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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: markortiz@vnet.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

QUADS ON PAVEMENT

I am a student at the University of Ulster in Northern Ireland studying Mechanical Engineering. I am currently working on a project which involves designing a suspension for a purpose-built road going quad [quadricycle].

I am sure you are familiar with quads. The quad I am working on is similar to existing quads. However, it will be approved to go on the road, and it will handle better on the road than current quads, which are designed exclusively for off-road conditions.

Current sports quads have a single swing-arm at the rear which connects to a solid rear axle. This has long travel, and a relatively soft suspension. Re-bound is slow on these quads. At the front, a double wishbone set-up is used on each side. A similar long shock is used, however re-bound is slightly faster. The suspension set-up is mainly for high jumps and being used on rough terrain.

When this set-up is used on the road it produces a very soft ride. There is too much pitch during retardation and acceleration, and sufficient roll to lift the inside rear tyre, almost without fail, when there is even a slight change in direction. This wheel lifting problem is also attributed to the solid rear axle and single swing-arm set-up.

The quad I am developing has no differential, and is driven by the rear wheels. This can make acceleration from tight corners at slow speed very difficult. You can't put the power on until you are in a straight line. Can suspension set-up affect this? Often, the front wheels lift completely when the power is being applied. This results in massive understeer.

What would you suggest to be a cheap and effective method to design a new suspension set-up for a quad bike for the road? It should solve the following problems:

1) High levels of pitch and roll on hard surfaces.
2) Inside rear wheel lifting during cornering.

3) Understeer when applying power.

I don't know what laws you have in Northern Ireland that would allow licensing a quad for the street, but you definitely couldn't do that over here. Anything with an engine and four wheels is considered a car in the US, and has to comply with windshield, side impact, and other standards that a quad has no hope of meeting.

It would be legal to race quads on pavement almost anywhere in the world. As far as I know nobody has tried it, probably due to the vehicles' poor handling properties on pavement, which you have observed.

The ride and handling problems you describe are largely inherent in the layout of the vehicle. To get away from them, you would need a rear suspension with a wheel rate in roll comparable to the front, a differential, and a much lower CG and/or longer wheelbase and wider track. You could conceivably design such a vehicle, and still have the rider sit astride it instead of in it, but there would be safety and aerodynamic penalties, with the only advantage being that using body english would be somewhat easier. For good results, a pavement quad would have to look dramatically different from a dirt one. You can't just doctor the links and springs.

What you can do with the links and springs, keeping the existing layout, is make the front suspension very stiff in roll like the rear, and stiffen the wheel rate in pitch. If you do this with interconnective springing (anti-roll bars, anti-pitch bars, diagonal bars, or equivalent devices), it is still possible to keep the wheel rate in heave fairly soft. You would then essentially have a suspended go-kart with a motorcycle-style operator position. This will give you a vehicle that will bicycle, or flip, instead of tricycle, and will pitch less on its suspension due to longitudinal accelerations. However, there will be more sprung mass pitch due to bumps. The tendency to overturn -- laterally in cornering, rearward in forward acceleration, forward in rearward acceleration -- can only be controlled by the suspension up to the point of wheel lift. Beyond that, it's purely a matter of where the center of gravity resides relative to the four contact patches. To change that, you have to fundamentally redesign the vehicle.

The whole logic of the quad is that it gives you a very short, narrow package, allowing the machine to operate on many trails that would otherwise require a motorcycle or a mule. If you make the track and wheelbase sufficient to work well on pavement, you throw away the main advantage of the motorcycle riding position.

I have mentally toyed with an idea that poses some similar problems. I am a bicyclist, and I have noticed that the world could use a human-powered on-road vehicle that will work decently in snowy, icy conditions, and also on dry pavement. Such a vehicle would probably need four wheels, and would have to be narrow enough to allow cars to pass, and preferably narrow enough to fit through a door and be brought in the house like a bicycle. The realities of operation in snowy conditions would require a conventional riding position; a recumbent would expose the rider to cold, dirty baths of snow, ice, water, and slush thrown by passing vehicles, and would be too hard for motorists to see. The rider would have to sit slightly *higher* than on a bike, for reasons of pedal-to-ground clearance. The rider's legs must be straight enough to give good pedaling efficiency. So this would be a really

tall, narrow device, with a really high CG -- even worse than what you're contemplating. Pitch stability would not be a big problem, due to the modest power, but roll stability would be a major issue.

In the UK, some people build high-tech pedal-driven tricycles, and even race them. These vehicles are almost never seen on my side of the Atlantic. They obviously have the same stability problem that has caused quads to replace trikes in the ATV market, only even worse. The riders coast through turns with a knee hooked over the top tube, hanging off the inside of the trike like a sidecar monkey -- and cornering speed is still limited mainly by overturning rather than grip.

I think the best approach to a tall, narrow vehicle with more than two wheels would be to give up on trying to make the vehicle corner flat like a car, and instead make the suspension extremely *soft* in roll. The rider would then lean the vehicle into the turns like a two-wheeler. The suspension would resist this, but only gently, up to perhaps 20 degrees of lean. The rider would also have to hang off the inside of the vehicle to corner hard on pavement. One thing that works in our favor with human power is that the rider is the majority of the mass, making the CG highly mobile.

I think you could build a self-propelled pavement quad that cornered like that. You'd need motorcycle tires if the wheels leaned with the vehicle, as they would with independent suspension. If you used beam axle suspension instead, that would call for shaft drive. You could then use quad or car tires. To my knowledge, nobody makes quad tires for pavement, so I expect you'd want to adapt car tires. Quad tires I've seen are not only unsuitable for pavement in terms of tread design, they are very likely incapable of coping with the speeds and temperatures they would see on pavement, even if you retreaded them.

The vehicle would dramatically outweigh the rider, so it would still be desirable to have a fairly wide track and put all masses as low as possible. Even at that, I would worry about having the vehicle "high-side" or flip toward the outside of the turn, as motorcycles sometimes do. In that case the rider would either be thrown off, or crushed by the vehicle.

A couple of years back, Daimler-Chrysler showed a three-wheeled vehicle that leaned into the turns. As I recall from published reports, this was accomplished via semi-active suspension on the two front wheels. If I understand correctly, the control system was a simple hydraulic valve operated by the steering; it leaned the way you turned the steering wheel, and the more you steered the more it leaned. I could be wrong about that, because such a control system would pose a problem if you needed to countersteer to correct oversteer. The vehicle would lean the wrong way, and immediately high-side. Also, the lean angle could not be optimized for both high and low vehicle speeds at a given steer angle. To get around these shortcomings, lean must be controlled by something other than steering position.

The way to make the vehicle lean itself would be to control the tilt electro-hydraulically from an acceleration sensor. Since the sensor would lean with the frame, the system could simply add tilt

until the sensor no longer detected lateral force, or until active suspension travel was exhausted. For smaller vehicles, especially where we are trying to minimize cost and complexity, it makes more sense to let the operator sit astride the vehicle, and lean it with body english.

The power push you describe is a universal problem in all vehicles without differentials, except those that only turn one way and can use tire stagger. It is also a universal problem with vehicles that are easily capable of wheelstands, at available grip level. You have both of these problems at once. Therefore, you have to solve both of them to obtain satisfactory performance.

Quaife makes limited-slip differentials for chain drive, which are popular for motorcycle-engined cars. These are usually used with independent rear suspension.

Go-karts race without differentials, but only because the rules demand this. One strategy for getting the karts to turn sharp corners on pavement is to deliberately try to make them lift the inside rear. Since all suspension is prohibited, tuners can't achieve this with soft front wheel rates in roll, so they do it with large scrub radii (long front spindles) and lots of caster. When you have no differential, lifting that wheel isn't necessarily a vice. You can still put power down. It doesn't mean the vehicle is about to bicycle, although I do think a quad on pavement would bicycle pretty easily. It's actually a form of warning, and therefore arguably a safety feature. If neither inside wheel lifts until they both do, you have less warning of overturning. Of course, when you get on the power hard, and all the load is on the rear tires, the inside rear plants and you get the push. So for a quad on pavement, I think roll-compliant rear suspension and a differential would probably be the way to go.

The tendency to wheelstand depends on the ratio of CG height to the longitudinal distance from CG to rear axle. Suspension has little influence, except that upward or downward jacking can make the CG rise or fall a bit under power. Having ample load on the rear wheels is basically a good thing, but we also have to steer. Optimal balance between these two concerns can only be achieved for a fairly narrow range of forward acceleration. A vehicle with a high CG and short wheelbase is well suited to low-grip surfaces, but is wheelstand-limited when grip is good. When the vehicle is cornering hard and trying to gain speed, power understeer sets in before the front wheels will actually lift. This is a characteristic of dirt vehicles operated on pavement. Sprint cars on pavement have the same problem as your quad. In sprint cars, it helps to lengthen the wheelbase, adding most of the length between the engine and the rear axle. This results in less static rear percentage, in addition to a smaller ratio of CG height to CG-to-rear-axle distance. In moderation, the added front percentage doesn’t hurt the car, because sprint cars are so tail-heavy to begin with. To maintain static rear percentage while suppressing wheelstanding and power understeer, we would have to lengthen the front of the car as well.

The way to put power down best, over the widest range of grip levels, is to use generous static rear percentage, a low CG, and a long wheelbase -- think dragster. I don't mean that a pavement quad, or a pavement oval track or road racing car, needs a 300 inch wheelbase, but

longer and lower is the direction you need to go when adapting dirt-optimized vehicles to pavement.