrier bags was considerably improved towards the end of the war; they were still made of leather, but were enclosed in a sheet metal casing on all sides except the front. Messrs. Douglas further improved the bags by letting them into the frame of the carrier, thus supporting them by tubes on the four sides, the bottom tube carrying the weight.

That bolts and nuts, etc. work loose if subjected to vibration is well known, and the bolts and nuts on the machines in France were no exception to this rule. It was only in the case of exceptional riders that they were tightened up at once; usually they were not noticed for some time, during which period parts worked that were intended to be bolted up tight, and holes were enlarged, etc., thus causing extra expense when the machine eventually came in for overhaul.

In France, all the motor cycles and sidecar combinations were fitted with acetylene lighting only. The effect of vibration and road shock on the lighting qualities was that if the lamp burner was at all furred up or the carbide was getting low, the road shocks would jar the light out; if, on the other hand, the generator was charged and working well, practically no trouble at all was experienced. In regard to the mechanical details, the nuts on the attachment used to work loose, and the lamp would swing over; even with the nuts dead tight in some cases the lamp would not keep straight owing to the frictional surface of the clamp being insufficient. On the lighting equipment as issued at the commencement of the war and for some time after, the lamp was fitted on the handlebars and the generator on the front down tube, the two being connected by a rubber tube. This meant that the generator was out of sight when the machine was being ridden, and there were countless cases where the generator was jarred loose, and finally jumped off its bracket and was lost.

Later on in the war, a much better bracket was designed, the lamp fitting on one end and the generator on the other, the bracket being bolted to the handle bars in the centre, so that the lamp and generator more or less balanced each other, thus taking a lot of strain off the clamps; another advantage was that the lamp and generator were directly in the rider's view.

One very important side of the question of bad springing has not been touched on yet, and that was its effect on the personnel. Riding the standard machines in France, over the bad roads prevalent there, was very tiring for two main reasons: firstly, because the rider was being shaken the whole time, and, secondly, because of the continual vigilance and concentration necessary to keep the machine on the road, and to counteract the effect of bad pot holes, etc. on the steering. The author contends that if the machines had been fitted with spring frames during the war it would have made a very great saving in personnel by increasing the despatch rider's range and by reducing sickness. On the standard machines in France, front fork springing only was fitted, and helical springs were used throughout to take the road shocks. Some were wound slightly conical or volute, in which case their action was more or less progressive, while on other machines the springs were parallel wound, acting either in compression or extension.

After having ridden practically all types of machines in France over all sorts of conditions of roads, the author's criticism is that the springs were not responsive at all to the small and average shock, though they came into action for hard shocks, and for the very severe shock the springs either came up solid, when acting in compression, and the frame took the final blow, or, in the case of the extension type, the springs were overstressed; if a stop was fitted on this latter type, the frame again took the final blow.

The allowable movement from the normal, under load, was on the average from 1 in. to $1\frac{1}{2}$ in. This seems to be the crux of the argument, as in the author's opinion it is impossible to design a spring with this allowable movement to be responsive to the range of shocks which it is known from experience it will be called upon to include. In consequence of the springs being too stiff, parts broke and shook loose, etc., as has been stated earlier in the paper, and the springs themselves broke frequently.

It is difficult to say why the Triumph springs broke, though probably it was partly due to their being overstressed and partly to the rebound. Earlier in the war the Triumph spring was made of rectangular section, but later this was changed to one with very round corners, the section being more or less elliptical, and there were fewer breakages with this later type. With this design of springing there was the same very limited movement, the springs being stiff with high periodicity, and consequent

vibration. In the author's opinion, this type of springing, where the fork is hinged from the bottom of the fork stem, means that much of the road shock is transmitted direct to the frame, especially when the spring is stiff.

The extension springs broke through being overstressed, and the author has often broken the springs when riding over one bad obstacle or hole, though it is quite probable that these particular springs had been weakened before by being stressed just up to their limit.

With the helical wound spring acting in extension, on one or two types of machines the top and bottom ends of the spring were bolted up solid. The front forks were connected to the head by links, the movement of the forks being thus circular, the radius of the circle being the length of the link. If the two ends of the spring are in line with the spring straight, when the spring is extended under load one end will move along an arc, and it must move out of line with its other end, thus bending or distorting the spring as well as extending it. The angular movement of the spring ends can be altered slightly by having the top and bottom links of different lengths and at different angles in relation to each other; but with these modifications the spring still distorts, and they have their own objections. In such cases it is usual to have the spring bent when in the normal position, so that it tends to straighten when further extended. It may possibly be said that the heads of the bolts securing the ends of the springs were so shaped that the spring could be free to find its own line, and this was possibly the wish of the designer; in practice, however, the spring distorts. Some people say that this was very detrimental to the springs, and was the cause of so many of them breaking; to what degree this is true, the author cannot say, but he thinks there is a considerable amount of truth in the argument, and this arrangement is without doubt unmechanical. It is surprising to note that on one or two of this year's front fork designs the springs are still bolted up solid, the ends not being allowed to swivel. The $2\frac{3}{4}$ h.p. Douglas machine was supplied with the spring ends bolted up solid during the war, but on the latest type this has been altered, and the spring ends now swivel on pins, Fig. 1.

These $2\frac{3}{4}$ h.p. Douglas extension springs broke (though by no means invariably) where the spring commenced to taper down at the ends, and where it became in fact a conical coil spring in

extension; it is well known that a conical coil spring in extension distorts, and this is the place that the author would have named as being the weakest in the spring, although he has not gone to the length of abstruse calculations to prove it. On the latest Douglas 4 h.p. machines the springs were all parallel, and the ends were allowed to swivel on pins; very little trouble was experienced with this type.

At one time Messrs. Douglas fitted an extra horizontal buffer

FIG. 1.—Douglas Front Forks.

spring box head clip, the allowable movement on which was small. The author does not think that it made any appreciable difference to the riding qualities of the machine, or to the number of broken springs, and on the latest of the firm's models it is not fitted. The link motion on the Douglas $2\frac{3}{4}$ was at first very light, but it was improved and made heavier. On all the makes, with the exception of the Triumph and Douglas 4 h.p., the link motion up to the last was too light, the chief faults

being the small diameter of the spindles and the lack of a proper method of lubricating them. The latter was ridiculous, usually consisting of a small hole, which no oilcan end would even look at, though occasionally toy grease cups were fitted, the cups being about $5/16$ in. diameter. The author practically never saw a link motion taken to pieces but that the spindles were dry. It is probable that if well lubricated even the lighter spindles would have stood up much better.

On the later type Douglas 4 h.p. machine, the spindles were of larger diameter and drilled up, the end of the spindle being screwed, and on this a greaser cup fitted; this was a big advance on previous practice, and very little trouble was experienced with them.

On the Triumph machines the front fork was hinged at the bottom of the fork stem, a ball bearing being fitted, which stood up well.

Except on the very earliest types of Douglas $2\frac{3}{4}$ h.p. machines, the author saw practically no cases on any make where the links had bent during ordinary wear and tear, though in collisions and accidents, of course, they suffered considerably. The links used often to "work" where they were bolted on to the spindle ends, and where they should have been tight. Sometimes this was due to lack of lubrication facilities, so that the spindles became dry and partially seized up, in which case the links would start turning on the ends of the spindle. The diameter of the spindle end, the thickness of the link at the eye, and the face on the spindle which the link came up against were all too small, and once the links started working at the eyes it usually meant new links and spindles to make a satisfactory job. The surfaces for taking the side pressure were small, though any play developing could be taken up by washers, and later in the war some makers fitted hardened steel washers.

In the author's experience, when lateral play developed, a great part of it was usually, in addition to play in the head, play in the spindle bushes and sometimes the links working slightly on the ends of the spindles, which allowed them to rock. If these features were improved there should not be much trouble with lateral play developing. The fitting of double coil flat spring washers between the faces of the castings and of the links was a good arrangement.

Saddle springs stood up well, but chiefly because the saddles

bumped before the springs were overstressed; sometimes they broke, but it was unusual.

An account of two or three special models that were sent to France for test, and of some special machines built up in the R.A.S.C. Workshops there, should be of interest.

An early test machine that came out from England was a Douglas $2\frac{3}{4}$ h.p. rear spring model, Fig. 2. It was fitted with two

Fig. 2.—Douglas Laminated Spring Model.

cantilever springs, one on each side of the rear wheel. The forward ends of the springs rested on a bracket about 8 in. along the middle rail, the centre of the springs being hinged by the seat pillar lug, and the rear ends shackled on to a stay that went over the wheel. Unfortunately, the author did not test this machine himself; he has been told, though, that the early reports were good. The next experimental Douglas machines that came out were two $3\frac{1}{2}$ h.p. machines, one fitted with rear springing; the

machines came down to the 3rd Heavy Repair Shop from up the line, where they had evidently had hard work. Helical springs were fitted as shown in Fig. 3, which is self-explanatory. The bracket on the middle rail anchoring the forward end of the springs was broken, and this was repaired. The author rather believes that a new middle rail was also put in. The spring cages showed that the movement had been to the end of its travel fairly often and fairly hard. The machine was good and very comfortable to ride, but the springs were too stiff to be responsive to the light shocks. As far as the author remembers, there was no appreciable wear on the pins, or the main spindle bearings. He had, of course, no means of ascertaining how much running the machine had actually done.

FIG. 3.—Douglas $3\frac{1}{2}$ h.p. Helical Spring Model.

Another spring frame machine to come out for test was the Royal Ruby. This machine differed from the latest model shown in Fig. 4 chiefly in the position of the rear spring. It was more or less vertical then, it is now horizontal; the shackles also were different, with one or two other minor details, but the front spring was much the same. This machine, as it came to the author, had had some fairly severe work to do, but again it was impossible to say what mileage it had done. The only criticism was that the wheels were out of track a little, and care had to be exercised when riding the machine. The springing was very comfortable, and the machine was very much less tiring to ride than one with a solid frame. An objection to that design was the ragged appearance, but as far as the author can remember the spring details

were standing up to their work well, and showed practically no signs of wear. The makers informed the author that the reason

FIG. 4.—Royal Ruby Standard Model.

for the change in the position of the rear spring was that they got an improvement in springing and manufacture.

Of the machines built in France, the first was a Douglas $2\frac{3}{4}$ SAVAGE.

h.p. rear spring frame model designed by Capt. Francis and built at the 3rd Heavy Repair Shop. It had two leaf springs, one on each side of the rear wheel, level with the middle rail, the forward ends resting on a bracket bolted to the rail. After some running, this middle rail showed signs of sagging, and it was changed for one of a heavier gauge, after which it gave no trouble. The machine was, of course, only built up as an experiment. The deflection from the normal, as far as the author can remember, was 3 in. to 4 in., and it was a very comfortable machine to ride.

Another design, which was got out by the author, was the fitting

FIG. 5.—3rd H. R. Shop Spring Design on Triumph Machine.

of rear springing to a standard Triumph machine. There was nothing particularly original about the design, the general arrangement of which can be seen from Fig. 5. The carrier and rear mudguard were unsprung. The spring had a flat end, with no eye or shackle, but behind the end was a cross bar, which caught the spring on rebound or when the rear wheel dropped into a hole. The details of the main spindle bearing can be seen in Fig. 17. Grooves were turned just inside the bushes to collect any dust and mud, etc. that might work in. This design was simple and substantial; facilities and time did not allow

of the details being elaborated. It is regretted that the author has not got particulars of the strength of the spring, etc.;

FIG. 6.—Capt. S: J. Burt's Spring Design on Douglas Machine.

from memory he would say that the allowable movement from the normal was about $3\frac{1}{2}$ in. The difference between the riding

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qualities of this machine and those of a standard Triumph was enormous. One officer in the author's unit occasionally had to ride about 80 miles over bad roads, and he always complained of a very aching back on arrival at his destination. For one or two of his trips he took this spring frame machine, and he reported afterwards that at the finish of his run he arrived back comparatively fresh and a different man. The author himself, on a particular test run, covered approximately 90 miles over the Rouen St.-Omer road in well under 3 hours on this machine, and considering the very bad surface of the road the time was good. It would, in the author's opinion, have been practically impossible to do this time on a solid frame machine. It is interesting to note that after covering 15 to 20 miles of the return journey, at quite a slow speed the front wheel fell to pieces. The wheel was a good one as it had been looked over before starting on this test, and it had simply shaken to pieces on the outward run; a standard Triumph front fork with front fork spring was fitted.

Another spring frame machine made in France was one designed by Capt. S. J. Burt of the 61 Aux. P. Coy., see Fig. 6, and some exceptional results were obtained with it. The machine was a standard Douglas $2\frac{3}{4}$ h.p., but different front fork springing was fitted, which gave much greater movement, and on the rear two cantilever leaf springs were fitted, one on each side of the wheel, also with a large range of movement. In consequence of this large movement and the comparatively small ground clearance of the machine for its particular work, a special skid was fitted under the engine. The extra and additional load for this machine was a Hotchkiss gun and 360 rounds of ammunition, which it used to carry over fields and the very bad roads prevalent in France. This machine was, the author believes, built for duty with Mobile Motor Machine Gun Batteries, and after inspection by H. Q. it was approved for this work.

This finishes the account of the machines in France, the author having touched on the main points which cropped up during his experience and work with the M.T. He thinks that it would not be out of place now to give some points which in his opinion it is desirable to bear in mind when considering the design for front and rear springing.

Some of the results of bad springing have already been mentioned, but in addition to these, as higher speeds become more common, the springing must be developed not only for comfort,

but to enable the mechanical details to stand up to their work better. It would not appear that this should add much to the cost of the machine, as there will certainly, after a time, be a saving by making the whole machine lighter; even if the first cost is greater, however, provided that the springing is well designed, it should be one of the best investments that the motor cycling public can make.

In considering the design for an efficient front and rear springing arrangement on a motor cycle, one of the main questions is, How much movement of the front and rear forks and wheels can be allowed? On a car, within limits, the greater the amount of relative movement it is possible to allow between the chassis and axle, the more flexible the spring may be. This means that the oscillations are large, and the period is in consequence low, and as the criterion of the stiffness of a suspension is the spring period, so this tends towards good springing of the car. If the relative movement is reduced, the weight remaining the same, the springs have to be made stiffer and their period goes up, and there comes a point when the spring is either no longer sensitive to the smaller shocks, or is sensitive to the smaller shocks and bumps for the heavier ones. The relation of sprung to unsprung weight is an important point. Taking the instance of an unsprung car, its inertia would tend to keep it moving in a straight line, but if it meets an obstacle, the car must move out of this straight line, and this imposes a great strain on the tyres; if the car is sprung, however, only the inertia of the unsprung parts, axle and wheels, etc. (which are much lighter), has to be overcome, and the consequent stress is proportionately lower. On all vehicles this is the same, though whether the relation of sprung to unsprung weight is more or less the same on a motor cycle as on a car the author does not know; he thinks it probably is. It is, however, desirable to keep unsprung weight as low as possible. A point in which the problem of the springing of the motor cycle is easier than that of a car is that the load carried never varies much, while on a car it may vary enormously. The above only holds good if the carrier be unsprung, the tendency at present being to carry an extra passenger seated on the back, a point which will be dealt with later. On a car, even with its greater possible relative movement, it is difficult with a non-progressive spring (that is, a spring of which the deflection under any load less than its maximum carrying capacity is directly proportional

to the deflection under full load), to design it to be responsive to the small as well as to the heaviest shocks. On a motor cycle where the allowable movement is more limited, the problem becomes more difficult still. The reason that supplementary springs, or shock absorbers as they are sometimes called, are often fitted to cars is because the laminated springs by themselves cannot be made to cover both the light and the heavy shocks. Often the allowable movement is not large, or the variation in load carried is considerable, in which case the springs have to be designed to carry the heaviest load. The alternative solutions seem to be to have either very flexible springs and buffers to take the heaviest shocks, or to have laminated springs with supplementary springs,

FIG. 7.—Beardmore Precision Standard Model.

or to have a combination of springs, helical, for instance, where, as the main spring is compressed, other springs come into action. It would also be possible to alter the leverages of the helical springs, as they are either compressed or extended, or to alter the rate at which they are compressed or extended, which would achieve the same results.

Before proceeding further, a desirable and practical permissible movement from the normal under load for the front and rear forks should be decided on. The author suggests $2\frac{1}{2}$ in. to 3 in. for the front forks and $3\frac{1}{2}$ in. to $4\frac{1}{2}$ in. for the rear. There will, of course, be very considerable differences of opinion on this point, though, that the mechanical difficulties can be overcome

comparatively easily will probably be agreed; the point in contention will be as to the amount of the movement. The Beardmore Precision Co., for instance, inform the author that they have experimented with larger deflections than they at present allow on their standard spring frame machine, Fig. 7, and have rejected them. They found that the movements were too great in their opinion for the short wheel base of a motor cycle, and that the periods were too slow and the springs heavy. On their standard machines they allow a maximum movement of about $1\frac{1}{2}$ in. for the front wheel and 2 in. for the back wheel, and this, in their experience, gives full relief from all road shocks.

The Royal Ruby Cycle Co. say that their maximum allowable movements are about 3 in. on front and rear wheels.

The author has been informed by the Beardmore Precision Co. that in their experience the steering is hardly affected by the large movements. This agrees with his own experiences on the 3rd Heavy Repair Shop spring frame Triumph machine already mentioned.

With even the $2\frac{1}{2}$ in. to 3 in. and a $3\frac{1}{2}$ in. to $4\frac{1}{2}$ in. movement from the normal, there is no doubt in the author's opinion that a non-progressive action spring cannot be got to include the range of light and heavy shocks. The possible solutions of this difficulty are, as mentioned before, firstly, a non-progressive action spring with a buffer; this is not good though, as it means that the heaviest shock is taken finally on the frame. The second is a laminated spring with supplementary springs, and this is a practicable solution. Care must be taken when designing the above to see that the supplementary springs are called upon to take direct thrust only, the point of contact between the end of the spring and the wheel usually changing as the spring is compressed. There are many ways of effecting this, and two suggested designs are shown, Figs. 8 and 9.

The third is springing with helical springs, where, as the main spring is compressed, other springs come into action; this is already used, but not with such large movements as are suggested here; the system has advantages but also many disadvantages. A helical spring in which the free height is approximately 3 in. over the solid height, would require for the average weight machine to be about 12 in. in length. This would have to be enclosed or to have a centre guide to prevent its buckling, and it would be somewhat difficult to fit in on the machine. On a design of this sort, with

several long springs working in combination, care would have to be taken to see that the springs did not foul each other, and numerous guides would be required, while there would also have to be many small pins and eyes, bolts, etc.

FIG. 8.

FIG. 9

With extension springs it would be difficult to work in a combination type, and the only suggestion is to change the action from the non-progressive type to a resultant action in which the load was no longer directly proportional to the deflection. This

could be done without much difficulty by altering the leverage of the spring on the links as it was extended, or by increasing the rate at which it was extended for a given movement of the wheel. Experience has shown that in parallel wound extension springs, the safe value of the stress per sq. in. is only about two-thirds of that for open coiled compression springs of the same dimensions; other considerations may, however, outweigh this disadvantage. The author believes that pneumatic springs have been used on motor cycles years ago,* and they have much to recommend them if the mechanical difficulties can be overcome.

A last alternative is the volute or conical spring, which can be made to practically any rate of progression, and it would seem to be worth while experimenting with this type. In one type of front fork, conical springs acting in compression are already fitted, but they are short and are only very slightly taper. A conical spring is not satisfactory when used in extension, as sufficient load to fully stress the smaller or stiffer coils cannot be applied without distorting the larger coils.

Before leaving this side of the springing question, it would be as well to discuss the merits or demerits of friction, and this has lately been a much debated question. For perfection, a damping device which would come into action after the first big deflection either way, after the wheel has passed its normal position, is desirable. If the author could not have this, however, he would prefer to have friction in the springing of a motor cycle rather than none at all, chiefly to steady the springs and damp out oscillations, this especially when the machine is travelling over a road with more or less regular undulations which happen to fit in with the natural period of the motor cycle suspension. The objection to friction, as pointed out by Mr. G. H. Baillie in his paper before the Institution in 1913,† is that it increases the change of acceleration, and change of acceleration causes that jerk which is uncomfortable to the rider or passenger.

In the case of a car, as there is very little danger from the cumulative effect of regular undulations on the springing (which would be greater with no friction in the springs), comfort is the first consideration. On a motor cycle, however, the case is different; the machine is in a state of unstable equilibrium, and as

* See Proc. I.A.E. Vol. IV. p. 87.

† See Proc. I.A.E. Vol. VII. p. 451.

this cumulative effect on springing could be very dangerous, the extra or excessive comfort must be a very secondary consideration.

On a considerable number of machines now horizontal springs are also fitted on the front forks; the wheel is thus sprung in two directions, and that these springs do useful work can be appreciated by riding a machine so fitted. In the author's opinion, however, these are only useful when vertical springs are too stiff, and on a front fork fitted with reasonably flexible springs the horizontal springs would not be required, especially as the motor cycle front forks are already at an angle of about 30 degrees to the vertical in the direction of the shock.

A point that has been raised in objection to these horizontal springs is that the steering lead is continually changing, and that there would be danger when riding round a curve. A movement of about one inch is fairly usual on these horizontal springs, which would be $1\frac{1}{2}$ in. to 2 in. on the wheel. In the author's experience, these horizontal springs do not have any particular effect on the steering, although it is possible that they might at high speeds.

The question arises as to whether it should be arranged that the springs give lateral support to the forks. That the laminated springs do give lateral support on most makes of cars is well known; at the same time it should be remembered that a certain amount of side play on the axles of the ordinary touring car does not matter, while on a motor cycle practically no play at all can be allowed. The question is a compromise, and the author only says that if possible it would be better to arrange that suitable faces should give lateral support, and the springs take their direct load only. On the type of spring which is fitted with an eye and shackles, if the bearing in the spring eye is to work nicely, it must have some clearance on the sides, so that before the spring can help in the lateral stability the bearing in which the rear fork is hinged must have worn enough for the fork to rock over and take up this clearance. In the author's opinion, by the time this bearing is worn to that extent it requires renewing. In the A.B.C. type of springing, Fig. 10, the spring does give lateral support to the wheel, as it is bolted solidly at each end to the frame and the rear fork respectively.

Dealing with the eye of the leaf spring, on several makes shackle plates and pins of good proportions are employed, and on the Royal Ruby patented roller bearings as shown in the upper part of Fig. 4 are fitted to eliminate lateral play, and they should

work well. The author thinks, however, that these shackles are a refinement, and he would recommend in a great many cases simply a flat end to the spring and no eye. A roller for the spring to work against is unnecessary, it should simply work against a flat face; at the end of the back of the spring should be a crosspiece, with possibly a rubber buffer to catch the spring on rebound or when the wheel drops into a hole. An objection to this type is that there would be a tapping noise if the end of the spring left this face, but the author has ridden a machine so fitted, and he experienced no inconvenience. This type is much cheaper to make, and the possible noise could hardly be counted a serious objection until the motor cycle engine

FIG. 10.—A.B.C. Spring Frame.

is more silent than it is at present. English designers throughout should remember Ford practice a little more—cheap and simple and doesn't look nice, but the public gets used to it, and it works—Ford taught the public, and didn't let the public teach him.

It would be as well to compare the different designs of front forks, of which there seem to be three distinct types. The most usual is the parallel link motion type, where the links connect from the top of the front forks to the head of the frame, then the type as on the Triumph and the Beardmore Precision, where the front fork is hinged at the crown, and lastly the design which seems to be popular on American machines, and which is also embodied in the Phelan and Moore front forks, where the con-

necting link comes straight off the wheel spindle. It would be hard to say which type is best, as they are, in common with most engineering problems, a compromise; of the three, the author prefers the first mentioned, where the links bridge from the top of the front forks to the head.

The bearings in this type are long, easy to lubricate, easy to adjust, accessible, simple and out of the dirt, and in practice they stand up quite well. The tendency is now to make the link spindles of larger diameter, as on the Douglas type shown in Fig. 11, which is a move in the right direction; they will, however, stand further increase still. Some makers are also providing an easy adjustment for taking up any side play that develops, which is satisfactory as long as it ensures that the links are still

FIG. 11.—Douglas Front Fork Link Arrangement.

held solidly on the spindle ends, or on a connecting tube in some designs, while preferably the links should be screwed up against shoulders. The type of front fork as fitted by Triumphs has, the author knows, already been the subject of a considerable controversy, and personally he considers that on this type a lot of the road shock must be transmitted direct to the frame, or at any rate a great deal more than on the other two designs mentioned; the more flexible the spring, however, the less will this be felt. Where the front fork is hinged at the steering crown, there is the advantage of only one bearing against four, see Fig. 12, and this bearing can be made long and of large diameter.

On the P. & M. and American type, there is the advantage that when using helical springs, the angular movement of one

end of the spring in relation to the other when being compressed or extended is less than with the first mentioned link motion type, and another advantage is that there will be slightly less unsprung weight. When the wheel is in front of the bearing it hinges from,

FIG. 12.—Beardmore Precision Front Fork.

it would seem that one advantage of this type is destroyed; if the wheel is behind the bearing, it is trailing, and its position could be such that it would be readily responsive to road shocks from a large range of directions. At the same time, however, the

author does not like this design, as it still has four bearings, which are and must of necessity be very short, and these bearings are working in a position where they are open to a maximum of wet and dust; it would also seem that even slight wear on these bearings would show itself as quite a considerable figure on the rim of the wheel.

With reference to the lubrication facilities on all these different types, some makers are regarding this question seriously; a great many, on the other hand, even on their latest standard models, fit designs which are useless. They do not seem to realise that unless it is possible to lubricate the part with absolute minimum of trouble to the rider, and unless the system is efficient, the part will go unlubricated. They may say that it is up to the rider, but it is also very much to their interests that the machine should wear well. The design in which there is simply a small oil-hole, covered by a pivoted flat spring, is bad in practice, as the oil can end never fits the hole and the hole also holds practically no oil, and in consequence most of it simply runs over the outside.

Fitting absurdly small greasers is another favourite design. Personally, the author would either recommend the oiler with the hinged lid, which is ideal for the lazy man, or a greaser of reasonable dimensions.

Rear springing on a motor cycle is a comparatively new feature, and it would be as well to regard it separately. The considerations in the design seem to be accessibility for viewing, repair and lubricating, and efficiency, cleanliness of design and cheapness; it would in fact be a compromise as usual. The maximum allowable movement from the normal should, the author thinks, be from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches.

Vitally connected with the problem of rear springing is the practice which is becoming more usual each day, that is, the carrying of an extra passenger on the carrier. It seems absolutely unreasonable to expect the manufacturer to design a machine to give good springing with one passenger, and also with two passengers, one sitting on the carrier; it is, as a matter of fact, impossible, and the public must not expect it. So long, however, as the extra passenger is being carried, the additional load must be unsprung, which could be arranged either by temporarily cutting out the entire rear springing, making it solid, or by having the carrier unsprung; this point of the carrier will be dealt with later. The comparative merits of helical and leaf

springs have been already discussed, and as the author has intimated, for this work he prefers the laminated leaf spring. Satisfactory designs have, however, been got out with helical springs for the rear springing, and there is no reason why they should not give very efficient results.

The Douglas $3\frac{1}{2}$ h.p. machine, which is sprung at the rear with helical springs and is a very original design, is shown in Fig. 3; the author is, however, unable to describe it fully as it is being experimented with further. The illustration is self-explanatory. The author has ridden one of these machines, which was sent over to France for test purposes; it was very comfortable to ride and

FIG. 14.—Clyno Standard Model.

was well made, the only criticism is that the springs were of necessity rather stiff, the allowable movement of the wheel being small.

Another well known machine which has helical springs for the rear springing is the Matchless, Fig. 13, Plate I—it is to be regretted that on this type at present the ends of the springs are held solidly, and as the spring is compressed they move out of line, or rather, in the normal position they are out of line, and as the spring is further compressed they move into line, which comes to the same thing, as at one position they are being distorted. The carrier is sprung on this machine, so that if an extra passenger

is carried, the springs on the rear wheel would have to support the extra weight.

In some machines a spring is fitted on each side of the wheel, an example of which is shown in Fig. 14. In this design, if one spring is made or becomes a little weaker, or has a different set to its fellow, or if the deflection ratios are different, it would put side strains on the main spindle bearing. One designer told the author that he had ridden such a machine for some way with a spring on one side only, and it had worked quite well; this would probably be so for short distances and while the bearing was in

FIG. 15.

good order, but the twisting strains on the bearing would be severe. The position would be improved if the springs were bridged across, with a central point of contact for the springs and wheel.

On some designs where leaf springs are fitted, they are on the short side, which calls for care in seeing that the deflection per unit of length is not too great.

It is difficult to say what would be a best position for the spring, and from the point of efficiency in springing there are a number of positions which would be equally good; accessibility, cleanliness of design, working out of the dust and wet protected by the

mudguards, and cost of manufacture would be the next consideration.

FIG. 16.

Saddle springs act as supplementary springs or shock absorbers for the weight of the rider only. As these saddle springs are part

FIG. 17.—Main Spindle of Special Triumph Spring Frame Machine.

of the springing, it does not mean that supplementary springs need not be used in combination with the main spring, or that the main spring could be stiffer. If it did, the power unit, gear box, etc.,

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which weigh about one and a half times as much as the average rider, would still be badly sprung, and apart from the bad effect of road shock to these units, the rider would feel the vibration. What should be aimed at is to spring the machine and rider as perfectly as possible, and simply look on the saddle springs as the equivalent of the cushion springs on a car.

We now come to the main spindle bearing design. On the majority of machines this is a plain bearing, examples of which are shown in Figs. 15, 16 and 17, though on at least one design ball bearings have been fitted. All these bearings, although sound, should be of considerably larger proportions, and as long as possible, ample faces for the side thrust should be allowed, and these should be adjustable. When these machines have been in the hands of the average rider for a longer period, there will be more particulars available as to how they wear. This bearing is an extremely important feature; if it develops wear soon (possibly through not being lubricated well, and through careless usage, from both of which it will suffer) slack will be set up, which will destroy the balance of the machine and prejudice may arise in the mind of the inexperienced rider. This it will be difficult to remove as the completely sprung frame is only comparatively in its infancy at present. On account of the under-lubrication which this main spindle bearing, in common with all others, will undoubtedly receive, the author rather favours ball bearings as on the Beardmore Precision machine. It is difficult to estimate the amount of journal and side thrust this bearing will be called upon to stand, and these figures can only be satisfactorily arrived at by test and experience.

It is therefore hard to say in the present stage of development how one bearing will stand up from the point of view of lateral stability, and an alternative is another stay higher up, which would approximate to the links on a front fork. This is already embodied in one or two designs, although judging from the size of the hinge pins, it cannot be with the idea of assisting lateral stability. In both types of bearing, plain and ball, great care must be taken to keep out dust and wet, as the bearing works in a very vulnerable position; on the plain bearing type, the author favours a groove turned on the inside diameter of the bushes on the extreme outside edge, where any foreign matter could collect and not work further in.

The position of this bearing, as is obvious, should be as near to the centre of the gear box pulley or chain wheel as possible. In the normal riding position, the centre of the wheel should be $1\frac{1}{2}$ in. to 2 in. below a line produced from the gear box pulley through the centre of the main spindle bearing. Actually, the shortening of the distance between the gear box pulley wheel and the wheel centre is practically negligible even with a 4 in. movement, and the author has never had trouble with a belt slipping on this account. With a belt there is the elasticity, and a chain never runs dead tight.

We now come to the carrier, and although it is more difficult to effect, it would undoubtedly be preferable to have it as sprung weight, providing the machine is ridden solo. If it is sprung, it saves the carrier bags and their contents considerably. While the present tendency of carrying an extra passenger continues, it must, however, undoubtedly be unsprung, as a protection to the manufacturer.

The back stand should if possible be sprung, thus doing away with the clip on the rear of the mudguard, which is intended to hold the stand up. This spring clip is now being replaced by a positive screw fixture, but this is a nuisance and is always exposed to the wet and dust. The best position for the back stand seems to be under the rear down tube, where it has been fitted on one or two machines already. For keeping the stand up, the design of a spring as on the Royal Ruby machine would seem to be simple and satisfactory. These stands should be made much stronger than they are on the average machine, and fitting them in the last mentioned position raises the objection that the crossbar by the feet has to be done away with. This could, however, be replaced by a circular cross stay fitted as far down the legs as possible. In France these back stands broke continually; they are always very badly used, often the machine is balanced on one leg of the stand when draining oil out of the engine, etc. When lifting the machine up, too, it is usually brought down on to the stand very hard, but this is all the more reason why the stands should be designed much stronger.

Whether to make the springs adjustable for different weights and for bad roads or not seems to be again a question of Rolls-Royce versus more or less Ford design. The Royal Ruby Co. embody this adjustment on their machine, as

shown in the lower part of Fig. 4, and it is without doubt a very pleasant refinement; if, however, a low-priced machine is being built, the author thinks it unnecessary. Adjusting the spring would not, of course, alter its stiffness; it would simply give larger clearances. On a machine with non-adjustable springs, larger clearances must be left to accommodate the increased movement when ridden by a heavier rider or over very bad road surfaces.

Before closing, a word should be put in for larger tyres. That it is more economical in the end and gives easier riding probably everyone agrees. The objection to this from the motor cycle manufacturer's point of view is, of course, the greater first cost of the machine, and at the present time this is a serious item.

The author wishes here to thank Messrs. Royal Ruby, Beardmore Precision, and Douglas Motors for their kindness in helping him to carry out his idea of showing drawings of some of the most progressive types and thus illustrating the general trend of spring frame design. There are, of course, other machines on the market with spring frames, the Coulson, for instance, which did very well in the recent A.C.U. trials, and other manufacturers are, no doubt, experimenting with spring frame machines, but have not yet put them on the market.

The author has not criticised any make of machine in particular, as his arguments for and against springing in general can be applied if desired. The main argument is that the springs must be more flexible, with greater permissible movement, which could be achieved with either helical or laminated springs, only, in the author's opinion, with helical springs the working parts are likely to be more in number, and it is more difficult to attain the desired objective. The flexibility of the springs, front and rear, and the permissible movements are increasing on the best machines, which is all to the good, and the machines are without doubt an improvement on any that have been made before; at the same time he would emphasise again his opinion that to obtain really good springing there must be some arrangement of supplementary springs or combination springs fitted, and this could be done comparatively cheaply.

The author, in closing, would like to say a word on the value of the experience gained in France for the motor cycle industry. It has been, in his opinion, with one or two exceptions, neglected or is

not realised. The desire of every manufacturer is, he imagines, to turn out a machine that will do its work and not break down even when very badly treated, and that there is plenty of scope in this direction has been indicated in the paper.

The period in France was, as he has said, a test to destruction spread over varying periods of time, and it was conducted on an enormous scale. Many of the faults which developed in France showed up for the first time, and in consequence a number of makers seemed hardly to believe the reports or thought they were exaggerated, and they seem to have disregarded the trouble and to have taken practically no steps to prevent its recurrence or to cure it.

They say now, Why should we go to the expense of altering the design to meet conditions which the machines will practically never be called upon to undergo again? At a time like the present, when output is large and export on a large scale must follow, this is an especially fallacious argument.

Although the author believes that the first more or less practical motor cycle was made by Daimler, yet to English manufacturers is due the credit of developing the motor cycle to its present state of high efficiency, and of putting England in undoubtedly the first position in the world for knowledge and manufacture of these machines. Many countries that six years ago took practically no interest in motor cycles realised during the war their usefulness, and to a certain extent the pleasure to be derived from riding them. This all means that England, if it is to keep its premier position, must be prepared to make machines that will stand up to the prolonged tests which they will receive on the Continent, tests that are much more severe than are found in England.

A great many of the failures that were experienced in France do occur in England, though much more seldom, and this test has shown that they were due to weakness in design and not to faulty material or extraordinary circumstances in those particular cases, as may have been imagined.

With the more prolonged test, in certain cases there has been also a very rapid rise in the breakage curve, showing that the factors of safety were small. It has shown, too, how by altering the design of some part, weight might be saved on parts that worked in relation to it, in fact that the weight and strength of the various units and structure of the machine can be distributed much more efficiently.

There are, however, a hundred and one arguments why the war experience was and is the most valuable this industry has ever had, and it will only be wearisome to reiterate them. There is no middle road, the author believes; it is either advance or go back, and that to work on the experience gained in France is the road of advance there can surely be no question.

THE DISCUSSION.

Captain H. D. TEAGE: The author questions whether rear springing in particular is an advantage or a necessity. Personally, I think that for our English roads springing is a luxury and not a necessity. On the other hand, for the appalling surfaces over which our present-day trials are held I should welcome any first-class forms of springing. I have had some experience of the three special machines mentioned in the paper; on the $3\frac{1}{2}$ h.p. Douglas I rode over 6,000 miles, and it gave admirable results for solo use. Both the forks and the frame were adjustable for side play. The forks were as comfortable as those on any machine I have ever ridden, and in this connection it may be pointed out that what is a reasonably good fork on a rigid type of frame may appear very bad when used with a spring frame. During the whole of the time I possessed that machine I adjusted the spring frame for side play once, and even then the slightest adjustment locked the frame almost rigid. I am inclined to doubt whether, especially with sidecars, the spring frame machine provides the same wheel grip on the road as the rigid machine. For solo riding, however, I do not think there is any difficulty. The design of the steering head races requires very much more attention than it has yet received, although a few manufacturers are now giving attention to it. Very few steering head races will stand up for 5,000 miles without constant adjustment, and it would appear that many of them are not designed to take any axial loading, but merely an end thrust. Springing has a bigger effect on the life of wheel spindles than is generally realised. The type of fork pivoted at the bottom of the head is notoriously hard on front wheel spindles unless the springs are extremely flexible. Another point which has been raised is the question of the increase of average speed which is possible with springing. I think that has to be experienced to be realised. The degree of movement to be allowed for springing is an important point, because it is, as the author states, quite impossible to get reasonable springing with very small movement, and a large movement complicates matters. It is undoubtedly desirable, but it means providing greater ground clearance and sometimes trouble is experienced in

(Captain H. D. Teage.)

providing clearance between the mudguard and the bottom of the steering head. Adjustment for the weight of the rider is probably purely a luxury, and it is quite obvious that rear springing is impossible if it is to do both for pillion riding and solo work. Perhaps rear sprung machines may do something to stop this practice.

A rather interesting spring fork was patented some years ago by a Mr. Waterlow, which appears to comply with the stated requirements very well, although, to the best of my knowledge, it has never been manufactured. It was a fork of the link type that is usually described as the Druid type, but the action was controlled entirely by a leaf spring lying parallel with the steering head and working through a link motion, on the lines of the Saxon. This fork should be admirably suited to present-day requirements. The author mentions that if proper springing were incorporated in a machine it could be made lighter. Certainly some parts of the machine could be made lighter, but if laminated springs are used, and this appears to be desirable, I rather doubt if the total weight of the machine could be reduced. Speaking of unsprung weight and forks, the great majority of British forks are of the link type, where the whole fork is unsprung, and from experience with many types of machines, I have come to the conclusion that the unsprung forks are apt to lead to more chatter than with the very light moving parts. A fork which has not been mentioned in the paper, which has particularly light moving parts and is very satisfactory in action, is that used on the Scott machine, and with this exception I think the P. and M. is the only unsprung fork of British manufacture. With regard to leaf springing, it might be possible to use a modification of the rear springing on the Marmon car, which provided, to all intents and purposes, a variable fulcrum for the base of the spring, i.e., transverse springs were inverted back to back, with hard wood blocks between, so shaped that the spring took up on the block as the load increased.

Recently I have had some experience with the Beardmore Precision machine and found it to be most admirably sprung, although the movement is rather larger than is provided in most spring frames. It is, however, extremely comfortable, and does not appear to have the disadvantage of giving undue side play. With regard to means for damping the action of the springs, many years ago a very admirable fork, the Trufault, was fitted to the Vindee machine; this was provided with a leather pad friction device,

and I still say it was the most comfortable fork I have ever ridden. It was, however, very ugly, and probably for that reason its use has been discontinued. Lubrication is a most necessary point, and has not received very full consideration, but during the last eighteen months one or two manufacturers have begun to adopt a grease gun with an end screwing into the parts to be lubricated. This is probably the best possible form of lubrication. It is absolutely fool-proof, and it is merely necessary to remove a screw and replace by the grease gun and inject. Spring carriers are obviously desirable, especially if the tool bag has to be carried on the carrier, but if the springing system makes it almost impossible to spring the carrier, a simple way out of the difficulty appears to be to carry the tool bag or tool box on the top of the tank, or somewhere near the centre of the machine, where the movement is less. The use of the stand as a stay for the rear mudguard was, I think, perhaps the most unsatisfactory point with the $3\frac{1}{2}$ h.p. Douglas machine, and in spite of strong stays I have broken up two mudguards. For machines which have no spring frames, the use of larger tyres makes an extraordinary difference in comfort, which must be tried to be realised. The machine which I possess at the present moment has 28 by 3 in. instead of 26 by $2\frac{3}{8}$ in. tyres, and the difference between the two is wonderful.

Mr. J. E. GREENWOOD: I think the paper rather leads us to suppose that very little has been done in this country with regard to experimental work on spring frames, but that is not so. Personally I have been carrying out experiments for five or six years, and I daresay I have ridden 20,000 to 25,000 miles on various experimental models. The first machine I tried was fitted with the Druid type of fork, with auxiliary springs at the top which gave a backward and forward movement. I fitted a leaf spring to the rear wheel of the machine with a 4-inch motion, but it straightway gave the impression that the front fork was rigid, and I had to start and design a front fork with at least 3 inches movement in order to get the full benefit of the rear springing. The rear spring part I fitted on plain bearings, and for nearly 6,000 miles they were satisfactory, but then they began to show signs of wear. This caused a whip in the frame, and the machine skidded in grease and on wet cobble stones.

I think a sidecar complicates the matter of springing very much indeed. There is a peculiar rolling motion on a spring frame

(Mr. J. E. Greenwood.)

with a sidecar which is very unnerving; in fact, the machine seems as if it would turn over at corners due to the centrifugal force trying to throw the weight outwards, so that the outside spring goes down; it is very disconcerting at first. The bearings for the spring part of the frame should preferably be ball bearings. I have used these up to from 10,000 to 12,000 miles, and they show no signs of wear whatever. I do not think the round tubes with which the majority of spring frames are hinged behind the gear-box are sufficiently rigid to prevent deflection of the wheel from the vertical position. Some year or two ago I patented an idea to make the two side members triangles and connected them together behind the bearing with a large diameter tube. This takes up the strain in torsion, and that is the only stress to which it is subject, by trying to deflect the wheel from the vertical. A frame of this type is practically rigid without any outside help from the springs, although, of course, the leaf springs do help to support the wheel to a certain extent. The Matchless Co. have got over this rolling motion by connecting the spring part of the back wheel with the spring part of the sidecar wheel, and fitting a very rigid truss with pin joints across the back of the sidecar. Personally, I think there will be trouble with this, because, if the machine is being driven fast and the sidecar wheel or the back wheel jumps upwards very suddenly, it cannot possibly lift the other wheel up at the same time and to the same extent, which must throw a tremendous stress on this connecting strut. Mudguard stays and the mudguards themselves have given a great deal of trouble in connection with spring frames. If these are connected to the unsprung part of the machine they break up very quickly. I do not think there is very much difficulty in the sprung carrier to carry an extra passenger. The ideal springs would not carry the extra passenger, but springs can be made which will be quite comfortable on a solo machine, and also be capable of taking another passenger. I have proved this conclusively. I think the greatest requirement now is a light weight solo spring frame machine. For sidecar combinations at present I think the ideal is a rigid frame, with large tyres, with possibly a spring wheel to the sidecar, but not to the machine, and a good fork. This combination gives very comfortable riding. The Brooke's laminated spring saddle will give as comfortable riding on a rigid frame machine as a spring frame machine. I have ridden a machine with this saddle over

the tramway blocks in Wolverhampton, and with $2\frac{1}{2}$ -inch tyres the shocks on the saddle when going over these blocks cannot be felt; the machine only appears to jolt forward a little bit. If it is possible to make a saddle so good, and to retain the other advantages of the rigid frame, I think it will form an ideal combination with a sidecar.

Major R. V. C. BROOK: The question of designing spring frames is not a simple one, as Mr. Greenwood and the author have told us. Yet I agree with the author when he says, "With well-sprung machines the halt and the lame would soon be riding motor cycles, while the range would be considerably increased for the hale and hearty." Many who are not motor cyclists still hold the perhaps mistaken belief that the motor cycle is a very tiring and vibratory machine to ride, and I believe that, by bringing out a well sprung machine, designers and manufacturers would tap a very much larger market than they can at present. The author also mentions the use of head lugs of steel in place of the usual malleable iron casting. I believe some designers to-day are considering the use of mild steel castings in place of malleable iron. The malleable iron of to-day is not so good as it was before the war, but is very much more liable to fracture. The majority of motor cycles have their front forks sprung, and yet the author points out that that is one of the places where there was most trouble, so that we must take it that even front springs are not as satisfactory as they should be, and we have not only to aim at rear springing but also better front springs. The author refers to bolts and nuts working loose. I often wonder why greater use is not made of helicoid or similar lock nuts, which, I believe, would be better than spring washers. Then with regard to the question of the lubrication of spindles for spring forks, I should like to know whether anyone has had any actual experience of graphite bushes after a year or so's running. It appears to me that if they will stand up to the work they would be ideal for motor cycles, because the average motor cyclist will not bother to lubricate his springing. I think we must agree with Mr. Greenwood, however, that ball bearings seem to be the real solution of the spindle lubrication question. Then there is the question of the effect of springing on the weight of the machine. To some extent weight to-day is due to the need for strength, largely on account of the fact that there is so much unsprung weight. A good system of springing would, I believe, tend to

(Major R. V. C. Brook.)

a reduction in weight, although, as has been pointed out, if laminated springs are used it is a question whether there would be any great saving.

I should like to add my experience with regard to the Beardmore Precision machine, which I rode in one of the recent Trials over very rough ground. I found it magnificently sprung. One objection that I have heard raised is that a machine sprung front and rear does not give the same wheel grip as a rigid machine. I can only say that I did not experience any ill-effects whatever in this direction. The author mentions that care must be taken to ensure that the links on sprung forks are held solidly together. I believe it was the usual practice to hold the links merely by means of a key or dowell in the spindle. I think a better result would be obtained by broaching a square hole in the links and squaring the spindle ends. I suggest that designers ought to consider the question of enclosing the springs. It is a practice which has not been widely enough adopted in car design, but I feel that it must come, and that the springs must be so enclosed that they can be continually immersed in oil. The author says that stands should be made much stronger, but my experience is that the stands have been strong enough but that more attention should be paid to the question of making them automatic in action. It does seem desirable to make frame springs adjustable as on the Royal Ruby, because the proportionate weight of the machine to that of the rider is very much more liable to variation than in the case of a car; the rider may weigh 7 or 8 stone in one case, and 16 stone in another. I am entirely in agreement with Capt. Teage with regard to larger tyres, if the cost will allow it, and I think it would be in the interests of the public that the Press should endeavour to educate the public up to the fact that larger tyres are better for the rider and for the machine, even though they cost a little bit more in the first instance. Engine vibration has a very large influence on the comfort or otherwise of the motor cyclist, and, whilst springing is a very important question, in my opinion the comfort of a two-cycle machine or a small twin-cylinder machine is very much greater, especially on long distances, than that of a single-cylinder four-cycle machine.

Captain S. J. BURT: I find that the spring frame machine evolved by me in France, and which is illustrated in Fig. 6, embodies, with one notable exception, almost every feature which

is advocated by the author. Before proceeding to describe the machine, I hope I may be allowed to endorse the appeal to manufacturers to profit by experience gained in France, and to find means of increasing the reliability of their machines in certain directions. During the four years I spent with the M.T. in France, I saw every one of the failures mentioned occur again and again. I can add to the information given by the author concerning two of these failures by giving a close idea of the frequency of the breakages in my unit. These two parts were the front fork springs and the front down tube of the frame on $2\frac{3}{4}$ h.p. Douglas machines. The machines on my unit were covering on an average about 25 miles a day on the very bad roads around the Souchez district, and it was found that the front fork springs lasted only about ten days, and that the life of the front down tubes was almost three months to the day. It was the constant failure of these parts which drew my attention to the matter of springing. I then re-designed the suspension of one of the Douglas machines, so that the front and rear forks were sprung as illustrated in Fig. 6. The object of the design was to allow very large movements of the wheels yet at the same time to call for the least possible deflection of the elastic media. To begin with the front springing, it will be seen that by means of longer links the permissible movement has been increased to $2\frac{1}{2}$ in. actually, and even this was readily adjustable to give a movement of $3\frac{1}{4}$ in. to $3\frac{1}{2}$ in. The links were fitted with tubular distance-pieces and bolts, which rendered them thoroughly stable laterally. The helical springs, of which there were four instead of two, were provided with an easily swivelling anchorage and so relieved of the distorting stresses mentioned by the author on page 44. To digress for a moment, the effect of fitting this improved front springing arrangement on a frame otherwise standard was to prolong the life of the springs something in excess of twelve times. It also greatly improved the comfort of riding and prolonged the life of the frame. When failure of these springs did eventually take place, it took the form of a gradual extension, a distortion of the coils or "permanent set" becoming noticeable about half-way in the length of the spring. The springing of the rear portion of the machine was carried out by two cantilever springs located just above the foot-board. These were pivoted upon a spindle running athwart the frame under the main engine bearer. The front end of the

(Captain S. J. Burt.)

springs took their bearing upon aluminium rollers which were free to turn on a second transverse spindle. This spindle was located at the base of the front down tube. The rear end of the springs bore on aluminium rollers carried by a third spindle, which was fixed to the pivoted back forks and which controlled their movement in a vertical plane. The position of this spindle in relation to the back wheel will be noted, providing, as it does, the minimum movement of the springs with a very large back wheel motion. Concentric with the axis of the pivoting of the back forks, a frictional damping device, or shock absorber, as it is sometimes miscalled, was located. The design of this was simple, and such that, if it were so desired, a certain amount of fork movement could take place before the device came into operation, thus tending in the direction suggested by the author. Owing to the special nature of the work imposed on the machine, it was found desirable to fit a skid under the silencer and gear box. This skid was made reasonably strong and utilised to strengthen the main tube carrying the engine and the central spindle of the springs. It will be noted that the position of the swivelling point of the back forks is by no means ideal, but this position was the best that could be arranged with the facilities at hand. The fact that no trouble was experienced with the belt slipping or the fastener pulling out may be taken to prove that more latitude in the positioning of this point is permissible than might at first sight be supposed. The permissible movement of the back wheel was between $5\frac{1}{2}$ in. and 6 in. The displacement mentioned was utilised to the full under the conditions of use to which the machine was put. The low frequency of the springs gave great comfort in riding. In view of the author's remarks regarding the advantages of adjustability, it will no doubt be of interest to state that the substitution of a pair of rollers of $\frac{1}{4}$ in. greater diameter resulted in increasing the range of possible back wheel movement by 1 in. In view of the point raised in the paper on page 55, I should like to say that my experience was that the large movement in the suspension does not adversely affect the steering. The riding of the cycle was most luxurious, even on the worst roads. In fact, its remarkable efficiency in swallowing the worst road bumps was responsible for the search for some obstruction which would really test it, and it was its efficiency in dealing with these that suggested the possibility of taking a machine gun across country. During the search for suitable

obstacles to test the springing to its limits, the machine was repeatedly ridden both up and down a flight of steps. No difficulty was experienced in surmounting a full petrol can placed in the track of the machine. It was after these tests that the machine gun was mounted on the cycle, and tests were made over such obstacles as might be expected on a cross-country run. These tests proved satisfactory, and the cycle was brought to the notice of the First Army Commander, General Lord Horne. The machine was then demonstrated to the latter and his Staff at the review of the Guards' Machine Gun Brigade held in 1918 on the Arras—St. Pol road, and also later at our own testing ground. Some of the tests were as follows:—

The machine, complete with machine gun and 350 rounds of ammunition, was ridden at a reasonable pace over the following obstacles—

- (1) Sandbags piled up to a height of about 18 in.
- (2) A large diameter telegraph pole.
- (3) A heap of stones 3 ft. high, the angle at the sides being at least 30 degrees.
- (4) Down into a hole 3 ft. 6 in. deep and between 8 and 10 ft. wide, which was constructed to be a very realistic imitation of a shell crater.

After the ease with which the machine could deal with each obstacle had been demonstrated, General Horne said that he was astounded and more than favourably impressed with the possibilities of the machine as an instrument of war, and stated that if request for the trial of the machine were put through the usual channel he would forward it to G. H. Q. with a strong recommendation.

Mr. R. T. MORGAN: Some time ago I had a machine in which the front forks were of the ordinary link pattern, and these links rapidly developed an angle of about 15 degrees slack, and consequently the machine steered itself within that range. I scrapped that fork and started again to design a fork which would not have any links at all. In this case the front wheel was carried on two laminated springs bolted to the crown at the bottom of the steering column. Each spring had three leaves, one of which was $\frac{1}{4}$ in. thick carried between the other two of $\frac{3}{16}$ in. thickness. To give proper stiffness, I provided very great compression between the springs, and in order to get friction without harshness I fitted perforated sheet brass plates charged with tallow

(Mr. R. T. Morgan.)

between the leaves, which gave sufficient friction to damp out excessive motion, the idea being that the springs should be auxiliary to the pneumatic tyre. The pneumatic tyre dissipates nothing. It takes the shock and gives it all back again, and it is necessary, in my opinion, to damp out these shocks by dissipation of the energy. This front fork worked extremely well, though it looked weak. The extreme range of movement was about 4 in. forward and 4 in. aft, and owing to small clearances it gradually hammered a large dent in the silencer. Its comfort by comparison gave me the impression that I had not got a tyre on the back wheel at all. One of the troubles of the steering column is with the ball races, which appear to be manufactured and fitted without any proper regard for squareness of the seatings of the races. In a great many cases the balls hammer in locally and make little depressions in the races, until each ball takes up a part of the load, by which time the races in many cases are split open and scrapped. The races should be on spherical seatings in order to get equal distribution of the load amongst the balls. There is not sufficient metal put into the races, and, moreover, the metal is of a very poor quality. At any rate, that is my opinion of motor cycle front fork and other races. I cannot say anything about the springing of back wheels, but the springing of carriers is very important, and very bad at present. There is a particularly smart invention in regard to railroad traction which has eliminated all breakages of drawbars due to sudden snatches by the engine. It has been passed by the National Physical Laboratory as possessing shock absorbing qualities considerably in excess of rubber, and it might well be applied to spring forks. It consists of two links which are made convex, and the two convex surfaces are in rolling contact. The shock is applied so as to compress together one pair of ends, and a spring is applied to compress the other ends together, with a double see-saw effect, the convex surfaces giving a rolling fulcrum which reduces the leverage of large shocks and proportionately increases the leverage of the spring to overcome them, giving a continuous and progressive diminution of the initial deflection, so that quite a small spring can damp out a very large shock.

Mr. R. H. PEARSALL: From the point of view of one whose business it is to produce a suitably sprung motor cycle, there arise two main questions. In the first place, variation in loading has to be encountered, and I disagree with the author when he

says this is small in a motor cycle. The rider's weight may vary from 7 to 17 stone, and to that may be added a passenger on the carrier, a sidecar, and three people in the sidecar. It is clearly difficult to provide for so great a variation. Secondly, as Mr. Greenwood points out, the spring frame cycle rolls badly with a sidecar. This, I believe, can be got used to, and if Mr. Greenwood can get the public used to it so much the better, but as the change from rigid to sprung frame is alarming at first, I feel the right course for the sidecar is the rigid frame. The general difficulty is that we are forced to provide motor cycles which will be ridden both solo and sidecar, and what is good for one is not good for the other.

It has been stated that spring frames add to the speed, and the author quotes experience in France, where speeds averaged perhaps six miles an hour. Over such roads I agree, but is it not a fact that professional riders in competitions frequently bind up their springs, when they have spring frames, to reduce their action? And if so, why? Watching the Six Days' Trials, I was impressed with the value of frame stiffness. The stiffer the frame, the better the machine held the bad roads, and I think there is no spring frame machine on the road to-day that does not suffer from loss of lateral stiffness.

Also, with a chain drive and a sprung back wheel there is continual snatch on the chain, causing either wheel slip or chain breakage, generally both. This is very serious, and apparently cannot be relieved by a cushion drive, and is probably the reason for the professional practice I have cited. With a belt, slip occurs every cycle of the engine and the effect is less marked.

Capt. Burt referred to springs with three or four inches motion in front and little more at the back. Such a combination will probably cause pitching; it certainly would on a car.

Mr. W. H. M. HIGHAM: I can fully endorse the author's remarks on the weaknesses of the machines generally, especially breaking of head lugs and front down tubes, although I found that the great majority of these fractures occurred on Douglas machines. I can only remember one case of a Triumph frame breaking. Mudguards and carriers were also a source of trouble, especially on the lighter machines. With regard to dirt in bearings, I have fitted rings after the fashion of oil throwers with benefit. To return to the question of springing, the author does not mention the fact that most Triumph front forks were strapped up, it

SAVAGE.

(Mr. W. H. M. Higham.)

being suicidal to ride a machine without this. On my own machine they were strapped up as hard as I could get them by putting my full weight on the handle bars. By this means I appeared to obviate the usual effect on the steering due to the design of the Triumph fork. In fact, out of all the machines attached to my workshop, mine was noted for holding the road best at all speeds, from a walking pace up to the limit. Whether this was due to the strapped-up fork spring or just an inherent peculiarity I cannot say with any certainty, but perhaps the author could enlighten me on this point. Of course I lost in resilience, as I discovered when on Belgian pavé, so I coiled half an inner tube round each handlebar to form grips, and thereafter rode many miles in comfort. The rubber barrel-shaped buffer issued out to be tested did not find favour with my men as it was too solid. To test the relative merits of the two standard examples of springing, I fitted Rudge Whitworth forks to my Triumph, with great benefit to the steering at speed. From the point of view of springing, I preferred the Triumph fork, as there was a most unpleasant vibration in the handlebars noticeable with the Rudge fork. I transferred to the Tanks soon after, and was told that in the end the Rudge forks practically fell to pieces, really owing, I believe, to insufficient lubrication. Douglas fork springs were far too weak, in my opinion, for the conditions abroad. On the other hand, they appeared strong enough in comparison with the strength of the frame. On occasion, we used to fit a third spring in front, and the inevitable result was that the front down tube or head lug fractured in a very short space of time. This little tip was rather useful when a Douglas was in such a condition that it was getting more than its fair ration of spares and attention, but not bad enough to send down to the base. Most of my springs on that make broke at the point where the taper commenced. In any case, I think the design was altogether too light for war conditions, thereby causing much too much work for the mobile workshops.

The author has practically ignored sidecar combinations. I had a certain amount of trouble with the 4 h.p. Douglas. Some connections broke, and sometimes the sidecar chassis itself. In fact, it seemed to be a question of chasing the weak spot in the chassis. If it were repaired in one spot it would break in another, and so on. It is my firm opinion that the average sidecar coupling is far too rigid, and as a result an unfair stress is placed on the

cycle frame. This was my deduction from the war experience I had, and it was fully borne out by last year's official report on the Six Days' Trial. To remedy this, I have recently introduced a spring sidecar coupling, which is so designed as to be virtually rigid under ordinary conditions of riding, but will yield under shock. Excessive yield is prevented by a damping device limiting the amount of "give." The effect on alinement is nil, and there is only a very small lateral movement of the sidecar wheel. The device is applicable to any make of machine and is not much larger than the ordinary coupling. The principle would also be applicable to springing in the ordinary way, and embodies the author's wish for a damping device, which would come into action after the first big deflection either way.

Captain T. E. B. CHALMERS: I agree that the lubrication of steering joints is extraordinarily weak. At the moment I am riding a very well known make of Birmingham machine, and find it suffers excessively from sticky joints. This is practically entirely accounted for by the employment of very tiny spring-covered oil holes. I am afraid I do not take the trouble to insert the necessary small oil can into the said tiny holes; hence the shackles stick and rust up and the spring forks become practically useless. Were the shackles lubricated by means of a screw-nozzled grease gun, the situation would be entirely different. One injection could be easily put in and would last a very long time. We used this system on the track bearings of the Tanks, and, although we had a very large number of bearings to grease, we found it quite the best method of lubrication. Capt. Teage mentioned the Truffault spring fork. I think it was quite the finest spring fork, without exception, that I have ever been on.

The matter of tyres is very important when considering springing. In France the $2\frac{1}{4}$ in. and $2\frac{3}{8}$ in. sections were universal. I re-built the wheels of my Triumph to take $2\frac{1}{2}$ in. tyres, and the difference in comfort was extraordinary. Further, the machine was much more easily controlled on greasy roads. The distribution of the weight of the rider also appears to have a lot to do with comfort in riding. I proved this when we substituted the straight T. T. bars for the standard touring bars.

I had the pleasure of testing Capt. Burt's Douglas machine in France, and spent a very pleasant and profitable afternoon with him at his workshop negotiating the various obstacles he has told us of. It was a truly remarkable machine, and, although I

(Captain T. E. B. Chalmers.).

came off several times during my initial attempts, I was thoroughly satisfied that, for comfort in riding, I had never been on a more luxurious motor cycle. It is quite impossible to imagine the easy floating motion over roads full of pot-holes without actually driving the machine.

Mr. MAURICE HOLROYD: With regard to wheel grip, I quite agree with Major Brook that on a smooth surface there is no apparent difference between a spring frame and a rigid frame, but I have my doubts as to whether a spring frame gives the best results on a loose or bumpy surface. Going up a steep incline, with a bumpy surface, I find we are troubled with wheel-spin. This wheel-spin, however, in my opinion, is rather an advantage as it allows the engine to pick up speed again. In the case of a loose surface I find that the wheel digs in and progress is impossible. With regard to ball bearings as a substitute for hinges or phosphor bronze bearings in conjunction with spring frames, I quite endorse Mr. Greenwood's remarks. If we use a hinge or a plain phosphor bronze bearing, the machine is subject to side roll which is most objectionable.

The question of sprocket centres is a most interesting point. I find there is a certain amount of chain snatch, even with a shock absorber on the countershaft or on the rear wheel. I have broken two driving chains, and it has been on occasions when I have ridden over an excessive bump, and I attribute this to the sprocket centres being thrown out of their original distance in relation to each other, thus causing the chain to get out of pitch with the teeth on the sprockets. My firm, Messrs. F. G. Baker, Ltd., is now experimenting with a driving sprocket having only ten driving teeth, the intermediate teeth acting as trackers so that as the distance between the centres becomes altered the chain will not ride over the driving teeth.

Mr. J. J. RICHARDSON: Being a designer and patentee of spring forks and spring frames, I feel that I am responsible for a few of the faults attributed to motor cycle manufacturers, yet if we were to incorporate the whole of the improvements suggested in the paper and the discussion into motor cycles we should immediately get up against the question of cost, the whole of which has to be borne by the customer, if businesses are to be commercially successful. The difficulty is that people will not pay for these improvements.

It has been suggested by various speakers that when an

ordinary spring fork is fitted to a spring frame motor cycle it immediately shows up the shortcomings of the front system of springing. In the main, most of these forks, apart from those which are designed exclusively for the purpose of accommodating a spring frame, are made to give certain results in conjunction with a rigid frame motor cycle. If a very flexible spring fork be fitted to a rigid frame motor cycle, complaints are received of the movement being excessive, because the two things are not comparative. Therefore, it is not fair to the manufacturers of spring forks to condemn them when a fork which was originally designed for a rigid frame motor cycle is fitted to a spring frame motor cycle.

In order to provide comfort with a spring frame motor cycle it is necessary to give greater clearances than are usually provided. Some designers of motor cycles ignore the fact that a spring fork has got to be fitted, they do not give sufficient clearance, or arrange for the angle of the head lug to be sufficient to give the fork a proper trial. These and many other things have to be taken into consideration before a really well designed motor cycle can be arrived at.

The whole of the criticisms made as broad generalities can be supported, but it would be more useful if a particular type of spring fork and spring frame were taken and subjected to criticism. The broad generalities which might apply to one type would not apply in the case of others, whilst the whole of the generalities would not apply in every case. Personally, I have had some little experience with the difficulties indicated, being responsible for the design and production of many hundreds of spring forks and a fair number of spring frames every week.

Respecting the spring forks used on the Motor Cycle Machine Gun Batteries, which were supplied by the firm I am connected with, I would like to say that the manufacturers were not consulted as to the suitability of the model used. A certain standard type of fork which was available at the time was fitted, and it is not surprising that shackle pins broke fairly frequently when the weight of the outfit (12 cwt.) and the services required were taken into consideration. The authorities instructed us that the springs fitted were not strong enough to carry the weight, and springs were fitted to carry a 50 per cent increase of load; the result was that the shackle pins sheared. We tried to persuade them to take an improved arrangement of the shackle pins and links, but owing

(Mr. J. J. Richardson.)

to the spare part difficulty in the various depôts we were not permitted to change the design.

The other design of fork submitted for the job was used in connection with the M.T. Dépôt, and we have never received a report that a single shackle pin has broken since this arrangement has been used. The shackle pin is of uniform diameter throughout its length, and provides for adjustment without the addition of any extra parts beyond those normally required in the non-adjustable type that is fitted with location shoulders for the links to be screwed up against.

These and other little difficulties we had to contend with during the war, and while forks have failed under abnormal conditions for which they were not designed, when we have offered better forks they have been refused, and when manufacturers are offered a better motor cycle spring frame, which anticipates all the suggestions made in the paper and the discussion, probably manufacturers will again refuse, because it seems too good to be true.

Mr. G. H. SAVAGE, in replying on the discussion, said: I cannot agree with Captain Teage when he says that "the grease gun is probably the best possible form of lubrication." The operation of lubricating a machine should be as easy as possible, whereas the filling of a grease gun is most unpleasant, and unless the grease is of the right consistency, it is a strenuous operation. In my opinion, the quickest, easiest, and what could be quite an efficient method, is the large oiler with a flap lid and an oil can. It may be argued, of course, that the lids of these oilers break off, to which the obvious reply is that they should be better made, and this would seem to present no special difficulty.

I agree with Mr. Greenwood when he says that ball bearings are probably better for the rear main spindle bearing, for the reasons stated.

I purposely did not refer in the paper to the sidecar machine which Mr. Greenwood mentioned, through lack of time. In the paper I endeavoured to show some of the advantages of springing, and rather than sacrifice these benefits for a sidecar machine, an anti-rolling device (of which there are several on the market) could probably be cheapened in cost and embodied in the springing.

Mr. Greenwood goes on to say that "this rolling was very disconcerting *at first*," and I am inclined to think that the danger is more imaginary than real. A spring frame machine, with its

greater freedom of action, would naturally feel different from the rigid frame machine. With reference to his criticism of the Matchless design to deal with this rolling action, it would seem that this "tremendous stress" would be no worse than that which at present occurs in the same way on the rigid frame machine.

A last point raised by Mr. Greenwood was that of fitting extra springs in the saddle. In my opinion, this is quite satisfactory, but I would like to emphasise the danger which lies in this direction. The tendency now is to spring the rider well by means of these extra springs, which act between the rider and the frame only. As I stated in the paper, by these somewhat makeshift means, the engine, gear-box, and the other units of which the machine itself consists, remain unsprung. Thus, the greatest advantage of the complete springing, namely, that these units can be re-designed and made considerably lighter, is neglected.

With reference to Mr. Pearsall's criticism on the variation of weight, I would like to point out that my remark was confined to the solo machine—that I have not discussed sidecar springing at all. I would also recommend to the somewhat abnormal man of 17 stone who is thinking of taking up motor cycle riding that he should have other parts altered specially for him besides the springing.

I cannot understand where Mr. Pearsall obtained the figure of six miles per hour for the average speed in France. The only speeds quoted in the paper were those attained on the special 3rd Heavy Repair Shop spring frame Triumph, and these averaged over thirty miles per hour. It is, of course, impossible to say what was an average speed for the motor cycles in France, but it was certainly much nearer twenty than six miles per hour.

Several speakers raise the question of the amount of wheel grip on a spring frame machine compared with that of a rigid frame machine. On a spring frame machine the wheel grip is better, as the wheels tend to follow the inequalities of the road, and are consequently in better contact with the road surface. One advantage of a well designed spring frame machine is that the tyres have a longer life.

Why so many people doubt the merit of a spring frame machine, and also raise this question of wheel grip, is to a considerable extent because they hear of professional riders binding their standard springs up when riding in competitions. The reason for this is not so much to reduce the action of the springs, as to

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get greater friction between the leaves. The springs must, of course, if they are to be comfortable, be designed for more or less the average loads which they will be called upon to withstand at the average speed. In competition riding the springs are suddenly called upon to withstand very much greater loads than they were originally designed for on account of the greater speeds and worse road surfaces, and the only thing to be done under these circumstances is either to fit stiffer springs or to increase the friction by binding up the existing springs.

As was pointed out in the paper when discussing the "merits or demerits of friction in the springing," the springs must take the road shocks, but at the same time it is desirable that the oscillations be damped out as soon as possible, and that there shall be no risk of any cumulative effect arising from regular undulations; for this reason, in abnormal circumstances, extra friction is given to the springs by binding up the leaves.

I cannot agree with Mr. Maurice Holroyd in his remarks as to chain snatch. In the longest position the chain should always be a little slack. Then with the maximum movement of the rear wheel of 3 in. to 4 in. the shortening of the centres of the sprocket wheel and road wheel will on most machines be $\frac{1}{8}$ in. or under, and this should not be detrimental to the chain.

I think that Mr. Higham is rather extreme when he says that "it was suicidal to ride the Triumph machine without strapping the front forks up." This saved the springs from being overstressed, but it also had the serious effect (as mentioned later by Col. Davidson) of helping to break the top tubes and head lugs. Naturally, with a great part of the spring action cut out, the shocks transmitted to the frame were much heavier.

COMMUNICATIONS.

Mr. R. T. MORGAN wrote: I would like to amplify my somewhat impromptu remarks in the discussion. The spring fork to which I alluded was the very height of simplicity, though its great advantages were tempered by several disadvantages. In appearance it resembled an ordinary bicycle fork, except that the two fork members were laminated springs. I believe that road springs should not absorb the energy of shocks, but should dissipate it. The chief trouble is the tendency for a quick rebound, as the leaves of laminated springs are usually made to support the main plate in one direction only. Consequently, a wheel moves rapidly into a pothole, and the upward movement immediately following is resisted by all the leaves. Special leaves should be provided to prevent the wheel from reaching the bottom of the pothole. Accordingly, in my spring fork, the main leaf spring was clamped between two thinner leaves in order that the friction should damp out or resist a deflection in any direction. The use of perforated sheet brass strips charged with tallow and inserted between each pair of leaves was excellent in practice, as the lubrication was permanent and the springs developed no harshness. A special spring clamp was fitted to each fork member to damp out independent motion likely to cause wobble in steering, and this was found to be fairly efficient in practice. At high speeds there was a tendency to sluggishness in the steering due to gyroscopic action of the front wheel. Also, on a rutty road, the wheel had a slight tendency to follow the ruts rather than the handlebars, which could be much reduced by more careful design. The comfort was really remarkable, particularly at higher speeds. The majority of the shocks were in the form of end thrusts up the leaves, but the fore and aft components were sufficient to swing the wheel through a range of about 7 in. or 8 in. I think that the fork would have been much improved by the addition of another leaf to each fork member.

The chief objection to the fork was the extreme simplicity, the absence of any form of "girder" making it appear weak by comparison with existing types. This "girder" construction is, no doubt, excellent when properly designed, but I have seen

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several instances of "girder" forks in which the combination of strength and weakness was truly comical. My fork was designed so that the greatest stresses should occur at points where the danger from fracture was least, and on one occasion I rode on over 100 miles after discovering a broken leaf without the breakage affecting the running in any way. I should say that the fork would be very suitable for light weight machines without sidecars.

Lt.-Col. A. E. DAVIDSON wrote: In France during the war those responsible for the type of machine to be demanded from England felt that great advantages would arise if a thoroughly efficient spring frame motor cycle could be introduced. These advantages are referred to by the author on page 43. It is only desired to add that the strain of supplying fresh machines to replace casualties was very heavy, and undoubtedly could have been reduced if there had been available a really well sprung frame which would have suffered less damage from shock and bad roads. The qualities which were considered essential in a spring frame before it could be recommended for adoption were as follows:—

- (a) Absolute reliability of all the additional parts introduced.
- (b) No adverse effect on steering or steadiness even after running a considerable mileage.
- (c) No increase in wearing parts liable to require renewal.

Since none of the machines sent out from England fulfilled these requirements, it was arranged that one of our repair shops should set to work to endeavour to tackle the problem. Capt. Savage was in charge of the work, and his experiences in testing models sent out from England and making up others form the basis of this paper.

The Douglas spring frame shown in Fig. 2 failed owing to the top tube being too weak to take the additional stress brought on it by the spring anchorage. After the tube had been replaced by one of considerably stouter gauge, it stood up well and was, in my opinion, much more comfortable to ride than the later model with coiled springs. This was probably due to the fact that the range of movement was greater.

On the question of the range of movement and its effect in relieving the machine of stresses and road shocks, some facts regarding the Triumph and Douglas front fork springing may be

of interest. The various Triumph springs tested in *quantities* were as follows:—

- (a) Standard spring giving *full range*.
- (b) Long soft rubber buffers (about 5 in. uncompressed)—*medium range*.
- (c) Short rubber buffer (about 3 in. uncompressed)—*very short range*.
- (d) T.T. pattern felt buffer—*very short range*.

Frame breakages occurred in the earlier years of the war with (a), but were greatly reduced when a thicker gauge top tube was introduced. After that, top tube breakages were probably due in a large measure to the practice referred to by Mr. Higham of strapping up the forks so tightly that movement was restricted to the equivalent of that given by (c) or (d).

(d) was the device used by T.T. riders in pre-war days. It gave a very small range of movement—a restriction which riders consider desirable with the Triumph type of fork for high speed work.

(b) The long buffers of soft rubber could only be obtained in small numbers, and

(c) was the locally made substitute.

Frame breakages occurred with (b) after a reasonable mileage, but with (c) and (d) types after a small mileage. The point to note is that the frequency of frame breakage was more or less proportional to the range of movement allowed by the spring or buffer.

In addition, one trial machine was sent out with a specially long spring with wider range of movement, and although the spring and frame stood up well, the range was too great for safe or comfortable steering. Another trial machine was sent out with double springs, which in practice amounted to a very stiff spring with a small movement for normal road shocks. The frame broke with this device after a short mileage.

In the case of the Douglas, the spring fork eventually fitted to the $2\frac{3}{4}$ h.p. model, *vide* Fig. 1, was first introduced for the 4 h.p. model. The range of movement of the two types was as follows:—

$2\frac{3}{4}$ h.p. models before 1914 with straight links...	1 in.
$2\frac{3}{4}$ h.p. 1914 model with curved links	1-3, 16 in.
4 h.p. model	$2\frac{1}{4}$ in.

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The 4 h.p. model fork was generally pronounced by riders to be one of the best spring forks ever used by them, and this tends to show that a large range is necessary for real comfort in riding and for saving the machine from shocks.

Mr. F. STRICKLAND wrote: I feel sure that the future motor cycle ought to be sprung both back and front, and therefore that all information on the subject of springing is of great value.

Taking the paper in order, a good deal is said in the early part about the various breakdowns. As mentioned by the author, part of these were due to bad roads, but I agree with him that this was not by any means the whole reason, and that machines should have stood up better than they did. It seems to me that a great many of the breakdowns were due to the fact that the machines were in constant use every day, and that before the war the ordinary motor cycle had not been made so that it would stand such continuous use. Both in motor cycles and pleasure cars it has often been considered that if the machine would stand some years' use in the hands of the average owner it was a very durable machine, and it has been rather forgotten that the ordinary man does not use his machine every day or all day, in the manner other types of machinery are used. It may not be necessary that a motor cycle should stand for twenty years doing eight hours' work a day (say 900 miles a week), which would be the equivalent of what many machines do, but they should be made more durable than they are.

In this connection it appears time that the diameter of the tubing composing the frame received real consideration. Motor cycle designers appear to have adopted a tube diameter about the same as that of the ordinary pedal bicycle and simply thickened it to make it stronger. This cannot be right, and if tube about $1\frac{1}{2}$ in. diameter is right for a pedal cycle, as appears to be the case, it cannot be anywhere near right for a motor cycle. Further, it cannot possibly be right to make the tubes the same diameter for the real light-weight and for the heavy-weight machine.

Coming to the question of springing, I absolutely agree with the author as to the desirability of this, both from the point of view of the machine and the rider. If anyone will consider what other vehicles would be like without springs, the advantage of them for motor cycles will be obvious.

I was rather disappointed on reading the paper to find no reference to the springing of the Indian motor cycle. This make

has been sprung for a great many years, and I believe that the system of springing has not been very greatly varied. There has, therefore, been enough experience to ascertain the advantages and disadvantages both of the principle and of the various details, and remarks on this point would be interesting.

In general principle there appear to be two points worthy of discussion, first, the direction of movement of the wheel, and, second, the question of leaf versus spiral springs. With regard to the first, it appears to me that the direction of motion of the wheel should be in the direction in which the shock is received. This is generally a little inclined backwards from the vertical. In cars, lorries, etc. the direction of the motion of the front wheels is usually almost vertical, though it may be slightly inclined back if the springs have any material camber. The back wheels often have a motion distinctly inclined back, as when controlled by a radius rod with a very distinct slope to it. In the front fork springing of motor cycles, however, there are patterns where the direction of motion inclines very much forwards, and the motion is therefore not in the direction of the shock but at some considerable angle to it. It might in some cases be almost at a right angle to certain shocks, and this, of course, would entirely neutralise the spring effect.

With regard to the question of leaf versus spiral springs, it is worthy of note that spiral and volute springs have been tried for all sorts of other vehicles, but have never come into general use on account of the fact that they have no damping effect. If a spring were perfectly elastic, a vehicle fitted with it would continue to oscillate for ever once it had been started doing so by going over a bump. Leaf springs have a considerable amount of friction between the leaves, and this friction damps out the oscillations. The very fact of the friction, however, means that the spring does not move at all till a certain minimum pressure has been put on it. A leaf spring with very few leaves may have very little damping effect, and I have driven a car in which the front springs oscillated violently for some time after going over a bump, and the result was very unpleasant indeed. A spiral spring would have had still less damping effect and presumably been worse. Hence spiral springs are not used in other types of vehicle unless there are in addition enough leaf springs to give the requisite damping. Thus, it is very common in locomotive practice to find *one* axle on spiral springs, as they are far the most convenient

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constructively, but they are never used for all the axles. It does not follow that spiral springs will be a failure on motor cycles, for it sometimes happens that a method of construction which is unsuitable for general use serves some special purpose, but it seems probable that if motor cycle springs are given the same range of movement as other vehicle springs, leaf springs, either with or without additional volute springs, should be the best.

I cannot agree with the author that carrying a passenger on the carrier varies the load on the springs of a motor cycle to any materially greater extent than on other vehicles. The ordinary weight of the motor cycle with driver is about 400 lb., often more. The extra passenger is usually a lady, quite often young, and therefore with a weight of some 120 to 140 lb. This is approximately 33 per cent of the weight of the machine and driver.. A motor bus with driver weighs about 70 cwt. and carries over forty passengers weighing some 60 cwt., or 85 per cent of the weight, with driver only. In a lorry, the weight of the load is a still larger proportion of the weight of vehicle and driver. I do not, therefore, see any greater reason for making the extra passenger an unsprung weight than there is for making the load of a bus or lorry unsprung. No doubt it is easier to arrange correct springing if the load is constant, but this applies to cars and lorries as well as motor cycles. Most nominal 5-seated cars will at a pinch carry a good many more, and often do so, and yet are fairly well sprung with the driver, and I would suggest that motor cycle designers should be able to provide for equally varying weights.

The question of the wear of the shackle pins and various parts is very important. Here it is to be hoped that the shackle consisting of flat plates will soon be obsolete, as it now is in cars, owing to its lack of lateral stability and liability to work loose on the pin.

Lubrication is important, but it must be remembered that lubrication takes time, and time is equivalent to money. It is quite possible to spend more time preventing wear than it is worth.. Every effort should, therefore, be made to economise the time required for lubrication. Oil cups usually take less time to fill than greasers, and the tops of the latter often shake off. Hence many firms at the Commercial Motor Vehicle Show exhibited vehicles with oil cups to the spring shackles, etc. in place of

grease cups. The ideal would, of course, be oilless bearings, and it appears that it would be quite worth while making a serious effort to fit them.

In conclusion, I would suggest that it would be of great interest if the author could give any information as to the actual stresses under which the springs work. In several places it is mentioned that springs failed from being overstressed, but there is no information as to what the stresses are. This matter of stresses in springs is one on which there is very little information, but from calculations I made on lorry springs when in France it appeared that most of the failures were due to the steel being stressed to a higher load than any steel will stand, and that they could have been very largely avoided by calculating out the stresses beforehand and limiting them to a reasonable amount. What is wanted is the stress on the metal when the spring is compressed to the maximum possible in practical work.

In reply to the written communications, Mr. SAVAGE wrote: In reply to one point raised by Mr. Strickland, I did not intend to say that carrying a passenger on the carrier varied the load to a greater extent than on other vehicles. I think Mr. Strickland will find that the variation of load on the motorbus, lorry or car is the chief difficulty of the spring suspension designer on all these vehicles. If the designer knew what the approximate load on his vehicle would be, he could design a very much better suspension than he does at present. My point, which was dealt with fully in the paper, was that a very good suspension could be designed for the motor cycle if it was not subjected to the unfair loading of an extra passenger on the carrier—a load which the solo machine was never intended to carry.

Mr. Strickland asks if the stresses on the springs can be given. When writing this paper I endeavoured to find out by inquiring from the makers, and by test to a certain extent, if there were any clear ideas as to the maximum stresses these springs would be called upon to withstand. My inquiries were not very successful, however, and it looked as if either the makers were somewhat reticent, or that it was, in many cases, being left to trial and error to decide the question. There is no difficulty in checking, if desired, as to whether any particular helical spring is being overstressed, either by practical experiment or by making use of ordinary well-known formulæ.

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On some of the machines in France the amount of the extension of springs was observed, and by ordinary substitution it was found that they were being much overstressed, which fact was, of course, borne out in practice. It is, however, only misleading at present to compare the different springs on the various makes of motor cycles. Nearly all the springs differ as to diameter of coil, diameter of wire, leverages, loads, etc., and each case must be judged on its own merits.

In reply to a further question by Mr. Strickland, in a parallel wound compression spring with open coils, the safe value of the stress per sq. in. is generally reckoned at 80,000 lb. A factor of safety of 3 to 4 should be allowed, however, as the spring is frequently compressed.

With extension springs, the safe value of the stress per sq. in. is only about two-thirds of that for open coiled compression springs of the same diameter.

FIG. 13.—**Matchless Standard Model.**