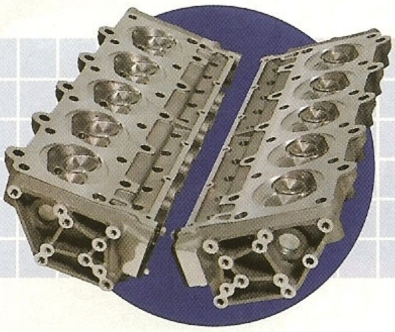
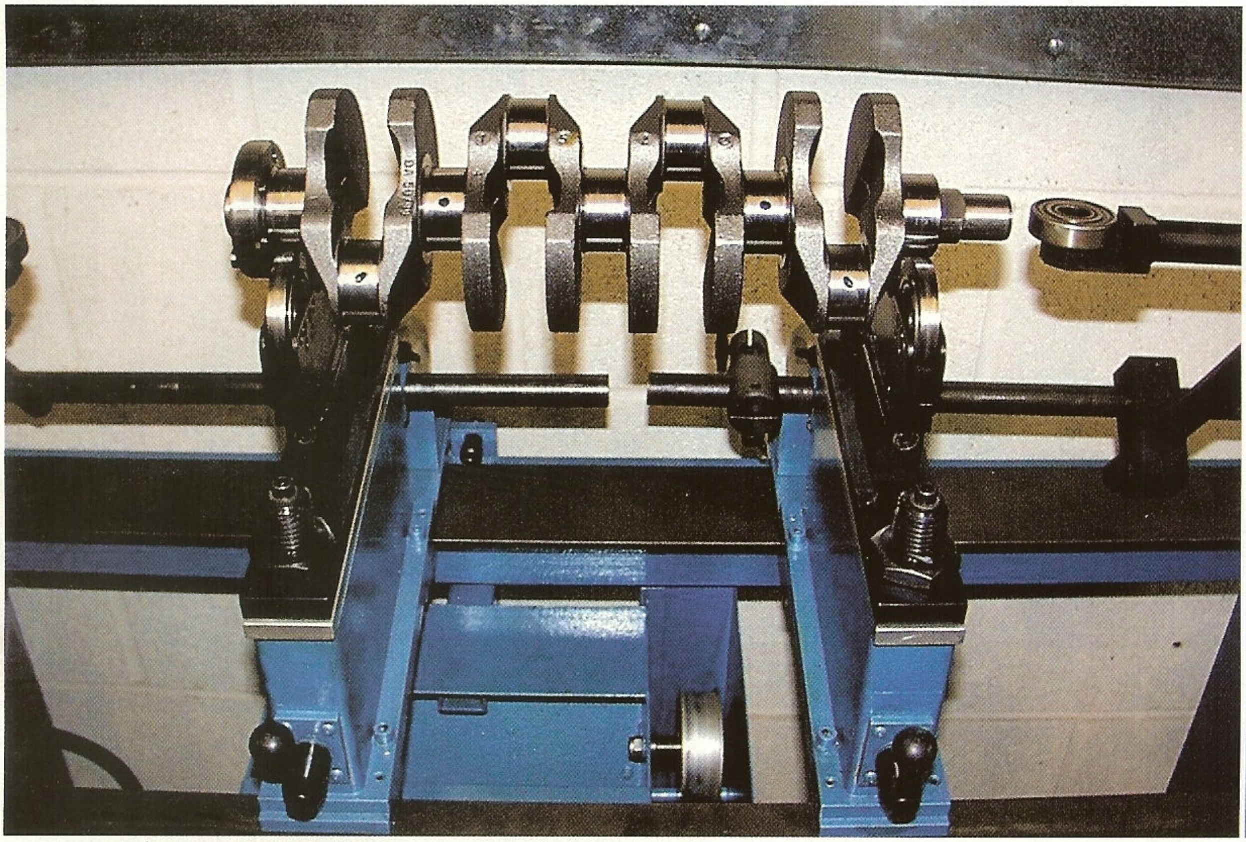


How it works

WORDS & PHOTOGRAPHY_DAVE WALKER



Balancing act: a crank balancing machine in use at Steve Smith's Vibration Free company. In order to check the dynamic balance of a crank it needs to be spun up on one of these. Sensors are placed on either end of the bed holding the crank to check for movement due to imbalance

Do you know the difference between static and dynamic balance? Do you really understand what a balance factor is? Neither did I. But I do now after a visit to a company called Vibration Free, which is run by Steve Smith.

I had been told that Steve was *the* man in the balancing world, and that he worked on a farm in the middle of nowhere with the blinds down to protect his balancing secrets. I have to say that talk like this worries me. Generally there are no secrets in the engine world and if someone thinks he knows something that the manufacturers do not, then maybe he also has silver foil about his ankles to protect him from the control rays emanating from the planet Mars? I'm sure you've got the picture.

Actually I couldn't have got it more wrong. When I finally met Steve he turned out to be one of the most down to earth blokes you could wish to meet. His business is vibration, not balancing, and he takes on anything from an engine to a printing press – you could say anything that moves when it isn't supposed to.

The Basics

Staying with engines and starting with static balance Steve explained that you can put a simple single cylinder crankshaft on a knife edge and then balance it until it will stop in any position. It's like balancing a wheel so that it stops in any position, rather than the heavy spot always ending up at the bottom.

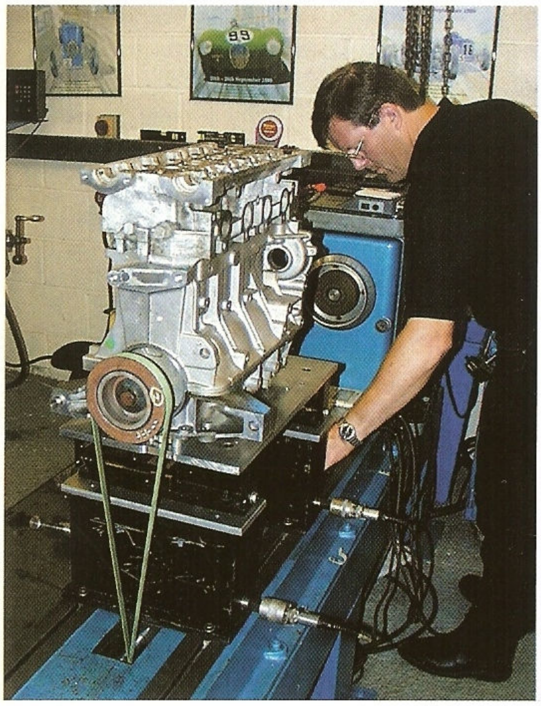
To balance the wheel you can either add weight opposite the heavy spot, or remove the heavy spot, the end result in terms of balance is exactly the same. The problem with static balance is that the wheel can still wobble.

If you have pictured the wheel in your mind from the side view, rotate your view in your mind and look at it from above. In order to obtain your static balance you might have added a weight exactly opposite the heavy spot, but off to one side. Now you have two heavy spots opposite each other when viewed from the side, but to the left and right when viewed end on.

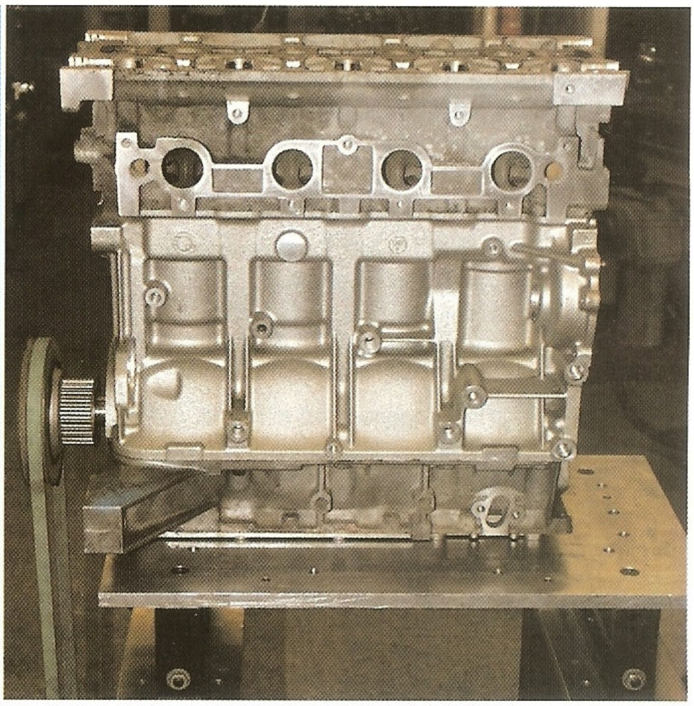
This left/right combination results in a wobble when the wheel starts to rotate at speed. This is called dynamic balance (actually, imbalance in this case). To get a clearer picture think of static balance as a view from the side and dynamic balance as a view from above – remember, we live in a 3D world.

Now apply this theory to a four-cylinder crankshaft. It can be statically balanced but if the two heavy spots are opposite each other at either end of the crank it will wobble when it starts to rotate. The way to make this discovery is to spin it up and measure the movement on a balancing machine.

Engine Balancing



Balance of power: a K Series on Steve's engine balancing table. To balance the entire assembly he puts it all together, without the rings to avoid friction, then spins up the engine. He then measures the forces with sensors



Steve Smith used to work for a company making balancing machines, then he set up as a specialist in vibration having bought some of the best machines that he had previously sold. The first thing to understand about balancing machines is that they do not measure balance, they measure movement. You sit the component to be balanced (crankshaft in this case) on a moveable platform and spin the component up. If the bed moves it is due to imbalance and the amount of imbalance is measured by sensors recording the movement.

I'd always imagined that the faster you spun the crankshaft the more it would move. That's not the case. In fact the level of movement stays exactly the same at all rotational speeds. This is because the force increases by the square of the speed in all directions. The force pulling the crank towards the sensor moves to the opposite side faster as you increase rotational speed. The result is a level of movement that remains the same.

This is very convenient because it means you can balance a crank at a few hundred rpm and it remains in balance at 10,000rpm. The trick is to measure the movement very accurately and for this you need some trick sensors and a computer. Having measured the movement you then need to know exactly where the out of balance force is located. A piece of reflective material is stuck to the crankshaft as a position locator and a light sensitive optical device picks this up. Connect the optical device to the computer reading the load cells and you have not only the amount of deflection but also the position.

By putting sensors at either end of the bed holding the crank you measure dynamic balance as well as static. Basically if it doesn't wobble when you spin it up, it is in balance. What the computer tells you is how out of balance the thing is and where that out of balance force is located. Then you get the drills out and start putting it right.

Steve said that most manufacturers make the end counterweights in a crank heavier than the rest so that you can drill them out for balancing. But so far we have only looked at the crankshaft in isolation, what about the flywheel, pistons and rods? The flywheel has a major influence on balancing the crank basically because it unbolts. If it doesn't bolt back on in exactly the same place the balance will be affected. Steve did some basic calculations that showed an offset of just 0.001in, with a 5kg flywheel, put the whole shooting match out of balance by 2000g/mm. This is why flywheels are located with a central boss, or dowel pins, or both – it has nothing to do with stopping the flywheel falling off!

Numbers

Steve works in Metric so that's what we will stick with here. The numbers relate to how much weight you have and how far it is spinning off centre. A 1g weight which is spinning in a circle at 100mm from the centre is a force of 100g/mm. Bear in mind that 1g is not a lot of force, I can blow on my scales and record 10g without really trying.

To get a handle on what really counts Steve told me that a typical stock balance factor for a crank is within 200g/mm. Formula 1 engines are balanced to 26g/mm, while the K Series engine has a factor of 100g/mm, which is pretty tight for a production engine...

Once the crankshaft and flywheel are in balance you next have to consider the connecting rods and pistons. Balancing the pistons and rings as a set is straightforward enough, you just need accurate scales. Some

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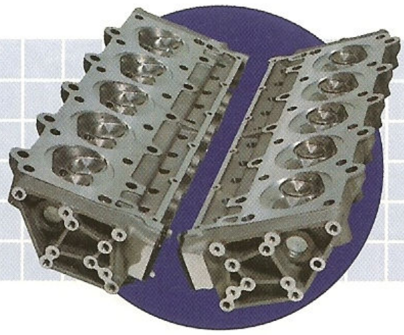

How it works

people balance to remarkable degrees but having once scraped the carbon off a piston and weighed it at 8g I felt that one gram was close enough. Steve argues that the carbon should be the same on each piston but for a race engine it shouldn't be there in that sort of quantity in the first place. It's a fair point.

The connecting rods are another story. I confess to just balancing rods in the same way as pistons, just equalising the weights. Lots of people do a better job by balancing end to end. You make each little-end weight the same and each big-end. The problem is doing the measuring. Scales with supports have friction at the pivot point, springs can be dangled from the ceiling and angles of dangle measured but it is very much a trial and error method.

Steve has come up with a balancing system for rods which not only gets them right from end to end, (top to bottom) but also puts the balance point in the same place from side to side. He did tell me how it is done but this is not something he wants to pass on to other balancing companies so you will have to take my word for it that this system is very clever and also very accurate.

Class Act

Engines with opposing pistons, that is, one up for every one going down, are called class one balance. Odd engines like single cylinder or V6 and V8 are called class two.

The simplest class two engine is a single cylinder. If the counterweight in the crankshaft is exactly the same as the combined weight of the piston, con rod, rings and bearings then the balance factor is 100 per cent. This sounds wonderful in that the balance must be perfect, and it is at TDC and BDC. But, and it's a big but, when the crank is at 90-degrees the counterweight no longer has all the piston and rod weight to counter its force. The result is that it tries to escape out the side of the crankcase. Basically your engine does not wobble up and down, but it vibrates like hell going forwards and backwards.

The best you can do with this engine type is compromise the balance factor to distribute the vibration as best as the frame holding it can cope with. If the frame is very strong in the vertical plane then the balance factor can be reduced from 100 per cent, perhaps to 65 per cent. It's a question of experimenting with an engine that is never going to be in balance.

V6/V8

Now it gets complicated. The conventional way of balancing V engines is to clamp a weight onto the crankpin to represent the piston, con-rod, small end, etc. Traditionally engine designers use a percentage of the components' total weight. Problem number one is getting all your clamp weights exactly the same. Steve has found that if you rotate the weight around the crankpin you get a different reading because the CG of the weight isn't always centred about the crankpin. In other words, the clamp weight is not in balance.

Being a practical man rather than a theorist, Steve just assembles everything up in the block and bolts it to the balancing table. He then spins the engine up and finds the out of balance forces by measuring, rather than calculating. He uses the pistons minus the ring packs to avoid friction but glues the ring pack weight to the centre of each piston. It's a very simple answer to a very complicated problem.

In order to tackle a V engine in this manner you do need a balancing table big enough to take the whole engine plus a motor drive with the power to drive it. Steve has all the kit for balancing and he also has portable equipment for site visits. I may well get him to come and balance the rolling road at a later date – perhaps when I run up his Sunbeam Alpine.

Incidentally, it gave me a lot of confidence in Steve's work to discover that he is a racer. He has campaigned his Sunbeam Alpine for many years now and is about to switch to a Ford Mustang. His workshop boasts a two poster ramp which can only be used for the race car. Now you don't spend that sort of money on kit if you are not 100 per cent enthusiastic about your motorsport.

Steve Smith at Vibration Free can be contacted on: 01869 345535 or 07774 468726 or check out the website at www.vibrationfree.co.uk

Balanced personality: Steve Smith is well aware of the needs of his company's motorsport clients – he campaigns this Sunbeam Alpine (above). A load cell to record movement (below left)