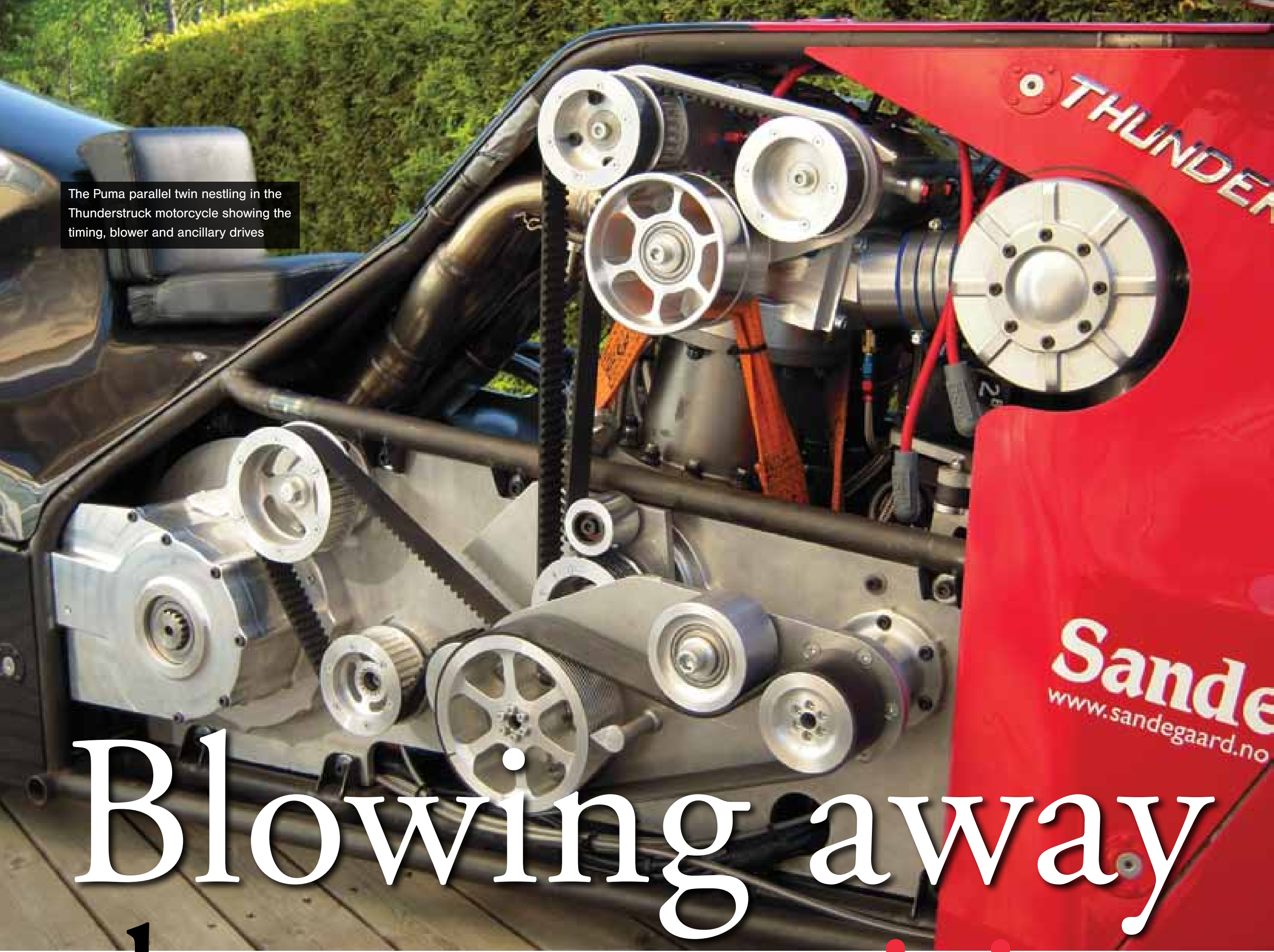


The Puma parallel twin nestling in the Thunderstruck motorcycle showing the timing, blower and ancillary drives

Blowing away the competition

Ian Bamsey investigates a fascinating engineering exercise to produce a brand-new supercharged, nitromethane-fed parallel twin

The most outrageous engines in all of motorsport are those that gulp the sweet-smelling, eye-watering adrenaline which is nitromethane, and are supercharged to boot. Mostly these are Top Fuel and Funny Car motors, which are loosely derived from the Chrysler Hemi pushrod V8. Alas, while unmatched for sheer spectacle, these days they are caught in a regulatory straightjacket; for engineering experimentation we have to look to the world of motorcycle drag racing. Blown Top Fuel Motorcycle (TFM) and Super Twin provide the engine design freedom that Top Fuel and Funny Car lack – they harbour the most sophisticated nitro engines in the world!

A specialist in TFM and Super Twin drag race engines, Puma Engineering has recently completed a radical new blown-nitro parallel twin for Norwegian rider Hans-Olav Olstad. This 1683 cc double overhead camshaft, eight-valve parallel twin is in effect a pair of single-cylinder engines sitting side by side on a common crankcase, each having its own head, barrel and crankshaft, with the two crankshafts splined together.

A unique experiment in the esoteric world of blown-nitro engines, the newly completed Puma parallel twin is a bold adventure far beyond the boundaries of conventional race engine technology.

Running on nitro

The blown-nitro I4 that powers Puma Engineering commercial director Ian King's TFM was described in *RET* 42 (November 2009) and its subsequent development was charted in *RET* 58 (November 2011). The original engine was 1327 cc, whereas the latest version is 1585 cc and it has three rather than two valves per cylinder.

Invariably, blown TFM and Super Twin bikes use a twin-screw type supercharger that is more efficient than the Roots-type, to which Top Fuel/Funny Cars are confined by regulation. Plenum pressure builds through the run as fuel vapour accumulates in the intake system.

Towards the end of a run, plenum pressure can exceed 3.5 bar absolute.

However, increasing plenum pressure can strangle the engine – the key is how much nitromethane the engine can handle. We discussed the unusual characteristics of nitromethane fuel in the Puma I4 article in *RET* 58. Nitromethane makes maximum power in an extremely fuel-rich state and continues to release energy even after all the charge air has been consumed. The challenge is feeding it into the cylinders.

Of the new parallel twin, Puma Engineering's technical director Gerard Willemse remarks, "The ports are huge; they are not designed to generate a careful flow pattern but simply to dump the fuel into the cylinder. You cannot hope to create any sort of tumble or other swirl with a nitro-laden charge!"

He adds, "In fact, if the speed of the air in the port is too high then the fuel cannot keep up with it. Nitromethane fuel is so heavy it is difficult to move it. The highest speed of the charge is when it flows around the head of the opening valve."

To be exploited to the full, nitromethane calls for bespoke engine design, as we saw in the case of the Puma I4. Very few race engines are nitro-fuelled, and rarer still is the parallel twin configuration.

The parallel twin configuration

These days in the automobile world the parallel twin (aka vertical twin) engine configuration is in fashion thanks to Tata and Fiat. Tata has used a 624 cc parallel twin for its Nano, designed to be the ultimate in affordability, while Fiat's 875 cc Twin Air parallel twin is powering current Panda and 500 models, initially in turbo-supercharged form. The Twin Air was announced as the International Engine of the Year at the 2011 Engine Expo in Stuttgart, Germany.

Parallel twin engines have long been popular for motorcycles, although these days they tend to be associated with small displacements. However, although characterised by its flat twin motorcycle engines, BMW makes the 798 cc GS parallel twin while Kawasaki makes the 773 cc W800 parallel twin. The W800 is a retro-style machine that harks back to Kawasaki parallel twin models of the late 1960s and early '70s. In turn, those bikes were derived from a British BSA parallel twin.

The parallel twin configuration was popular among British motorcycle manufacturers from the 1950s through to the '70s, with BSA, Triumph, Norton, Ariel, Matchless and AJS all producing examples during those years. Willemse campaigned an 880 cc blown-nitro parallel twin in the '90s, which was derived from a '70s Triumph road bike. It became the fastest sub-1000 cc drag bike in the world and won him European Super Twin titles in 1996 and 1998.

Nowadays the only established parallel twin Super Twin is that ridden by the 2011 European Super Twin Champion, Per Bengtsson. The Swede's bike, The Beast, is a 1700 cc blown parallel twin that has run the quarter-mile in 6.47 s. Strictly a one-off, Bengtsson has won multiple European Championship titles riding it.

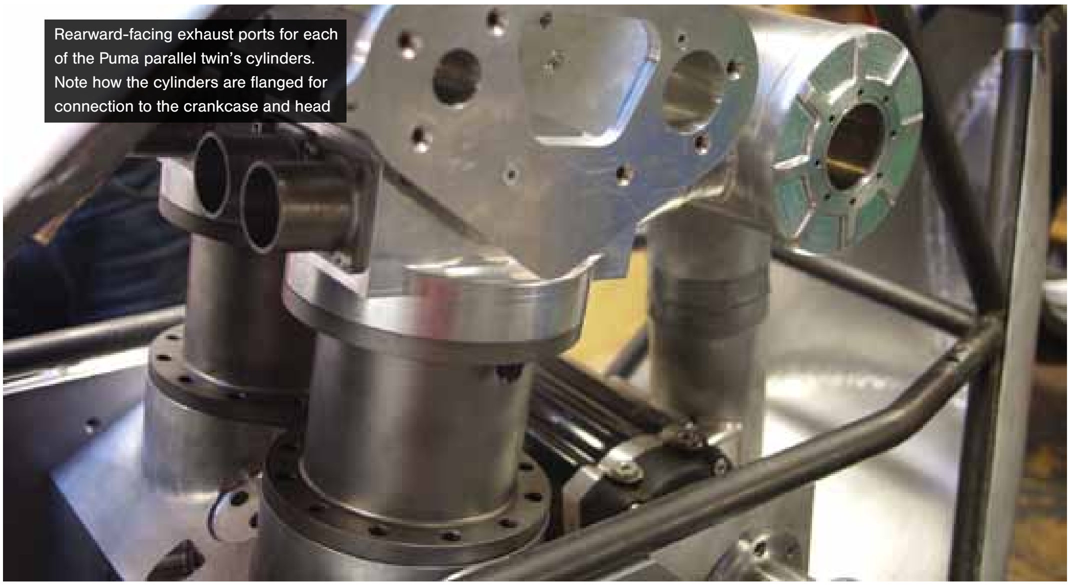
Willemse is a good friend of Bengtsson and helped him during his title-winning campaign last year. He explains that development of The Beast started with a Chrysler Hemi head that Bengtsson cut in half to form the top of a parallel twin. He built the rest of the engine from scratch underneath it and later developed his own head, retaining pushrod operation of two valves per cylinder.

Parallel twin pros and cons

For ultimate performance a double overhead camshaft blown-nitro I4 TFM is hard to beat, which is why twin-cylinder bikes have their own Super Twin class. UEM Super Twin Top Fuel Bike caters for nitro-fuelled twins up to 3278 cc naturally aspirated or 1700 cc blown (2000 cc if blown but confined to 90% nitromethane). The current quarter-mile record for a European Super Twin is 6.458 s.

The most popular configuration in Super Twin is the unblown vee twin with 45° or 60° bank angle. However, large-capacity vee twins suffer from a relatively long stroke, which together with pushrod valve actuation limits crankshaft speed: the largest displacement engines don't exceed 5000 rpm. Having a significantly smaller displacement per cylinder and using overhead camshaft valve operation, Puma's new parallel twin has the potential to run significantly faster – up to 9000 rpm. Willemse says, "Higher rpm means more firings through the course of the quarter-mile run – that is an important gain."

He acknowledges though that an I4 fires twice in each 360° revolution of the crankshaft, a twin only once. "This means that an I4 has inherently superior power roll-out. Power roll-out is the key – how you are applying power to the rear wheel. Our parallel twin has twice as many power strokes as a single-cylinder engine – it is in effect a pair of singles firing alternately. We have a 360° crankshaft, and with even fire we have an even loading on the rear tyre, unlike a vee twin, which has uneven firing intervals. That even spacing of the thrust is important all of the way through a quarter-mile run." ▶


Rearward-facing exhaust ports for each of the Puma parallel twin's cylinders. Note how the cylinders are flanged for connection to the crankcase and head

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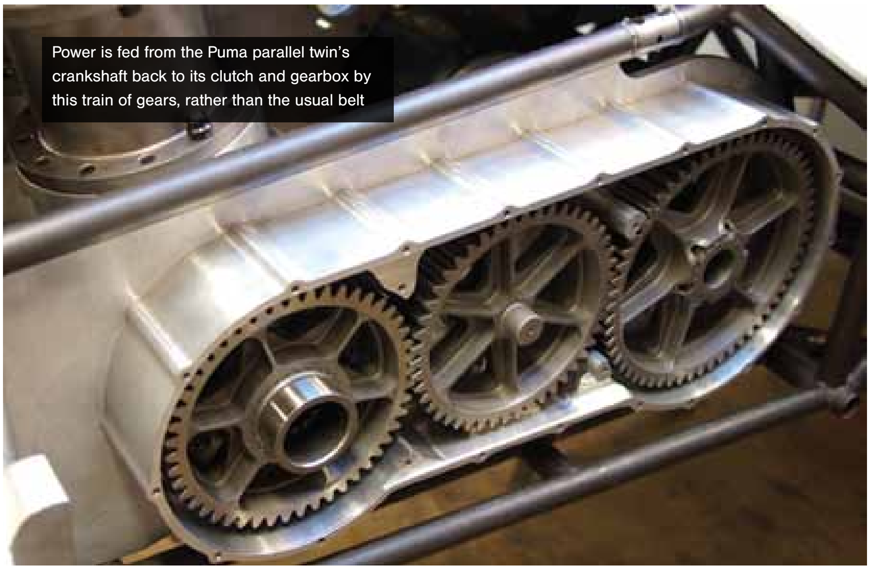
The Puma parallel twin has twin spark plugs for each cylinder, accessed as shown here


Power is fed from the Puma parallel twin's crankshaft back to its clutch and gearbox by this train of gears, rather than the usual belt

"These bikes have a very high level of traction – they don't normally spin the rear wheel, provided you have a good grip surface. If it does spin you are running too rich and you back off. Also, if you have higher rpm you get more nitro through the engine in the course of a quarter-mile run."

Willemse also notes that compared to a vee twin, the parallel twin's wider crankshaft "provides a wider span for the various flywheels, all of which are acting as gyroscopes operating in the same plane. This provides more stability as you run the quarter-mile. You can see that Per Bengtsson's parallel twin has more stability on the track than the vee twins it races against, which have a narrower crankshaft. Of course, an [across-the-frame] I4 is even better again."

Willemse agrees that the new Puma parallel twin with its 850 cc displacement per cylinder is significantly harder on its rear tyres than an I4 with less than 400 cc per cylinder. There again, an unblown vee twin with 1300 cc or more per cylinder is harder still.

The parallel twin's per-cylinder displacement is comparable to that of a Top Fuel V8 car engine, which means the reciprocating components can be carried over from such engines. Willemse says, "The use of such proven components is one advantage of this parallel twin!"

Willemse says that in drag racing, smooth power roll-out provides the best acceleration. He accepts that in road racing the so-called 'big bang' approach of uneven firing intervals can assist traction on corner exit, but says that when there is no lateral force involved, only longitudinal, smooth power roll-out is quickest for acceleration. "We don't need to compromise like that as we only run in a straight line."

Given the 360° interval between successive combustion events, Willemse highlights the importance of the flywheel effect of the crankshaft (including its output drive), in absorbing the energy of the combustion stroke and carrying it forward to the next power stroke. He notes, "The [unblown] vee twins have a massive crankshaft to store energy – it is a bigger problem for them as they run at lower rpm so have less bangs over the quarter-mile!

"Ultimately you want the lightest flywheel possible, but it must be sufficient to store the energy required to keep the motor turning."

Willemse emphasises the importance of engine speed. "The combustion stroke that accelerates the bike comes once every 360° – the rest is down to the flywheel effect. If you have more torque but less rpm you can have the same bhp, but that torque doesn't accelerate the bike, it is the rpm.

Parallel twin balance

The parallel twin has two cylinders mounted side by side, each having its own crankpin on a common crankshaft. As such, the crankpins can be arranged at 360, 180 or 270°. Given the 360 crankshaft favoured by Willemse, both cylinders rise and fall at the same time but are fired at 360° intervals. This produces the same dynamic balance as a single-cylinder engine but with two firings per four-stroke cycle.

Like a single cylinder, a 360° crankshaft parallel twin suffers from a vertical imbalance caused by the change of direction of its reciprocating mass every 180°. The lack of balance causes the entire unit to shake, puts uneven loading into the crankshaft and its bearings and can affect the integrity of the timing drive.

Applying sufficient counterweighting to the crankshaft opposite the crankpins to fully balance out the reciprocating as well as the rotating weight can more or less completely cancel out vibration in the plane of piston movement. However, it will do so at the cost of substituting another vibration, practically of equal magnitude, at 90° to the plane of piston movement.

This is unavoidable due to the differences in the movement of the reciprocating weight and that of the rotating mass counterbalancing ▶