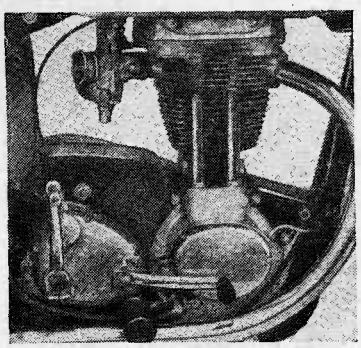
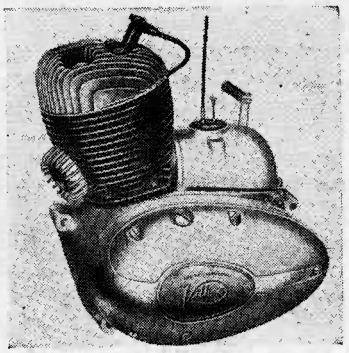
MOTORCYCLE ENGINEERING—17



Separate or Unit?



Problems to be considered in determining engine-gearbox relationship

by PHIL IRVING

WHEN motorcyclists ceased to consider that the simplicity of the single-geared machine made up for its deficiencies and demanded a multi-speed transmission complete with clutch, various attempts were made, with some degree of success, to use three-speed rear hubs or two-speed engine-shaft gears which could be added to existing models. With these devices, however, limitations on the permissible size hampered design. The obvious move was, therefore, to attach a separate gearbox to the frame in the space between the engine and rear wheel which the now unwanted pedal mechanism used to occupy, and drive it by chain from the crankshaft.

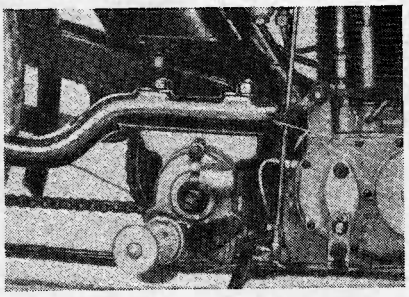
Generally, though not universally, the final drive was on the same side. This circumstance relieves the gearbox mainshaft of some of the transmission stress and reduces the tendency for the box to twist about a vertical axis, which is very great when the drive is crossed over (i.e., with the primary drive on one side and the final drive on the other).

The early boxes were mounted on a simple bracket, with provision for adjustment by bolts in slotted holes, but this system was replaced by pivot mounting, in which there is a wide, substantial pivot-lug below (or above) the box and a slotted lug clamped to engine-plates or a frame lug above (or below). The pivot layout provides a much firmer anchorage with a reduction in value of the local stresses developed at the attachment points, and is universally used today by makers who retain the separate engine and gearbox system.

That so many do choose to retain the "separate" system is not due merely to conservatism. One very cogent point in its favour is that an extensive range of models can be produced by using a single basic frame and ringing the changes on a number of different engines and gearboxes. Should one model prove to be in heavy demand whilst some of the others sell slowly, it is easy to concentrate production on the popular choice without becoming seriously overstocked with redundant components. New-season variations—such as the introduction of a twin-cylinder engine into a range of singles—can also be made without too great an outlay on new tooling.

From the user's point of view, and especially that of the competition rider who does his own maintenance, removal of the motor for overhaul is relatively quick, and a "blow up" in either this component or the gearbox does not affect the other. The separate gearbox can be provided with a large range of adjustment permitting a selection of engine-sprockets to be used for altering the gear ratios without resort to an undesirable cranked link in the chain.

Simple in principle as it is, the "separate" layout demands care in detail design. For one thing, it is essential that the sprockets are maintained in alignment at all times. In the past this point has sometimes been given scant attention, engine-plates and lugs being inadequate in size, whilst in endeavouring to utilize proprietary engines and gearboxes which did not match well in the first place, some makers sank to the level of mounting the engine sprocket with far too much overhang from the nearest bearing. However, such engineering misdemeanours, which lead to a reduction of transmission efficiency and greater bending loads in the frame and engine mountings, are fortunately not seen today.



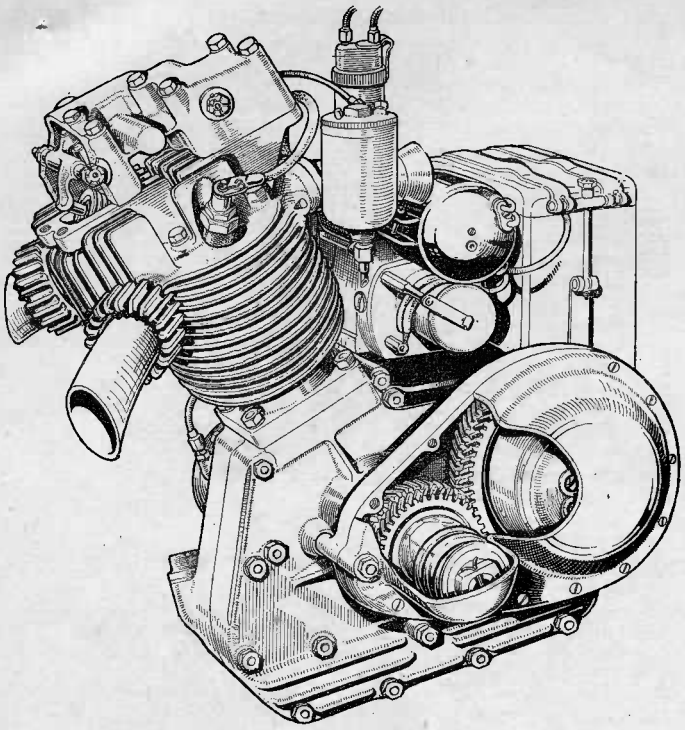
Typical of its period was this slot-mounted gearbox on the chain-stays of a 1922 A.J.S. Heading pictures are of a 1960 Matchless G3, with pivoted gearbox, and a Villiers unit.

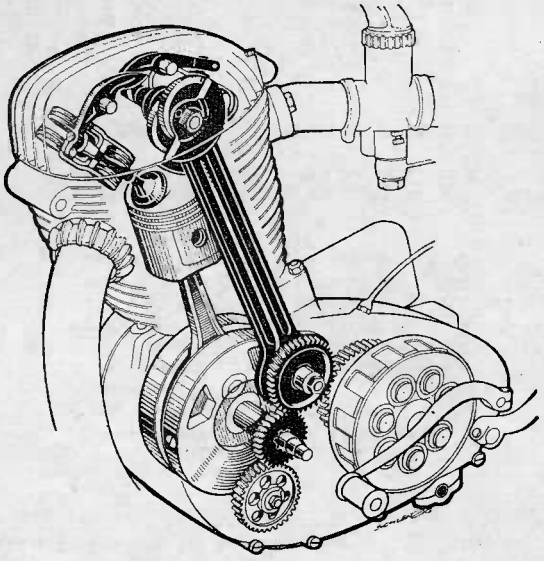
Sprocket overhang is particularly damaging if a duplex or triplex chain is employed, because when deflection occurs the load is thrown on to one set of rollers instead of being distributed equally. Breakage of the links on the over-loaded side then becomes almost a certainty, although it may be some time before the chain parts completely.

With the wide rear chain line required to give adequate clearance beside the large-section tyres used nowadays, the primary chain, if on the same side as the final drive, is bound to lie several inches from the centre-line. This is especially true when a cast-aluminium chaincase is fitted, since space must be provided between the two chains to accommodate the thickness of the rear wall.

To reduce sprocket overhang, it is usual with single-cylinder engines to provide either one very wide bearing or a pair of bearings on the drive side. In the latter case, it is advisable to make the inner race a roller bearing, as it is subjected to very heavy loads, whereas a ball bearing of approximately the same diameter and width can be used for the outer race, which can also serve to locate the flywheel assembly laterally.

An exception to this practice is to be seen on the single-cylinder Velocettes, which are unusual in having the primary chain located on the *inside* of the rear chain, with





Unit construction with gear primary drive—ancient and modern. The engine of the 1938 New Imperial (left), driving through two double-helical gear wheels, had to run "backwards." In the NSU "Max" series, "forward" engine rotation is secured by the interpolation of a third pinion, which drives the eccentrically operated valve gear.

the engine-sprocket placed as closely as possible to the single drive-side bearing—a design feature which the late Joe Craig averred he would have been glad to adopt, had the design of his gearbox permitted.

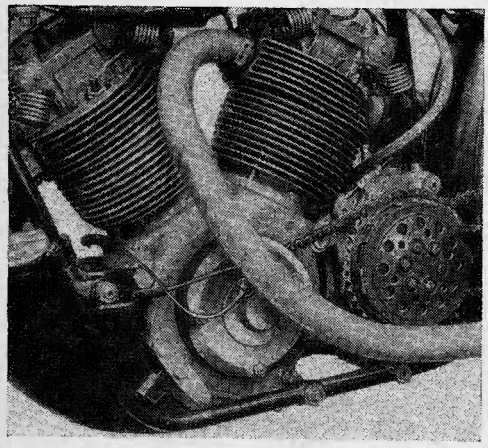
The system demands some ingenuity in the design of the clutch because of the relatively restricted space in which it must be fitted. It employs a rather complex lifting mechanism which is often misunderstood by people who endeavour to adjust it without first ascertaining the correct method and then blame the design instead of themselves—a fate which many another unconventional, though well-thought-out, feature has met. On the other hand the Velocette system, in addition to its mechanical soundness, has the merit of permitting alterations of gear-ratio to be made in a matter of minutes merely by changing the accessible final-drive sprocket and readjusting one chain. No other layout can equal it in this respect.

With the additional width occasioned by the extra cylinder, the crankshaft main bearings of a parallel twin are so wide apart that there is no need to use two on the sprocket side to reduce overhang.

Whatever the general design of the engine, fitting an "outrigger" bearing in a housing surrounding the sprocket would, of course, give support on both sides of the sprocket and deflection would be ruled out completely. This device has been used on some racing engines, notably the T.T. J.A.P.s in 1934 and the V-four A.J.S., in which the bearing housing also contained the coolant-pump impeller; but the idea, though excellent in itself, has never been greatly favoured, possibly because of the manufacturing difficulties involved in attaining perfect alignment of the multiplicity of bearings involved.

Taken by and large, the "separate" system has many features in its favour and is still in wide use, especially for four-stroke engines. However, with the general adoption of frames with either duplex down-tubes or a single vertical tube behind the box, the usual method today is to interconnect the crankcase and gearbox shells with engine plates and bolts in such a way that they can be built up as a sub-assembly, complete with chaincase and electrical accessories, on the bench and then placed in the frame as if they were a unit. In some cases, the entire sequence has to be reversed in order to get either the engine or the gearbox out—in other words, neither can be detached without first removing the whole sub-assembly from the frame.

Mainshaft deflection was eliminated by fitting an "outrigger" bearing on the 1936 Senior T.T. New Imperial.



From the engineering point of view, and discounting any advantage which the "separate" system possesses in the way of expediency in manufacture or accessibility in service, it is preferable to eliminate all stress-carrying joints between the engine and gearbox and design the crankcase and gearbox shell as a unit, split at right-angles to the major stresses into the minimum number of parts necessary to permit the flywheel assembly and the gears to be installed.

This conception has the effect of making all primary transmission stresses internal to the unit which, being very stiff laterally owing to its inherent width, will deflect by only an infinitesimal amount even under shock loading such as occurs when a rapid change-down is made on the overrun. Also, as outlined in the section dealing with torque reactions, greater smoothness of running is almost certain to accrue and local loads present at the points of attachment to the frame are considerably reduced in intensity.

Since the centre distance between the engine-shaft and clutch-shaft is fixed and unalterable, it becomes possible to employ spur gearing for the primary drive—a method which has always had more appeal to Continental designers than to their opposite numbers in England who, as a rule, prefer to retain the roller chain for this duty.

But chain drive now poses a problem. As the gearbox cannot be moved, it becomes necessary either to get along with no adjustment at all, or to devise some other method, such as a flexible spring blade or a hardened slipper applied to the slack side of the chain. Either way, it is imperative to enclose the drive in an oil-bath case, which itself can be made to add considerably to the stiffness of the whole assembly.

When the chain-loading is light and the

sprockets can be arranged close together, as in small two-strokes with diminutive crankshafts and outside flywheels, a non-adjustable drive will run satisfactorily for a very long mileage if the chain is "pre-stretched" before fitting (i.e., is driven over slave sprockets for long enough to run-in the bearing surfaces of the pins and bushes of which it is composed). This system, which is very simple and light, has long been used on Villiers, B.S.A. and kindred units.

For duty of a more arduous nature, especially on four-strokes with internal flywheels whose size forces the sprocket centres to be wider than on a two-stroke, some form of tensioner is necessary. It must maintain its effectiveness when the direction of drive is reversed, which rules out the self-adjusting spring-loaded Weller type, since on the overrun this would simply go flat and let the upper run of the chain become slack, so that "snatch" in the transmission would be uncomfortably evident at low speeds.

Satisfactory tensioning can be provided by positively altering the curvature of a blade of hardened spring steel by means of an adjusting screw in compression or a tension rod. Undue wear, however, may occur unless the chain is of the right type. It should be duplex or triplex, of $\frac{3}{8}$-in. pitch, and with links which are straight-sided instead of "figure 8" shape, in order to obtain a large and therefore lightly loaded area of contact between chain and tensioner.

Blades which are given an increasing amount of curvature by endwise compression take up a roughly parabolic shape over which the chain runs very smoothly, but their life is not unlimited as the metal cannot be very thick. Consequently some designers prefer to employ a solid hardened steel slipper, suitably curved and moved about a fixed pivot by means of an adjusting screw. In either case the range of adjustment is necessarily so limited that it is difficult to accommodate sprockets of different sizes, therefore ratios can be changed only by alterations to the final drive.

The efficiency of a chain drive under these ideal conditions is very high—98% has been claimed—and, even with no particular accuracy in sprocket cutting, it is almost dead silent.

Gear drive is a little less efficient and the teeth must be generated with great accuracy if quiet running is to be obtained. Even with extreme care in cutting and hardening, noisy gears may occasionally be made; this is not a serious problem in racing machines but it is in touring models where a high-pitched whine can be very irritating.

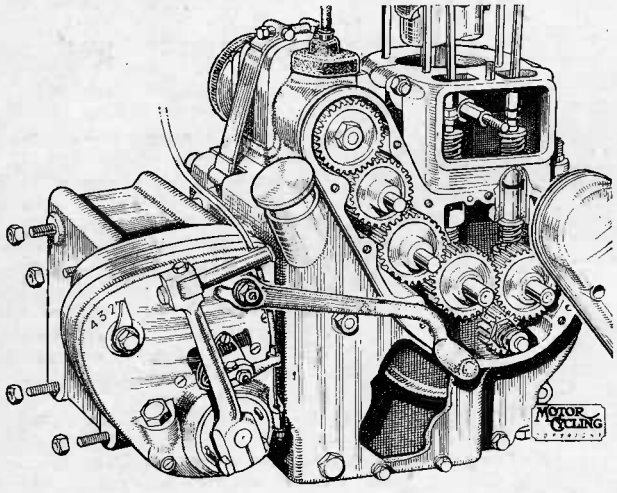
The fewer the number of wheels, the less the noise is likely to be. Units have been made with just a pair of gears, the engine in consequence running "backwards"—an arrangement which does not help autostability of the whole machine, because the gyroscopic precession generated when the model is put into a turn will act in the opposite direction to the rider's effort to apply bank. At least, that will occur when a gearbox with direct drive in top gear is employed; but if all the ratios in the box are indirect—as in the M.Z., for instance—a second reversal of rotation occurs and the engine rotates "forward," so that a single pair of primary gears is suitable.

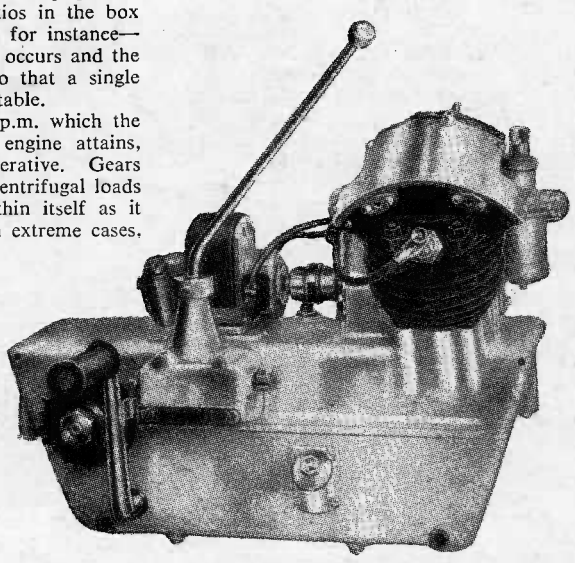
In fact at the 10-15,000 r.p.m. which the modern short-stroke racing engine attains, gear drive is becoming imperative. Gears are not subject to the high centrifugal loads which a chain generates within itself as it goes round the sprocket. In extreme cases, these loads eventually lead to the chain committing mechanical hara-kiri, although this state does not yet exist in touring engines.

Another disadvantage of a two-gear drive is bulk. Since the wheels must be large enough to inter-mesh, the overall length is greater than that of a chain and two sprockets giving the same reduction ratio. This may not be a serious matter; in any case, by using an idler gear in the middle the overall size of the drive (and especially of the clutch-gear) can be reduced, and the engine rotation becomes correct in conjunction with a conventional gearbox.

Since all the primary transmission loads are carried internally to the assembly, there is no longer any need to keep both drives on the same side. In fact it is more logical to use the "cross-over" system, thereby reducing clutch overhang to a minimum and eliminating one potential source of oil-leaks. This method is prone to curtail the amount of room available for the gears—for example, those in the Vincent V-twin, though designed to transmit 100 b.h.p., had to be fitted into a space only $4\frac{1}{2}$ in. wide. But this restriction may be a blessing in disguise because it ensures that the mainshaft and layshaft are short and stiff, a condition which is essential in the interests of silence and efficiency.

The cross-over drive also introduces some complication into the layout of the foot-change mechanism. A designer may consider that on this account, and also to utilize as many existing parts as possible, it is better to retain both drives on the same side and leave the arrangement of the final drive, rear wheel and brake mechanism as before.





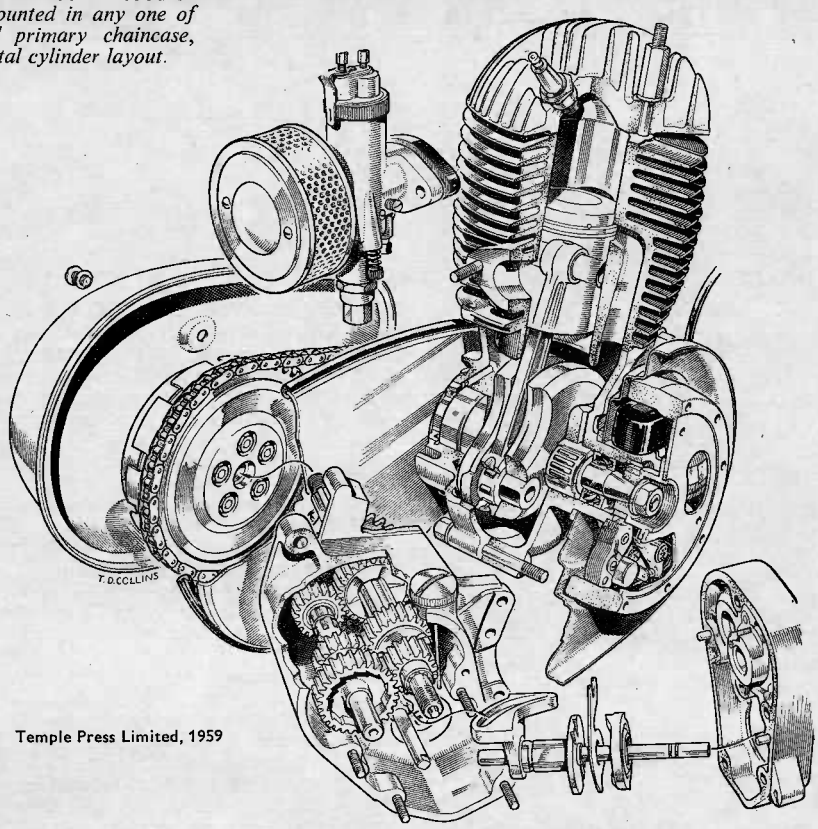
An early example of "horizontally split" unit construction was the 250 c.c. P. & M. "Panthette" (above). Typical of English "semi-unit" construction is the Royal Enfield "Bullet" (left), in which the flat front face of the bolted-on gearbox mates with a similar surface on the rear of the crankcase.

One method of laying-out a unit is to split the main casting vertically so that the flywheel can be assembled in the usual way and the gears inserted through an opening in one wall, which is subsequently closed by an end-plate. Relatively simple, smoothly contoured castings can then be used to enclose the primary drive and the timing gear, the finished product having a clean appearance in keeping with modern styling trends.

An interesting variation of this idea is to be found in the Triumph "Tiger Cub," in which the vertical joint is moved off the centre-line so that the cylinder rests on an unbroken face and the gearbox section has no split. The crankcase is closed by a component which is, in effect, a large cover plate housing the main bearing and extended back to enclose the clutch, which is on the same side as the final drive.

The drive-side cover houses the A.C. generator stator and the timing-gear cover

Ingenious variation on the "semi-unit" theme is the 150 c.c. A.M.C. two-stroke, the crankcase of which may be mounted in any one of three positions relative to the gearbox and primary chaincase, corresponding to upright, inclined or horizontal cylinder layout.



is extended backwards to enclose the change mechanism. The whole arrangement provides a neat, light and rigid construction with the additional advantage that the engine can be dismantled without disturbing the gears—which is not usually the case with unit construction and can be cited as an objection, especially for competition work.

The A.J.S. " Porcupine " provided another example of a main casting with no vertical split, but whereas the Triumph design lends itself to die-casting the " Porcupine " crankcase could only be made with the help of sand cores, a matter of little moment for racing machines but quite unacceptable for production models.

Continental designers, who are consistently in favour of unit construction, have translated the idea into reality in a variety of ways. The 250 c.c. Guzzi racer, for example, used an outside flywheel which reduced the block bulk of the main casting, and a little further economy of space and weight was effected by eliminating the wall between the crankcase and the gearbox, the wheels being lubricated by oil thrown from the big-end.

This arrangement has been criticized on the grounds that the engine is likely to be damaged by particles of steel thrown off the gear teeth and dogs, but the results in practice seem to indicate that this objection is not so serious as it might appear. Certainly, precautions against such damage can be taken by fitting a magnetic drain-plug and an efficient oil filter.

With a transverse four-cylinder engine, excessive width would be created if the drive were taken off one end of the shaft. On the Rondine, the ancestor of both the Gilera and M.V. racers, this situation was avoided by taking the drive from the centre of the shaft and transmitting it by gears in a central casting to the box, a secondary train being provided to actuate the twin overhead camshafts.

Engineering-wise, it is difficult to find any fault with this arrangement; all the loads are internal, the gears are supported on both sides and cannot be deflected out of line, and the possibility of destructive torsional oscillation in the crankshaft is reduced almost to vanishing point. From the rider's viewpoint, the widest part of the unit is well forward of his feet and, despite this width, the cornering angle is good because the depth of the crankcase below the centre-line is relatively slight.

It is not surprising, therefore, that the central drive idea has been applied to other engines, including the four-cylinder Honda, the twin 125 c.c. Ducati and the 250 c.c. MZ twin two-stroke. The layout adopted both for the Ducati and the MZ consists, in effect, of two single-cylinder engines bolted to the centre section; each has its own crankshaft assembly splined to the primary drive gear.

There would appear to be quite attractive possibilities in combining this layout with A. A. Scott's ingenious idea of a central drive taken from a built-up crankshaft with two overhung crankpins. With only two main bearings, there would be no difficulty in obtaining accurate alignment and the whole assembly could be as rigid as, or even more rigid than, a conventional built-up crank assembly.

There has been a tendency in recent years for English designers to adopt what might be termed " semi-unit " construction. In this system, a flat face is machined on the back of an otherwise conventional crankcase and bolted thereto is a gearbox which has a mating surface machined on its front face. The rear half of the chaincase may be cast integrally with the drive-side half of the crankcase, as in the B.S.A. twins, or it may be a separate bolted-on component (Royal Enfield).

In this construction, there are no shear loads applied to the joint, and the assembly is very rigid. From the production and spare-part viewpoint, all the gearbox internals can be identical with those of some existing " separate " gearbox. During a major overhaul, the box can be detached in its entirety and remain undisturbed while work proceeds on the engine, thus reducing the time required for the job.

Although at first sight it does not appear to do so, the 125 c.c. MZ utilizes this built-up principle, but in conjunction with an all-indirect gearbox and cross-over drive, which results in a neater and stiffer unit than would be obtained with both drives on one side.

With shaft drive—or for that matter, with chain drive in conjunction with a fore-and-aft crankshaft and integral bevel reduction gears—unit construction is a natural choice, but again there are alternative forms. The joints required to permit assembly may be all in vertical planes, as exemplified by the B.M.W. and Douglas (ante-dated by many years by the A.B.C.), but it is also possible to split a combined crankcase-and-gearbox casting horizontally, as in the American Henderson in-line four and the transverse-Vee-twin P. and M. " Panthette."

It will be seen that there are so many ways in which the engine and gearbox can be coupled together that making a positive choice is not an easy matter—unless there is some overriding circumstance which dictates the selection, such as the employment of a proprietary engine which cannot be made in unit with the gearbox. On the score of absolute merit, no one system can claim to be outstandingly superior, given the same standard of design in every case, because examples of each have at times shown themselves to be equal to, or better than, their rivals.

Generally, however, for machines produced in quantity but with an eye to future development at a moderate outlay on additional tooling, it is probable that the semi-unit, or built-up, system scores most heavily on all-round value. Given cunning design, this can provide an excellent combination of ease of manufacture, light weight, rapid assembly, the good mechanical life conferred by inherent rigidity and full enclosure of the working parts, and a reasonable degree of simplicity in carrying out routine overhauls.

NEXT WEEK—the choice of engine type. Two-stroke or four-stroke? How many c.c.s? How many cylinders?

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