CHAPTER 8.
ENGINE RELIABILITY.

Hopefully, the preceding chapters will have guided you through the selection options, helping you to select a group of modifications to suit your individual performance improvement requirements.

Now these modifications have to be built into an engine in such a way that it will successfully survive the increased stresses that they impose.

The best and most highly technical tuning advice in the world is of no use without a starting point of the four essentials….

A CLEAN WORKSHOP
GOOD TOOLS
DEDICATION and
PATIENCE.

Without these, you may as well forget it and hand the job over to someone else.

All assembly operations should be carried out using a thin coating of clean light oil.

Even during pre-assembly operations, i.e. operations to check vital measurements such as deck height etc., this is vital, because even slow-movement of unlubricated mating parts will cause minute dry scuffing that will, in turn, cause galling when the engine runs on power.

Valves - quality check
Check exhaust valve heads with a magnet to ensure that they are non-magnetic austenitic, heat resisting alloy steel.
British specification is 21/4N or Nimonic 80.
They may be of two-piece welded construction as are many production valves, in which case the stem will be magnetic and the head non-magnetic.
These are O.K. for use in stages of tune up to St. 2 Rally but not for full race.

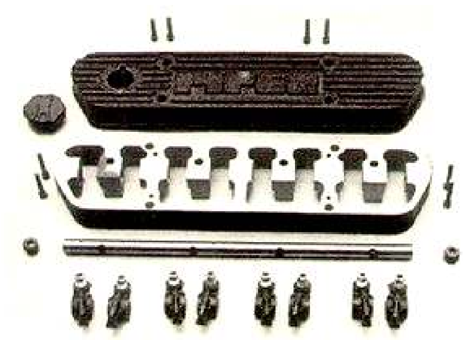
Inlet valves will probably be magnetic silicon chrome steel.

Don't use valves with sharp cornered cotter grooves. The corners of these grooves are potential failure points.
Grooves should be semi-circular in section and the cotters should not butt-face to face so that the valve can rotate, but grip the stem. Many stock valve assemblies are purposely made to allow the valve to rotate within the cotters. Great for extended valve seat life, but no good for a high performance engine.

Valve guides should ideally be nickel bronze (British trade name Hidural 5).
Cast-iron guides in good condition are useable, but will wear quickly and require repeated renewal.
If the valve guide is cut back to assist gas flow in the intake port, then be sure to leave adequate guide support length.
A reasonable rule of thumb is that there should be **at least** a length of 4 times the valve stem diameter, left to support the valve.
Do not remove any of the exhaust valve guides, as this is vital to remove heat from the exhaust valve stem.

The cam supplier should recommend valve springs, but anyhow use the assembly checking procedures described on pages 33/34.

O.H.V. (Pushrod) Engines.



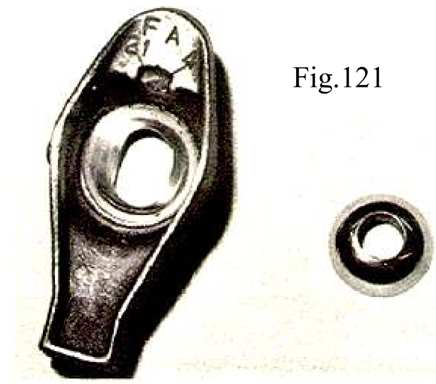
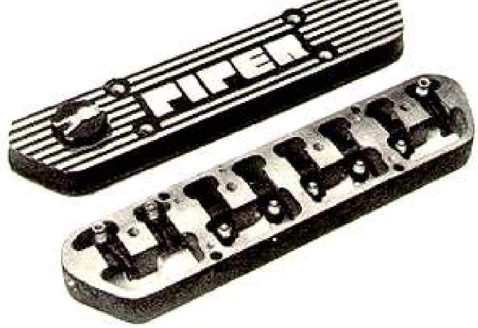


Fig.121

Fig.120



Check rocker gear for bush and shaft wear. Overhung end rockers should ideally be supported by additional bracketing or by using special rocker gear (Fig. 120).
Check seating condition of spherical and shaft seated rockers for adequate lubrication and that there are no signs of scuffing. (Fig. 121)

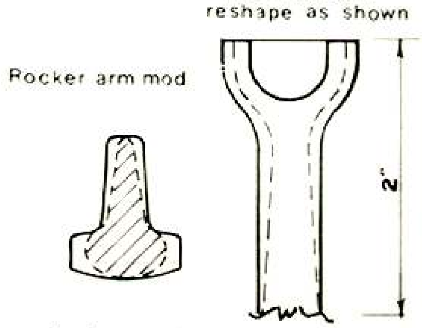
Check pushrods for straightness and tappets for good fit in block.

Fit spacers on the rocker shaft instead of springs; lighten rockers in vertical plane only (do not reduce height, only width).
Lighten pushrods by slimming ends only (Fig. 122).

Smooth and shot-peen rockers and pushrods.

Replacement rocker pillars in solid steel are also an acceptable modification but make sure that a true clamping action takes place on the rocker shaft to be fully effective.

Fig.122



O.H.C. Engines

Check cam bearings and see that caps are on original matched seating.
Light annular scoring is O.K. providing there is no evidence of hammering or lack of lubrication.

Check fit of followers in head. If cam has been reground to smaller base circle, make sure that followers are not impinging on adjacent protruding bearing surfaces or other obstacles.

Check clearance of cam lobe rotation in rocker box.

Check clearance of valve to valve and valve to piston clearance in hemispherical and part spherical combustion chambers.

Minimum valve-to-valve clearance at overlap T.D.C. should be 1.5mms.
Remember, the inlet valve will be opening across the face of the exhaust, so the safe way to ensure clearance is to recess the exhaust valve seat and get it safely out of the path of the inlet.

Earlier references have already explained that exhaust breathing does not suffer with judicious recessing procedures.

Closest proximity of valve to piston will occur at approximately 10 B.T.D.C. for the exhaust and 10 A.T.D.C. for the inlet.

Minimum clearance, valve to piston, should be 2.5mms, to allow for rod and piston stretch, and also momentary variations in timing caused by over-revving.

If pistons have to be pocketed, remember to check side clearance as well as face clearance.

The use of hydraulic tappets should really be avoided for any serious tuning operations.
If hydraulic tappets or pedestals are used with high performance cams, there is a possibility of valve train "jacking " occurring.
This is the condition caused when, at high rpm, the engine oil pressure extends the tappet during the small periods of light loading in the valve train when the valve is at full lift.

Combustion chamber.

Ensure that all sharp edges are broken and burrs removed.

Check plug nose position when fully screwed home.
There should be no spare threads in sight, either on the plug or the head.

"Run-out " threads, left by the tapping operation in the head, should be smoothed away.

Any small protuberances within the vicinity of the combustion chamber can cause detonation.

Detonation is secondary ignition, a result of inefficient combustion control, often started by superheated and glowing prominences in the combustion chamber.

The pressure wave, generated by the detonating flame-spread, meets the flame-front of the normal ignition process somewhere in the centre of the chamber, and the resultant shock can cause severe damage, often witnessed as a hole in the piston crown or a melted valve head or plug.

Detonation, (not to be confused with the "ping " of pinking, which is the harmless noise usually the result of over advance), is audible at low speed as a dull crackling knock, but is often inaudible at high speed, at which point it can cause the most devastating damage.

Head and block faces and gaskets should be treated as described in the turbo charging and supercharging section.

Deck height.

The closest point that the piston crown comes to the head controls squish efficiency.

Allow around 0.7mms including allowance for head gasket etc.

Any less than this may mean that the piston will touch the head as the rod stretches under inertia loads at high rpm.

Pistons and rings.

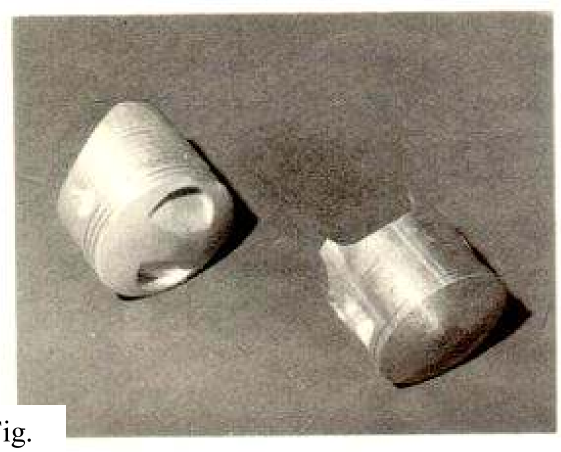


Fig. 123 *4-stroke and 2-stroke pistons, showing single ring and lighter construction of 2-stroke piston.*

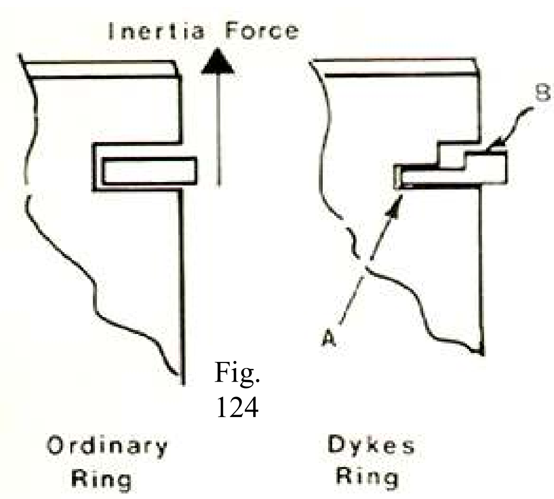


Fig. 124

It is essential to keep the piston as light as possible for reasons described later. (Fig.123)

With engines revving consistently over 8000rpm, the top ring should not be more than 1.0mms wide to keep its weight down.

This is necessary in order to prevent the effects of inertia sticking the ring to the top of the groove and preventing combustion pressure from getting down behind it to create the sealing pressure.

The way in which the top ring works is such a seemingly small thing that is also misunderstood, yet is vital to efficient power production.
As the piston is rising, the top ring “floats” to the bottom of its groove, allowing the small gap between the top of the ring and the top of the groove to remain open to let high-pressure gas get behind the ring and expand it to momentarily seal the piston in the bore.
At high speed, the inertia of the ring allows it to be floated against the top of the groove, stopping the gas getting behind it and destroying the sealing effect of the ring against the bore wall.

This inertia induced gas leak effect is also the reason for using a “Dykes section “ ring (Fig. 124), which uses the horizontal section “A “ to hold the ring in place, thus keeping the door open at “B “ to allow entry of gas pressure for sealing.

Unlike compression rings, the oil control ring should be a snug fit in the groove, ideally of two-piece, simple bridge construction (Hepolite code MSO), but if not available, then three-piece (two slim rings with an expander between), but not pressure backed.

Oil clearance should take place through drilled holes at the back of the groove and below the ring, at the top of the skirt.

Pistons with slotted grooves are not advisable for high-speed use, due to potential failure at the roots of the slots.

If forged pistons are available then these should be used, but only if the design is suitable.

The old fashioned "slipper " design, with two straight walls, joining the thrust faces at right angles to the gudgeon pin is not desirable and does not make sufficient allowance for the expansion limits created by the wide operating temperature range of the modern engine.

The ideal piston is of "jam pot " or near circular design (Fig. 123), with a generous skirt correctly ovalled in the horizontal plane and barrelled in the vertical plane.
If they are forged, they should be fully machined inside and out in order to reduce the excessive weight introduced by the necessary forging process that leaves solid metal above the gudgeon pin bosses internally.

Cast piston designs avoid this problem and thus do not require internal machining.

Well-designed and produced cast pistons are adequate for stages of tune up to Stage 3 as listed in the cam selection table on page 41.

Turbocharged engines.

Generally the operating rpm range of these engines will be lower than that of naturally aspirated units.
It is therefore not necessary to use ultra-light top compression rings.
In fact a wider ring is desirable to lower the specific loading created by the excessive combustion pressures.
For the same reasons it is not necessary for the piston to be of such lightweight construction.

These rules do not apply, however, for highly specialised engine designs conceived specifically as turbo full race power plants.

Connecting rods.

Often considered the big villain of horrendous engine blow-ups, the con-rod can be a perfectly reliable component if its function is understood and the correct treatment given accordingly.

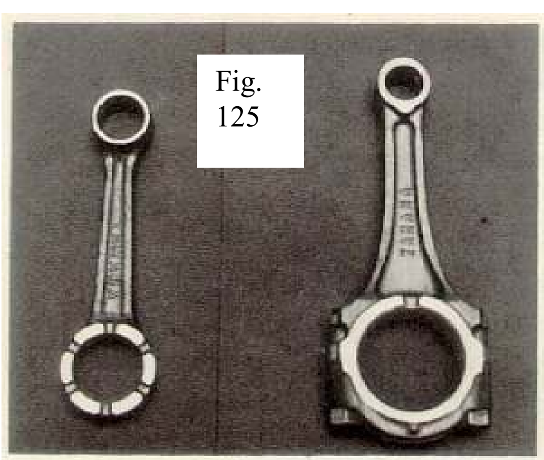


Fig. 125

Those who have dismantled both two-stroke and four-stroke engines will probably have noticed that the two-stroke rod is always of lighter construction.(Fig.125)

The reason for this is that the con-rod and piston, like all other bodies, exist in a state of inertia.
Inertia is a resistance to any form of change to their existing state (often also found in many human beings!).
That is, if they are moving, then they don't want to be speeded up or slowed, and if they are stationary, then they don't want to be moved.

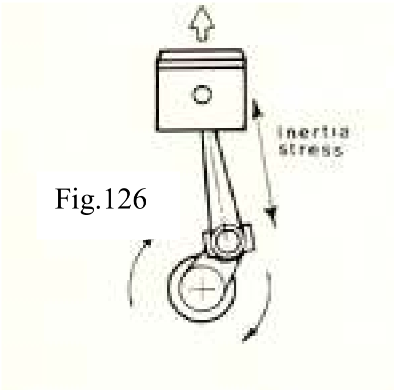


Fig.126

So as the rod and piston reach the top of the exhaust stroke in a four-stroke engine, the con-rod wants to carry on going up, but the crankshaft starts to pull it down.
The two opposing forces try to stretch the rod and piston and create inertia stresses. (Fig.126)

Not generally realised is the fact that loads created due to inertia in the four-stroke are considerably greater than loads created due to combustion. For example, a rod and piston that weigh a few pounds normally, will effectively weigh several thousand pounds at 10,000rpm.

However, this weight is considerably offset the top of the power stroke, by the cushioning effect of combustion pressure.

Now it becomes easier to understand why so many engine-blow ups take place on the overrun.
With the throttle closed, the combustion cushion is lost and the components are being subjected to twice the number of inertia loads.

Of course, the same thing happens again at the bottom of the stroke, but this time the rod is in compression by the effective weight of the piston and the load is much easier to resist.

To sum up then, this is the usual sequence of con-rod failure.
Inertia loads of rod and piston work on the big-end bolts, the bolts stretch or loosen, oil is lost from the big-end bearing, the bearing seizes and tears the rod apart somewhere between big and small end.
On the next rotation, the broken rod end is usually thrown out of the side of the block.
This is the common failure, but if the big-end bearing is still intact and not blued, but the top of the rod is off, then that is due to inertia weight of the piston being too great for the rod design.

Moral! If you're going to increase rpm, then keep piston weight to a minimum.

Also, renew big-end bolts at regular intervals.
Torque them up carefully and don't use lock washers of any kind, but use Loctite.

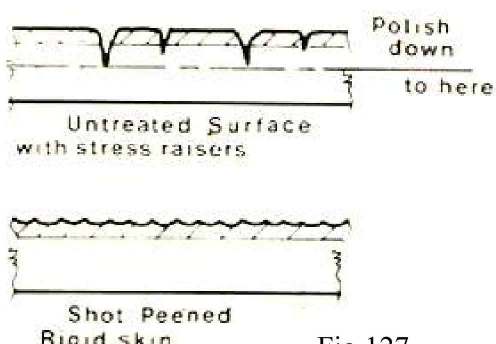


Fig.127

Con-rods can also be further protected by having the flanks polished and shot-peened.
This process has the effect of removing stress raisers or potential breakage points and then adding a compressed, tough skin to improve its rigidity. (Fig. 127)

The two-stroke con-rod is never subjected to this kind of treatment because, at the top of each stroke, it has the compression or combustion cushion, and, at the bottom of each stroke, it has the pumping cushion of the transfer process, hence the lighter construction.

Crankshafts.

Modern crankshafts are generally designed and constructed to withstand far heavier loads than the standard engine can impose.
Consequently the level of tune can be lifted quite high, certainly to Stage 3, before a special purpose crank need even be considered.

A popular modern construction material is graphitic nodular iron, an alloy cast-iron of such high specification that it could justifiably classified as cast steel.
This material has graphite inclusions that protrude at the machined surfaces to create an oil retaining finish of ideal characteristics.
As produced, however, the graphite pockets can be left with sharp edges which can be removed by "reverse lapping " the crank.
"Reverse lapping" is carried out on a lathe by rotating the crank in the opposite direction to normal rotation and using a very fine lapping medium to smooth the surface and thus break the trailing edges of the graphoidal pockets.

"Tuftriding", a high temperature surface treatment that introduces nitrogen to the surface layer, will also result in extending the high performance life of a standard crank.

Crank failures almost always occur at the fillet radii between journals and webs, so careful attention to these areas is critical when preparing the crank for assembly.

The radii should be absolutely smooth and of generous size and can be improved by "roll-peening", a rather difficult but worthwhile process of work hardening and smoothing the standard finish.
Watch out for reduced fillet radii when having a crank reground and, if possible, get the grinders to pay special attention to this detail.

However, the main cause of crank failure, apart from lubrication breakdown, is due to torsional vibration loads imposed by the transmission of uneven power pulses through an irregular shaped component.

Production engine crankshafts are not as fully counterbalanced as they might be, due to cost and weight penalties and consequently, however much special treatment they have, can never truly qualify as racing cranks.

Correctly designed racing crankshafts are designed with full counter weighting for each cylinder assembly and are fully machined all over from high grade alloy steel forgings, thus reducing torsional vibrations to an acceptable minimum.

Crankshaft supports or main bearing caps in current engines are adequate for all requirements to Stage 3 in most cases, but support straps should be fitted to those older units that are still popular for tuning.
The re-emerged but still competitive Austin Rover A-series that was fitted in the Metro was a typical example.

Flywheel lightening.

Often considered vital to good engine tuning and much misunderstood, the process of flywheel lightening is often quite unnecessary.
Flywheel lightening cannot measurably improve power or acceleration.

What it can do is to improve speed and smoothness of gear changing for rally and circuit race cars so that it “appears” to enhance power output.

The engineering explanation of this is quite simple ...
As the weight of individual components is reduced, so the power needed to accelerate them is reduced or, for any given power; the rate of acceleration is higher.

But compared to the total weight of a complete vehicle, even a lightweight single seater racing car, the reduction in flywheel weight is insignificant, so the improvement in vehicle performance is immeasurably small, and gets even smaller as the vehicle weight increases to that of a road car.

So it is unlikely that the cost of flywheel lightening will produce any worthwhile return other than the pleasure of a lumpy and unreliable tick over created by the reduction in “flywheel effect”.

In the event that the decision is taken to lighten the flywheel, the job should be taken to an expert. Considerable skill is required in order top get optimum weight reduction, i.e. as close to the periphery as possible, for maximum effect, but leaving sufficient material to support the ring-gear and avoid distortion due to clutch load and heat dissipation.

Alternatively the production cast-iron flywheel can be replaced by a lightweight steel component.

!WARNING! Indiscriminate lightening of a flywheel can be damaging to your health.

Balancing.

All modern production engines are balanced to a degree, but fine balancing should be carried out as well.


Fig.128

Balance pistons weight for weight including rings and pin.

Balance con-rods so that all big-ends weigh the same to within 4 or 5 grams and correct small ends as near as sensibly possible. (Fig.128)

Dynamically balance crank, including flywheel and clutch, but **not** including the centre-plate. (Fig.129)

Don't forget to mark crank, flywheel and clutch relative positions for re-assembly.

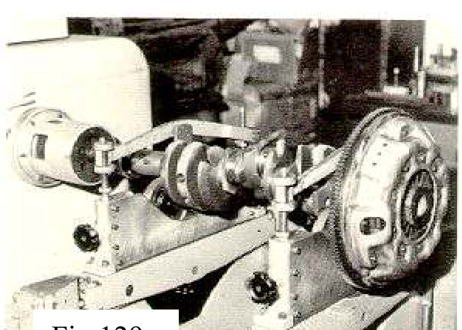


Fig.129

Double check two-stroke crank assembly alignment, together with crankcase seals and gaskets, to ensure high crankcase gas seal efficiency.

In order to avoid write-off damage occurring in racing engines through fatigue failure, vital components such as crank and rods should be crack tested with ultra-sonic or x-ray methods before re-building for the season.

Assembly hints.

Double-check all oil ways for cleanliness, even the difficult ones. They had to be drilled somehow, so there must be an access plug. These may have to be drilled out and replaced, but when you see what comes out of them you'll realise how worthwhile it is.

During assembly, make sure all parts move freely.

Even a four-cylinder bottom end assembly with pistons should be able to be rotated by hand effort alone, without the use of a bar. This is worth a lot of horsepower.

Make sure oil-pump, relief system and filtration system are all in perfect condition. The engine relies on an oil cushion between all running surfaces, particularly bearing shells and pins. Any raw, metal-to-metal contact will cause instant failure.

Composite friction reducing coatings such as Xylar are now available and can considerably lower friction losses if used on all metal-to-metal contact surfaces.
These coatings combine a fine ceramic inclusion suspended in Teflon to give a hardwearing, yet low friction surface.

There is no point in spending money on the latest highly tweaked camshaft or ignition system if you have not paid attention to all of the above details of your engine build.

The odd half-kilowatt/horsepower gain in power here or there can be immediately be lost due to a slightly tight bearing.

And this rule applies to the whole of the rest of your vehicle.
One of my most frustrating searches for lost power was when tuning a car on the rolling road.
The engine had been tested on a dynamometer bed and was known to be giving good power at the flywheel.
Three days of attempting to tune for lost performance resulted in no improvement at all, until we decided to inspect the rest of the transmission.
A slightly bent half-shaft was discovered, just a few microns out of line. Replacing that half-shaft recovered over twelve horsepower and put the expected engine performance right where it should have been.

The moral is... if the car is not performing as you believe it should, don't automatically suspect the engine!

Be suspicious of every component in the entire power transmission train.

Good luck with your efforts!