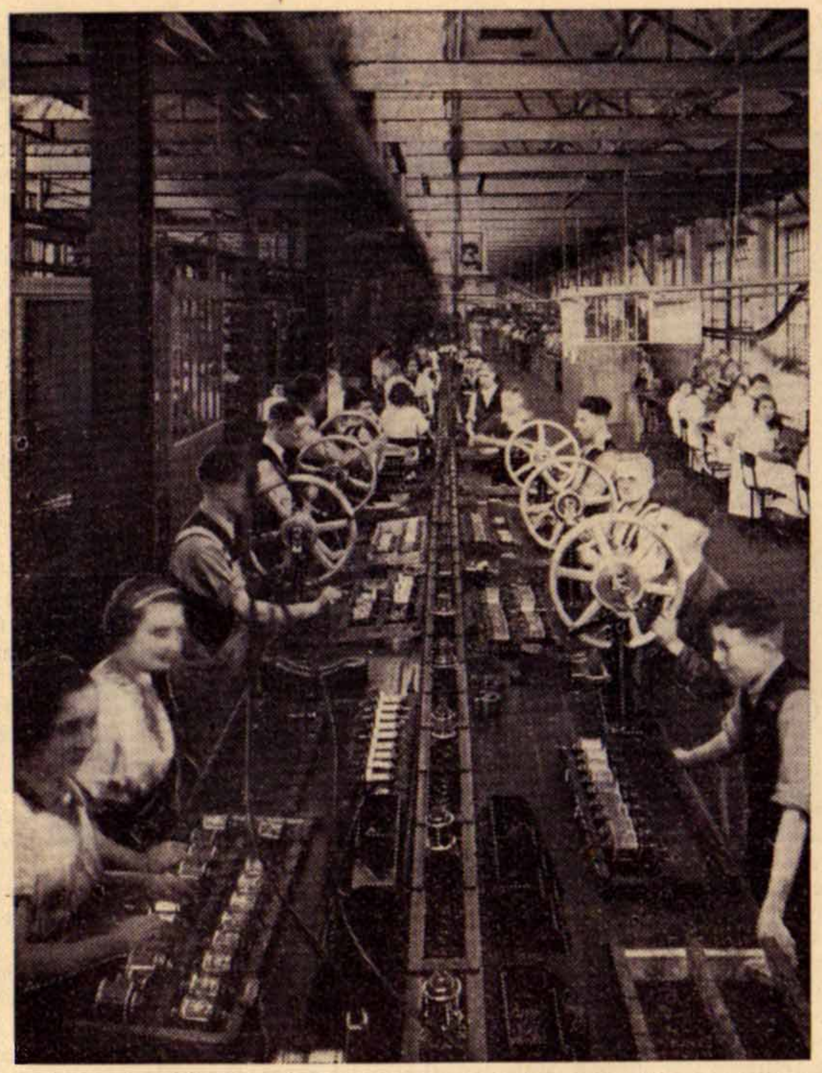
Technical Topics

HUB GEARS

How they are made and how they work

The greatly increased use of change-speed gears has been a feature of recent cycling development; here is an article which takes you right into the workshop and shows you manufacturing processes and constructional details of the famous Sturmey-Archer Hub



Sturmey-Archer Assembly showing 100 foot assembly conveyor handling the various components at one end, with finished hubs, viewed and tested, coming through at the other

"MR. FRANK BOWDEN'S flair for assessing the prospects of any new device soon interested him in the Sturmey and Archer variable gear patents of 1901, and in 1905, after exhaustive testing and the incorporation of further improvements, its manufacture and marketing were taken over by the Raleigh Company through its subsidiary, Sturmey-Archer Gears, Ltd."

That sentence occurs in a short description of the history of the Raleigh concern, published in a jubilee souvenir booklet issued this year to celebrate fifty years of Raleigh cycle building. The Mr. Frank Bowden was, of course, the late Sir Frank, father of the present chairman and managing director, Sir Harold Bowden, Bt., G.B.E.

It can therefore be fairly claimed that, of all the different types of variable gear for use in cycles today the Sturmey-Archer is by far the oldest. However, it is not the purpose of this description of S.-A. principle and manufacture to draw distinctions between these many different systems but to explain some of the many interesting processes which are involved in its making and how it works.

Ignorant of Technicalities

There must be millions of cyclists who use one form or other of the S.-A. gear but who have yet only a vague idea of what happens inside that compact hub-shell when the little control lever is moved from one position to another.

If the majority of riders are ignorant of the working principles, the number which has any conception of the ingenious manufacturing processes must be very small indeed. It is quite true that there are riders in this year of enlightenment who actually regard an S.-A. hub as a box of magic. There are coloured cyclists in various parts of the world who are quite convinced that little devils live in those chromium-plated shells!

Seriously, though, even to people with mechanical minds, there is something almost magical in the way in which the dozens of small but incredibly accurately made parts in an S.-A. hub come together from all parts of a huge factory and issue forth as a complete three-speed gear which, if it is only kept in proper adjustment and supplied with the correct quality of lubricant, will give everlasting service.

It can well be imagined that some of the machines which make the smaller parts for a hub gear must be capable of working to a degree of accuracy which would not be out of place in watch-making. Just glance, for example, at the delicate-looking yet extraordinarily strong piece of chain which protrudes from one end of the wheel spindle and which operates the gear-selecting mechanism. The pins of that chain are only 1-16 in. in diameter and yet it will withstand a tension of over 100 lb.

A Laborious Business

It would be a laborious business to attempt to describe in detail all the different machining processes. For instance, gear-cutters are gear-cutters "the same the whole world over," and those which turn out the small pinions and driving-wheels of the S.A. gear are, of course, extremely accurate in their work.

On the other hand, there are several processes which are quite unusual. For example, how would you think the hub-shell, which encloses all the mechanism, is made? To look at it most people would think it was a short length of tubing.

Actually, it starts life as a flat sheet of steel. This sheet-steel is cut into discs, and each disc is belled out in a huge hydraulic press until it becomes cup-shaped. Then the bottom of the cup is cut off, and you have the hub-shell in its basic form.

Further processes add the flanges, which are drilled with spoke-holes, screw-threads are cut in the ends to take the bearing-plates, then the whole is given a most thorough chromium plating, the oiler is added, and the shell is complete.

The actual Sturmey-Archer factory is filled with wonderfully up-to-date machinery, operated by work-people who combine almost uncanny skill with extraordinary speed.

Many of the machines are, of course, entirely automatic. For instance, there are big batches of gear-sharpers which turn out the little pinions from solid blanks by the thousand. One man may have charge of a dozen or so and, except for occasional adjustment, has but to see that they are fed with blanks and lubricant.

Then there are clever screw-cutting machines which eat up great lengths of steel rod, ejecting at their "business ends" completely finished screws, threaded, headed, and slotted.

Other machines are making pawls for the free-wheel part of the hub and broaches are cutting the teeth on the internal toothed rings which form an essential part of the gear change system on which the S.A. hub operates.

The cones, lock-nuts, spindles, and so forth are taking shape at the rate of millions a week, and all these pieces are steadily flowing through various sections where viewing and inspection take place, so that the possibility of a flaw is completely eliminated, until they reach what is perhaps the most interesting department of the works—the assembly shop.

The backbone of this long room is an endless conveyor, 100 ft. in length. On each side of it, at staggered intervals, sit the assemblers. The conveyor passes slowly between them, and its chain-drive is fitted, at 2 ft. intervals, with hardwood blocks drilled to carry the hub-spindle vertically. The whole process of assembly begins with these spindles.

Perpetual Tests

Although every component has previously been tested many times in the course of its construction, further tests take place during the actual process of mating all these parts together.

And now, how does it work? For descriptive purposes we will deal first with the well-known three-speed K type of Sturmey-Archer hub, which is in use on millions of machines all over the world. The principle of the two-speed hub is on exactly the same lines, except that, instead of providing high, low, and normal gears, it only gives a choice of normal and low. The very latest ultra close-ratio model we will leave until we have dealt with the standard pattern.

In the ordinary three-speed hub the drive on normal gear is direct, that is to say, nothing happens inside the hub, the gears being free, and the hub still revolving at the same speed as the sprocket as it is docked directly to it.

The basic gear for normal is chosen in the usual way by chain-wheel and sprocket sizes, and it is on this basic gear that the internal changes in ratio are made. The K type of Sturmey-Archer hub gives a 33 1-3 per cent. increase on this ratio when in high, and reduces it by 25 per cent. in low.

The KS model gives closer ratios, having an increase of 12.5 per cent. from normal to high, and an 11.1 per cent. decrease from normal to low. There is also a medium ratio pattern, the KSW, providing ratios of 16.6 per cent. and 14.3 per cent: high and low respectively. In each case the internal operation is similar.

A Universal Principle

All Sturmey-Archer gears depend upon the principle of the epicyclic train. In its simplest form an epicyclic gear consists of three principal parts, a sun-wheel, a planet-wheel, and an internally-toothed ring arranged concentrically with the sun-wheel and geared to it by means of the interposed planet-wheel.

The sun-wheel, being in one with the axle, is fixed, and does not revolve, but if the planet-wheel is rolled round it the gear ring must also revolve in the same direction, and the amount which it travels round in relation to the distance travelled by the planet-wheel is the gear ratio, and this is decided entirely by the relationship in size of the sun-wheel to the gear-ring.

The planet-wheel, being merely a connecting link between the two, does not figure in these calculations, and its size has no connection with the ratio. If the sun-wheel is half the size of the gear-ring and the planet-wheel is revolved once round it, it will be found that the gear-ring has done one-and-a-half revolutions.

Increase the ratio by three-quarters and the gear-ring will advance one-and-three-quarter revolutions to one revolution of the planet. Within practical limits, the larger the sun pinion the greater the gear increase, and the smaller the sun pinion the less the gear increase, the controlling factor being that there must be room for a planet pinion in the higher gears, and obviously the size of the sun pinion cannot be reduced below certain limits.

Imagine this principle in a Sturmey-Archer hub. When high gear is engaged the sprocket turns the planet-cage and the hub-shell is connected to the gear-ring. One revolution of the sprocket turns the cage which holds the planet-wheels once round the axle.

Four Planet-Wheels

In actual practice four planet-wheels are employed to give strength, and they are arranged equidistantly round the sun-wheel and supported in a carrier, or cage.

If the sun-wheel is one-third the size of the gear-ring, one revolution of the planet-cage round the sun-wheel will turn the gear-ring, hub-shell, and wheel of the cycle one-and-a-third revolutions. In other words, the drive is geared up 33 1-3 per cent.

In normal gear the driving force is applied direct to the gear-ring and thence to the hub itself, and so the epicyclic action is cut out and a direct drive results.

For low gear the "high" action is reversed. The drive is transmitted from the sprocket to the gear-ring, and it is the planet-cage which is connected to the hub-shell. This means, of course, that the planet-cage does not travel so far round the sun-wheel as does the gear-ring when the latter makes one revolution.

In fact, if the gear is such that, in high, the driven part turns four times to the three of the driver, the reverse happens if their functions are alternated. Thus we get a reduction of a quarter or 25 per cent., in a gear which produces an increase of one-third, or 33 1-3 per cent.

By altering the diameters of the sun-wheel and the gear-ring larger or smaller amounts of increase or decrease can be arranged, but obviously there are mechanical limits.

It will be seen, therefore, that, with the ordinary type of epicyclic gear very close ratios are impossible. Actually, 33 1-3 per cent. has been found to be the smallest reasonable increase.

Sturmey-Archer engineers, however, succeeded in obtaining a closer ratio than this by the employment of a system of double planet-gears. The epicyclic practice is the same as in the single train of gears, but in this type of hub, which is known as the KS and the KSW, the planet-cage carries special planet-wheels. These are formed in one piece, and consist of a double-ended pinion, and have the effect of gearing the drive up or down as it is transmitted between sun-wheel and gear-ring.

Closer Ratios Wanted

But even this method has limits and is not capable of producing, satisfactorily, ratios closer than 12.5 per cent. for high and 11.1 per cent. for low. These ratios present far too big a gap for the speed-man, who requires only a very small amount of up and down change—actually, somewhere about the difference of one or two teeth on his sprocket provides an adequate variation. The closest that the KS hub provides is equivalent to about two teeth, and therefore the hub gear was not generally favoured by sporting riders.

But the Sturmey-Archer engineers had a card up their sleeves, and by producing their AR ultra close-ratio hub they have provided cyclists with a change-speed mechanism which will actually give ratios of one tooth difference from the normal gear.

It would take too long to describe, bit by bit and piece by piece, the operation and mechanism of this hub—indeed, no description was given earlier of the methods by which the driving effort is transferred from planet-cage to gear-ring and vice versa.

In the hubs already described this is carried out by means of a system consisting of a sliding dog, clutch, and two sets of ratchets and pawls, matters being so arranged that when one component is locked to another the other gear is disconnected either by having its pawls put out of engagement or through an over-running free-wheel.

This arrangement is reproduced in the AR hub, but the closer ratios are achieved by means of a complete extra train of epicyclic gears, though the main principle of the device still depends upon the ratio of the sun-wheel to the gear-ring.

In the hubs already described it will be remembered that the sun-wheel is stationary; in fact, it is actually part of the spindle. In the AR hub the first sun-wheel revolves. As we saw in the K-type hub, if the plane cage revolves once round the sun-wheel in high gear the gear-ring made one-and-a-third revolutions, because the sun-wheel was one-third the size of the gear-ring.

Effects of "Sun-Wheel"

Imagine, then, the effect of a revolving sun-wheel. Whilst the planet-cage is turning round the sun-wheel and the latter component is also turning in the same direction, the turning action of the planet-wheel will be delayed, and this delay will be transmitted to the gear-ring.

The faster the sun-wheel is turned the greater will be the delay action, or, in other words, the gear-ring will travel proportionately less far on its journey round the spindle. The sun-wheel is driven by the additional gear train already mentioned.

In brief, the ratio between sun-wheel and gear-ring is being reduced. For practical purposes this reduction is so arranged that 7.24 increase is provided for high and 6.76 per cent. for low, these being amounts which have been proved most satisfactory for all purposes.

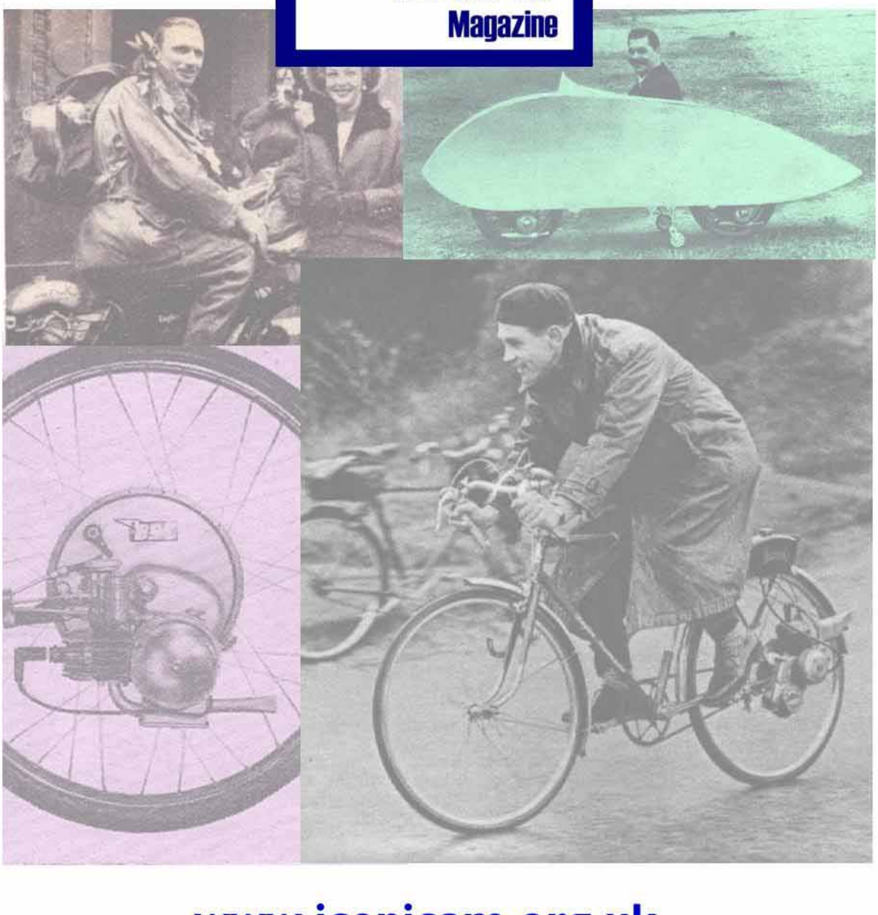
The actual means by which the sun-wheel is made to revolve and the methods of connecting the drive through the various components would make the subject of another long article; but, though it may sound complicated on paper, the device is really extremely simple and has the merit of being capable of really hard use, for it is actually constructed on most robust and sturdy lines.

Furthermore, since the gear-speed is much lower than in the normal double-train type of gear-hub, longer life for the parts ensues. Since there are just about the same number of parts in it as there are in the double-train gear the question of extra weight does not arise, whilst a very big advantage accrues in the ease with which gear changes can be made.

However, like its companions in the hub gear range, it must be lubricated; but if it is well looked after in this respect it need never require any more attention than the occasional adjustment of the ball-bearing cones.

IceniCAM
Information Service

The Iceni CAM Cyclomotor Autocycle & Moped Magazine



www.icenicam.org.uk