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### [SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Thu Dec 15, 2011 11:30 am

This is the start of a fascinating article from "The Bike Book" that looks at many of the engineering inadequacies of motorcycles, based on hard scientific research in the 1970's.

Dr Geoff Roe and Dr Terry Thorpe have established the first truly scientific research facility for motorcycles in the world. Some of their findings are startling, some merely confirm suspicions experts have held for some time. But perhaps the clearest fact to emerge from their research is that motorcycling can no longer rely on haphazard development – the factories will only survive the '70s if ...

## "SUCK IT & SEE" MAKES WAY FOR SCIENCE

DR GEOFF Roe MA, PHD (Cambridge) and Dr Terry Thorpe Bsc, PhD (Nottingham) are one of the few research and development teams available to the world's motorcycle industries. Roe is a senior lecturer in mechanical engineering and Thorpe is a lecturer in the same subject, at Simon Engineering Laboratories in Manchester University, England.



Dr Roe and Dr Thorpe (leaning forward) began their experiments into motorcycle stability by using caster wheels, because that's basically what a bike wheel is anyway. Their findings have already resulted in better bikes from some makers, but most factories have adopted the attitude that they're outside the industry and the industry knows what it's doing, thank you.

To negate any suggestions that a purely academic approach to a very down to earth problem is likely to produce nothing but impractical results and idealistic results, both men are not merely enthusiastic motorcyclists, but skilled ones, using two wheels for everyday transport. Roe prefers a BMW R75/6: "Whatever it's failings, it is still probably the most practical motorcycle made.: Argue with that if you dare. Thorpe sticks to his faithful old Velocette Venom: "It's still about the best machine around for the kind of money I can afford."

In early 1971 the pair began constructive research into the phenomenon causing them great concern – stability, particularly on high speed motorcycles. This more than any other aspect of motorcycling has tended to dominate their research, although inlet and exhaust silencing, brake efficiency, wheel design, suspension variations and engine durability have also featured largely in their program.

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Wed Dec 21, 2011 11:50 am

At the time Roe had a 750 Norton Commando, which he calls "a rather nasty motorcycle". This was a reference to its instability at high speed, although the crude and unreliable nature of the power unit's mechanicals also influenced the comment. Roe approached Norton, hoping to be able to contribute something towards curing what was obviously a major defect, one by which at all accounts was giving the factory some savage headaches.

Instability, that peculiar flutter you occasionally notice, is front wheel wobble, usually an under-65 km/h indication of a lack of lateral stiffness. Many manufacturers prefer to use tyres with strong damping characteristics to stifle this, so that because of the tyres,

combined with the riders weight, instability remains virtually un-noticed. Once over 65 km/h, the flutter is overcome by the gyroscopic forces created by the front wheel.

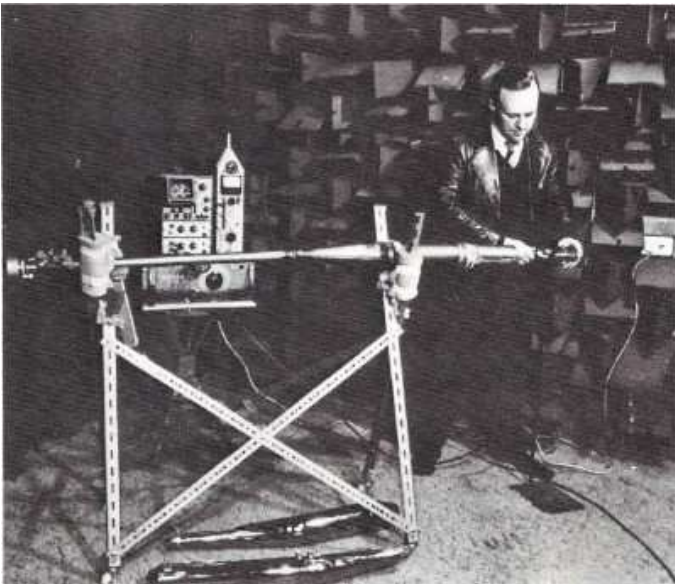
High speed instability is an echo of this, brought about by the same unstable caster effect, but as the trail involved is so much longer the effect is that much greater. Frames of insufficient lateral rigidity contribute largely to it.

You must know the feeling. Along a fast highway when the bike begins to feel vague at a certain speed. Nothing you can put your finger on, just an unsettling, indefinable, negative reaction. That's the start, and its probably caused by the rear wheel getting out of line with the front one. The cause could be a weak frame simply flexing because of the tremendous mass involved at speed. It could be the rear wheel's lack of lateral stiffness.

Whatever it might be, the slightest defect anywhere in the system will aggravate it – sloppy spokes, weak spindles, a weak pivoted fork, worn bearings, underdamping. Once it starts it's difficult to stop, and reducing the effect of some contributory ancillaries, such as tyres and dampers, merely delays the final outcome.

"In every case", says Roe, "the fundamental cause of instability has proved to be a lack of lateral stiffness at the contact patch – the tyre's point of contact with the road surface."

At this point it seems sensible to explain exactly what Roe and Thorpe mean by stability. Most motorcyclists, including a great number of journalists, refer to all high speed behaviour in the completely unspecific and non-descriptive term, "handling". Not only is this indicative of laziness on the part of the machine's analyser, but lack of skill and experience as well. It conveys nothing of any real value to the reader either.



Dr Geoff Roe working on exhaust silencers in the "quiet room", specially designed to deaden all outside noise and completely eliminate all echoes inside.

Stability refers to the inherent ability of a motorcycle to either firmly and unwaveringly retain its chosen path, or to return to it should it be interrupted. This is probably the most important dynamic element concerning today's motorcycles, and the one around which is woven more legend, lies and misconceptions than any other. It, and it alone, dictates high speed safety, roadholding and even handling characteristics.

Handling is nothing more than the response of the machine to its rider's demands, including everything from traffic crawling to high speed lane changing. It's a general, blanket description of what might be called "feedback" information from the bike which, while loosely including characteristics like stability, is totally un-selective and should therefore be used carefully, with this in mind.

Roadholding is probably the most difficult of the three characteristics to define, but is probably best described as the willingness of a motorcycle to follow a path, more usually around bends, chosen by the rider. The danger is that it and stability overlap, bringing about the possible situation where a machine might well be stable, thanks to its correct frame and steering geometry, but nevertheless provide unsafe road holding due to poor damping, incorrect tyres or whatever. The reverse could also apply, and these days often does due to all too frequent instances of corrective ancillary equipment, such as improved tyres and suspension damping, being used to camouflage instability.

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Tue Dec 27, 2011 7:05 am

The most dangerous aspect of this tradition – a fast growing one – lies in the fact that in skilled, brave hands, such as those of a skilled and experienced racer, the instability factor can often be circumnavigated via various cleverly applied techniques. An example of this can be seen most frequently at its best in the preparation of British production racing bikes, where cycle part modifications are permitted.

The commonest contributors are without doubt the big Japanese machines. Many of them have frames of such incredibly poor design that even the most inexperienced riders must, at some time or another, wonder at the sheer innocence – or in some cases, ignorance – of the designers involved. As a matter of interest, that they probably were innocent, or ignorant, of the necessary background in motorcycle engineering when the bike in question was drawn up, is due to a tradition peculiar to Japanese industry.

Honda, for instance, design by committee, a continually changing committee with no roots sunk into the highly specialised processes involving the production of motorcycle frames. For, say, three years, a young engineer is employed in the motorcycle division before moving on to agricultural engines, or cars, or marine engines, or even aircraft! For this reason there is no continuity or build-up of experience purely in motorcycles.

This policy is adopted to inhibit stagnation and stimulate progressive attitudes to all product design and production, and doubtless plays dividends in a general sense, where skilled marketing techniques can largely foil any worthwhile engineering criticism. And if you adopt the principle of success being measured in profit alone, who can criticise Honda at all?

A fascinating story has emerged from within the Honda factory: The tremendous acclaim afforded to the CB400 is well known and well deserved. Honda's first "European" motorcycle, it does indeed contain all the elements of the best European machinery, the main one being a high degree of stability which, often unknowingly, is the foundation of its manifold congratulations. The most interesting aspect of the story, however, lies in the fact that it was a production, not of the research and development department, but the motorcycle division itself. However cock-eyed this might sound, remember that many big Japanese companies work along the constantly flowing staff lines, claiming that such a policy allows them to draw on the combined experience and skills of the entire group, rather than a single, isolated unit.

Honda was going through a bad patch because of the American sales recession, and didn't have its usual near unlimited budget to invest in a new bike which, of necessity, had to zero in on Europe, it enjoying a more stable and faster growing market than the American one. Thus, at a time when things were gloomy and cash was tight, the Honda bike division came up with their own offering. That it has been designed (or should we say redesigned, as it is based on the old 350 four) by motorcyclists and not by the usual gaggle of all-powerful yet shockingly inexperienced, showroom oriented technicians, is delightfully obvious. A quick check over the riding position, the fuel tank shape, the foot controls, the suspension damping etc, is indicative of a high degree of experience and sympathy with dynamic motorcycle engineering at its best.

But has Honda learned anything from it, we wonder?

Look too at Yamaha's inability to appreciate any connection between its racing department's long standing experience in correct frame design, and that of their original 650 production team. If ever there was a case of sheer stupidity this is it.

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Thu Dec 29, 2011 1:08 am

So to get our original theme of improving basic bad designs with ancillaries such as high grade tyres, suspension damping systems and hydraulic steering dampers to disguise a basically unstable frame. That they do, but, combined with the skill of their racing jockeys and the company's exploitation of the eventual success, the hidden dangers of the standard production jobs are immense to the inexperienced road rider. He does not necessarily appreciate that the faint wavering at 110 km/h is indicative of impending and uncontrollable yawing at 140 km/h under certain, entirely predictable conditions.

So often this is regarded as being part and parcel of the thrills and spills associated with fast motorcycling; thus, motorcycles, in the minds of an ever growing band of antagonists, are indeed dangerous, a fact proven also in the minds of the unfortunate buffs involved in the unstable syndrome. The sad thing is that because the majority of fast bikes sold are thus afflicted, a general consensus of opinion is springing up that the relatively few machines sold presenting a stable ride at high speed are, by some miracle, freaks, and should not be accounted for.

An even sadder fact is that it could so easily be avoided, thereby providing us with an entire world wide range of safe motorcycles which would not provide detractors with such powerful ammunition.



The Norton 750 Commando, Roe describes it as "a rather nasty motorcycle", mainly because of stability problems. Roe and Thorpe approached NVT with the idea of improving the Norton, but the company wasn't receptive. NVT used Roe and Thorpe's annular discharge silencer design though, apparently because silencing was more important than stability!

Roe and Thorpe's refusal to accept the Commando's instability led them to find out what they could about instability in motorcycles. They concluded wheel wobble induced it, so they read up what they could about it, only to find precious little information was available. "we read what Phil Irving said about wheel wobble but it did not coincide with our own experience, so we decided to investigate."

They began before the beginning, studying the most basic form of caster wheels available, because that, after all, is what motorcycle wheels are, and found themselves researching tea trolley caster wheel flutter and, once more, were stumped by lack of information about the phenomenon. "We could find no previous reference for the reasons of wheel wobble on caster anywhere. One otherwise authoritative book even referred to it as being "not fully understood"!



They built their own test rigs, this being a simple, endless rubber rolling road driven by a variable speed electric motor, above which was suspended a caster on a fully adjustable and steerable rig. They found that wheel wobble was caused purely by lateral play in the associated mountings which, on a motorcycle, approximate to such components as spoke lacing design and tension, wheel spindle strength and mounting and clamping systems. Fork stanchion structural strength and resistance to bending, fork bush free play, head bearing type and adjustment, and so on, right through the machine to the identical requirements of the rear wheel also a caster of course.

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Sat Dec 31, 2011 3:02 am

On arriving at this premise, the two engineers at Manchester univesity found themselves up hard against the establishment, which appeared to strongly resent their interference. Firstly they were academics, and therefore their motivation was suspect. Secondly they were outside the establishment, so not to be tolerated by those within who were jealous of their positions and reputations. Thirdly they found the basic problem to be directly associayed with the mainstay of current production traditions – the disc brake, spoked wheel, tele-fork syndrome. Fourthly, they quickly discovered that claims they did make about their discoveries were immediately refuted as being not new at all, but were claimed as belonging to the establishment anyway.

Other technical journalists have said much the same thing: Two emphatically claimed the root cause of instability (wheel wobble induced by weak lateral stiffness) to be a well know fact. Now, you think about it yourself. Said like that in so many words it is indeed so obvious it makes you feel stupid for not knowing it yourself, or alternatively, because it is so simple you are fooled into believing you knew it all along. But whichever, Roe and Thorpe found no willing partner in what was left of the British industry even then.



Dr Roe eventually gave up on his Norton and bought a BMW. The team then developed a working relationship with BMW and in fact did a lot of work on the latest series of Bee Emms on stability and roadholding.

Dunlop, to its everlasting credit though, did indeed request the advice of the team when researching the instability discovered in some machines equipped with the famous TT100 "cure-all" boot. This led to the development of the current range of Red Arrow tyres, these being non-triangular in profile, besides providing greater damping characteristics than the TT100, which was never intended to

dampen out wheel wobble anyway.

Evidently Norton considered silencing was of greater importance than stability and engaged the team to develop improved silencers. That they did exactly this can be seen in Norton's famous annular discharge units which are probably the most efficient motorcycle silencers in existence, and more effective than BMW's. There remains some controversy as to who finalise the current production pattern, but there is no argument at all that it was Roe and Thorpe who conceived the annular discharge principle and who successfully reduced the original noise level of the Commando from 98 to 86 decibels overall by exhaust silencing alone. No mean feat when you consider the high induction and mechanical noise emanating from the engine – under MIRA (British-Motor Industry Research Association) tests, they made more noise than the exhaust did.

In Roe's opinion, of equal importance to that is the period and cash involved: "Something I do wish was more widely realised," he says, "was that we exceeded Norton's target figures in performance yet undecut the development budget. I have a great deal of respect for Dennis Poore, but the company in general was often completely non-receptive."

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [blairb](#) » Mon Jan 02, 2012 7:35 am

Hey Crispin I just rode back from Jindabyne today, I'm so glad I didnt read this before I left I would have spent the whole ride trying to work out why I was staying upright. This is a great thread, I have fond memories of that little Honda 400 /4 . Did you know Julius Sumner Miller?



[blairb](#)

**Posts:** 130

**Joined:** Tue Sep 21, 2010 5:02 am

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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Wed Jan 04, 2012 11:55 am

*Hey Blair,*

*glad you have been paying attention, as you will be our key test rider to experience many of the hidden gems we will implement out of the Old School Engineering thread.*

And now to more from Roe & Thorpe...

Norton, once silencing was solved to its satisfaction, thought it needed no help on the stability factor, so, reluctantly, the team turned towards BMW, because by this time Roe had bought one in preference to his Commando. They made contact with Bob Lutz, the Sales Director of BMW. "We felt BMW would appreciate our assistance and we were right, although naturally enough it has taken a year or

two for us to develop our present position of mutual trust.”

As they originally wanted with Norton, this time all their efforts were aimed into improving stability. Although we are unable to reveal exactly what Roe and Thorpe’s contribution has been during this three year period, it has been considerable. Revealing details would not only display BMW’s secrets to alert competitors, but would spoil an excellent working relationship so carefully matured through mutual respect for each other’s work and position during the period.

Anyone with experience of BMWs will be fully appreciated of the tremendous improvement they have undergone in the past few years. Not so long ago they were of questionable stability, but current models are as good as the world’s best.

The technique Roe and Thorpe have adopted over their five year research into stability is split into three distinct approaches: “Mathematical, model and road machine. The first is the sum of our experience, and from this we can calculate exactly the design required. We then construct a model and laboratory test it to ensure it behaves as we anticipate. Once it satisfies us we build a proper motorcycle. We have done this, in fact, to our own satisfaction.”

Until now at least motorcycle frame design has been empirical, or “suck it and see”. Other approaches include the face-lifted duplicate of an older, proven one or, as the old AJS company used to say, “race bred”. It all means approximately the same thing, with the fortunate and only partial exception of the last.

As any engine development engineer will tell you, although the track is the final test of any power unit, the time saved by use of a dynamometer during development is not just incalculable, these days it’s vital, primarily because the progress of each successive improvement attempt can be measured, logged, and analysed within the laboratory. Roe and Thorpe claim, with considerable justification, not only could they provide a similar service to any manufacturer requiring assistance with cycle part development, but that because of the time and expense involved, their system has to be the one of the future: “Given all the necessary information regarding a machine we could – we have – supply either a pre-production frame or the necessary information to build one within a few weeks which should require no further development along stability lines.”

Previously, such an exercise involved a minimum of two years while the company concerned went through the heartbreak, trauma and often public derision in race testing a frame before putting it into roadster production.

Ducati claims it has to race, whether it wins or not, in order to maintain its high standard of performance. Unfortunately this meant it had to be contained within Italy, because it didn’t have the money to devote to suitable power unit development in order to compete with the bigger factories. As the public could not, or would not, understand this on an international scale and would consider anything but a win or high placing contemptible, national meetings it had to be. But at least it proves that Ducati has its heart in the right place, for, as Roe and Thorpe pointed out: “Of all the machines we have tested (which excludes Moto-Guzzi only) the Ducati, although not perfect, was aimed in the right direction. It was very good really.”



Dr Terry Thorpe on the Honda 90 step-through which was handed to them for evaluation by the (British) Road Research Laboratories. The discovered it was unstable above 45 km/h, but because of the low mass involved it was relatively unimportant.



To which any man should respond, with every justification: “Yes, but look how long it’s taken them to achieve it.” To which a defensive reply might be that at least they have achieved it, while a company like Yamaha, deep into racing, is still unable to connect production and competition, so it would seem, presumably because of a lack of interdepartmental communication, or maybe a genuine inability to interpret the experience of the racing team into roadster terms once outside any direct machine relationship. How much simpler it would be if the computers which supply all the Japanese manufacturers’ power unit information could also feed similar cycle part data when necessary.

Only a short time ago even top designers like Taglioni and Doug Hele argued convincingly that frames could not be designed, but had to develop slowly with the machine as a composite part of it. How times change.

Roe and Thorpe were quick to point out they could not design a specific frame layout to meet every conceivable motorcycle configuration and potential application simply by pressing a few buttons. What they have done is to uncover the basic shortcoming of existing systems and provide remedial measures. From this point they could then investigate more thoroughly the unique requirements of a specific model within a matter of weeks instead of years.

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Sat Jan 07, 2012 11:42 am

And it’s these shortcomings that are undoubtedly going to provide the main objections of foreseeable developments. They see tubular steel frames remaining for a long time yet. Unlike more sophisticated monocoque, space frame, box section or pressed steel units, they are exceptionally adaptable to changing production needs and varying power units and assembly systems, require no expensive machine tooling operations or high capital investment, amply fulfill all possible foreseeable performance requirements, are singularly simple to repair, and are difficult to damage. Equally important, their structural performance is almost exactly suited to a single tracked vehicle.

The changes Roe and Thorpe foresee centre on wheels, brakes and suspension, all of which detract from what should so easily be an excellent frame performance. Each one interacts with another, but for the sake of simplicity let’s take the failings of them separately. Firstly the telescopic fork.

From Roe and Thorpe’s point of view, they are highly undesirable pieces of equipment, offering nothing but instability, expense and discomfort. Basically they are weak, tending to flex under stress, together and independently, a problem only partially solved by immensely strong and heavy wheel spindles and bridge pieces across the sliding legs. As they extend, wheelbase and steering geometry alters, simultaneously encouraging further flexing via the increased unsupported length, and steering problems occur because of the alteration in characteristics. The Italians manage better than most by refusing to compromise and concentrating on performance, rather than customer needs, and ensuring what little movement there is is securely disciplined by rigorous hydraulic damping. In order to ensure minimum play, bushes are machined to minimum tolerances, thus ensuring unnecessarily long running-in periods before they slide freely. The resultant performance might well be superior in machine stability, but at what sacrifice to rider comfort and convenience? Because of the high grade materials used, required to resist flexing etc, and the cost of top quality machining, the final price is exorbitant, as any owner involved in a shunt will agree.

The Japanese ignore the side effects, concentrating upon creating a good impression immediately to impress the potential owner, and then put the rest down to faith, hope and charity, while relying on strong tyre damping to either control or hide any wheel wobble. But it doesn’t always work.

For some inexplicable reason disc brake popularity has involved the continuation of drum brake hub width, with the unfortunate effect that wheels are now weaker than ever before. The old drums made for good short spokes, with their roots relatively wide apart, but now, squeezing twin discs into the hub, plus the need for the necessarily straight spokes to clear the fat calipers, has reduced lateral

rigidity within the wheel itself.

Not that Roe and Thorpe, from either laboratory or practical experience on the road are convinced of the need for discs. They have carried out some intensive testing of various wheels and this revealed a fascinating fact, this being that of all those included in the experiments, the best was from a Vincent. Its spokes were correctly aligned and its twin drum brakes correctly positioned out in the airstream. Undergoing development right now are duplex drum brakes in high grade alloy, similar in style but identical in concept to those of the two Phils, Irving and Vincent.

Their rejection of disc braked wheels, incidentally, is purely on grounds of safety after a few dangerous and frightening experiences during wet winter rides, and snowy ones, on disc brakes, when build-ups of foreign matter under the pads reduced friction to zero.

tbc...



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## [Re: SUCK IT AND SEE makes way for science](#)

by [XBCoupeJota](#) » Mon Jan 09, 2012 4:26 am

An even more revealing piece of information they discovered was that of all the cast wheels they tested, none were more rigid than Vincent's wheel, which suggests there is nothing wrong with spoked wheels providing they are correctly designed, but that there is a lot wrong with cast wheels because quite obviously few of them are designed with any sound scientific grounding behind them.

Spoked wheels have yet to undergo research at Manchester university, but when they do you can assume it will be with the same thoroughness that the leading link fork was recently tested to and built.

Not satisfied with the telescopic fork, Roe and Thorpe looked for an alternative. One by one they rejected various types, including such things as pivoted fork/hub centre, because of public resistance to anything so radical. Earles forks, as used on BMW and DKWs a decade back were rejected as "dreadful things", with nothing but good springing to their name.

Both men were highly critical of past attempts at leading link systems by manufacturers. Few of them, it seems, had much idea of how to utilise its potential performance characteristics.

The leading link fork, correctly applied for roadster use has few disadvantages for either user or maker. It involves none of the tele's initial bush sticktion, has totally variable damping and spring rating, does not rely on absolute equal spring rating for equitable unit performance, alters steering geometry only nominally, and wheelbase not at all during movement, and is much more rigid due to the long single length of wide diameter tube involved (in the Roe/Thorpe unit). The only moving parts are a couple of taper roller bearings each side, and if necessary the whole thing, yokes included, could be made up from a single stamping. Were it not for a strong, yet entirely irrational public dislike of anything not traditional, doubtless bike makers would by now be using such equipment, for, as anyone who has experienced a good set of leading links will tell, they are infinitely preferable to anything else, especially telescopic forks.



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