MOTORCYCLE ENGINEERING—29

Valve Gear Details

The "why" of top end design

by Phil IRVING

VALVE gear can be divided into two broad categories, depending upon the basic method of operation. This may be either indirect, through the medium of push-rods, or direct, by means of one or two overhead camshafts.

The o.h.c. layout, especially in its double-camshaft form, is the logical selection for pure racing engines, partly because the valve-actuating mechanism is as light as it is possible to make it, and partly because the existence of flexure or lost motion between cam and valve is also reduced to the minimum. The second point however, will not guarantee that valve-motion bears the designed relationship to crank-pin position at all times, irrespective of speed and load, unless the drive to the shafts is itself free from backlash or torsional "wind-up."

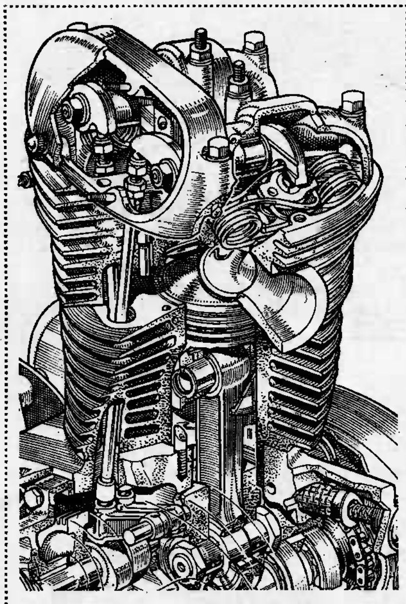
A really satisfactory overhead camshaft is an expensive thing to produce compared to a push-rod design which, though not so good in theory, is in practice adequate for all everyday needs and even for many forms of competition. Consequently all British touring machines in production today, whether single or twin, employ push-rod operation.

Apart from the question of first cost, it is much simpler to achieve oil-tightness with push-rods because of the relatively small amount of lubricant required as compared to the copious flow demanded by an o.h. camshaft. Routine maintenance and decarbonizing, too, are much simpler.

Where a parallel-twin or straight or "square" four is concerned, the position is somewhat different, especially if only a moderate power output is aimed at and parallel valves are adequate for the job. The original Ariel "Square Four" and the post-war Sunbeam twin both provide good examples of compact and inexpensive overhead-camshaft valve gear.

The best form for a rocker (as for so many things) is the simplest, consisting of a light, stiff beam with a central bearing, square to the plane of the beam, which is preferably of "I" section to provide the greatest strength with the least weight. This design is very simple to forge and machine and is the natural selection for use with parallel valves, but does not lend itself well to installations with inclined valves.

One design rule which must be rigidly observed if good valve-action is to be obtained is that the axis of the rocker-bearing must lie in a plane which is square to the axis of the valve, and it is difficult to adhere to this condition if the valves have an included angle of 70° or more, without an extreme amount of splay in the push-rods. Occasionally, designers have tried to get away with straight rockers and inclined valves by installing the push-rods approximately parallel to the cylinder axis, in which



Straightforward o.h.v. layout in a modern engine—the 250 c.c. A.M.C.

position they apply a most undesirable cross-loading on the rocker bearings, a treatment which the bearings will not successfully withstand unless specially designed to do so, as on certain aircraft engines.

An ingenious method of avoiding this side-loading was used on the Francis-Barnett "Stag" engine of the middle thirties, the push-rods being crossed and engaging at their lower ends with normal lever-type cam-followers.

Straight rockers, engaging on collars about half-way up the valve stems instead of on the ends, are used in Vincent engines in conjunction with high camshaft location. This layout was originally adopted partly to keep the valve springs well away from heat and partly to reduce the overall height of the engine to that of the 500 c.c. Python which it replaced. The Python (*née* Rudge) had, of course, four valves and was consequently shorter for its capacity than any other engine then in existence.

By far the commonest method of mounting the rockers is with the bearing centre-lines arranged horizontally and square to the plane in which the valves are situated. Since the arms at the valve ends of the rockers lie approximately at right angles to the stems, the bearing centres must be higher than the valves by perhaps half an inch or so. Looked at in plan view, each rocker is roughly of Z shape, with both arms square to the central portion; the major stress in the arms is therefore almost pure bending, while that in the central part is almost pure torsion, so that the metal is not subjected to the heavy combined stresses which are conducive to fatigue failure.

The central portion is best made of tubular section, bushed to run on a spindle, or merely drilled through but ground externally to act as a bearing surface. This construction has been standardized on push-rod Velocettes since their introduction, and the bearing areas are so great and the unit pressure therefore so low that the rockers can be run direct on the aluminium which forms the rocker-box cover, as wear is practically non-existent. This design necessitates splitting the rocker-bearings along the centre-lines; the lower half of the box is cast integrally with the cylinder head in the all-aluminium engines.

Rocker Features

In A.J.S. singles, the rockers are carried in bronze bushes in the cover portion, but are unusual in that each is composed of a hardened and ground spindle to which a pair of arms stamped out of steel plate are splined—a method of construction which lends itself well to quantity production and has been a feature of these engines since it was introduced in 1926 to replace the forged aluminium alloy rockers used for a year or so on the Wolverhampton products.

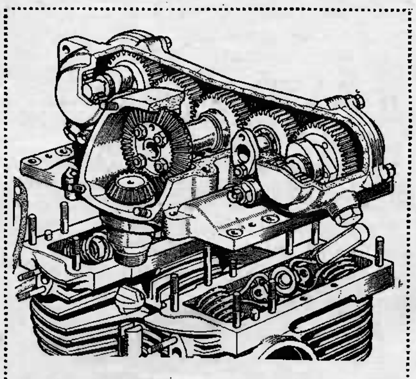
Speedway J.A.P. rockers are unusual in being carried in roller bearings, the inner tracks of which are formed integrally with the rockers, a construction which, besides being very low in friction, requires practically no lubrication. There is, however, always a danger that rollers, when used in the presence of an oscillating motion which travels through only a few degrees, will indent their tracks locally; this effect can be minimized by using a large number of rollers of very small diameter so that their areas of contact tend to overlap, but most designers prefer to retain plain bearings.

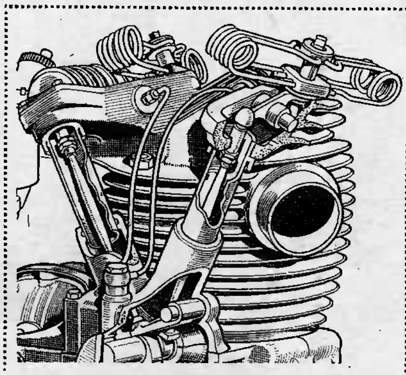
Noisy operation sometimes results from excessive end-float. As end-float is not an easy thing to control in manufacture, springs or double-coil spring washers are frequently employed to take it up. Excessive pressure from these devices can sometimes give rise to an unsuspectedly high frictional drag which can knock one or two hundred r.p.m. off the maximum dictated by the onset of valve-float; therefore, for racing it is best to control the float by some positive method which introduces no friction.

Suppression of valve-gear noise has always been something of a problem by reason of the varying amounts of expansion in the cylinder and head, the valves and the push-rods creating significant changes in tappet clearances as between cold and hot conditions. Barrel expansion widens the clearance, while push-rod expansion and valve expansion have the opposite effect. The "cold" clearances must be such that at no time is there any possibility of a valve being propped open as, if so, valve failure or undue wear of the cams or followers is bound to take place.

An austenitic-steel exhaust valve may expand in length as much as thirty or forty thou. under full-throttle conditions, while the expansion rates of the other components concerned varies according to the metals used and the temperatures they attain. For that reason, rather than considerations of weight, some engines use aluminium push-rods in preference to steel, or vice versa.

By a careful selection of materials and also by the provision of quietening ramps on the cams whereby the clearance is taken up very gradually before true valve-lift commences, a very high degree of silence can be attained. Copious lubrication also assists in this direction by providing some hydraulic cushioning, but horizontal fins which react to valve impact like tuning-forks are a hindrance and are sometimes braced together by webs, thereby helping to achieve silence at the expense of good cooling.





(Left) Five-gear drive train to the o.h. camshafts of the 1951 250 c.c. T.T. Velocette. (Right) Head of an early Vincent-H.R.D. single, showing rocker arrangement.

Placing the camshaft overhead does away with a considerable proportion of valve-gear weight and there was at one time quite a vogue for the single o.h. camshaft on sports models, even before the advent of the Velocette which so convincingly demonstrated its superiority over push-rod operation for racing.

Many of these early designs paid for lightness with other defects, chiefly noise and lack of oil-tightness. Furthermore, the actual saving in weight, when rockers have to be used anyway, is not quite so spectacular as might be thought when compared to a thoroughly well-designed push-rod layout. In the latter, one is free, within wide limits, to do what one likes in proportioning all the components to reduce their effective weight, whereas with a single o.h. shaft each rocker must perforce be nearly equal in length to half the distance between the valve-ends.

The o.h.c.'s virtual absence of flexure, which is desirable in the interests of accurate valve control, unfortunately increases the stresses created in the rockers by shock loading and they must be made of a strong, deep section to avoid failure from this cause. In the upshot, the weight advantage may be little more than the equivalent of one ounce in ten.

On some Guzzi singles the length of the rockers was appreciably reduced by arranging them to bear midway along the valve-stems, the rocker ends being forked and bearing on collars in a manner similar to the Vincent scheme. Incidentally, for calculation purposes, the *effective* weight of a rocker can be taken as being one-third of its actual weight, as the heavy central portion moves at a slower speed than the ends.

A small but useful contribution to reducing the effective weight is provided by mounting the rockers on eccentric spindles and thus eliminating screwed clearance adjusters; but the amount of movement must be limited to about 90° in a direction at right-angles to the rocker, otherwise an undesirable variation in valve timing may be introduced, especially if the cams are of small base-circle diameter. Eccentric spindles are sometimes employed with push-rod engines, but generally screwed adjustment, either on the push-rods or the rockers, is preferred.

Satisfactory oil-tightness of an overhead camshaft can only be achieved by total enclosure, either within the actual head casting, as per Velocette, or within a separate casting as on the A.J.S. 7R, a construction which allows the two components to be made from different materials. In this instance, the cambox is in magnesium, which is 40% lighter than the RR53 aluminium alloy used for the head.

It is, of course, also possible to mount the camshaft and rocker bearings in the head and enclose the lot with a simple cast cover, as on the Grand Prix Ducati and the racing B.M.W. The German twin is peculiar in possessing two camshafts per cylinder, tucked in between the valves, which are actuated by rockers. Presumably, this construction was adopted in order to reduce the rocker weight without increasing the overall width, which would have been unavoidable if the conventional double-o.h.c. arrangement had been employed.

The orthodox plan is to locate each shaft immediately over the valve—or valves, if a twin or in-line four is concerned—merely interposing a light tappet between cam and valve to absorb side-thrust and give a straight push on the valve-stem, a desirable feature for high-speed work. On single-cylinder engines, it is usual to use a train of five gears to distribute the drive from the central bevel or spur gear to the camshafts—clearly an expensive and potentially noisy design, but one which permits each camshaft to be timed individually, either for accuracy or to suit the circumstances.

On some Norton engines, for example, the inlet valve timing can be retarded by 10° for use with a straight exhaust pipe instead of a megaphone on occasions when the superior tractability of the plain system outweighs its reduction in power. Nortons have remained faithful for years to the use of a separate cambox, which leaves the valve-springs and the outer ends of the valves exposed—an arrangement excellent for cooling but detrimental to cleanliness, as leakage of oil past the tappets is difficult to prevent entirely and oil fed to the valve-guides also contributes its quota.

English racing engines retain the bulky hairpin springs which were adopted originally to overcome the breakage of coil springs that was a stumbling block to further progress at the time.

Coil Springs for Racing

However, improvements in the general design of coils, methods of reducing the surging which was the underlying cause of the trouble, and better material and manufacturing technique, have since made it feasible to run them at very high speeds, as on the Italian four-cylinder engines, where the space available is so restricted that coils are much easier to work into the design. In this application, they have the additional attribute that piston-type cam-followers surrounding the springs can be used, thereby allowing the camshaft to be lowered or the floor of the valve chamber to be raised to obtain better air-flow between it and the head, whichever is deemed more desirable.

O.h. camshaft valve clearances are subject to greater alteration than push-rod clearances under the influence of temperature changes because the self-compensation which can to some degree be provided in the latter is absent in the former. On the other hand, they are less liable to capricious changes at intermediate temperatures and their rate of change through wear is low. Adjustment is usually of the "fixed" variety, made either by the addition of shims or by using tappets of appropriate lengths. This means that adjustment must be made at the time of assembly and cannot afterwards be easily altered, if at all, but the final result is the lightest possible and the risk that loss of tune may occur through the loosening of a screwed adjustment is totally avoided.

From time to time, engines with vertical or near-vertical camshafts have been produced, but none of these appear to have any marked advantages. The most interesting current development is undoubtedly the so-called "desmodromic" valve gear, of which the only successful example, in motorcycle practice, Ducati's, was very fully described by John Griffith in "Built for Speed," No. 26 (December 3, 1959).

NEXT WEEK:
CARBURATION