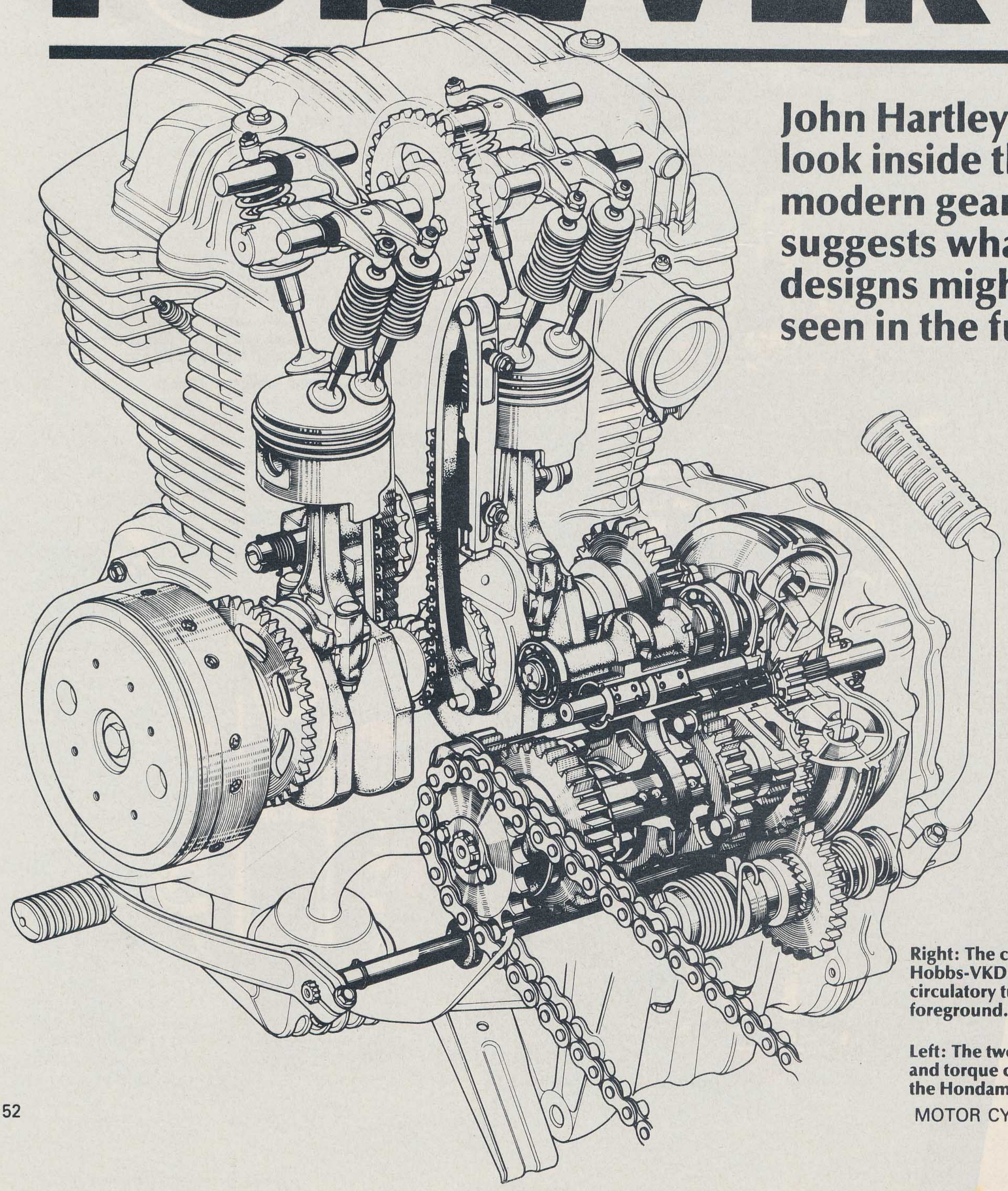
GEARS FOR EVER?



John Hartley takes a look inside the modern gearbox and suggests what new designs might be seen in the future

Right: The components of the Hobbs-VKD transmission. The circulatory turbine is left foreground.

Left: The two-speed gearbox and torque converter fitted to the Hondamatic 400.

DESPITE some moves being made on the automatic front, gearbox design looks pretty static just now — so does this mean we have now reached the ultimate in design, or that we are about to see some big changes? If you've missed a gear recently, you certainly won't accept that things can't be improved, but apart from the need for some detail changes, the new automatics are the only area where there seems to be much development going on.

To most motorcyclists, the very idea of an automatic gearbox represents almost the ultimate in degradation, but as more bikes are used for commuting, so the use of automatics is bound to increase. You've only got to ride across London in the rush hour for your left wrist muscles to tell you that constantly pulling in the clutch is not what they are meant for! So, even if you don't want an automatic, the chances are that you would like to see slicker shifting — some manufacturers are better in this than others — and less clutch effort.

Over the past twenty years or so the motor cycle transmission has settled down into a standard of gear primary drive, multi-disc clutch and all-indirect gearbox. Some engines have inverted tooth primary drives, and on the CZ and MZ, the clutch is mounted on the end of the crankshaft instead of being on the input shaft to the gearbox. And, of course, left-foot gearshifting is now virtually standard on road machines thanks — or really no thanks — to the American legislators.

Many of the earlier machines had what is called a three-shaft gearbox, in which the drive is taken through an input shaft down by gear to a layshaft, and then back up to the mainshaft or output shaft, which is in-line with the input shaft. In top gear, the input shaft is locked directly to the output shaft, giving a 'direct drive'. In theory, this direct drive is a bit more efficient than the current system in which there is a gear drive in top, but this does not really make any practical difference. In motor cycle transmissions, it was not uncommon for the input shaft to be fitted inside the hollow output shaft, so that the drive sprocket for the rear chain could be tucked in beside the clutch. With this layout, the clutch is fitted on the end of a slim shaft which is housed within the hollow output shaft, there being an input gear at the far end of the shaft. The drive is taken down to the layshaft, and back up to the hollow output shaft. Alternatively, the input and output shafts can be on opposite sides of the gearbox. Although that arrangement works well enough, it involves the use of some extra bearings, and it is less simple than the all-indirect gearbox.

So, if we look at a modern transmission, then, we start with a gear or inverted tooth chain primary drive from the crankshaft to the clutch, which is on the end of the input shaft. The output shaft is normally directly behind the input shaft, with the drive sprocket being on the opposite side of the casing from the clutch. In the gearbox itself, you have only two shafts and four bearings.

To keep the overall diameter as small as possible, multi-plate clutches which run in oil are used, although dry clutches, which can tolerate much higher temperatures, are used on racing bikes. From the sprocket or gear, the drive is usually taken through a damper to the clutch drum. The damper, which usually consists of rubber blocks or steel springs, absorbs any shock loadings, giving a smoother drive.

There are a number of slots in the clutch drum, while the sleeve inside it is splined. The drive plates have lugs that mate in the slots in the drum, and the driven plates have splines to register in those on the hub. Therefore, if all the plates are squeezed together by some springs, you get a solid drive from the drum to the sleeve — and that is what happens when the clutch is driving normally. In fact, the open end of the drum is closed by the pressure plate, and there are usually five or six springs on long bosses in the hub which press the pressure plate against the pack of drive and driven plates — one set of these is faced with a friction material, of course. Every time the clutch is slipped — and it slips for a fraction of a second every time a shift is made — the friction linings wear, and so gradually, the pressure plate moves in towards the drum. Normally, the clutch is released by a pushrod which comes across from the other side of the casing inside the hollow input shaft. Therefore, as the friction facings wear, so the pushrod is pushed back slightly, so from time to time it is necessary to adjust the clutch cable to maintain a little clearance in the system. If there is insufficient clearance, the pushrod may hold the pressure plate slightly off the pack of plates and the clutch will slip. Alternatively, if there is too much clearance, the pushrod may not be able to move the pressure plate far enough to take the load completely off the friction plates, so the clutch will 'drag' — it won't clear fully.

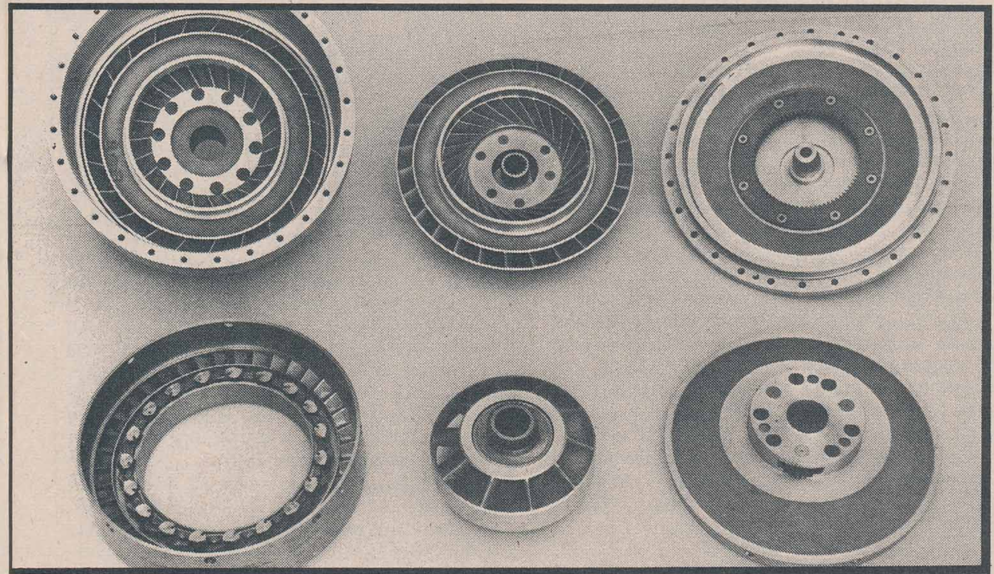
But what are the pros and cons of mounting the clutch on the end of the crankshaft or on the gearbox input shaft? Well, it is torque that makes the clutch slip, and if the clutch is on the crankshaft, it has to transmit engine torque only. On the other hand, if it is on the gearbox, it has to take engine torque multiplied by the primary reduction ratio, which is usually in the region of 2-3:1. That means that if the clutch is on the crankshaft, it takes only one-third to one-half the torque that it must take if it is on the input shaft to the gearbox — so it can be smaller and lighter.

However, the engine-speed clutch is at a disadvantage when you change gear. In a motorcycle gearbox, you change gear by moving sleeves along the shaft to lock the gears to the shaft. Although you blip the throttle when you change down, and close the throttle as you change up, you rarely get the speeds right — well not exactly. So, when the dog teeth come up to the holes or teeth in the gear, the effort the rider applies to the pedal forces the teeth into mesh.

In a typical case, the input shaft may be revolving at 6,000 rpm, and the output shaft at 4,000 rpm, but during the shift, the input shaft has to be slowed down to 4,800 rpm. As the rider closes the throttle, he allows the shaft to slow down — but there is a resistance to slowing down, and that is inertia.

Now whenever any shaft or wheel is rotating, it has some inertia, and that is the force that keeps it rotating. You can easily see this by spinning a wheel on your bike while it is on its stand. Then, try to stop the wheel spinning with your hand. Spin it faster, and you need to apply more effort. But, if the wheel is heavier, you also need to apply more effort still, and the worst situation of all is where all the weight is concentrated at the rim — a drum or flywheel. Since the gears in a motorcycle gearbox are small and light, they can be slowed down or speeded up quite easily, but unfortunately there are other things involved as well.

And that brings us back to the clutch. When it is released, the hub driven plates and whatever is between the hub and the gearbox input shaft must be speeded up or slowed down as well. And here's the crunch: if the clutch is mounted on the input shaft, then only the clutch hub remains connected to the shaft. On the other hand, if the clutch is mounted on the crankshaft, the primary drive is also connected to the input shaft and must be slowed down or speeded up. Whether the primary drive is a chain or gears, it has quite a lot of inertia, and so gearshifts are likely to be a bit more clunky. In addition, since the engine-speed clutch is turning faster than the gearbox mounted clutch, it has more inertia to be overcome in any given shift. It is for this reason that the gearshift on the BMW is not quite as slick as on most transverse engined bikes — there's no prim-



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ary drive to cause trouble, but there is the extra inertia of the fast-spinning clutch.

When it comes to clutch operation, there is the oddball arrangement on the CZs — in addition to the normal lever and cable control, there is an automatic control actuated by the gearshift lever. There is an extra lever projecting inside the casing from the gearshift lever, and this actuates a mechanism to free the clutch when the pedal is moved, the return action of the pedal engaging the clutch again. In theory, this is an excellent idea, but in practice it seems to give riders some difficulty, especially if they ride a CZ for a brief spell only. The automatic clutch operation is only available when the bike is on the move, and of course, in city traffic, it is the constant shifting from first to neutral, or slipping the clutch to ease through the traffic, that causes fatigue.

Inside a typical modern gearbox, there are input and output shafts, the clutch being mounted on the end of the input shaft, and the drive sprocket being on the output shaft, but on the opposite side of the gearbox. Normally, the shafts are carried on ball bearings — or each on one ball and one roller bearing — and the gears are in constant mesh. Therefore, in each pair of gears, only one gear is splined to its shaft, the other being free to rotate on a bush or directly on the shaft. To engage a gear, therefore, the 'free' gear must be locked to its shaft, and this is done by a combination of dog teeth and sliding sleeves. There are dog teeth on the sides of the gear, and also on a sleeve that is splined to the shaft, and which is actuated by the gear selection mechanism.

In practice, to save space, it is quite common to use a gear as the sliding sleeve, but although the gear slides on the shaft, it remains partially in mesh with its own mating gear all the time. For example, in a typical layout, the gear sets, from left to right are: second, fifth, third, fourth and first, so that first and second gears, which transmit most torque are nearest the bearings. On the input shaft, first and second gears are fixed to the shaft, fourth and fifth are on bushes, and third, which incorporates two sets of dog teeth, is splined to the shaft. On the output shaft, first, second and third are the floaters, while fourth and fifth, which have dog teeth, are splined to the shaft. So, the fourth driven gear slides along its shaft to engage the dogs when first is selected; it comes back to its normal position for neutral; then the fifth speed driven gear is moved to engage second gear; for third, the fifth speed driven gear slides back again, and the fourth driven gear slides to mesh dog teeth with the third gear, locking it to the shaft. As the next shift is made, the fourth slides back again, and the third drive gears slides to the right. To engage fifth, the third gear moves back through its normal position across to the left, locking the fifth speed drive gear to the shaft.

That's all very well, but we need some sort of mechanism to transmit the motion of the gearshift pedal to those gear/sleeves. At the gear end, there are grooves in each of the sleeves that slide, and a selector fork lies in this groove. To shift gear, the selector fork must be moved sideways, taking the sleeve with it, and in some cases, two sleeves have to be moved to make a shift.

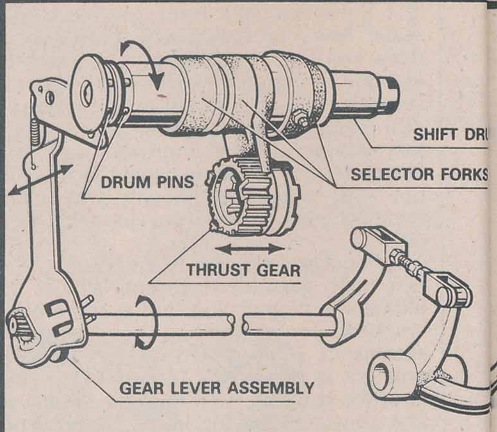
The selector forks themselves are carried on a shaft on which they can slide. Each selector has a projecting lug which engages in a slot in the gear selector drum — now the standard method of selecting the gears. The gear shift pedal normally has some form of ratchet and pawl mechanism so that it can rotate the drum the desired amount, and then returns itself to its original position, leaving the drum in its new position. Machined in the drum are a number of grooves, one for each selector, and the lug on the selector fork fits in this groove. Thus, when the drum is rotated, the sides of the groove push the selector fork across to engage/disengage a gear.

So what makes a good shift, and why are some boxes much slicker than others? Well, to start with, the inertia of the masses between the clutch and the gears being selected needs to be as little as possible — and for this reason, fourth and fifth, which have less inertia than the lower gears are usually the easiest to engage. The second important point is the design of the dog teeth. If the teeth are a very close fit in the grooves, then they will have to line up precisely before they can be engaged, so there is usually some clearance, at least in the leading portion of the teeth, which are often chamfered as well. But this is one area where tiny details can make quite a difference.

The other problem is that there is a clearance between the lugs and the grooves in the drums, and another clearance between the selector forks and the grooves in the sleeves. In due course, the lugs and forks wear, and there may be difficulty in getting full engagement, with the result that the bike may jump out of gear occasionally. Then, if two selector forks are being moved, the excessive wear can lead to the second fork moving before the first has fully disengaged. But in practice, most missed gearshifts result from the teeth butting up against one another instead of sliding into mesh smoothly — and the elimination of that problem is a matter of detailed design.

But if we want to improve gearboxes in other ways, what should we do? First, lighter clutch action is desirable, especially on the bigger machines. One idea that might have helped here had it ever gone into production was the clutch drum with angled slots. This was one of the ideas dreamed up by Doug Hele and his men at Triumph, and the slots in the clutch drum were inclined at 15 degrees, so that as the drum drove the discs, it tended to force them further into engagement. The greater the angle, of course, the greater this 'servo' effect. With the 15 degree angle it was possible to use springs from the 500 on the 750 cc engine, which made quite a difference to the effort. As soon as the throttle was closed, the servo effect ceased, and it was an easy matter to free the clutch.

There are other possibilities: for example, most cars now have diaphragm spring clutches, in which a spring looking like a dished washer replaces the coil springs. These also reduce effort, because once the spring has been depressed for about half its travel, it goes 'over-centre' and then releases itself. It is also possible to free the clutch plates partially by hydraulic pressure from the engine lubrication system — power-assisted withdrawal.

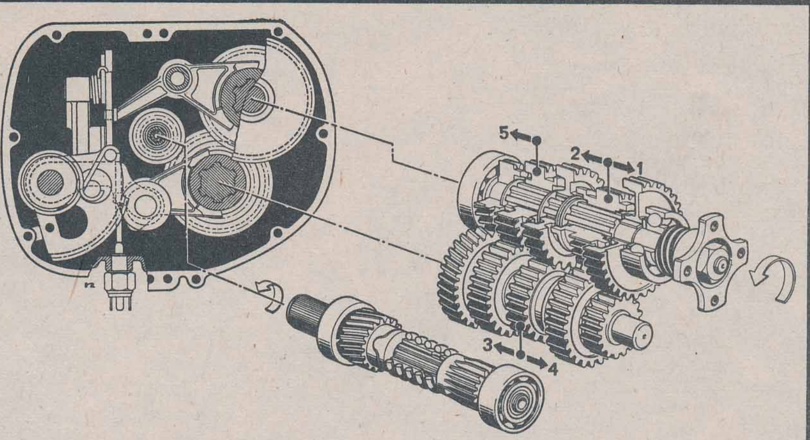


Selector mechanism on the Kawasaki 250/400 triples. There are also two selector forks whose pins locate in grooves in the drum.

Since most of the fatigue from clutch operation results from use in heavy traffic, a transmission that took up the drive from rest automatically, like many mopeds, might be the answer. The solution here, in theory, is the centrifugal clutch, in which a number of bobweights operate the release mechanism. As engine speed increases, the bobweights are thrown outwards, and through a system of levers, they engage the clutch when a certain speed is reached. These clutches are not the most reliable devices when they are handling a lot of power, and they have the disadvantage that they normally always engage at the same speed, giving a sluggish start from rest. The addition of a conventional clutch control, which overrides the normal centrifugal effect, and which is needed anyway for shifting at speed — when the centrifugal clutch remains firmly locked up — overcomes this problem.

With the normal progression we get in development, though, some form of automatic transimission was inevitable, although those available at the moment don't really compete with conventional transmissions, they are offering something quite different. First, there is the Husqvarna automatic for moto cross racing. Now this is a four-speed gearbox with a clutch for each ratio, and this is engaged by centrifugal force at a certain speed. Each gear also has a freewheel, so that once the higher gear is engaged, it just freewheels along. This is a neat and simple design, with no more power losses than a normal gearbox, but the gearshift always takes place at the same speed, and it is likely to be fairly jerky. In other words, it may be fine for moto cross or eduro work, but not for quiet running in traffic.

Currently, the alternative is the torque converter transmission of the Honda 750, and now the new 400, and the Moto-Guzzi V1000. In all these systems, a torque converter is combined with a two-speed gearbox,



The BMW five-speed gearbox showing input shaft, layshaft and output shaft. The input-shaft carries the input pinion at the front and the kick start pinion at the rear.

the method of shifting differing — on the Honda 750 gear shifting is effected hydraulically, while the Moto-Guzzi has a conventional clutch with lever operation and a rocking pedal.

So what is a torque converter, and what does it do? It consists of three basic components: an impeller, driven by the engine; a turbine, acted on by the fluid leaving the impeller so that it can transmit drive; and a stator or reaction wheel, which is stationary. The impeller and turbine are like large dishes, with a shaft in the middle, so that the assembly is like a large ring or circular section — or toroidal section, as it is called. The impeller forms one side of the ring, the turbine the other, with the stator surrounding the shaft in the middle.

The system is filled with fluid, and when the engine rotates the impeller, the centrifugal force throws the fluid outwards so that it passes through the turbine, then through the stator and back to the impeller. Now, there are a number of vanes or blades in each of these members, so as the fluid circulates, so it strikes the vanes, and imparts energy so that the turbine rotates.

When the fluid strikes the stator, its direction is turned around so that it imparts extra energy to the impeller. This extra energy is added to that provided by the engine. When the engine is idling, there is insufficient energy in the circulating fluid to have any effect on the turbine, but as the engine speed increases, so the energy increases, causing the turbine to rotate. When there is a big difference between impeller and turbine speed — say, with the engine at 6,000 rpm, and the transmission just moving — the stator has most effect on the fluid, giving maximum torque multiplication. As the turbine speed increases, so the multiplication effect gradually reduces, until both the impeller and turbine are rotating at the same speed when there is no torque multiplication.

So what does all this mean when you ride the bike? Well, to start with, you don't have to declutch to start off from rest. You just twist the grip, the torque converter takes up the drive, and off you go — the wider the throttle opening, the faster you take off. In any situation, the drive is taken up smoothly, without any jerking or juddering. Then, when you are cruising along, if you want to accelerate, you just twist the grip, and the engine speeds up, increasing the effective 'gearing', and you accelerate more quickly.

On the Honda and Moto-Guzzi, the torque converter is used with a two-speed gearbox, which in theory gives a similar ratio spread to a manual box, owing to the torque multiplication effect of the torque converter. On the Honda 750, the overall ratios are 8.63 and 5.79:1, compared with a spread of gears from 14:1 to 5.44:1 on the manual. The torque converter increases the effective ratio spread to about 17:1 to 5.79:1. The fact that the gearing of the automatic is numerically higher — 'lower gearing' — tells us that some power is absorbed in the transmission, and so the lower gearing is needed to give reasonable acceleration.

Of course, the manufacturers try to tell us otherwise, but the fact is that conventional torque converters absorb a lot of power as they churn the oil around — hence slightly worse performance and fuel consumption. In practice, they give a 'gear ratio' of 2-2.3:1, but when they are actually multiplying torque, they are least efficient — when you really need them! So, the existing torque converter is only really worthwhile when you have plenty of power and don't mind wasting fuel.

So are there any transmissions that give the advantages of automatics, without the power losses? Well, there are a few possibilities — the Hobbs-VKD converter, the Daf belt or chain drive, and the GKN chain drive. The Hobbs-VKD design is a lever modification of the torque converter with an extra 'circulatory turbine' which is gear driven. This extra turbine has the effect of increasing both the torque ratio and the efficiency of the unit, and in doing so, overcomes the main disadvantages of a conventional unit — its inefficiency, and its need for extra gears. So, the Hobbs-VKD torque converter replaces the complete transmission and has an overall torque or 'gear' ratio of about 4:1, equivalent to overall gearing of 21:1 to 5.44:1 if applied to that Honda 750. This means that the 'low' gear is lower than on the manual, giving really zippy acceleration, while 'top' could be higher, giving effortless cruising and good fuel consumption. What's more the unit is very responsive, so as soon as you twist the throttle open the engine speeds up, the torque converter multiplies torque like nobody's business, and off you shoot.

The Hobbs-VKD unit would fit neatly into any motor cycle — in-line or transverse engine — and within about two years, there should be a unit in production suitable for most big bikes. Oh, and if you think that such a transmission is for old men and grannies, you might be interested to know that Keith Duckworth of Cosworth Engineering is developing one of these Hobbs-VKD units for Formula 1 car racing.

In terms of reducing power losses, though, the variable pulley designs, such as the Daf Variomatic and Transmatic and the GKN CVT should be the ultimate. All these are based on the use of pulleys whose effective diameters can be altered to change the reduction ratio. The belt is similar to a V-belt in shape, but much wider and shallower. On the Variomatic, a rubber/fabric belt is used, while the others use steel belts.

There is a drive pulley, and a driven pulley, each formed in two halves, one of which can slide along a splined shaft. Air or hydraulic pressure is used to operate pistons that move the pulley halves in or out from the other halves of the pulleys, and as, say, the driven pulley half moves outwards, so the drive pulley half moves inwards.

To reduce speed, as in low gear, the drive pulley needs to have a small effective diameter, and the driven pulley a large one. Therefore, in low the drive pulley halves are far apart, and the driven halves are close together. Usually, a centrifugal clutch is used to take up the drive, and then the drive takes up, in the lowest 'gear'. Gradually, as the speed increases, so the pulley halves are moved to alter the gearing. If you keep the twist grip wound fully open all the time, the transmission won't get into top gear until you reach maximum speed! On the other hand, if you accelerate at half throttle, say, it will get there much quicker — in other words, so long as the control system is designed correctly, the unit responds precisely to your demand.

These transmissions can quite easily give you a ratio spread of about 4:1 — 21 to 5.4:1 — although it actually goes from a reduction ratio of about 3:1 to an overdrive of about 1.5:1. Although the controls are reasonably simple, they are inevitably more complex than those of the Hobbs-VKD. Because the pulleys are wide, the unit wouldn't be quite as simple to install either, but it should not present too many problems.

The Daf Variomatic, which has a rubber belt drive, has been in productionn for many years, of course, and is now used with engines of up to 1.4 litres, and is clearly quite acceptable for small motor cycles. For the larger bikes, one of the systems with a steel belt might be needed.

These three systems — Hobbs-VKD, Daf and GKN — are 'continuously variable' transmissions or CVTs, in which the ratio is changed automatically to suit the conditions whenever this is needed, and so they should not be confused in any way with the other units that are called automatics. For this reason, they could well replace ordinary gearboxes on many machines one day. After all, if you can change gear by twisting the twist grip, why bother with clutches and gear pedals? But it will probably be 1980-5 before many manufacturers have the courage to use them.