# Good vibrations

Within the home workshop it is possible to check and often rectify crankshaft alignment and static balance the crankshaft. Dynamic balancing may often lead to an even smoother running engine but is a process outside the scope of even the well equipped home workshop.

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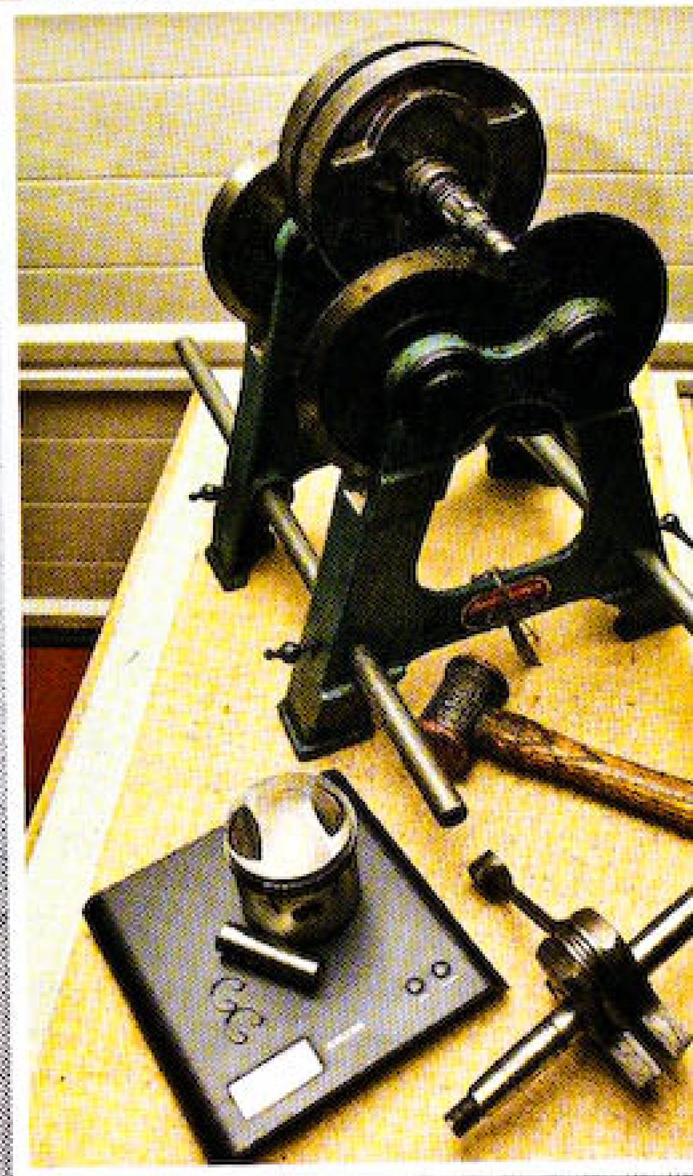
**Photography by** John Wilkinson



Parallel knife-edges make an almost friction-free jig for static balance crankshaft checks. Another alternative is knife edge wheels with what the makers describe as 'frictionless bearings for greater accuracy.' While parallel knife edges are arguably more accurate the wheels may be used for alignment checks too and, being clumsy, I prefer such wheels as it's not been unknown for the crankshaft to escape from knife edge and land with a bruising 'thump' on the floor... Although such equipment is ideal, and can be used for many other applications other than balancing crankshafts (including checking suspect fork stanchions) good results are achievable with a DIY jig comprising the edge of two angle iron or similar strips, as detailed within illustrations.

In basic terms, crankshaft induced engine vibration is usually due to one or more of four distinct factors: Poor design and/or manufacture, misalignment on assembly, damage or it's out of balance. However, due to design and the compromise required to balance a crankshaft it's often not possible to create an engine which is totally devoid of crankshaft induced vibration, unless assistance in the form of contra-rotating balance shaft/s or the like are employed.

While re-designing and remanufacturing a crankshaft is not a possibility for most of us, we can evaluate damage, may be able to do something about misalignment and, often, can re-balance or have the work done.

Typical questions the YWA column fields are, 'Is all this work necessary?' and 'What standard of accuracy is required?' With familiar Rosenthal evasiveness here's two tales to illustrate the extremes of viewpoints.

During the mid-1960s know-it-all spotty youth (me) comments to schoolmate's dad as he assembles the bottom end of his daily ride-to-work hack, ohv Norton single,"Lot of flywheel wobble there, aren't you going to align them better?" Harassed and angry parent; "They're not hitting the crankcase sides, I'm not spending all day on the job, the bike's a wreck and I don't go fast, so it'll do me." Time proved the poor old Norton trundled to work for two more years, until the MoT tester could take no more of its (lack of) braking efficiency...

Working in his well equipped workshop (the front room of his South London home) renowned racing engineer Steve Lancefield spent much time ensuring the bottom ends of his engines ran true, with minimum friction and minimum vibration which, with regard to balance factor employed, had been moved out of the racing engine speed range. His stance is summed up by his viewpoint on the work as any less than wise journalists discovered if they described him as a 'racing engine tuner.' In a rather excited voice, he'd proclaim;"I'm a racing motorcycle engineer [or similar], not a tuner. Tuners tune pianos..."

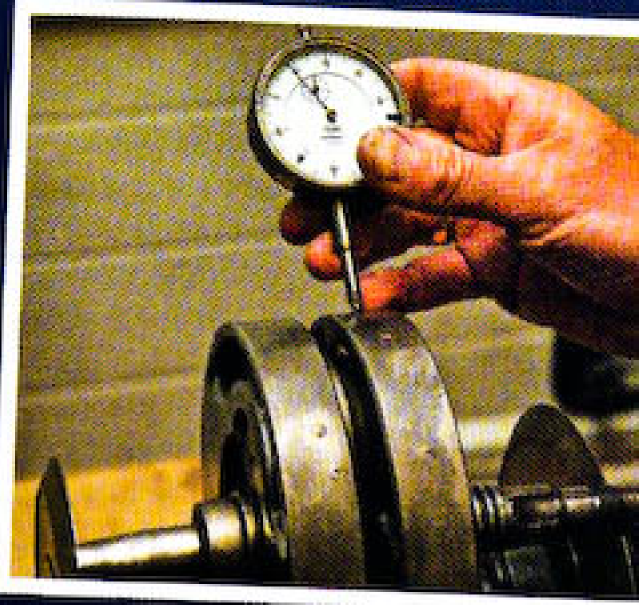
They were the comments of a truly fastidious man, who knew his engines would lose less power through friction and vibration and be more durable and smoother at racing speeds than those of many rivals. While Lancefield's approach may be the goal, limitations of original design and manufacture, wear, parts available or the facility to make them, age and rarity will limit what we can achieve. As often with life, a compromise somewhere in the middle will often suit.

## DAMAGE

Although design and manufacture is outside the scope of this feature, it's worth considering damage.

Assess any mechanical damage following an engine blow-up, past clumsy assembly or similar. Check the accuracy of fit of shafts to crankshaft flywheels if assembly is of bolt up or pressed up design. Examine for signs of fatigue damage, which occurs with older assemblies and may present as crack/s radiating from crankpin and mainshaft locations. Any crack, no matter how small, will travel as the engine runs and is put under load. Cracks open up, allowing the loosening of the fit of the crankpin or shaft to the flywheel, resulting in loss of rigidity and increased vibration.

Replacement is the only remedy an engineer will recommend – however, some enthusiasts will suggest identifying the end of the crack and drilling a hole at this site through the flywheel to prevent the crack spreading further. Certainly not recommended by many but mentioned for interest only.



For illustration only the dial gauge is hand positioned to indicate radial alignment check of flywheel rims. Choice of measurement set-up is down to the individual and the equipment available to them, hence actual set-up employed in the author's workshop is deliberately omitted.

## FLYWHEEL ALIGNMENT

To avoid power wastage through internal vibration, it's essential the crankshaft assembly is a rigid, perfectly aligned structure. While control of the manufacture of one piece structures lies with the maker, for assembled crankshafts the responsibility of the quality of work lies with its last builder.

Common methods of assembly include steep taper to pin and flywheel hole with fine thread nut drawing the joint together, shouldered shaft with light drive parallel fit (.001in oversize) with fine thread nuts to pull shoulder onto flywheel or pressed up interference fit. The later two options may also involve a very shallow taper of as little as .001in along the fit length, up to as much as .008in. The actual amount oversize of pin to hole for interference fit varies but often as much as four to six tons of force is required to push pin/shaft home.

Steep taper fit: One of the oldest methods of crankshaft assembly but still makes for sound construction. If the taper fit has become 'squared' or too loose, help from a well equipped engine machining workshop that specialises in assembled crankshaft repair work is needed. However, if the problem concerns taper fit, check with smear of prussian-blue on pin and rotate in hole. If contact isn't made over the entire taper it is possible to lap fitting parts together with abrasive, such as fine valve grinding pastes. Care must be taken not to lap out of true and work must be minimal as material removed from crankpin joints will bring flywheels closer together, reducing side-float of conrod.

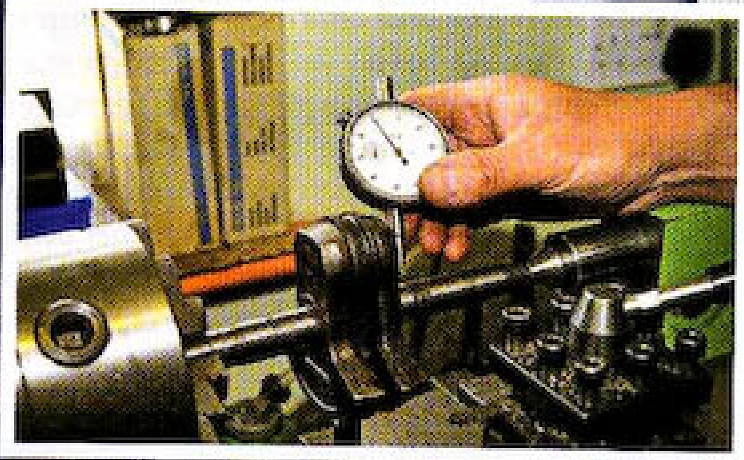
Shoulder fit and interference fit: Problems here are usually beyond our home workshop but often can be resolved with the manufacture of a new pin and re-machining to flywheels. On occasions with a loose fit it's possible to hard plate the pin and regrind fit.

### ALIGNMENT CHECKS:

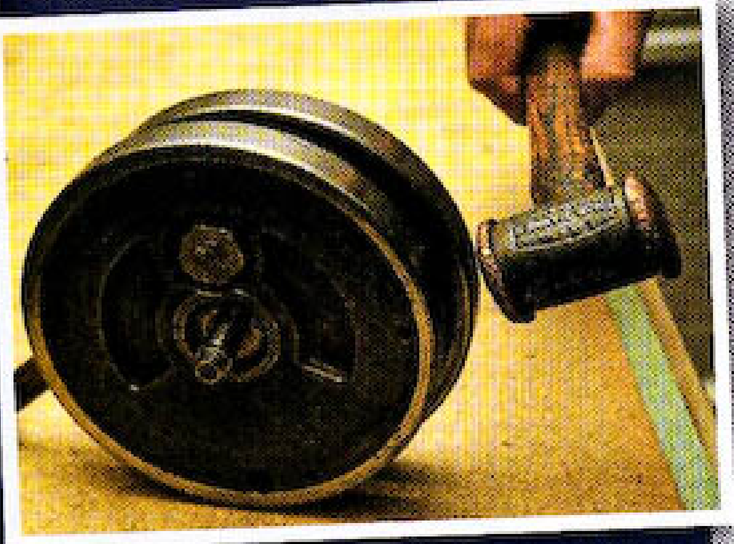
■ May be carried out using a production or DIY truing jigs, or some friction free (well, almost!) knife edge balancing wheels. In effect, equipment must allow crankshaft to rotate about its axis without moving position. It's also possible to set the crankshaft up between centres on a lathe for this purpose but extreme care must be taken not to over-tighten the tailstock, which would exert pressure on crankshaft, in effect squashing it and giving errant readings.

The accompanying diagram details examples of alignment points for checking as crankshaft is rotated about its axis. Method of measurement has deliberately been avoided as the professionals use many approaches including scribes, mechanical dial gauges or the digital equivalent, light or laser measurement and an elderly local professional checked them 'by eye!' Not

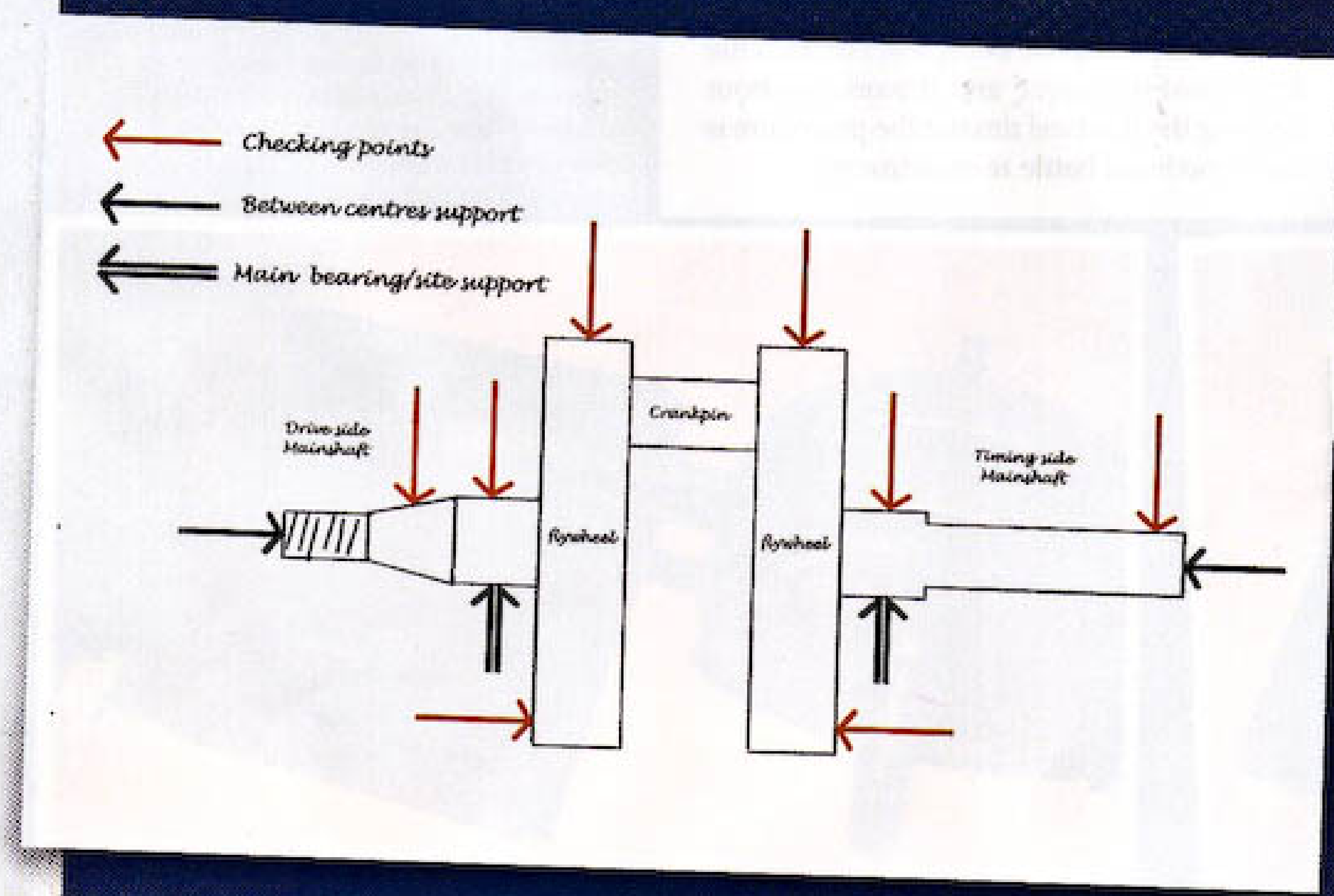
Again for illustration purposes, the hand held dial gauge indicates a suggested measurement position for mainshaft, which is supported near its end. If the jig supported near flywheel the measurement would need to be made at the other extreme.



Crankshaft supported between lathe centres, again with hand held dial gauge for illustration only. In practice the dial gauge, digital gauge, scribe or whatever you choose can be positioned with a block, magnetic (if working on ferrous surface) or other rigid support.



Bumping is effected by striking the rim of the errant flywheel with a copper hammer in a position at approximate right angles to the crankpin. Choice of crankshaft support while carrying out work is yours but of course such brutal work must not be carried out on the static balance knife-edge jig.




While measuring for run out on flywheels and mainshafts also check taper, as illustrated. for accuracy of machined taper surface not for mainshaft run-out. Measure mainshaft run-out near flywheels if flywheel supported near ends of mainshaft or between centres. If supported at position of main bearings measure run-out at extremes of mainshaft. A ground or machined sheath will be needed to measure run-out on threaded (or splined) portion.

recommended, but when I re-checked his work on a number of occasions the result was well within the limits detailed below, proving experience is everything.

Regardless of method of supporting crankshaft about its axis, the point of measurement of flywheels remains the same, but mainshaft measurement site varies dependant on method of supporting crankshaft about its axis. When supported within centres the mainshaft measurements are taken in region of main bearings and vice versa if supported in region of main bearings. If in the latter case when threads, splines or similar are present on mainshaft/s an accurately ground/machined sleeve with push fit over splines, thread etc is employed enabling 'truth' measurements to be made accurately.

■ How true should the shafts be? In an ideal world the sum of error for both shafts will be zero, but if the sum total error for the two shafts is .002in or less, the job is a good-un. Son Peter's Goldie lives with a .0015in error, is vibration free and after nine years of up to 6500rpm use hasn't yet destroyed its main bearings. Often struggling with damaged older crankshaft assemblies the error could be above .002in – although not desirable, it may be the best achievable. But the further away from the .002in figure, the greater the chance of vibration and the higher the risk to the engine's main bearings. Although total run-out of above .002in isn't recommended and for legal reasons this column cannot advise safe higher limits, it's worth remembering two-bearing (main bearing) crankshaft assemblies will tolerate a higher degree of run-out than three or four-bearing assemblies.

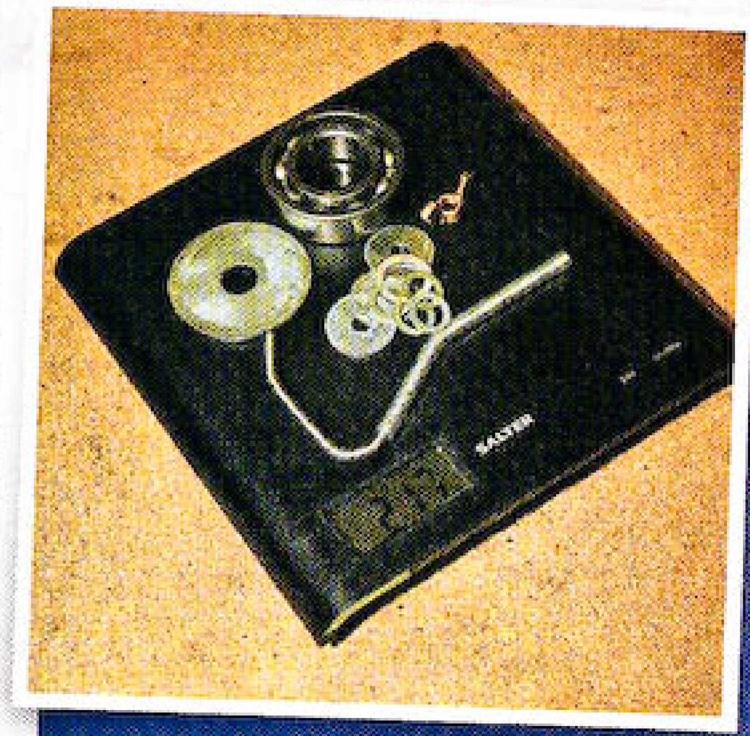
## GUIDES TO ALIGNMENT AND CORRECTION:

Consider this work at your own risk only or you may wish to entrust your crankshaft to a professional for alignment.

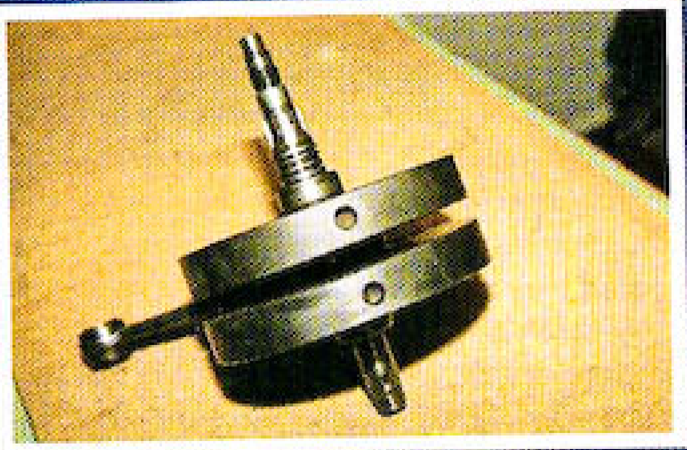
■ Ensure only matched pairs of flywheels are used or they have been matched by machining prior to assembly. Even a tiny difference, just a few thousands of an inch, in crankpin centre height will result in one flywheel and therefore mainshaft being higher than its mate. This will result in vibration and rapid main bearing wear.

■ Flywheels out of parallel. If spread in region opposite to crankpin it may be possible to nip them true in a vice and if narrower, wedge them apart. Both are brutal approaches and no substitute for accurate machining and assembly. A surprisingly small amount of pressure may be required to true such a problem and slender crankpins or fragile flywheels may be damaged beyond safety and use by this approach.

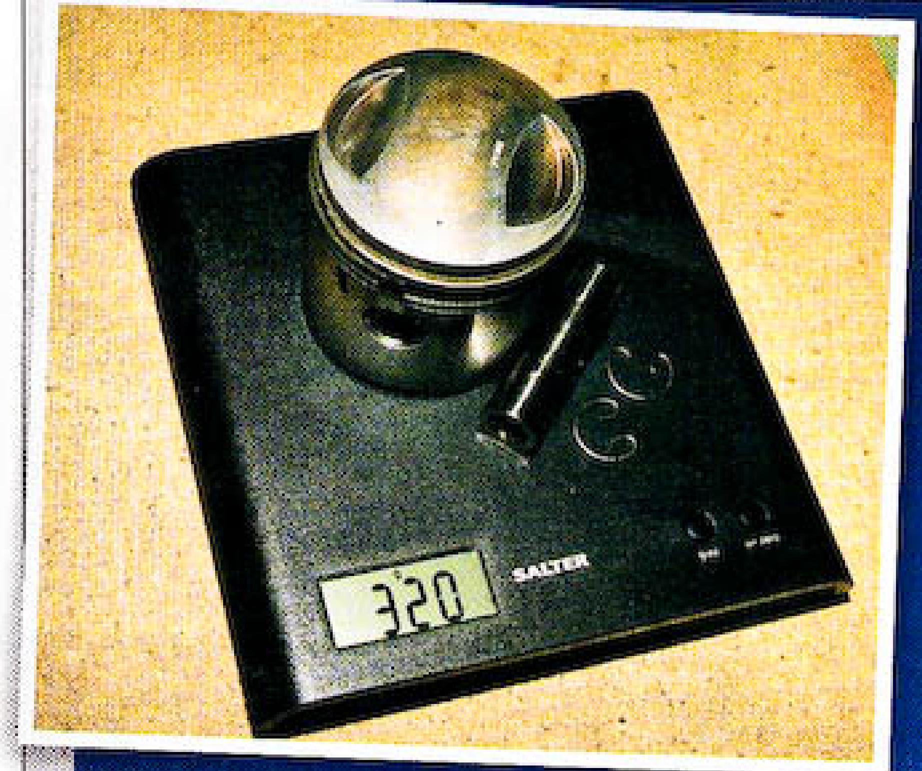
■ Flywheels out of alignment. One often needs moving (bumping) into alignment with its mate about the crankpin axis. Often achieved with an accurate blow at 90-ish degrees from crankpin to rim of errant flywheel, bruising can be further minimised by using lead or copper block held against rim at site of blow. Some prefer to carry this operation out on a bench while others prefer the crankshaft hand held. Safety aspects are down to you! Famously, renowned Australian engineer Phil Irving recommended bumping with either a lead block or the end grain of a hardwood fence post. Being me, I've tried the fence post technique and it works without bruising the flywheel rim but the procedure is like a medieval battle re-enactment!



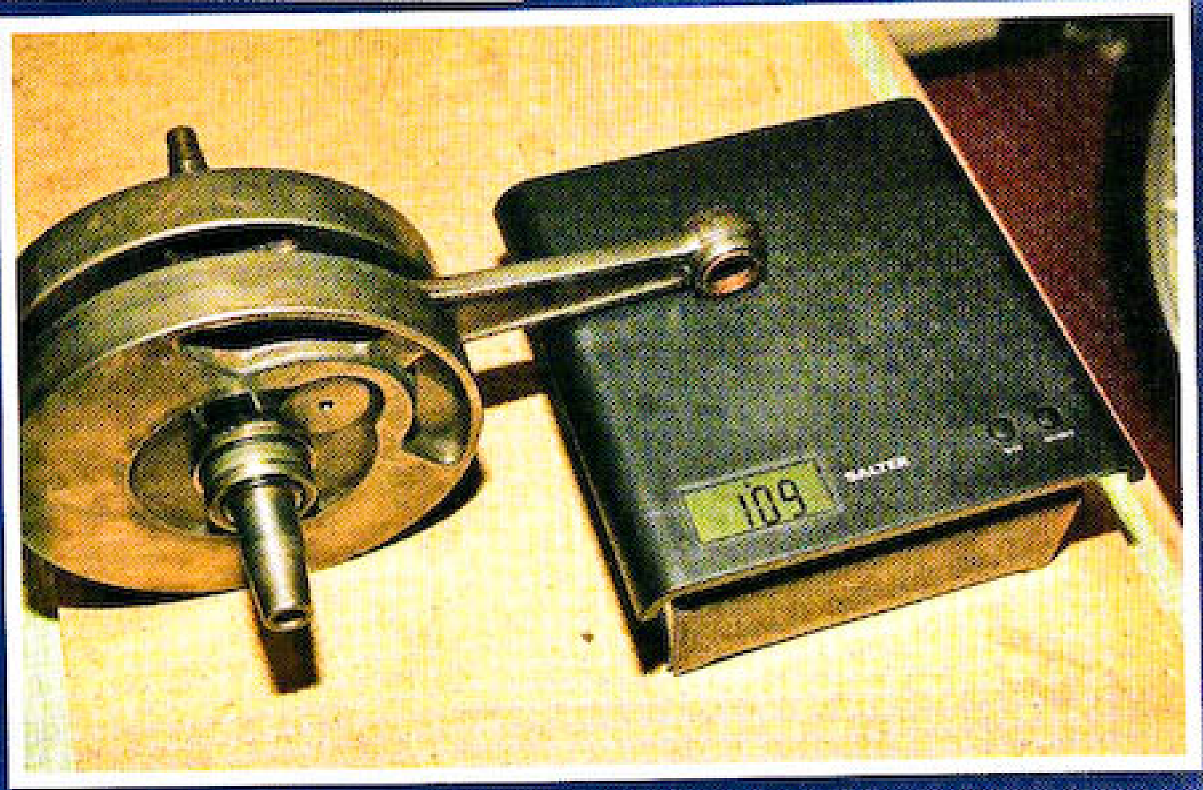

While neat weights from a hanger look professional any old scrap – so long as its compact due to space limitations – to the required weight is fine. As photographed 217gms of scrap on scales, so only another 66gms to find!



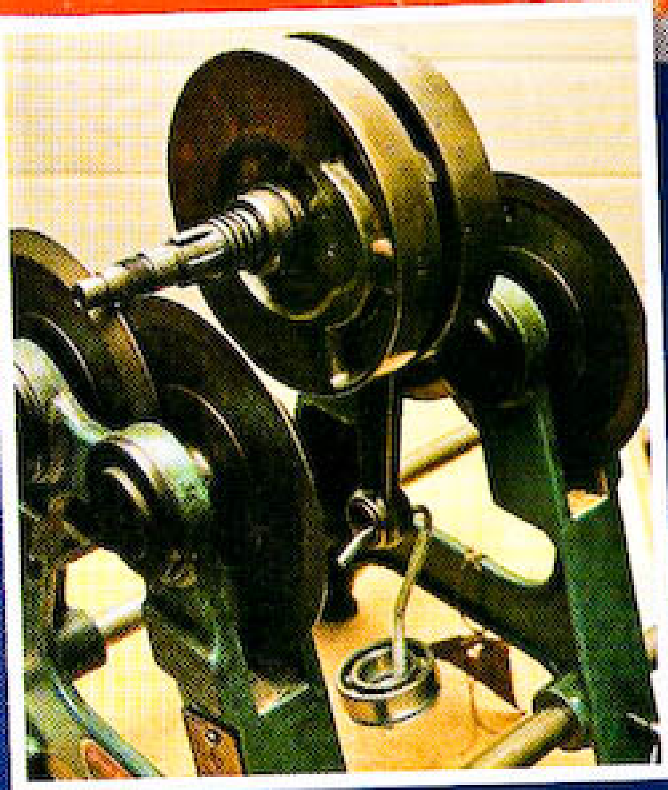
If crankshafts have been drilled in the past and need weight adding in this position holes can be lead filled and re-drilled to balance or often it may be possible to drill on crankpin side. However, care must be taken not to weaken flywheels, which may lead to premature cracking.




To discover total reciprocating mass of single cylinder engine weigh piston, piston rings, little end pin and clips (or pads if appropriate).

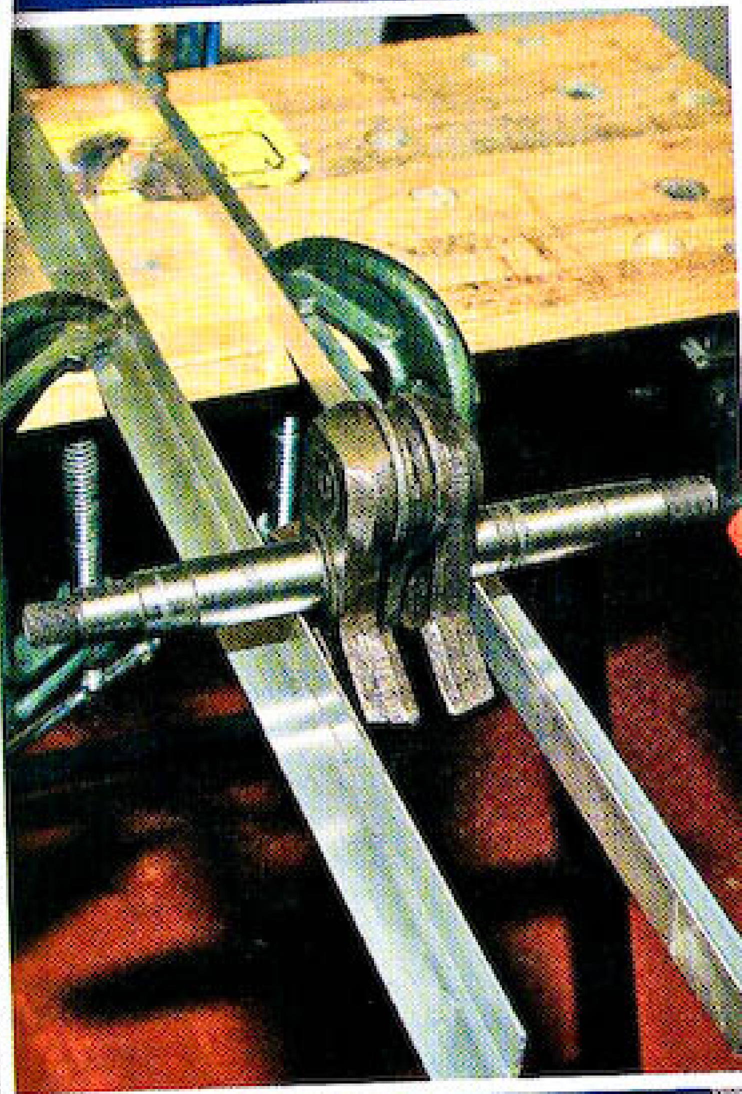



Position scales at a height to ensure upper half of conrod is weighed when at exact right angles to crankpin. Combine all reciprocating weight in this case and calculate balance factor.
So 320 + 109 = 429gms include balance factor eg 66 per cent = 283gms.



Hang weight from crankshaft and drill flywheel rims evenly on either side in line with the cylinder axis. Crankshaft is balanced to balance factor calculated weight when it rolls freely in/on jig and shows no tendency to settle in any particular position.

If no knife-edge equipment is available make your own from a couple of lengths of true angle strip as illustrated and with a spirit level ensure they are true to each other and level.



Proceed exactly as detailed earlier, regardless of jig used. Once the crank rolls freely and shows no tendency to settle in any given position, satisfactory static balance is achieved. Ideally whatever jig is used variance of no more than a gram should be needed to change the crankshaft's position on the jig. As a guide if the crankshaft with weights settles with the crankpin uppermost the counterweights (directly opposite crankpin) need drilling, if the crankpin settles at the bottom the flywheels are drilled adjacent to the pin. Conversely, if the flywheels have been heavily drilled it may be desirable to fill holes with lead and the converse of above applies.

## STATIC BALANCING

The crankpin – with fastenings if appropriate – and lower part of the conrod is regarded as a rotating weight, which one would imagine can be perfectly balanced by an equal and directly opposite reciprocating weight (mass of piston, associated parts and upper half of conrod). Accurate balance could be achieved by drilling or weighting crankshaft but with our single and 360 degree parallel twins, this great theory doesn't work in practice. Certainly, the engine will be perfectly balanced in the direction of the cylinder axis, both within the cylinder and directly below it but as the engine approaches a point at right angles to the cylinder axis it will become more and more out of balance achieving peak 'out of balance' at the 90 degree line to cylinder axis.

The solution to this unhappy state of affairs is a compromise, which involves balancing the crankshaft assembly with a percentage of the reciprocating weight. This percentage is known as the crankshaft's balance factor. Therefore, we don't need to know the weight of the crankpin and lower half of the conrod – instead, we only need to weigh the total reciprocating mass.

There is no such thing as an ideal balance factor as it's dependant on many considerations including engine type, state of tune, rev range the engine will most regularly use and even design of frame the engine is mounted in (scarcely believable, but true). Only the original maker will be able to detail required balance factor for their engines under given usage. Great, except many makers never quoted balance factors, some implying mere owners shouldn't interfere, and even worse makers often never agreed with regard to increasing or decreasing balance factor for specific uses such as racing or touring. Thus, some makers recommended a smaller balance factor for racing to move vibration below the high rev range, while others recommended a higher balance factor for the same purpose.

Regardless of the balance factor used, the object remains constant – to ensure the engine runs smoothly within the rev range it's most likely to operate in for the majority of its running time. A touring rider of a classic machine will want a smooth engine in the range 2500-4500rpm while the classic racing rider will want the engine to be vibration free at 5000-plus rpm. If no maker's balance factor is available, 66 per cent of reciprocating weight makes a good starting point.

Static balancing has limitations as implied above but for most of us it's the only possible approach to the job and so long as we balance to suit the engine's intended rev range, we will enjoy a smooth engine within that range and the unit in turn will enjoy a longer life with minimal vibration induced power loss. Dynamic balance considers additional factors, including forces created by eccentricity of the conrod. The consideration of such factors encouraged modern makers to run balance shafts in their engines, which revolve at twice engine speed. Despite the advantages of dynamic balancing – which results in crankshaft balance point being slightly out of line with cylinder axis – for most of us with slow running, up to 7000rpm engines, static balance vastly improves the smooth running of our engines in their commonly employed rev range.

## BALANCING

While the accompanying photographs and captions detail steps to be taken, it's worth checking the balance of the crankshaft devoid of devised balancing weight. In this state the crankpin should come to rest vertically upwards. Any deviation indicates bob weights or casting or entire flywheel is off centre. To rectify, drill equal holes in either side of the rim at right angles to the crankpin on the heavy side.