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BICYCLE guide

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GENETIC ENGINEERING FOR BICYCLES

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Genetic Engineering for Bicycles

Rick Jorgensen's Computer Modeling

By John Schubert

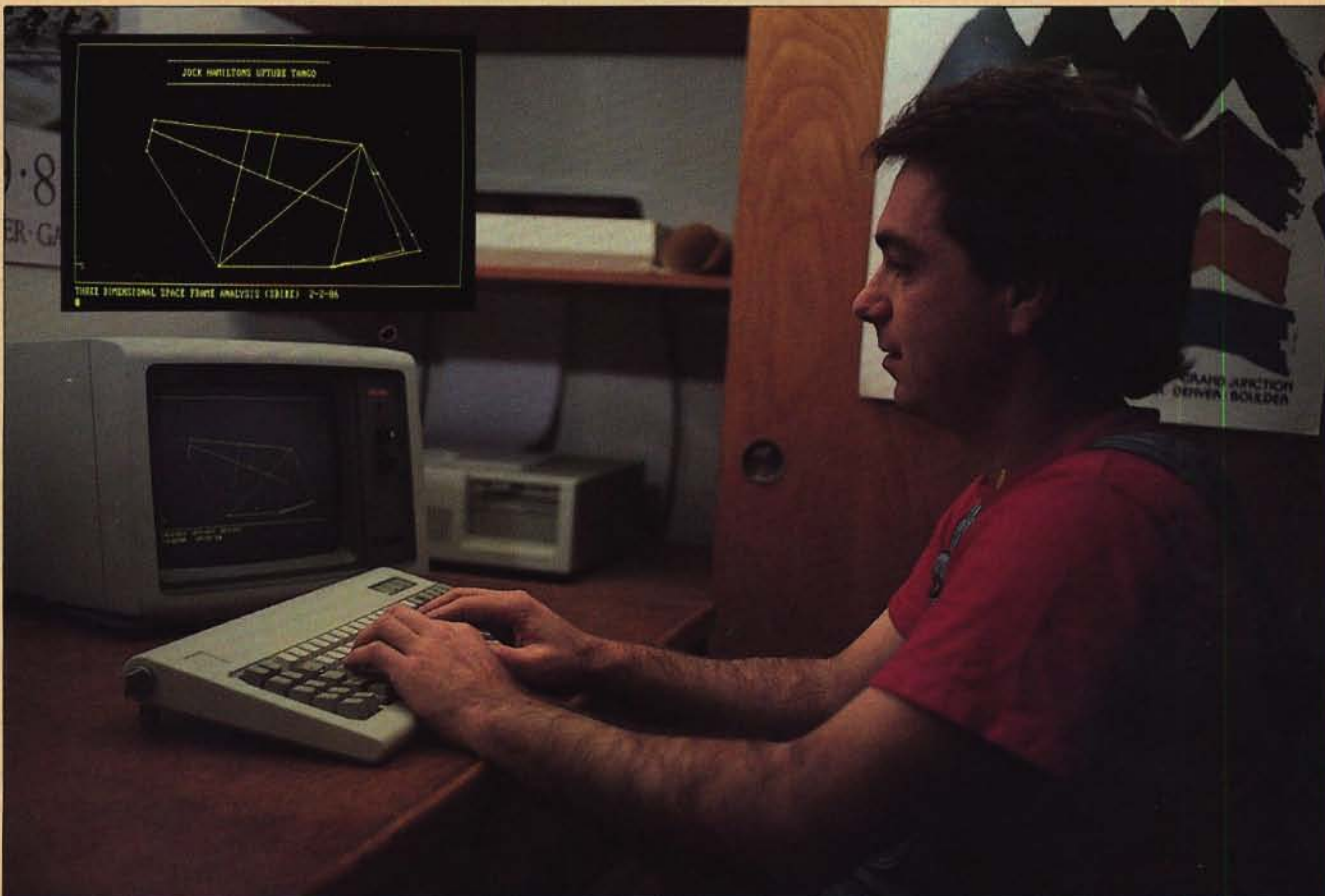


PHOTO & INSET BY JOCK HAMILTON

On occasion, computers have led to incremental improvements in bicycle design. Earlier in this decade, Ishiwata used a computer model of stresses in a bike frame to arrive at the wall thicknesses used in its quadrnple-butted tubing. Ishiwata's computer revealed a surprising and important result: A down tube needs more beef at its *top end*, not its bottom end, to increase bottom bracket rigidity. The company's quad-butted tubing is designed accordingly.

For the most part, though, compnters have played only a limited role in bicycle design. Companies reserve computer time to explore the unfamiliar bulk properties of aluminum and carbon fiber that they then craft into frames that mimic the behavior of traditional steel frames. Trek followed this route in rhe development of its new line of aluminum bikes. This application limits the computer to a role of reaffirming the ride qualities and design standards of bikes we've had for generations.

What about wholesale design changes? Is anyone using silicon magic to strive for something better than what our grandfathers had? Well, there is at least one compnter currently up and running, engaged in some of the most far-reaching work to date at improving the steel bike. At the keyboard is 31-year-old Rick Jorgensen, a part-time framebuilder who earns his living designing bridges—on a computer—for the California Department of Transportation (Caltrans).

At Rick's home in Davis, his IBM AT is loaded with a standard strnctural analysis program with special pre- and postprocessors. "The processors do most of the design work. All the structural program does is crunch a big matrix," said Jorgensen. The program models a bicycle frame as a series of beams of a certain size and shape connected ro each other at points called nodes. "We build a model, setting up coördinates and restraints, and design rhe frame members," he says. "Then we tell the model the properties of each of the members—their modulus of elasticity and shear, their moments of inertia, cross-sectional shape and area. We tell it how the axes of these cross sections are oriented," continues Jorgensen. "Then we put in certain design criteria, such as how you want the bike to ride—racing, touring, or whatever. After we've done that, the computer has a model of the bicycle. The program manipulates that model by applying the loads to it, generating forces, displacements, and stresses that we can look at and analyze."

After receiving the necessary data, the program puts together a preliminary design, flashes it onto the screen, and asks if the bike fits the rider(s). This is done before the structural analysis program kicks in; no sense enduring long bouts of number crunching only to design a bike that doesn't fit. After Jorgensen fine tunes fit, the computer launches into its structural crunch, analyzing one load at a time. Once done, another output lists specific performance criteria, allowing Jorgensen to see if this particnlar design meets his standards of stability and rigidity. If not, more changes can be made. "The computer can usually correct things, but I generally use engineering judgment to save time," says Jorgensen. For instance, if bottom bracket rigidity is insufficient, the computer will try one new tube at a time, seeking better rigidity. Jorgensen can usually tell right away which tube needs to grow in size or wall thickness. When he is satisfied with the numbers, the final stage of the program specifies wheelbase, trail, frame angles, all the tubing gauges, cut lengths, even the miters. All thar's left is to go to the shop and start cutting tubes.

Rick is a cyclist as well as a strnctnral engineer. "I've had three Cinellis, a Lejeune, two Jacksons, a Gitane Super Corsa and a Tour de France, three Colnagos, various Masis, Raleighs, Crescents and four tandems—a Jackson, a Gitane and two Taylors," he recalls. "I was struck with the mystique of the Italian ride so bad." Suffering this mystique helps. In Jorgensen's head, there's always crosstalk between his finite beam analysis and the wistful memory of his favorite Colnago. "The workmanship was really beautiful—like today's best American custom frames." That appreciation for the traditional bike's attributes gives Jorgensen a reference as he seeks to do existing designs one better.

Jorgensen started building frames while still in high school. He worked in a bike shop whose on-site framebuilder had just quit, leaving behind two dozen Columbus tubesets. With no instructions, no books, and no training, Jorgensen cobbled together frame after frame, always seeking to duplicate the Masi hanging on the wall.

Jorgensen's current single bike designs go well beyond simple duplication. His Tango single, reviewed in the accompanying article, combines several unconventional design touches, including a rising top tube, oversize tubing, and seat stays that tie into both the seat and the top tubes. The result is a frame with increased bottom bracket rigidity and a hint of shock absorption. None of these modifications is strictly original—examples of each are amply documented in cycling technical literature—but he *used* them all to good effect.

"Single bikes have evolved to a good design. With the computer, we can do genetic engineering on tandems, rather than letting them evolve slowly."

It is in tandems, though, that Jorgensen has found room to roam. "Single bikes have been beat to death—they've evolved to a good design," he says. "But in tandems, there hasn't been enough interest to get to that state of evolution. Now we can do genetic engineering on tandems, making changes in two days, rather than allowing them to evolve like the single bike did over 150 years."

In just a few short years, Jorgensen has broken much new ground in tandem frame rigidity, emergency handling characteristics, and stoker position. Admittedly, Jorgensen is splitting hairs—going to great lengths to get still more performance than is available on already excellent tandems from the likes of U.S. builders Santana, Rodriguez, and Davidson. Bur one thing Jorgensen knows, and something I found out, is that small improvements noted by the computer can equal large differences to the riders.

I believe a major factor in this perception is wrapped up in one of Jorgensen's pet phrases: biomechanical interface. "The biomechanical interface involves all the little vibrations, the frame's responses to steering and pedal inputs, and other factors thar give pleasing feedback to inspire the rider to greater effort. Testing machines don't measure these factors." Small differences can feel big because the end user is a human being and not a dial indicator.

Knowing what to look for is vital if you want the computer to come up with a successful design. Jorgensen's tandem design philosophy is a blend of riding experience and a keen engineering sense. "What I'm looking at in bike performance is lateral deflection at the rear seat cluster. This determines how well the bike handles in an emergency maneuver," explains Jorgensen. He likens throwing a flexible tandem into an avoidance maneuver to how a single bike feels when burdened wirh 50 pounds of baggage on a rear Pletscher rack. "It's that wiggly feeling, when the rear wheel feels like it doesn't want to follow the front wheel, that I want to avoid. Anyone who's ridden a tandem can relate to this."

Jorgensen next looks at lateral deflection of the fronr bottom bracket. "I want a bike that feels right when both riders pedal out of the saddle. A randem that washes out in rhe bottom bracket is very tiring—you keep having to fight the bike to keep it in a straight line."

Deflections in the electronic world are specified by displacements at the frame nodes. There are 28 nodes on Jorgensen's tandem frame model (one on each of the many tnbe junctions), and each of them is analyzed in translation and rotation in X, Y, and Z directions. The IBM AT is a bit underpowered for the job at hand. After entering the data, Jorgensen must let the machine cook for 41 minutes. (When I visited, he was using cruder disc access software and a slower clock, and it took four hours.) It uses three megabytes of hard disc space for temporary files as it chews on a 160 x 160 matrix, producing a ten-page report on the new design. It may sound slow, but it beats building dozens of experimental frames and testing them with weights and dial indicators.

The ten page printout tells how much each node deflects when you impose a hypothetical load on the frame. Jorgensen's favorite data point, the Z-axis translation (sideways bending) of the rear seat cluster, usually falls within the range between 0.05 and 0.06 inches for almost all good tandems. All numbers on the printout make sense only in comparison with each other. They are not absolutes. "The computer treats each frame fairly, telling us this frame's deflection is greater than that frame's deflecrion. It isn't telling us on an absolute level how big each one is," says Jorgensen. "We don't care about exact numbers. All we care about are comparisons."

In discussing frame design with Jorgensen, it is easy for him to pass over two other important aspects: strength and weight. He is mindful of both, but notes they always seem to come out in the wash. "We find that a bicycle that is designed for performance, that is, lack of deflection in the important places discussed, that its strength is more than adequate. I'm really not worried. Look at all the tandems on the market built with itty-bitty single bike tubes that don't break." Finally: "I do look at weight, but I find a way a bike rides is much more significant than what it weighs."


PHOTO BY JOCK HAMILTON

Jorgensen uses lugless brazing to join computer-selected tubing in all his framesets.

Jorgensen's tandem designs, sold under the brand name Tango, have migrated from odd to bizarre since he first started selling them in 1984. Most other tandem builders now use a reinforcing tube which runs from the head tube to the rear bottom bracket; before 1983, builders tended to favor running this tube to the midpoint of the rear seat tube, where it joined midstays which ran to the rear axle. These two reinforcing schemes are called direct lateral and marathon, respectively.

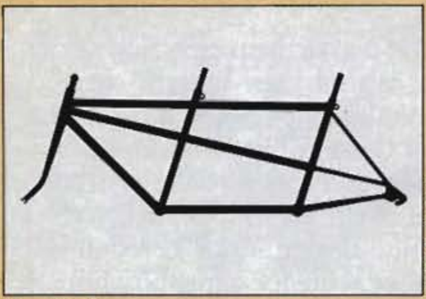
On the road, they aren't very different. The direct lateral gives a slightly more comfortable ride and better front bottom bracket rigidity. The marathon has a bit more torsional rigidity, which stiffens the frame in slalom maneuvers. At a time when most builders had decided to forego this slight advantage of the marathon frame, Jorgensen went in the opposite direction by combining direct lateral and marathon tubes on a single frame. The resulting bike got an A+ in the slalom when I tested it 2½ years ago. It weighed more, it cost more, and it seemed to give a harsher ride—but it was the ultimate bike for two heavy, strong riders who like high speed cornering.

His new frame design, first conceived when he was daydreaming in a bridge design seminar, sports what he calls an "up tube." An oval tube, with its long axis oriented sideways, runs from the front bottom bracket to the rear seat cluster. The frame also has a marathon tube, but no midstays. The seatstays utilize a variant of the bypass seat cluster—they are brazed to the sides of the seat tube a few inches below the seat cluster, and they terminate at the up tube. We aren't done adding tubes yet—Jorgensen favors brazing a short vertical tube behind the captain's seat, as a mounting point for the stoker's handlebars. ("It's more adjustable than putting a stem on the captain's seatpost," he explains.)

Structural analysis reveals the genius in this design. Of course, the marathon tube is perfectly placed to resist torsion between the head tube and the rear axle. The up tube helps the marathon tube keep the rear seat cluster from wagging side to side, and it adds much needed lateral stiffness to the front bottom bracket. Moreover, the up tube—which is supported in three places—only has to resist bending. In older designs, its job was shared by tubes trying to resist torsion, and the torsion was applied to those tubes through long lever arms. Of course, the oval top tube affords better lateral rigidity, as do the exceptionally beefy Santana fork blades and chainstays.

The bypass seatstays help stiffen the seat cluster area. They're 17 inches long where ordinary ones are 20, and they're reinforced amidships where they are brazed to the seat tube. Also, they theoretically allow a tiny increase in rear end shock absorption by transferring some of their traditional compression loading into bending.

All this tubing requires Jorgensen to pay about five times what most framebuilders pay for an entire single bike tubeset. But the result is wonderful. At long last, a tandem has front bottom bracket rigidity that feels like a single, and handles the slalom even better than

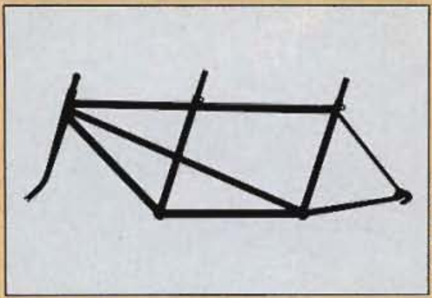


MARK E. ALSOP

Marathon frame

Jorgensen's earlier design. On paper the numbers are close, but on the road, ride improvement is notable. The stiff front bottom bracket overcomes the only dissatisfaction I've ever had with other good tandems, and it encourages you to stand and hammer when you would otherwise sigh and downshift. The enhanced slalom performance is less important to me, but a pair of heavier, stronger riders might really appreciate the extra rigidity.

This design may receive the ultimate test from two such strong riders: ultra-



MARK E. ALSOP

Direct lateral frame

marathon legends Lon Haldeman and Susan Notorangelo. Jorgensen recently finished an up tube tandem for Lon and Susan's forthcoming transcontinental tandem record attempt. Their requirements were extreme: Lon would be the stoker, and he wanted the exact same position as on his single bike. That dictated a 32-inch rear top tube, about five inches longer than most builders ever go. (Most tandem designers would tell you this is unnecessary overkill, but most stokers don't ride 22 hours per day.)

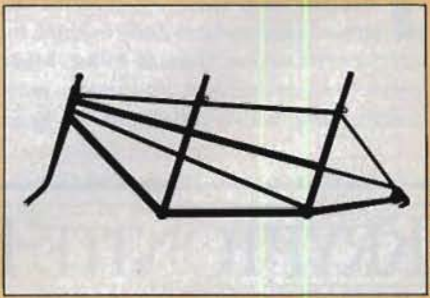
Jorgensen was entering uncharted territory. Sure, the bike could be built—but how much would frame rigidity suffer? How beefy would the frame tubes need to be to give the tandem the same emergency handling characteristics as, say, a Santana with a 25½-inch rear top tube? The computer supplied the answers, and I had the opportunity to compare the bike to several other fine tandems as Rick and I did some road testing.

We compared four Tangos and two baseline tandems. The Tangos included two of the earlier design, with 25½ and 28-inch rear top tubes, an up tube bike with a 28-inch rear top tube, and Lon Haldeman's up tube bike with its 32-inch rear top tube. Two Davis bike shops generously lent us baseline tandems: B&L provided a Santana Sovereign, and Wheelworks provided a Gitane.

The Gitane, a $700 casual use tandem, was thrown into a test of $3,000 and up machines on a whim. We rode it for laughs, but instead we learned something. Despite its skinny tubes and its nonreinforced open frame, it was reasonably rigid. The reason: shorter is stiffer. That wasn't obvious from the rear top tube measurement (around 23 inches), but the rear bottom tube was two inches shorter (giving an absurdly shallow rear seat tube angle). Its torsional rigidity was more than adequate for its intended use.

The next rung on the ladder was the Santana, lent to us with the proviso that we refer to it as "the most accepted high performance tandem on the market." And indeed it is. Santana President Bill McCready had once looked into CAD/CAM design and dismissed it as "impossible at any reasonable cost. The only way you can use a computer is to fill it with measured data first. The computer will only tell you what'll happen if you change something, based on what it did before." Instead, Santana chose the arduous task of test fixtures, dial indicators, and a garage full of prototypes to guide them in arriving at the design they and their customers prefer.

"I'm surprised how good the Santana is," Jorgensen said as we took it out to

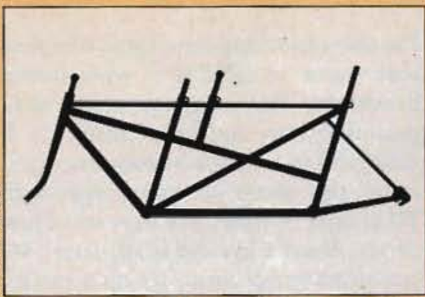


MARK E. ALSOP

"Old-style" Tango design, incorporating both a direct lateral and a marathon reinforcing tube.

watch crop dusters buzz suburban Davis. We stood up on it, we yanked it through corners, and we agreed that tandeming could, at most, get only slightly better than what we were experiencing.

The next bike on the list was the Haldeman/Notorangelo up tube machine. Because of the long rear top tube, we almost needed a walkie-talkie to converse, and the bike took longer to drag its rear end around a corner. Riding stoker on a bike with so much room gives new meaning to the phrase elbow room; riding captain on a bike made for Notorangelo's short arms and upright riding position does not. But both slalom and sprinting tests got excellent grades. Before Jorgensen built the bike, the computer told him to use top and up tubes with 0.049-inch walls, rather than the more usual 0.035-inch. The additional wall thickness gave the bike the rigidity it needed—and the computer eliminated any guesswork.



MARK E. ALSOP

Jorgensen puts final touches on new "up tube" Tango frame.

"Too close to call" would be my verdict in comparing the slalom performance of the Haldeman/Notorangelo bike with the two old-style Tangos. (They differed from each other in rear top tube length—25½ and 28 inches.) The computer gives nearly identical Z-axis translation readings of 0.054 and 0.055 for the two, and all three bikes are excellent. The old-style Tango with the 28-inch rear top tube is really a kick—perfect for those of us who are a half-foot shorter than Haldeman. Stokers can get spoiled by stuff like that. Now I see why Lon wanted 32 inches of room on the transcontinental bike.

PHOTO BY JOCK HAMILTON

By far, the most impressive tandem of our test was the up tube Tango with the 28-inch rear top tube. As described above, the captain's bottom bracket rigidity is wonderful, and I preferred its tighter wheelbase when I was steering. IBM's 0.052 Z-axis readout confirms what I felt—this is as stiff a tandem as you could imagine.

All this computer work—which Jorgensen would love to sell to bike companies on a consulting basis—has proven to be very successful. His program is so finely tuned that he has never second guessed it, never brazed in a tube with more wall thickness than the computer said was needed. "I haven't had a bike that's lied to me. Everything that the computer has told me is a guess in the right direction," he revealed.

Nevertheless, the program is still only good at making accurate comparisons among existing designs and those created in Jorgensen's mind. But Jorgensen outlines his plan to one day have exact numbers: "What we can do with the next generation is complete modeling of the bike. That's a dynamic simulation, a step beyond the static simulation we're doing now," he said. It would involve having enough data recorders and strain gauges for a 100-channel analog monitoring of on-the-road frame flex, an analysis done routinely by major companies to refine existing designs, but not yet done by mavericks like Jorgensen seeking radical changes.

"It corresponds closely to what we're doing with bridges. In 1971 we had the earthquake, and several bridges failed. The earthquake modeling in our bridges was not up to par. We used static loads. Now we're using dynamic analysis to generate earthquake loads on the columns, to build columns that won't break under a reasonable earthquake. Right now, with bicycles we're where we were with bridges in 1971—using static loads for guidance."

What else does the future hold for computers in the bicycle industry? "My market is opening up," Jorgensen said. "I've had a couple of companies approach me to help them design tandems. I'm also consulting for a small company that wants to develop a triple-butted handlebar. This company could build prototype bars and break them. Or it could call in a computer consultant and avoid the seat-of-the-pants approach. What type of loads will bars see? How do you detect and avoid stress risers? We can strain gauge them, set up a model, determine what material and gauge of material is best for the application, and finalize the design right on the computer—just like I've done with my tandem designs. I think there's a real future in design consulting." □

Tango Tandems and singles are custom designed and built one at a time, once every week or two, and the waiting list currently stands at six months. Both up tube and traditional tandems are available. Tandem framesets start at $3,000, complete bikes at $4,000.

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