BALANCING YOUR LOOSE FILLINGS

by Demon Tweaks

Graham, Terry, and Garry gave this newsletter its name based on their experiences and observations of motorcycle-engined race cars. They knew about the temporary loss of feeling in extremities, and blurred vision, as a result of high-frequency vibrations from bike-engined cars. So from those early life challenging experiences came the title ...actually suggested by Peter Addison ... *Loose Fillings.* According to the *Macquarie Dictionary*, 'to vibrate' is to 'move to and fro and up and down quickly and repeatedly.' ... And that describes vibration perfectly!

But why is this phenomenon universal in our bike-engined cars, particularly in singles and V twins? Surely in 2012 we must know enough about engines to eliminate this dreaded vibration. Man has gone to the Moon! So why can't we eliminate the vibes from our bike engined cars? Sadly we can't ... and the following explanation may help us understand why we can't.

Let's imagine we have a 500 speedway JAP engine stripped on the bench. Let's focus on the crankshaft assembly ... because that's where the vibrations come from. It's not the head, or the cylinder, or the crankcases. Those parts are the victims, not the culprit! We can see a pair of flywheels held together by a crankpin, to which is attached the connecting rod and piston assembly. So far so good.

Next question? What is the vital difference between these two items, between the flywheels and the con rod piston assembly?

The answer is simple. When the engine runs, the flywheels go round and round, whereas the rod assembly goes up and down. And there, in a nutshell, is our problem. Whereas the flywheels generate CONSTANT CENTRIFUGAL force, the piston rod assembly creates a totally different RECIPROCATING force. And to complicate things, they do this only twice per revolution at TDC and BDC! So here we have two distinctly different forces at work simultaneously, one constant, the other variable and intermittent.

Now it is very difficult to balance reciprocating mass. In fact about the only way to successfully balance a reciprocating mass is to have an equal reciprocating mass acting in the opposite direction, like in a opposed twin BMW. But our engines are single cylinders or at the best V twins. So what can we do to achieve a reasonable degree of smoothness in our JAPs, BSAs and Nortons etc?

It's a good question. And the answer is ... WE COMPROMISE! WE COUNTER BALANCE THE RECIPROCATING FORCES OF THE CON ROD AND PISTON ASSEMBLY BY UTILIZING SOME OF THE CENTRIFUGAL FORCES OF THE FLYWHEELS.

But you say ...'That can't work! The rotating flywheels generate a constant centrifugal force whereas the weight of the rod and piston act mainly at TDC and BDC! They are two different forces!'

Agreed ... but remarkably, if we get it right, the compromise works tolerably well. Not perfectly, but tolerably. It's a bit like apples and oranges. We have to use apples to balance oranges because apples are all we've got to work with! So with our motorcycle engines we have to use a rotating force to balance the reciprocating forces because that's all we've got to work with.

So ... next question? How much centrifugal force do we need to counter-balance the reciprocating forces in a single or V twin motorcycle engine ? The answer is ... nobody knows exactly ... because it varies with every engine in every installation! So what do we do?

We start by measuring things. First of all we weigh the reciprocating parts. That's the rod and piston. Let's say the piston weighs 20oz. (We'll work in oz because I understand oz). Now the rod.

That's not so easy to weigh because the big end section of the rod is purely rotational. We just want to know the weight of the part that goes up and down. To do this we support the flywheels so the rod is hanging out horizontally, with the little end resting on the scales. Say that weighs 5oz. Now we add the 5oz of the rod to the 20oz of the piston and we get 25oz. So for our calculations we will consider 25oz as being our total reciprocating weight. Now ... how much of the 25oz are we going to add to the weight of the flywheels opposite the crankpin to counter-balance the combined weight of 25oz of rod and piston? Well the logical answer would be 25oz ... that would be a 100% balance factor. And certainly 25oz on the flywheel would balance the rod and piston perfectly. BUT ONLY AT TDC AND BDC. We have to also consider what would happen at mid stroke when there was no reciprocating force taking place? With a 100% balance factor we would have cancelled out the vertical loads only to create the same loads horizontally! So obviously a 100% balance factor won't give smooth running. Nor will a 0% balance factor for the reverse reason. (A 0% factor is NO extra weight on the flywheels to balance the rod and piston).

The answer lies somewhere in the middle. Experimentation has taught us that most racing singles and twins will run tolerably with a balance factor somewhere between 60 and 70%. In simple terms that means we balance 60 to 70% of the reciprocating weight of the rod and piston with extra rotational weight on the flywheels. However depending on bores and strokes, rpm, engine mountings, and a dozen other significant factors, there could be a dramatic difference in vibration in the 60 to 70% range. The best factor can only be found by trial and error. 62% could give good results whereas 72% might result in destructive vibration.

It's as sensitive as that. At no % factor will the engine be in perfect balance through its entire rev. range. Obviously the engine needs to be stripped each time a change is made, because it involves drilling holes in the flywheels, either opposite the crank pin to reduce the balance factor, or around the crankpin to increase the factor.

Every engine has a balance factor to begin with. It's usually around 65% unless someone has previously fitted a heavier crankpin, substituted a steel rod for an alloy one, or used a heavier or lighter piston without considering the previous balance factor.

Left: to check your balance factor you can make a simple jig using two parallel rails which are absolutely smooth and level. This may sound hard but sturdy angle iron, carefully welded to form a frame, held one end in the vice, overhanging the bench and propped up with an adjustable tube will do the trick. When in position, check the rails are perfectly level by rolling a solid bar at least 1" in diameter along the rails. This is more sensitive than a spirit level.

So if vibration is spoiling the enjoyment of driving your car or things are falling off all the time, it's a good idea to find out what your balance factor actually is. Place the flywheels (less piston) carefully on the parallel bars. If the two mainshafts are of a different diameter, make up a steel bush to slip over the smaller mainshaft to equal the larger.

Now irrespective of the existing balance factor, the wheels should always roll along the bars and stop with the crankpin at 12 o'clock. Hang a piece of bent wire through the gudgeon hole in the rod, and gently add weights (Sockets and nuts do fine) to the hook until the flywheels remain static in any position they are placed.

Now remove the wire and weights from the rod and put them on the scale. Let's assume for easy arithmetic the total weight of the wire and weights is 10oz. To this we will add the 5oz weight of the rod. This totals 15oz. If the flywheels remained static on the bars with 10oz hanging on the 5oz rod, we know we must have a 15oz weight opposite the crankpin to achieve that balance. Now, this 15oz is 60% of 25oz (weight of piston and rod). In other words if our tests produced these figures, we could say we are using 15oz of centrifugal weight to counter balance 25oz of reciprocating weight ... which is a balance factor of 60%! If this is a bit hard to grasp don't worry ... just grab a calculator and think about it for a while.

Say we wanted to increase our balance factor to 65%. We would carefully drill holes in both wheels on the crankpin side of the flywheels until we needed 11.25oz hanging on the rod in weights to achieve equilibrium on the bars. And vice versa. To decrease the balance factor we would drill holes opposite the crankpin.

The formula for checking your existing balance factor is easy. Just divide the total weight of your piston and rod, into the combined weight of the rod and weights added to the rod to achieve balance and multiply by 100. In the above example 25 divided into 15 equals 0.6 multiplied by 100 equals 60%.

However despite all the above technical stuff, reducing vibration is essentially a trial and error exercise. 'Balancing' a single engine is a misnomer. We are really only making the best of a bad situation.

Finally ... irrespective of balance factors, it is vital to have our engines mounted as rigidly as possible. Make sure all engine bolts are tight, and that slotted engine plates are not worn wider than the bolts. If they are, try filing them out and fitting larger diameter bolts. Try a head steady to the chassis or a roll bar ... It may or may not help ... but it's worth a try. Knowing current balance factor is essential if you want to change it. As a guide if it's lower than 60% raise it. If it's higher than 70% try lowering it. If it's tolerable in the rev range you are using, best leave it alone. No engine is smooth throughout its entire rev range and it's easy to to make it worse.

Apart from using up precious horsepower, vibration is destructive. It breaks things. Then the car stops. And the race is over. And it's quite possible you could shake loose a filling ... and swallow it. And you can bet it will be ... the gold one!

POSTSCRIPT
Demon Tweaks' notes on engine balancing are mostly correct, except that he missed emphasising one all-important point.

It's this. ......WHEN AN ENGINE VIBRATES, THINGS INSIDE THE ENGINE FLEX...AND IF THEY FLEX ENOUGH TIMES THEY BREAK.

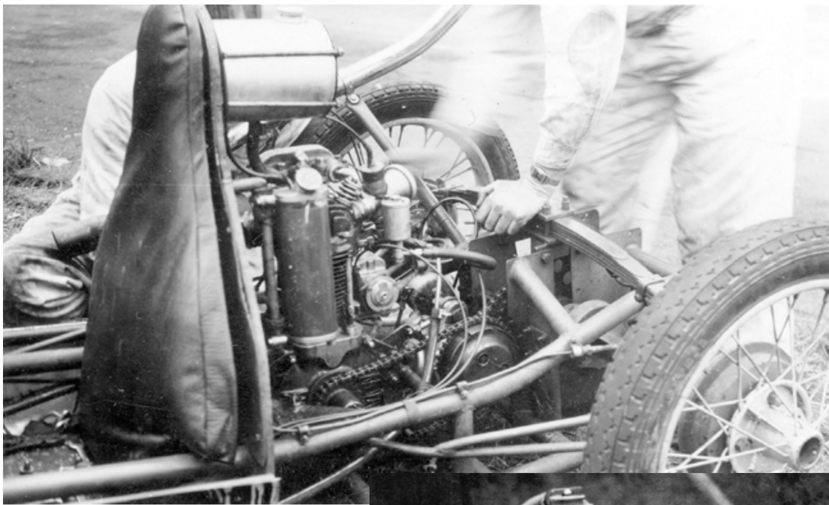
It has taken Tweaks and I twenty years of breaking crankpins and regularly replacing timing and drive side main bearings to fully comprehend the above self evident truth.

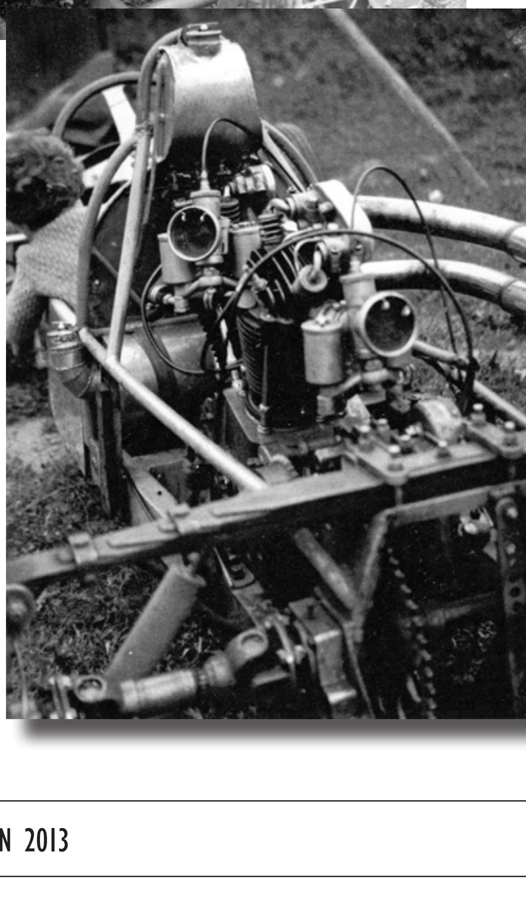
The recent installation of a new flywheel assembly in our 1100 MK9 Cooper JAP using parallel pressed in crankpin and mainshafts, all with 4 thou interference and with no nuts at all, has been a revelation.

Using the same 65% balance factor as before, the new motor spins freely to 6000rpm like a turbine. (That's maybe a slight exageration...). Conclusion..........

THE NEED FOR RIGIDITY OF THE FLYWHEEL ASSEMBLY IN REDUCING DESTRUCTIVE VIBRATION AND CONSEQUENT BREAKAGES CANNOT BE OVERSTATED.

Chas McGurk





THE BUSINESS END

Rob Saward kindly sent in the above picture of the engine of the Reg Hunt Special, one of the earliest and most succesful of Australian 500s. The simplicity and compactness of the set-up is quite clear. Photo by Jack Nelson.

Ditto the picture, right, of the Walton-JAP in its original 8-80 twin sprint form before Bruce decided to fit a 500 and go racing. The editor has been building a replica of this engine for the car and hopes to have it running again this year.