FUNCTIONAL, NOT FUNNY

BUILDING A BETTER FRONT END

Telescopic forks have been the norm for years but are far from perfect. The latest attempt to build the better fork is this triangulated steering and suspension system found on the prototype Motoinno TS3.

BY ALAN CATHCART
PHOTOGRAPHY BY STEPHEN PIPER

Ever since the telescopic fork was invented back in 1908 by Britain's Alfred Angas Scott, founder of the Scott Motor Cycle Company, engineers have been looking for an alternative means of mounting the front wheel in a motorcycle frame, while at the same time steering the vehicle with it. Scott's tele fork was undamped, but in the 1930s, BMW took the concept to the next level, and the first production motorcycles carrying a hydraulically damped telescopic fork were its R12 and R17 models, which debuted in 1935. Soon after, in 1939 Denmark's Nimbus concern introduced hydraulic damping on its four-cylinder models, which since 1933 had been equipped with an unsprung tele fork, and after the hiatus caused by WWII, in the late 1940s telescopic fork front suspension rapidly became the norm globally.

It did so complete with all the drawbacks that a telescopic fork is known to suffer from, including stiction caused by increased friction driven by the fork tubes bending slightly, aka deflection. This happens most commonly under heavy braking, when, moreover, excessive brake dive will use up wheel travel and thus diminish damping capability, as well as delivering inconsistent steering geometry during turn-in to a bend. This happens when braking forces fed through the suspen-

sion cause it to compress under load, and thus to reduce rake and trail, making the handling more nervous, while conversely assisting with turn-in to the apex of a given bend. Furthermore, the fact that steering and suspension are coupled together means that one influences the other to the detriment of each, especially, once again, under braking.

But the fact that a tele fork is still today the go-to option for motorcycle manufacturers in every single continent—irrespective of price or performance—results from technology having been developed to paper over these deficiencies, even if some of these solutions bring added problems in their wake. So, an upside-down fork is not only heavier and more costly to manufacture, but also has the propensity to lose all its damping oil should a fork seal fail—although its increased torsional stiffness can improve handling by reducing or eliminating deflection, while also decreasing the unsprung weight, which enhances suspension compliance. The reluctance of manufacturers—with the notable exception of BMW—to risk public disapproval by adopting avant-garde technology for the highly visible front end of their models, has meant that, more than a century on from when Scott invented it, the tele fork still rules.

That isn't for lack of trying to find an alternative, though—and not just from BMW, which

Alan Cathcart got the chance recently to test the latest—and much improved—version of the Motoinno TS3.

today remains the only volume production manufacturer to fit what mechanical luddites term a funny front end to their customer models. Still, so far the German company's engineers have yet to display much original thought in concocting an alternative front suspension design, since the Telever front end adorning their range of mainstream Boxer models is an outright duplication of the Saxtrak front suspension design created by British engineer Nigel Hill for the Motodd Laverda and Saxon Triumph road racers a decade before BMW dreamt up their copy, but which he unfortunately omitted to patent. Conversely, the Duolever fork BMW fits to its K-series models is a copy of the fourche Fior invented by maverick French designer Claude Fior

back in 1978, only it wasn't him who patented it. Zimbabwean F1 mechanic Norman Hossack had the same idea a couple of years later, and this time he did patent, even though by rights he should never have been granted that, since Fior had the idea first. But Hossack forgot to keep up the payments needed to renew the patent, leaving BMW free to jump in and appropriate it free of charge. Nice work if you can get it!

But there have been literally dozens of other attempts to build a better front end over the past century, starting with the hub-center Ner-A-Car produced on both sides of the Atlantic after its 1921 debut, on which Cannonball Baker rode from New York to Los Angeles in 1922, covering more than 3,300 miles in just over seven days on a device powered by a tiny 221cc engine. Comparable hub-center systems were developed by Britain's Jack Difazio in the 1970s, as used most famously on the Mead & Tomkinson Kawasaki endurance racer nicknamed Nessie, then by French designers Alain de Cortanze and Daniel Trema on the myriad different versions of the ELF 500GP and FIM Endurance racers, through to the modern day Bimota Tesi and its Vyrus cousin. Radically different non-tele fork designs have also come from, among many others, Ernie Earles, Jean-Bertrand Bruneau of @ToMo fame, Phil Irving of Vincent, Andy Stevenson of ASP, John Britten—whose later bikes carried what is essentially a Fior fork made in carbon fiber—and of course US engineer James Parker, whose RADD front end equipped the avant-garde Yamaha GTS1000 introduced in 1993. Sadly for those who believe that motorcycle chassis designers shouldn't stay rooted in the past, but instead invest in the future, the Yamaha wasn't a commercial success, and no other volume manufacturer—apart from BMW—has dared since then to swim against the tide of convention.

But that hasn't stopped smaller companies like Ariel, with its new girder-fork Ace GT that's just reached production, or enthusiastic engineers from outside the industry, from trying to develop a better front end that isn't just funny, but also

functional. The most recent such attempt has emanated from Australia, where Queenslanders Ray Van Steenwyk and Colin Oddy have founded Motorcycle Innovation Pty Ltd. in Brisbane to develop their hub-center prototype named the Motoinno TS3—standing for triangulated steering and suspension system. This proof-of-concept prototype uses a stock 2002 Ducati 900SS motor, fitted with a Power Commander to optimize the modified shorty exhaust, in a radical chassis that's essentially been milled from solid alloy billet, as the platform to develop their decidedly unique front-end suspension and separate steering system, for what they hope will be eventual worldwide sale. And since I may immodestly claim to have quite extensive experience

(Above) Despite looking heavy, the TS3 front-end design results in a lighter overall motorcycle. (Left) Leaned over or on the brakes, rake and trail stay the same.

of both riding and racing motorcycles with alternative front-end designs, they invited me to come and sample the result, and not just once, either. First time around was at a private test track near Brisbane, but then when I encountered a major fault in the design, I got a second ride on the TS3 Evo2 version earlier this year 1,000 miles further south, at the Broadford track in rural Victoria. To experience firsthand the effective way in which Van Steenwyk, the system's inventor, addressed the fault and completely corrected it, gave every confidence that he's on the right path with the TS3.

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Okay, but first off: What led to this? Van Steenwyk, 53, has over 30 years of advertising, feature film and TV production work to his credit, meaning he has a solid background in art direction, 3D animation, and media design and production. He's also a self-taught mechanical engineer who's proficient in CAD, and has studied motorcycle dynamics as well as much of the relevant data on alternative two-wheeled steering and suspension systems, with the aim of bringing the TS3 to fruition. Business partner Colin Oddy, 64, is also a veteran of the TV and movie sector, having enjoyed a 20-year career bringing high-end productions of the Australian film industry to fruition. Proficient as he therefore is in sourcing both finance and hardware to make abstract concepts achieve reality, Oddy makes an effective partner in pursuing Van Steenwyk's ambition to develop a radically different motorcycle front end.

"I started riding bikes when I was just 16," says BMW K1200R owner Van Steenwyk, "but without much understanding of how they worked. But in 1995 after finishing up a really tough movie shoot, I got laid low with chronic fatigue that put me in bed for eight months. During that time I had nothing to do except think, and since one of my passions was restoring old motorcycles, I'd started to notice all the different fork designs and steering geometry of various bikes. But I also became aware of the copious drawbacks of tele forks, so I figured there must be a better way to do this. After gathering up everything I could find written about alternative front suspension, I started work on designing something different than teles. But this had to be squeezed in between my film industry work, so it actually took me 10 years to figure out this current design. Having done so, my business partner Colin urged me to quit playing with the CAD mouse, and actually build the bike. I was up in Canada working on the Incredible Hulk movie when he convinced me to give it a shot, so I quit the same week and came back to Australia to set up Motorcycle Innovation with Colin. The TS3 is the result."

Since then the Motoinno TS3 has been developed over a seven-year period, with CAD designs and FEA component

simulations completed early in 2009, then fed to a CNC fabricator who unfortunately made them lose momentum by doing nothing at all for twelve months. "We lost $20,000 in parts and materials to this man of daily excuses," says Colin Oddy. "We finally had to pull the plug on him after only two finished and usable components were made within the space of a year. We were hemorrhaging money, so we borrowed a UTE and arrived at the workshop unannounced, loaded the engine and left without retrieving any of our raw materials, which had somehow got used for other people's jobs."

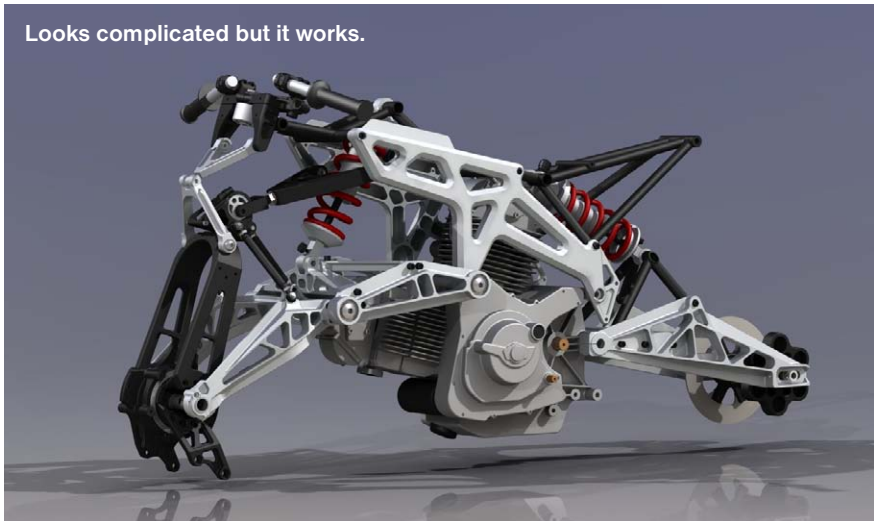
Still, this meant that Van Steenwyk was forced to adapt his film industry talents to become a self-taught expert in CNC machining and chrome-moly welding. "It wasn't a total loss in the end," says Ray. "My bullshit meter is now very well refined, and I got an apprenticeship in fabrication, even though it was an expensive and frustrating one."

In 2011 the TS3 was finally assembled on behalf of Motorcycle Innovation by Sydney-based Arthur Spink, whose MecFX company builds all manner of complex machinery for the Australian film and TV industry. Initial track testing got under way in November 2011, with eminent expertise on hand to dial in the suspension in the shape of MotoGP setup guru and former star rider Warren Willing, who in between trying to make the factory Ducati Desmosedici handle properly for Valentino Rossi, worked with the duo to produce a compliant and stable handling bike which delivered impressive results in a same-day comparison test with a Suzuki GSX-R750. This was conducted by Greg McDonald using his Track Motion telemetry system with a sampling rate of 100 times per second (three times greater than the MoTeC norm), and analysis of the data gathered identified the Motoinno TS3 as having a consistently higher turn rate than the Suzuki, for less lean. It was able to enter a corner faster under brakes, hold a tighter line through the turn, and could be picked up faster on the exit of the corner. Each test recorded showed that the Motoinno gained up to one second per corner over the GSX-R750 in the hands of the same rider. That's a lot!

At this stage the Australian Federal Government stepped

(Above) Aussies Ray Van Steenwyk (left) and Colin Oddy founded Motorcycle Innovations Pty Ltc. in Brisbane to develop their hub-center prototype Motoinno TS3.

Looks complicated but it works.



in with a Skills and Knowledge Commercialization grant amounting to $50,000. "This essentially funded our patent protection process on the front end design," says Van Steenwyk. "The next step will be a $250,000 manufacturing grant, to enable us to start producing bikes for sale, and they're relatively rare; with the decline in Aussie manufacturing, only two or three other manufacturing people have applied for such a grant, compared to IT and suchlike. We have to bring an investor to the party to obtain that, so that the government will effectively match their investment, but we're hopeful of finding someone who's interested in turning back the tide of manufacturing that right now has been leaving Australia, and will back us to get started. We want to build a sportbike powered by the 2014 Ducati Testastretta 11° Monster 1200 powerplant. Even though this engine is down on horsepower compared to other Ducati engines, with *only* around 150 bhp compared to the top end 200 bhp Panigale 1300, the TS3's great power-to-weight ratio will easily make up for this, and this engine has great midrange torque, exactly what's needed for a well-balanced motorcycle that is safe and fun to ride. The Testastretta engine retains all the necessary hard points to be able to put the design of the TS3 straight into production."

So that's the future, but now how about the present? What are we dealing with here? What is the objective of this design? "Telescopic forks are plagued with many well-known problems including stiction, fork collapse under heavy braking, inconsistent steering geometry in braking and acceleration, a long shock load path from the front wheel to the [center of gravity] of the motorcycle, and so on," says Ray. "But the biggest problem with any fork, including even Telelever or Duolever, is oscillation harmonics, which is a sometimes imperceptible vibration frequency that unsettles the front of the bike. The most well-known of these, because it's the most violent and obtrusive, is the dreaded tank slapper, but many smaller frequencies can also lead to instability as well, as in a commonplace front end low side. Oscillation harmonics will occur to some extent on all bikes with the steering pivot set or held above the front axle and which retain any form of stanchions, tubular or otherwise, to hold the front axle. That's because the stanchions or fork tubes act as unbalanced levers up to 30 inches long in the case of some telescopic forks, which flex both horizontally and laterally when the front wheel encounters either a road force deflection through the tire, or braking forces are applied to the

contact patch in any of several scenarios, such as inline acceleration, corner lean, or braking. These forces can be multiplied three-fold to the steering headstock, before traveling down to the center of gravity of the machine. A hub-center system like ours can overcome most of these vibrational frequencies by separating steering from suspension and braking, and by placing the steered kingpin in the center of the front wheel."

"However, there are still substantial loads placed on these kingpins at the center of the wheel hub," continues Ray. "These create oscillation harmonics due to the commonplace 600mm diameter of the front wheel fitted with a tire that surrounds it. This is where our TS3 technology comes into its own,

Here is the preliminary design of the TS3.

(Above) Will the Motoinno TS3 chassis ever see production? It's still too early to tell but its certainly heading in that direction.

as the only system with a virtual kingpin that starts at the contact patch of the tire, travels through the hub center along the steering axis, and ends above the front wheel. The whole system is perfectly triangulated from the wheel axle back to the suspension arms, and then to a point above the front wheel, making it extremely strong and reducing the chance of oscillation harmonics arising from the wheel or the kingpin to almost zero."

But that's not all, because in addition to separating steering and suspension, the TS3 has parallelogram swingarms, which together with the triangulated steering mechanism, keep rake and trail geometry constant throughout suspension travel, as well as providing inbuilt pro-dive or anti-dive, and speedy rake and trail as well as damping and preload adjustment all very readily. And with braking separate from suspension, it means you can also trail-brake deep into the apex of a turn, because there's only as much front-end dive as you choose to dial into the setup, meaning the fork doesn't freeze because of excessive dive, but suspension continues to be provided as per normal by the fully adjustable front shock. On the TS3, a pair of fully adjustable AFCO T2 shocks specially developed for the radical chassis package are fitted, the rear one operated by the machined billet-aluminum swingarm pivoting in the Ducati engine's crankcases, via a direct-action cantilever.

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The unusual format the partners have chosen sees the TS3's front swingarm pivot directly off the Ducati engine's front mounting lug, making the engine a fully stressed chassis member. Because steering is separated from the suspension and braking force, there's no need for a bulky, strong and heavy chassis such as those required on normal designs with telescopic or BMW-type steered stanchion systems. This reduces the overall weight considerably, so in spite of being over-engineered and therefore heavier in prototype form than it would be in production, the TS3 has a dry weight of just 354 pounds, with a 52/48% split on a tight 54.9-inch wheelbase. This is 66-pounds lighter than the stock 437-pound Ducati 900SS, which the engine unit and not much else was sourced from, thanks not only to the aviation-grade aluminum chassis and swingarm, but also the eventual substitution of the original metal wheels by South African-made BST carbon wheels. These notably reduce rotational mass as well as unsprung weight, meaning they help the bike accelerate and brake better, and also lighten up the steering because of their reduced weight and mass. That also comes from the bike's radical steering geometry, currently set at 19° of rake with 3.9 inches

MOTOINNO TS3

Currently, the TS3 is powered by a stock 2002 Ducati 900SS motor.

of trail, though the effective head angle can be adjusted between 15° and 24°. According to Ray Van Steenwyk, empirical track testing has indicated that when the steering rake is increased to its maximum of 24° the steering becomes lighter and quicker, while conversely when set to its minimum of 15° rake with decreased trail, the steering becomes heavier and slower, quite the opposite of a tele fork setup.

What struck me at once the first time I rode the TS3 in Queensland was how slim and nimble it was. I had a 900SS Ducati in my garage for six years, so I know how that handles, and the TS3 is way more agile in changing direction. It's flickable and highly maneuverable without feeling nervous, with a wide 54° steering lock compared to around 38° on a tele forked bike that results in an ultra-tight turning circle little more than twice the length of the bike. This would be a great bike to use in city streets, and ideal for courier use! And compared to the Bimota Tesi I raced for the Italian factory for three years (whose steering lock was adversely affected by the horizontal swingarms either side of the front wheel), there's no fear of running out of ground clearance on the TS3 by grounding either side of the articulated front swingarm, thanks to the shape and location of the good-looking vestigial piece of metallurgy on either side of the wheel. This encourages you to max out turn speed via heaps of faith in the front Pirelli Diablo Rosso, though only after I'd corrected the tire pressures from the bone hard 34/38 psi the team had started out with, to the grippy 32/30 psi we ended up with. This gave much more feel as well as improved grip and compliance.

However, that wasn't apparent first time of asking at my initial test of the bike in Queensland,

where as I speeded up I began encountering a severe front end shimmy if I hit a bump when even slightly leaned over from vertical. This lack of stability was dramatic enough to be frightening, though fortunately not terminal, in my case, but was quickly diagnosed just by holding the front wheel between your legs and wiggling the handlebars, which revealed a huge amount of slop in the steering. Yet how could such an eminent technician as Warren Willing have given such a design the thumbs-up? Turned out the rose joint in the steering had worn quite dramatically, necessitating a redesign as well as upgrading the component to the best available off the shelf. Ray Van Steenwyk redesigned the front wheel hub/kingpin unit on the bike and addressed all potential issues of bearing slop throughout the system, while also adapting it to the use of BST carbon wheels, which he calculates reduced the rotational mass by 50% on the front wheel, and 30% at the rear. Ten months later it was time for me to try the bike again, this time at Broadford where it immediately started ticking all the boxes.

I'll admit to some trepidation as I upped the pace at the tight, twisty Victorian track, which we were able to use thanks to the support of track manager Nick Selleck. Broadford is in fact an excellent test venue in spite of its short length, since it allows you to replicate a wide range of different situations dynamically. But I needn't have worried, because Van Steenwyk had done his homework well. The near-terminal shimmy had been replaced by a great sense of stability and composure; the Motoinno was now predictable in its behavior, and thus confidence inspiring,

"Each test recorded showed that the Motoinno gained up to one second per corner over the GSX-R750 in the hands of the same rider. That's a lot!

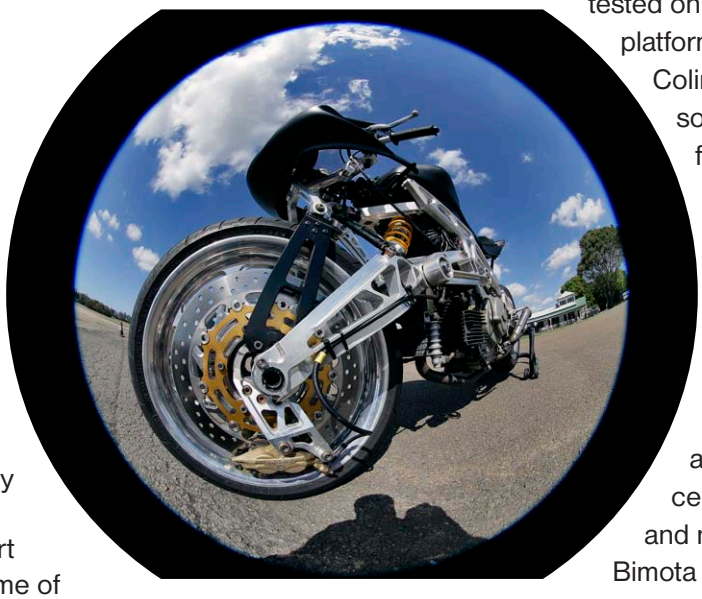
with the supple suspension sufficiently well damped to absorb Broadford's more significant bumps on the angle. As I upped the pace and gradually began using all of the front Pirelli's contact patch to increase and hold turn speed, the TS3 responded well. I could brake later and later on the angle into a turn like the 180° right-hander by the Paddock entrance, or best of all the uphill turn one at the end of the pit straight, where holding off the brakes to a point that would have been suicidal on a telefforked bike, allowed me to keep up hard-earned uphill momentum as I rounded the turn onto the top straight. There, the TS3 rode the bumps on what amounts to a tarmac staircase really well, even with enough torque from the desmodue motor to lift the front wheel over the first step, in which case even though there was no steering damper, it would only flap the front wheel once very quickly, before resuming normal service. And best of all it was very stable under hard braking from high speed, even trailbraking into the off-camber right at the end of the straight, with not a trace of the shimmy it had suffered from before. Job done.

The only slight initial quibble I had was that I got some bump steer descending through the esses, where the light, precise steering of the TS3 came into its own, as the quickest steering hub-center bike of the many I've sampled. That's especially so compared to the Bimota Tesi, which thanks to the copious links and changes of direction in the steering between the front tire's contact patch and the handlebars definitely didn't have the same front-end feedback that the Motoinno has. I doubt I ever went through the Broadford Esses quicker on any of the 50 or so bikes I've ridden at Broad-

ford down the years than I did on the TS3, although it was repeatedly briefly pushed off line riding over a bump on the apex of the right-hand exit while still off the throttle, most likely due to too soft a setting on the front shock to cope with the weight transfer going downhill.

However, after 25 laps or so I started getting the front end chattering on the only true left-hander on the circuit, the last off-camber bend before the pit straight. There wasn't any trace of this on all the many right-hand bends, only there. After narrowly avoiding hitting the dirt the second or third time of asking, I stopped to investigate, and after some searching the cause was identified by eagle-eyed Paul Barker, who'd brought the bike down from Queensland in his truck. The bolt holding the upper triangular link where it pivots in the left frame spar had sheared in half, with imaginable consequences. Still, that's testing! Ray Van Steenwyk reckons it should be made of high quality steel rather than stainless, and that's a given throughout such an unconventional bike as this, where unexpected forces are being fed through so many different components.

But I got enough seat time on the TS3 before that happened to be convinced that Oddy and Van Steenwyk are on to something here. Apart from looking pretty good in a completely radical kind of way, my hands-on assessment is that the Motoinno concept has



With the TS3 design, there is no chance of the front swingarm making contact with the tarmac.

a lot going for it. The constant front end geometry it offers at all times, even braking hard on the angle, means it has optimum stability yet a superior level of feel compared to other hub-center systems I've tried. This gives you more confidence. A key problem I had in racing both the Tesi and the Saxon Triumph was front tire feedback, and I can honestly say what I had in riding the Motoinno was comparable to a tele forked bike's. It's more agile and lighter/quicker steering than one of those, and has a better turning circle, plus there may well be more suspension travel at the front, though I didn't measure that. But I do think the system that Ray Van Steenwyk has come up with deserves to be tested on a faster, more potent platform, so I hope he and Colin Oddy are able to source the third party financial support that'll persuade the Government giveaway mob to uncork the taxpayer's money bottle to finance the building of that Testastretta-powered streetfighter, and thus create a 21st century version of the late and not entirely lamented Bimota Tesi.

Australia is the can-do country, a nation where problems are opportunities, adversity a challenge, and a glass is always half full, rather than half empty, a place where people don't wonder *if* they can overcome any problems or difficulties, only *how* that can be done. It makes you wonder why with the exception of John Britten in New Zeland, nobody Down Under that I know of, at any rate, ever tried to design an alternative-framed motorcycle until now. But now the partners in Motoinno have gone and done it and good luck to them. **CN**