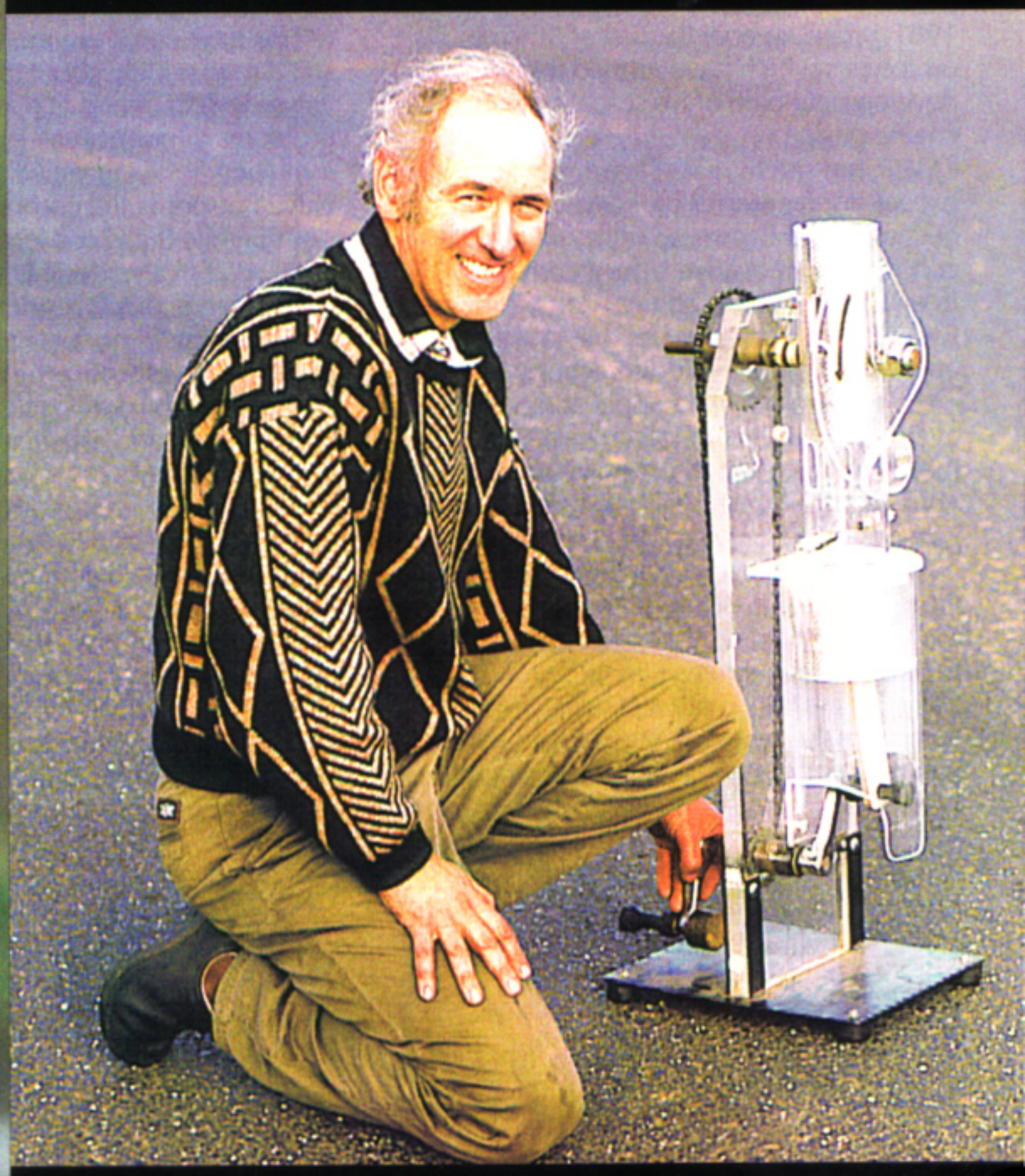
In yet another Australian technological breakthrough original thinker Malcolm Beare has developed a six-stroke engine based on a Ducati Pantah. Alan Cathcart has the inside story.

The capacity for original thought is a mark of genius, often accompanied by an innate determination to prove the worth of those ideas in practical form.

In the engineering arena, such a combination has delivered us countless technical advances in the past century — such as the diesel engine, pneumatic tyres, windscreen wipers and four-wheel drive, just to throw out a few examples at random. The practical application of these inventions has benefited mankind beyond measure.

Often, though, such advances have been achieved against the odds, in the face of reactions ranging from disinterest to scorn and even derision. Almost every engineer from Michelangelo onwards has had to deal with dismissive responses to new ideas, usually on the basis that if something is totally different from the perceived norm, then it obviously can't be any good.



On that basis, we should all today be riding single-cylinder side-valve motorcycles, fitted with girder forks and drum brakes. Daring to be different is an essential adjunct of original thought.

BUSH ENGINEER

Malcolm Beare may be no Michelangelo, but the 47-year-old Australian wheat farmer is indeed an original thinker, in spite of a day job apparently so far removed from the world of mechanics.

For the past 17 years, while working his 1300-acre spread in the sun-drenched outback of South Australia, Malcolm has had plenty of time in the midst of his agricultural labours to reflect on various aspects of his alternative profession: bush engineer.

The Beare Essentials

Like so many others at the sharp end of engineering — men who actually use the machines others design — Beare has had ample opportunity for original thought.

"City engineers usually spend their time trying to get more performance out of existing designs," says fellow-Aussie Ian Drysdale, creator of the 750-V8 hyperbike, and a vocal supporter of Beare's ideas. "Bush engineers however will often sit back and ponder as to why something was designed like that in the first place, then figure out a way of doing it better.

"Because they spend much of their time repairing badly designed farm machinery — quite often redesigning it as they go — this creates a reluctance to take anything for granted, which leads in turn to original ideas."

A BETTER WAY

Finding a better way for the motorcycle engine has been Beare's mission in life since 1981, when he built the first of the five prototypes which have formed the development path of his so-called six-stroke engine design.

Well, not strictly a six-stroke, perhaps — except insofar as four plus two equals six, because what Beare has done is to create a completely innovative hybrid design of internal combustion engine, combining a two-stroke top-end with a four-stroke bottom-end (really, more a middle section).

Various two-wheeled applications of this avantgarde bush technology have resulted in the latest proof that Malcolm is smarter than your average Beare, with a V-twin Ducati-based BEARS/Sound of Thunder racer incorporating Beare's self-built twin-shock frame clothed in Vee Two Alchemy bodywork the first multi-cylinder application of this innovative technology.

The bike is fitted with a 90-degree V-twin version of the Beare six-stroke engine format which uses the stock Ducati bottom-end.

The chance to ride the Beare 6S-V2 at Melbourne's Calder Park race track as an interlude to testing the Drysdale 750-V8 and Hunwick Hallam X1R Superbike not only offered a fascinating hands-on examination of some genuine Antipodean original thought, it also underlined the continuous flow of new ideas from the can-do country of modern motorcycling. The 6S-V2 is yet another innovative machine from the reservoir of engineering talent Down Under.

THE BASIC CONCEPT

Okay, what's it all about, Daddy Beare?

"I began working 17 years ago on a stratified-charge opposed-piston two-stroke design," recalls Beare, "but after building a couple of prototypes I realised flow control was a problem, with too many ports going everywhere.

"So I simplified it into a six-stroke, with the objective of improving efficiency and increasing performance compared to a conventional engine by overcoming the drawbacks of poppet valves. I wanted to apply rotary valve technology to a four-stroke engine.

"I do have some engineering background, so I'd read widely about the various rotary valve designs aimed at overcoming the problems of poppet valves in terms of inertia, inhibiting flow and especially the exhaust valve hotspot in the combustion chamber.

"But while the Cross, Aspin and various other rotary valve designs were advantageous because they didn't restrict flow or absorb as much energy as poppet valves, they still had significant overheating problems of their own, with associated drawbacks in lubrication, oil consumption and especially sealing.

"Of course, a two-stroke doesn't suffer from such problems because it has no poppet valves — so I decided to try to resolve these drawbacks by taking the basic components of a rotary disc-induction two-stroke engine, and grafting them on to a four-stroke engine to produce the best of both worlds.

"After a great deal of work and experimentation since building my first six-stroke prototype in 1990, I truly believe we've refined the concept, proved its reliability and established its worth, so now we have it fully patented — even in the USA.

"It's ready for commercial use in the variety of applications it obviously lends itself to, including motorcycles, stationary engines and, because of the exceptional torque at low rpm, propeller aircraft engines."

TECH TALK

Could this bush-engineered Better Way perhaps be the mechanical equivalent of a Saxon Saxtrack or BMW Telelever alternative chassis concept for volume production?

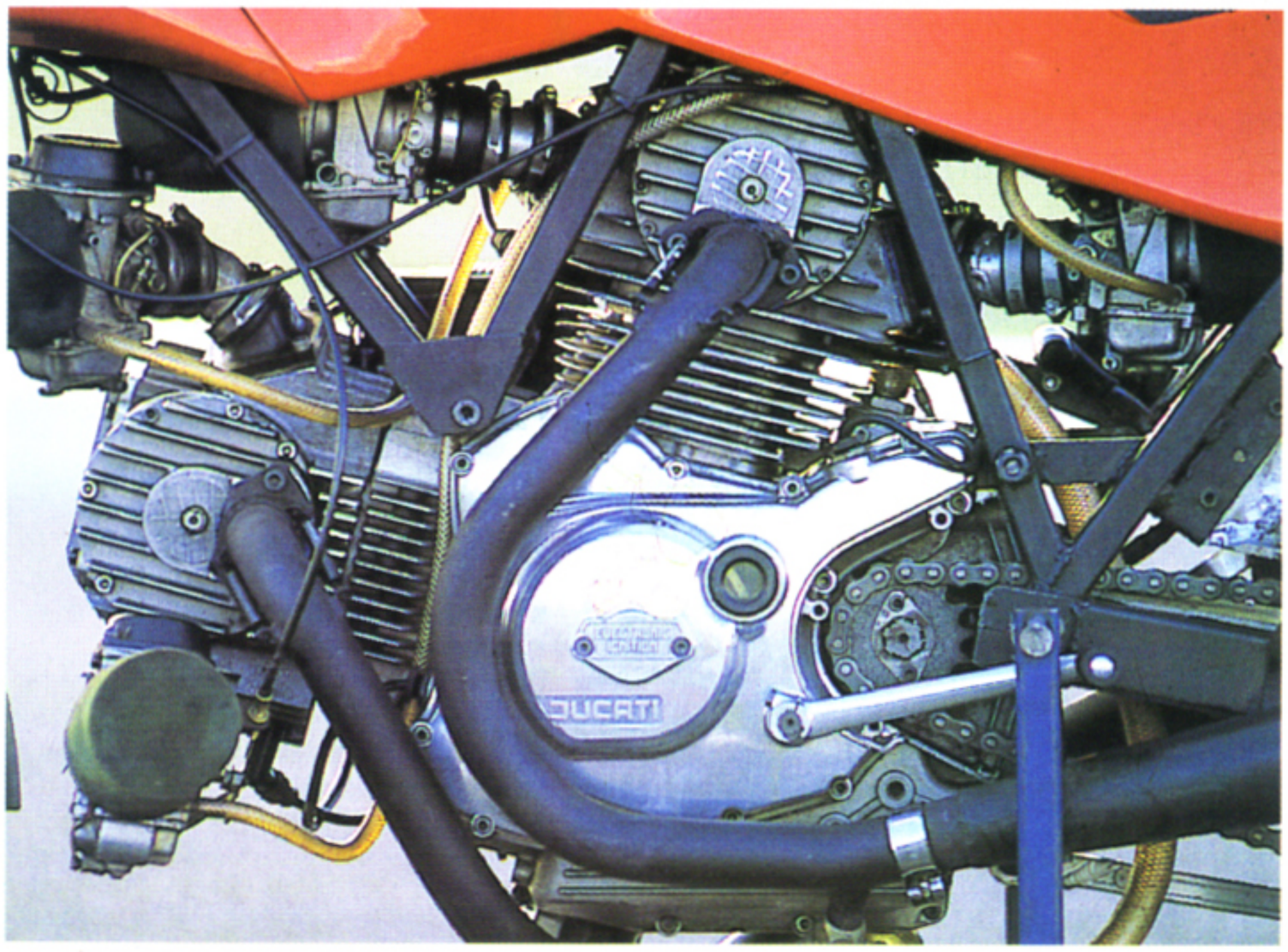
Well, let's see what it consists of. Below the cylinder-head gasket, everything is conventional, so one advantage is that the Beare concept can be transplanted on to existing engines without any need for redesigning or retooling the bottom-end, thus reducing start-up and manufacturing costs. But above there, he's thrown away the cylinder-head, complete with poppet valves (what, no desmodromics on the Beare Ducati?).

To replace the camshaft and associated valves, Beare has retained the cam drivebelt and fitted an ultra short-stroke upper crankshaft complete with piston, which the belt drives at half engine speed, just as it previously drove the camshaft.

This piston slides up and down in a sleeve, past inlet and exhaust ports set into the cylinder wall, very much like on a two-stroke. These are all exposed during both inlet and exhaust strokes. Continuing the two-stroke analogy, the two 35mm Mikuni CV carbs mounted on each cylinder of the Ducati-based V-twin feed mixture into it via a reed valve block, thus preventing exhaust gases exiting through the inlet port.

TAKE A DEEP BREATH

At the other end of the upper crankshaft is a



Left: two-stroke or four-stroke? There's no mistaking the 'Weird Harold' looks of the 6S-V2.

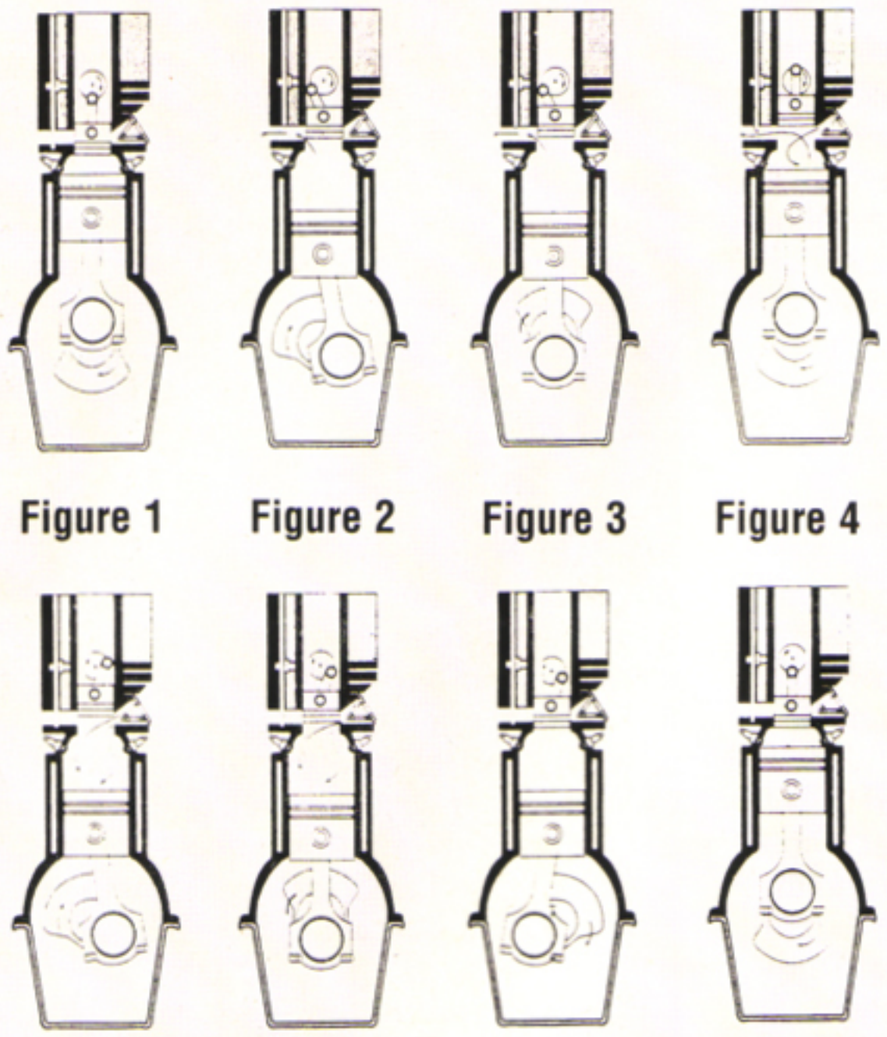


Figure 1 **Figure 2** **Figure 3** **Figure 4**

Figure 5 **Figure 6** **Figure 7** **Figure 8**

Fig 1: TDC combustion.
Fig 2: 60° BDC, piston port opens, allowing blowdown of exhaust.
Fig 3: BDC beginning of exhaust stroke.
Fig 4: TDC, end of exhaust stroke, beginning of intake. Rotary disc valve cuts off exhaust at any desired set degree, approx. 10°@TDC. Intake is automatic whenever pressure differences dictate.
Fig 5: Continuing dictate.
Fig 6: BDC intake almost closed.
Fig 7: Closed at approx. 40°@BDC by upper piston.
Fig 8: Now back to TDC compression.

two-stroke type rotary disc-valve that regulates the exhaust timing, cutting off the exhaust flow at the appropriate time to stop the gases returning into the cylinder, thus creating sub-atmospheric pressure during the inlet cycle.

This being its only function, the rotary valve has only a light load on it, reducing lubrication and sealing problems — though the close tolerances entailed did lead to warping problems with the stainless-steel disc Malcolm used on his first six-stroke design, based on a Honda XL125 farm bike. Replacing this with a cast-iron one on his next version, based on a Yamaha XT500, cured this problem at the expense of unnecessary extra weight, but the Ducati uses hardened anodised aluminium discs, which work well.

Then, during the compression and expansion strokes, the upper piston seals off both ports, leaving the pressure contained between the two pistons, with the lower one a conventional flat-top three-ring design, while the conical upper one (so shaped to aid gas flow during both inlet and exhaust cycles, by guiding it towards the ports) has two rings — one compression, one oil.

GREEN MACHINE

In the combustion phase, twin sparkplugs provide ignition via the stock Ducati CDI and a pair of Harley coils — one per cylinder — and not only does the engine run on pure petrol (no need to add oil, because all required surfaces are positively lubricated, in spite of the application of two-stroke technology), it's also happy on low octane unleaded fuel.

Obviously, there are no valve seats to suffer from a lack of lead, and Malcolm says the compression ratio can be increased significantly from the Ducati engine's 10.6:1 quite safely because of the lack of hotspots, without problems with detonation.

Okay, so the Beare six-stroke has impeccable green credentials, but that just gives a hint at the commercial and technical advantages Malcolm seems justified in claiming for his design.

The obvious benefit in strict engineering terms is that by eliminating poppet valves on a four-stroke, you also remove any chance of valve float and thus of bending them.

Okay, okay. I know this was once a desmo, but this is a much more cost effective way of achieving this than expensively machining a set of closing rockers for all the valves in a cylinder-head. This is quite apart from the unwanted inertia such a system still entails, which in turn implies a far higher safe rev limit for the six-stroke — 28,000rpm in theory, given the half engine-speed operation of the upper crankshaft, and the fact that GP reed-valve two-strokes peak at 14,000rpm.

PREDICTED POWER

But Beare says the rev limit, as on such two-strokes, depends only on what the main (conventional) crankshaft is able to bear — he's arbitrarily limited the Ducati-based 6S-V2 to 9000rpm for that reason, at which point he says 86ps is delivered at the rear wheel, according to computer predictions. There aren't too many Dynojet rigs in the Australian outback!

Comparisons are hard to make, because of the difficulty of determining the exact cubic capacity of the 6S-V2's six-stroke engine. What began as an elderly Pantah V-twin now has a total 744cc of compression/expansion volume, and 602cc of inlet/exhaust volume, and instead of absorbing about 10 percent of engine power in driving the camshafts, the cambelts now deliver about nine percent net power back to the main crankshaft after combustion, via the upper, conical porting piston.

But if you figure that a '97-model Ducati 900SS delivers 73ps at the rear wheel in stock form, that's quite an impressive claimed power increase. But there are other, much more significant apparent spin-off benefits from the Beare design.

SPINOFF BENEFITS

First of these is fuel economy. Beare claims

Above: Malcolm Beare gives Sir Al the drill at Melbourne's Calder Park.

his engine is 35 percent more economical at low revs/throttle openings than an equivalent conventional engine, and 13 percent less thirsty at high rpm/full throttle.

By definition, therefore, there are reduced hydrocarbon emissions, because you're using less fuel to achieve the same performance. Next, there's improved torque at lower revs — on both his Yamaha and Ducati-based prototypes, Beare discovered the six-stroke version produced the same torque as the four-stroke conventional motor 1000rpm lower down the rev scale, as well as producing exponentially more torque as revs rose.

But in a commercial application, perhaps the most attractive benefit is the reduced number of moving parts, compared to a four-stroke design — not as few as a two-stroke, but what you appear to be getting here is improved performance and torque, coupled with the inherent advantages of a four-stroke, on the cheap.

Because those fewer moving parts mean reduced manufacturing costs, and the fact that the upper two-stroke piston is driven at half engine speed (so it should have increased engine life over the lower four-stroke one), the Beare engine should experience reduced maintenance and component replacement costs.

TIME TO FIND OUT

It all sounds promising. Time to find out for myself, so while I hopped off the 750-V8 to let the Drysdale equipe carry out some R&D adjustments, Beare fired up the 6S-V2 to give me a hands-on impression of bush engineering at its best.

The Beare V-twin may appear a little rough at the edges, as it's obviously been built to a budget as well as acting as a rolling testbed for continuous modification. But let's ignore the looks and worry about the sizzle.

To start with, it has an absolutely unique engine sound, like nothing else I've ever heard in my life, not even a Norton rotary racer. You can clearly hear the ring-ding two-

The Beare Essentials

stroke signature tune above the trademark four-stroke V-twin boom from the twin megaphone exhausts.

Two engines in one — uncanny.

In fact, the engine seems very loud, but that's apparently only because the megaphones of this BEARs racer are unsilenced. In fact, says Malcolm, there's much reduced mechanical engine noise from the engine, because of the fewer moving parts.

FURTHER BENEFITS

"We silenced the exhaust on the XT500-based bike considerably," he says, "and the result was you could hardly hear the engine running. Without any tappet noise, it's remarkably silent — and that's in spite of being air-cooled, as all my prototypes have been.

"Heat dissipation isn't a problem, so while it'd be easy to water cool the engine by drowning the combustion chamber, there's honestly no need for the extra complication on grounds of noise or thermal efficiency.

"But one area I haven't done any work on is exhaust development — the six-stroke format would certainly lend itself to expansion chamber exhaust technology borrowed from performance two-strokes."

How so?

"We could overfill the combustion chamber during the intake stroke, trap a small portion of the mixture in the first two or three inches (50-75 mm) of the exhaust pipe, then use back pressure to force it back in just before the upper piston closes off all the ports.

"This could add significant performance, but it's an area I haven't experimented in — yet."

SIGNIFICANT ASSETS

Leaving aside the difficulty of calculating the six-stroke's engine capacity on an equivalency basis so it can go racing (the Norton rotary suffered a comparable problem), the Beare BEARs bike gives a taste of what's in store when he does so.

Riding it at Calder Park for a dozen laps showed up three significant assets for the six-stroke engine and one, maybe two negatives — one of those being the unreasonably loud exhaust noise, which I'll reserve judgement on but appears not to be an issue.

The other question mark was over the power curve. While there's no doubt it revs reasonably high by four-stroke standards, there seemed to be no direct benefit in doing so — there was no more power up high at, say, 8000rpm than there seemed to be 2000 revs lower.

Malcolm Beare says this is a function of cylinder porting and perhaps fuel mixture — the old two-stroke imponderables, here applied to a four-stroke based engine.

After the test, he discovered that the Mikunis were underjetted, and also believes the engine is over-carburetted — a theory I'd go along with, especially given the difficulty of balancing two carbs per cylinder correctly. He also wants to play around with the porting.

PROVING ITS WORTH

But Beare has so far concentrated on proving the essential worth of his six-stroke concept, and refining its basic application. Now that he's built the racer, he can worry about the performance angle.

One thing he certainly doesn't need to worry about is torque, which together with the crisp, responsive throttle pick-up and the reduced vibration — even compared to a smooth-action 90-degree V-twin — are the three strong points of the six-stroke engine.

The Beare engine is unbelievably muscular in terms of torque, and from very low revs, too. Ironically, you especially appreciate this because Malcolm's evident talents as a bush engineer are not matched by those of a tube-bender. The square-tube nickel-steel chassis is pretty awful in terms of handling, especially with a pair of oversprung Koni shocks at the rear.

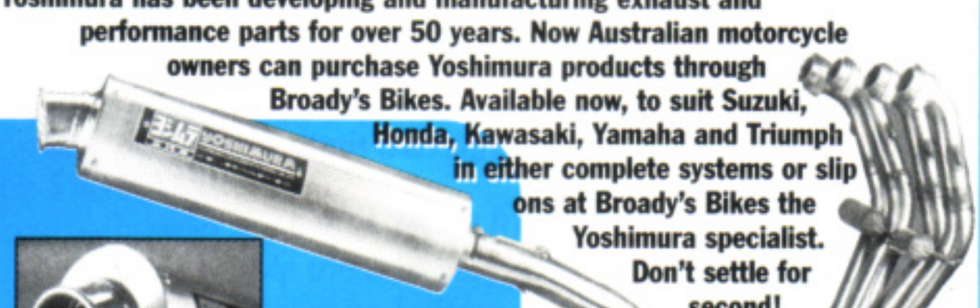
The stock Ducati frame would have been a better bet, except on that you need to drop the engine out to remove the top-end of the rear cylinder, which you can't do even with the original desmo cylinder-head in place, let alone the wider Beare arrangement.

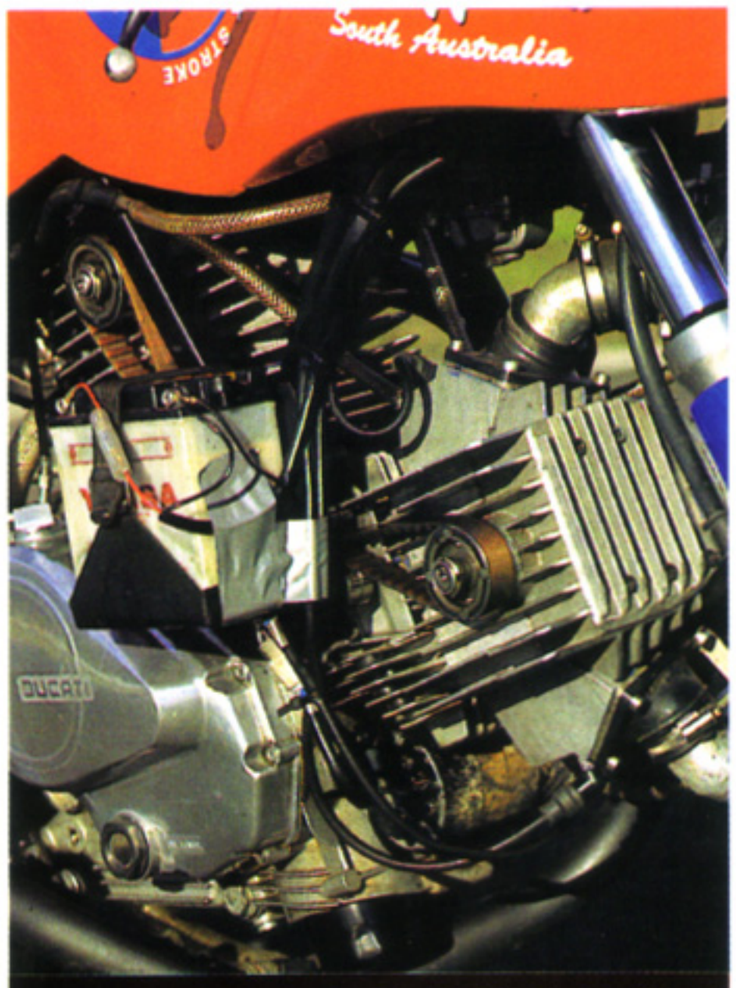
But the fact that the bike jumps around over bumps and doesn't steer very well actually helps you appreciate the engine's responsiveness, because you may need to back off the throttle in, say, the middle of the Calder Park chicane to allow the chassis to recover its poise.

PREPARE FOR A SURPRISE

But when you then get on the gas again — get ready for a surprise. Not only is there instant response when you twist the wrist, there's tractor-pulling torque at seemingly whatever revs the engine's turning over at — even as low as what felt like 2000-3000rpm or so (there's no revcounter fitted, but having ridden the odd Ducati V-twin down the years, I may claim to have a rev-sensitive seat of the pants).

There's also no transmission snatch at very low revs, indicating a responsive, torquey engine, while the way it pulls hard from way down low bears all the hallmarks of a long-stroke engine design, whereas the opposite is in fact the case. The lower 'four-stroke' crankshaft assembly has 86mm x 57mm dimensions, while the upper 'two-stroke' ones measure 60mm x 25mm. Yet the inherent nature of the Beare engine is one of a torquey





SPECIFICATIONS

BEARE DUCATI

ENGINE

Engine type ..... Air-cooled, opposed-piston, rotary-valve 90-degree V-twin
Bore x stroke ..... 86mm x 57mm upper/main volume; 60mm x 25mm lower/secondary volume
Displacement ... 744cc compression/expansion volume; 602cc intake/exhaust volume
Compression ratio 10.6:1
Ignition ..... Dual ignition with Ducati CDI/two Harley-Davidson 12v coils
Carburation ..... Four x 35mm Mikuni CV
Starting system ..... Electric
Lubrication system ..... Wet sump

TRANSMISSION

Type ..... Five-speed, constant mesh
Primary drive ..... Gear
Clutch ..... Multi-plate oilbath
Final drive ..... O-ring chain

CHASSIS AND RUNNING GEAR

Frame type ..... Square-tube nickel-steel spaceframe
Rake ..... 23°
Trail 98mm
Wheelbase 1400mm
Front suspension. ..... 40mm Yamaha telescopic forks
Rear suspension ..... Fabricated steel swingarm with twin Koni shocks
Front/rear wheels ..... Yamaha three-spoke cast-alloy 3.50 x 17 front, 5.50 x 17 rear
Front/rear tyres ..... Dunlop 120/70VR-17 front, 160/60ZR-17 rear
Front brake ..... Twin 300mm Yamaha steel discs with four-piston Yamaha calipers
Rear brake ..... 220mm Suzuki steel disc with two-piston Suzuki caliper

DIMENSIONS AND CAPACITIES

Dry weight (claimed) 153kg
Weight distribution 51/49%

PERFORMANCE

Maximum power (claimed) ..... 86ps at 9000rpm
Maximum torque (claimed) ..... 5.6kg-m at 6000rpm

MISCELLANEOUS

Test bike supplied by. Malcolm Beare, Kensington Park, South Australia. Fax (08) 8373 5022
Year of construction 1997

slugger, belying these measurements.

Allied with the so-responsive pick-up and a wide spread of usable power that seems to be the same at high rpm as it is way down low, this makes the bike ridiculously easy to ride. You hardly need to use the gearbox at all — just park it in top gear and ride it like a semi-automatic.

Even backing off the throttle in the middle of a turn to let the chassis straighten up and fly right doesn't require you to hook down a gear — just crack it open when you're ready, feel the front wheel start to aviate on you, and — drive.

INESCAPABLE CONCLUSIONS

My hands-on assessment of the Beare six-stroke leads to some inescapable conclusions, one of which is that in its present form, this isn't a performance concept. There doesn't seem to be the power on tap that the dyno charts say there should be, nor does revving the engine seem to deliver this.

But while I'm sure some experimentation with porting, exhaust pipe design, airflow and carburation might rectify this, that's not been Malcolm's priority to date.

Instead, what we have here is an elegant, hybrid engine design with the advantages already recounted above, allied with good squish, the ability to run radical bore/stroke ratios, quiet mechanical operation, and no exotic materials such as ceramic coatings or costly alloys required, nor complicated machining operations.

As such, the Beare design must surely be worthy of serious consideration for powering low-cost transportation in both developed and developing countries, where expense of manufacture, fuel economy and torque (delivering carrying capacity for people and/or goods) are variously all paramount factors, yet where emissions are a major issue, too.

BEST OF BOTH WORLDS?

The recent trend away from cheaper two-stroke power in favour of more costly but cleaner four-stroke engines in both Europe, Japan and South-east Asia makes a concept like the Beare six-stroke which offers the best of both worlds worthy of serious consideration by volume manufacturers.

I'd say Malcolm would be well advised to start teaching himself Japanese or Italian during those long, hot days working the Aussie outback. It'll help in making the presentations he should be embarking on in the next couple of years, in pursuit of the licencing deals he's chasing for his six-stroke better way!

Alan Cathcart
Photos: Helmut Mueller