

MOTORCYCLE ENGINEERING

The Outline of the Problem



PHIL ("SLIDE RULE") IRVING introduces his new series with the facts to be considered "before one can face a clean sheet of paper and a draughting machine"

THE title of this series may seem a trifle grandiose to those who are accustomed to view the single-tracker as little more than a toy in the engineering sense; but in fact the modern motorcycle is an engineering feat of no inconsiderable magnitude, on which a great amount of technical skill and manufacturing "know-how" has to be lavished in order to maintain any make in a highly competitive market, composed for the most part of customers who are selective and knowledgeable and not to be easily swayed by a copy-writer's catchphrase, unless it is backed up by public performances of indisputable authenticity and merit.

There are two outstanding factors which go to make motorcycle design a somewhat specialized art: one is that, in the ordinary run of events, the crew sit *on* the machine, and not *in* it; and the other is that, by its very nature, a single-tracker is in unstable equilibrium, i.e., it cannot, when stationary, stand up by itself.

The first of these factors automatically sets limits to both the height and the width, and, if reasonable proportions are to be maintained, to the length as well. An exception may be made of the all-enclosed record-breaker in which the rider lies either prone or supine, but for the moment it is only the more conventional type of mount which is under discussion; the others may come in later.

The second factor entails designing the machine in such a way that its condition of unstable equilibrium, when stationary, is converted into a condition of auto-stability when on the move—and, moreover, achieving this in such a way that stability can still be maintained, either automatically or by the rider's efforts, under such widely differing conditions as going downhill at three-figure speeds or climbing a rocky hillside track at little more than a walking pace. Rarely, of course, is there any need to combine in one model of motorcycle a superb ability to meet both these extreme cases; but the closer the approach which can be made, the safer the model will be under all the conditions likely to be encountered in normal use.

Let us deal first with the question of proportions and size. What the limitations described amount to in practice is that the space available for the engine and gearbox between the wheels is, at a maximum, 24 in. long after allowing for the necessary clearance between tyres, mudguards and frame members, and about 14 in. wide, except for local protuberances or projecting cylinders. In height, 24 in. is again

about the usable maximum, though for reasons of balance, and for ease of moving the machine by hand with a dead engine, the lower the height can be kept the better, especially with regard to heavy components which naturally raise the centre of gravity of the power unit if located towards the upper limit of height.

In this space, then, of 24 x 24 x 14 in., has to be housed an engine of whatever size is deemed necessary, a clutch, a gearbox, usually with four but possibly with anything from three to six ratios, some method of starting and all the electrical gear; whilst somewhere in the vicinity must be placed a tank holding anything up to four or five gallons of petrol and storage for several pints of oil, either within the engine itself or in a separate tank.

Nor must appearance be forgotten, for an eye-taking design, even of mediocre performance, is almost certain to sell more freely, in the first few months at least, than one of far better performance but lacking in good looks, whatever the virtues of the sounder machine may do subsequently to redress the balance. Strictly speaking, this is more the province of the stylist than of the engineer, but motorcycle design is one field where the stylist must not be allowed to wield undue influence at the cost possibly of propounding a machine which is unsuitable, or even dangerous, in some respect. The stylist's real function in this special field is to produce a design which will be pleasing to the eyes of next season's buyers and will remain so for two or three years, without in any way embodying something useless or non-functional just for the sake of being strikingly different. In this connection, of course, fashions change; total enclosure, for instance, is quite acceptable today, whereas attempts to introduce it 20 years ago met with failure.

Before one can face a clean sheet of paper and a draughting machine and start work with confidence, it is a first essential to know just what sort of motorcycle you wish to design. A man free from the trammels of commercial life might set out with preconceived notions to design a "dream-machine" which suited his own ideas exactly but would be quite an impossible proposition to produce at a competitive price; usually, however, the practising designer is informed by the sales or the competition department of the general overall specification that is required. This may vary from the cheapest thing which can be made on two wheels up to something in the 100-m.p.h. class with every conceivable aid to comfortable travel: or it

may be of the strictly functional variety, such as a road-racer or a scrambler, in which appearance and cost are secondary to performance and handling.

In this connection, it is always better to aim in one direction first. Experience, both with motorcycles and with other forms of transport, has shown quite clearly that if you make a machine to do one thing superlatively well it can subsequently be adapted to perform related, but different, functions equally well. But if you endeavour to make a model which can do everything, it usually ends up by not being able to do anything; consequently, it gains no real friends and will have but a short commercial span of life, though its loss of esteem may remain and give rise to considerable sales resistance to subsequent products of the same marque for many years.

Weight is another matter which calls for great consideration. From the point of view of ease of handling, the lighter the machine the better. But lightness must on no account be gained at the price of flimsiness, especially with regard to the running gear, or to parts which might readily fail under the battering administered by, for example, Belgian pavé or the corrugations traversed for mile after unending mile on dirt or gravel roads in Australia, South Africa and similar territories where smooth tarmac is by no means the rule.

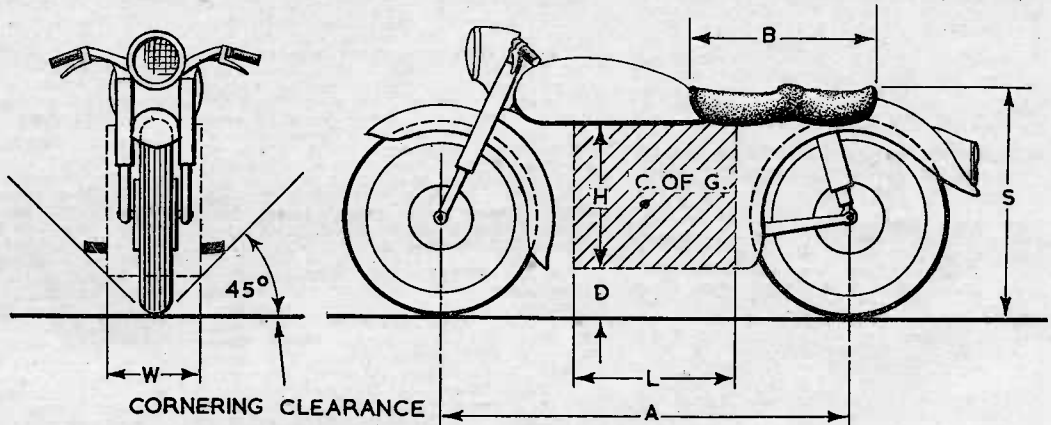
Weight, like appearance, can also be a matter of fashion. In the U.S.A., for instance, some of the population were so conditioned by high-power advertising into the belief that mere size was a measure of desirability and excellence that

or extra care in engine assembly, sell at something in the region of 15s. 1d. With these figures in mind, and knowing the ceiling price which the sales department have set on a new model, the designer can determine the maximum permissible weight within a few lb. either way.

That there is any close relation at all between cost and weight comes as a surprise to many people—in fact, it is sometimes hotly disputed. At first sight it may seem that an assembly made up of a large number of small parts, bolted or fixed together by any other means, will be more costly than a single casting or forging—but it does not work out that way. Roughly speaking, small parts are made quickly in large numbers on inexpensive automatic machinery, while big parts are more cumbersome to handle and are machined either one at a time by hand or automatically on large and very expensive machine tools. Then, again, aluminium is lighter than steel, but its much higher price just about evens the score.

What the total weight proves to be is less important, so far as handling is concerned, than its distribution. By "distribution" is meant the proportion which is carried by each wheel; assuming that the frame will be rear-sprung, reasonable handling should be attained with 50% of the weight on each tyre. This is, of necessity, only a first approximation, and work with the experimental models will undoubtedly have to be carried out to settle the best proportion, which in any case is dependent to some extent on the suspension characteristics at front and rear. Test reports upon handling can vary with personal tastes;

Designer's strait-jacket: the limiting dimensions within which the motorcycle must be built. They are the wheelbase A; ground clearance D; seat height S and length B; height H, width W and length L of the "engine room"; and the minimum permissible cornering clearance. Also indicated is the position of the centre of gravity.



the two best-selling home-grown makes became heavier and heavier until some models scaled over 550 lb.—and even then they were on occasion so bedecked with extra lights, flags, false radio aerials and such-like bric-a-brac that the total must have come to 600 lb. or more. Development along these lines must, of course, either reach its own limit or be halted by some other circumstance—which, in this particular instance, was the realization that the much lighter imported motorcycles gave as good, or even better, performance with less likelihood of crushing the rider to pulp in the event of a fall. Today 450 lb. is about the upper limit of weight which any market will accept, but lighter models are coming into more general favour.

A point not generally appreciated is that there is quite a close relationship between weight and cost. Given ordinary commercial materials, a motorcycle costs so much per lb. to manufacture—in other words, a model which weighs 300 lb. will cost half as much again as one which weighs 200 lb., within limits of $\pm 10\%$ to allow for differences between factory techniques and accounting systems. At the time of writing, the average list price per lb. of "the bread-and-butter" type of machine in this country is about 12s. 10d., while the more luxurious models, with costs which include additional equipment and, in some cases, special work entailed in polishing

for that reason, it is always wise to obtain a variety of opinions.

Consideration must also be given to the state in which the model is most likely to be used. A "straight" solo racer never has more than one rider on board and can be tailored accordingly, whereas a 500 or 650 c.c. road-going mount may do most of its work with a crew of two and is frequently burdened with luggage as well. In this condition it should be as safe as—or, better still, even safer than—with only one up, and though this ideal is difficult to attain in practice it should be aimed at in theory. Anything above the lightweight class is also likely to have a sidecar attached to it; this places additional and quite different stresses on the frame and forks and is another matter which must be borne in mind when designing for strength in relation to weight and rigidity.

All the foregoing remarks are by way of being a general introduction to the subject—a broad outline of the limits within which the designer must work. Only a passing reference has been made to the power-unit which, though usually given pride of place, is in a sense a secondary consideration at this stage, except insofar as it is the heaviest single component and may or may not act as a frame member. It will, however, come in for its fair share of attention later in this series, which will eventually deal with every portion of the machine. The subject to be discussed, next week, in detail will be steering.