Materials • Mechanics • Physiology • Engineering • Aerodynamics

BIKE TECH

Bicycling Magazine's Newsletter for the Technical Enthusiast©

February 1987 $3.00

NEW DEORE XT

Shimano Sets New Off-Road Standards

Fred Zahradnik and Don Cuerdon

Not that most of them would care anyway, but mountain bikers don't have to feel inferior to their road brethren any more when it comes to experiencing high-ticket parts lust. Finally, here's a 2nd-generation component group that takes looks, performance, and price up to a new level for off-road parts.

Shimano's New Deore XT will certainly please riders looking for a way to increase the distinction between their expensive, hand-made "dirt hogs" and inexpensive factory jobs sporting (until now) the same top-line components. With its projected retail price of over $500, you won't find New Deore XT hanging on many $450 specials.

But forget the snob appeal. This group works great! For starters, there's the Shimano Index System (SIS) rear derailleur and thumbshift lever. With a click of the lever, the derailleur grabs those big rear cogs (up to 32 teeth) quickly and cleanly. For us, one of the best features of SIS is being able to shift while standing up and not having to fuss with fine adjustment.

Front shifting with New Deore XT represents a step forward for mountain biking, too. Thanks to the front derailleur's rigidity, trailing action pantagraph mechanism, and the new Biopace II chainrings, front shifting is smooth.

Then, there's the new U-brake. It's actually an updated, beefy version of an old tourist favorite, the braze-on centerpull, which in this case is designed to work on braze-on bosses positioned for roller-cam brakes. The brake is powerful and easy to control. In addition, the New Deore XT brake levers, pedals, front cantilever brakes and QR seat lever all have their own nice touches that we'll describe in detail later.

Reliability and Performance

When they created the New Deore XT components, Shimano engineers must have spent as much time considering input from expert riders as they did at their CAD terminals, because the New Deore XT's features read like an off-road addict's wish list.

"We developed our goals for the New Deore XT by looking at what the top racers were using, and asking them what

■ *Biopace II's middle and outer chainrings feature ramped "plateau" sections and different tooth profiles to facilitate shifting. Note the cutouts in the plateau sections to aid chain pickup and the tabs on the inner ring which prevent chain jamming on a missed shift.*

PHOTOGRA JY JIM REDCAY

FORWARD TO THE PAST

WELCOME TO THE NEW *Bike Tech*. Or, if you prefer, the original *Bike Tech*. Don't worry, we're not bent on some nostalgia kick, or looking to turn back time. In fact, contrary to populist trends that have us electing aging film idols to the presidency, dressing like crewcut '50s jocks and bobby-soxers, and fantasizing about our parents' adolescence, we're taking *Bike Tech* forward to the past, not back to the future. Confused? Then let's contradict what I just said for one second and take what I hope will be a typical future step for *Bike Tech*: let's "go back" to some basics.

From its inception, *Bike Tech* has always been designed for the "technical enthusiast." Unfortunately, too often in the past being an enthusiast has meant initiation into the Brotherhood of Adopted Knowledge, or "BAK" for short. You know, "You've got to use this derailleur to be faster, and wear only these shorts; here, buy my old wheels," etc. While this approach is great for upholding tradition, and imparts a genuine feeling of belonging to those who pay their dues, it doesn't lend itself to defining new questions or searching for better answers. We find ourselves constantly looking to the equipment, the training, and the attitudes of the past to define what the future of the sport will be.

Anyone who's been in the sport for more than 6 years will avow that this unprogressive stance isn't a figment of my imagination. It's a mold in which the upper echelons of bicycling were smugly cast for decades.

But the mold has a large crack in it, caused mostly by the new cyclists entering the sport. They've arrived so fast and in such large numbers that the old guard hasn't had time to teach them their "manners." The hallowed names of the past mean little to these new barbarians (especially American riders!). They just want to ride their bikes.

We should learn a lesson from these newcomers, and all the old-timers with good focus. In almost every one of our own cases, it was the exhilaration of riding that hooked us originally, too. And whether it was the speed and fluid motion we achieved as we gritted our way up one side of a hill and flew down the other, or the solitude of a quiet solo through the countryside, we've all experienced the bicycle's magical extension of human movement.

Let's look forward to each new ride as an affirmation of that past, with an eye open to *all* new aspects of equipment *and* the human body that can improve our riding experience. We're not going to depart from the leading-edge technology we've presented in the past, but just broaden it and make it easier to understand. I'll work to make *Bike Tech* reflect this new, wider scope. Let me know what *you* think.

Jim Redcay
EXECUTIVE EDITOR

IN THIS ISSUE

Volume 6, Number 1

Materials • Mechanics • Physiology • Engineering • Aerodynamics

BIKE TECH

Bicycling Magazine's Newsletter for the Technical Enthusiast™

Bike Tech-Bicycling® Magazine's Newsletter for the Technical Enthusiast® (ISSN 0734-5992) is published bi-monthly by Rodale Press, Inc., 33 E. Minor St., Emmaus, PA 18049. Subscription rates: United States, one year $17.97; two years $35.00; Canadian add $5.00 per year, payable in Canadian funds; other foreign add $8.00 per year (includes air mail postage) payable in U.S. funds. Single copy price: $3.00. Inquire about bulk rates.

POSTMASTER: Send address change to *Bike Tech*, 33 E. Minor St., Emmaus, PA 18049. Second-Class Postage Paid at Emmaus, PA 18049. *Bike Tech* may not be reproduced in any form without the written permission of the publisher.

Editorial contributions are welcome. Send inquiry or write for guidelines. Include a stamped, self-addressed envelope for return of unused material.

■ *The heart of New Deore XT, SIS shifting for dirt riding. The extra cable adjuster on the rear thumbshifter typifies Shimano's attention to detail.*

they'd like to have," says John Uhte, of Shimano Sales Corporation. "We got plenty of feedback at the prototype stage from the best mountain bike builders, too."

The overall mechanical effect is one of solid reliability and performance, to the extent that light weight was obviously not a major consideration.

The overall look is svelte flat black and polished aluminum—components that visually *belong* together, rather than being separate pieces which happen to be on the same bike. This harmony is most noticeable at the handlebar, where the smoothly contoured black brake levers meet the flowing lines of the flat black shift-lever mounts. But good looks are a bonus with this group—XT's real forte is still performance.

Rear Shifting

The New Deore XT indexing shift lever and rear derailleur deliver state-of-the-art gear changing for off-road bikes. Our test riders were able to shift gears quickly under a variety of off-road conditions. Hearing and feeling the click, and getting the next gear, higher or lower, are nearly simultaneous. There's no need to overshift to get the next lower gear. If the system comes out of adjustment (it didn't for us), it can be easily corrected, *even while riding*, with the extra cable-adjustment barrel on the shift lever.

The rest position for both thumbshifters can be turned to any of three orientations by loosening an allen bolt underneath the lever-mount body. Just remember to shift onto the small freewheel cog or the inner chainring before you start, because cable tension can turn the lever as soon as you loosen the allen bolt.

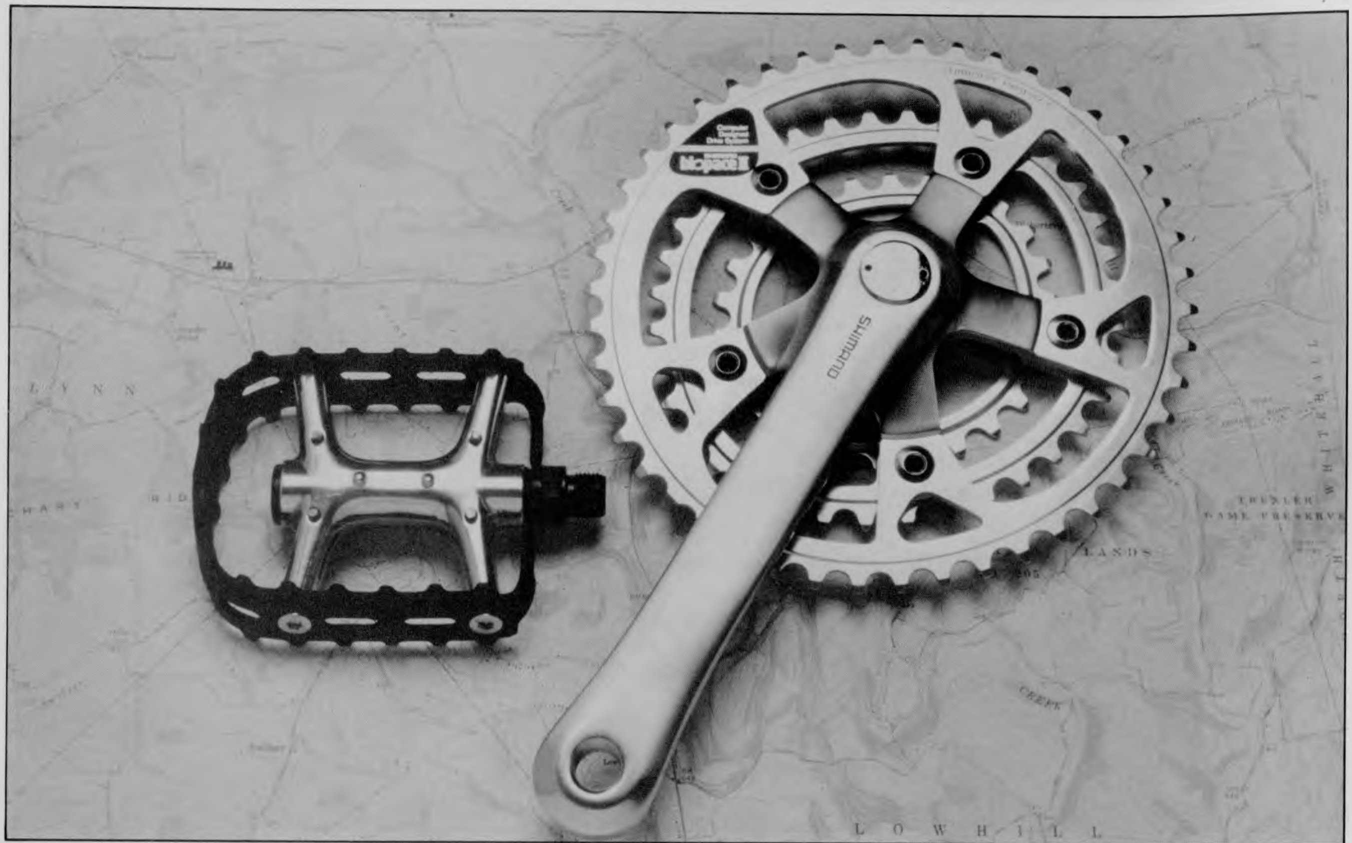
Another rider option is whether the SIS click-stop mechanism is engaged or not. A thumb lever opposite the shift lever, which has two stops, clearly marked "SIS" and "F," for friction, is much easier to operate than other off-road systems we've tried.

White hash marks on both front and rear lever bodies indicate the present gear, but are undoubtedly superfluous for the same reason indexed shifting is so suitable for ATB adventures. If you're riding fast enough to merit these components, your eyes belong on the terrain, not the shifters.

Although the thumbshifter is designed to work with the New Deore XT rear derailleur and freehub, the same shifter will index the 600 SIS rear derailleur for the racing hotshots who don't need freehub (or freewheel) cogs bigger than 26T and want a lighter derailleur. But don't forget that this road derailleur only wraps 27 teeth, and the 600 derailleur won't endure nearly the same abuse as the XT.

The converse setup is likely to be a far more popular one—just match any Shimano index-compatible freehub or freewheel with the New Deore XT rear derailleur and 600 SIS levers, and you'll have a wide-range tourist's delight. The XT rear will handle a freewheel range of 13-32T and a maximum front/rear sprocket difference of 38 teeth.

The New Deore XT rear derailleur appears stout enough to weather quite a bit of off-road abuse, with features intended to help it withstand constant exposure to dirt. First, there are the O-ring sealed pivot pins and the sealed pivot axle. Then there's the ceramic guide pulley bushing similar to the one used in the 600 SIS rear derailleur. The advantage of the ceramic material is that it's so hard, it can turn the tables on sand and other grit and grind *them* to powder.



■ *Shimano's New Deore XT pedal is toe-clip adaptable and sports a slanted cage and steel pins on the pedal body for sure footing. The crankset is strictly business—big and tough.*

Its only disadvantage is its higher friction. Brass pantagraph pivot bushings and stainless steel pivot pins also add to durability and strength.

The double spoke barrier, which prevents the derailleur cage from catching in the spokes if the cage happens to touch them, is more likely to prove its worth in the dirt than it has in the past on Shimano's road derailleurs. Two chain-retainer tabs restrain chain lash to help keep the chain on the pulleys in rough terrain.

A hanger-bracket adjustment screw permits adjustment of the distance between the upper derailleur pulley and the largest cog. Shimano has found that keeping that gap to a minimum results in the fastest, most consistent indexed shifting. With the chain on the smallest chainring, adjust the upper pulley as close to the freewheel as possible without interfering with the shift onto the largest sprocket.

Front Shifting

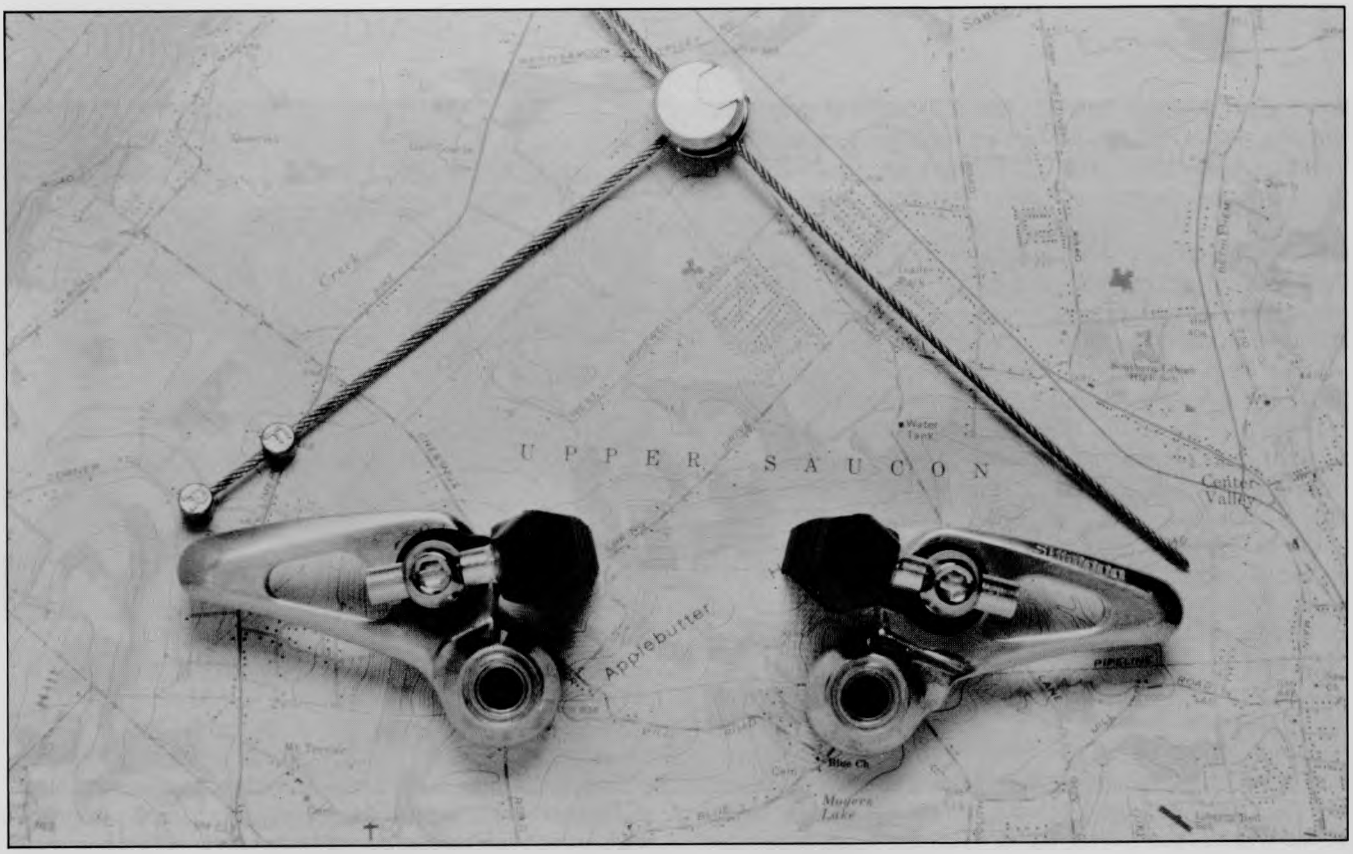
The "shift" toward indexed shifting on road bikes has focused attention almost exclusively on rear derailleur developments, but this ground-breaking component ensemble has enough improvements in handling the front end of the chain to almost reverse that syndrome. Shimano's New Deore XT front derailleur and Biopace II chainrings not only upshift and *downshift* smoothly with more pedal pressure than any other system we've ever used, they also make the dreaded 'tween-rings chain drop almost impossible, no matter how slowly you downshift. That control translates into more available gearing options when the terrain becomes steep or uneven, and, as a result, more effective hill-climbing.

The FD-M730-AL (alpine) front derailleur is a crossover type, with a deep, rigid inner cage-plate and trailing pantagraph action. That means the cage moves *forward* as it traverses from the large chainring to the smaller ones. That diagonal movement keeps the cage closer to the chainring and minimizes jamming, thereby assisting downshifting. The alpine front derailleur we tested requires a minimum of an 8-tooth difference between chainrings and handles a 26-tooth maximum chainring capacity with round chainrings. For Biopace chainrings, the specs are 8/22T. Shimano also has a half-step version (FD-M730-HS) which works with a minimum difference of 5 chainring teeth and a total capacity of 26 teeth with round chainrings. The half-step's Biopace capacities are 5/22T.

Biopace Upgrade

A lot of the improvement in the front derailleur's performance can be attributed to two developments featured on the Biopace II chainrings we tested. They feature the same "point symmetrical egg curve" as the original Biopace, but with three distinct shapes of teeth: normal, high, and twist-tooth. Our 26/36/46T set seemed to catch the chain at appropriate times to assist the front derailleur.

The second development, "plateau" or thickened, ramped sections on the sides of the outer and middle chainrings, helps deflect the chain away from the gap between chainrings during downshifting, and onto the



■ *The main brake cable forms half of the transverse cable with the New Deore XT cantilever cable yoke. The slight bulge under the cantilever arm on the right hides a set screw for spring tension adjustment.*

chainring teeth waiting below. Cutouts in the plateau sections minimize their interference with chain pickup during upshifting.

If all this idiot-proofing isn't enough to suit you, consider one of off-road riding's frequently suffered embarrassments, the shift onto the "smallest" chainring (otherwise known as the bottom bracket shell to all you innocent roadies). Often, component injury follows rider insult when the chain proceeds to wedge itself steadfastly into a new home between the underside of the chainrings and the bottom bracket shell. The small tabs projecting inward from the chainring bolt holes of the Biopace II's inner chainring prevent this calamity, allowing you to shift back up onto a real chainring and pedal away without having to dismount and untangle the chain by hand.

Currently, Biopace II chainrings are available in 26T inner, 36T middle, and 46T outer sizes. Shimano plans also to supply the new configuration sometime in 1987 in 28T inner, 38T middle, and 48T outer rings as well.

Crankset

Beefy doesn't quite describe the New Deore XT crankarms. Massive comes closer. Their shape is apparently derived from the Computer-Aided-Design profiles of the New Dura-Ace track crankset, and it's equally confidence-inspiring. The cranks are available in 165 mm, 170 mm, 175 mm (our test length), and 180 mm for all you Jolly Green Giants.

The bottom bracket is a conventional cone-cup bearing type, with the addition of Shimano's easily serviceable, effective, sealed mechanism in the cup apertures. Cup threadings available include English, French and Italian with the appropriate size axle.

Pedals

The New Deore XT pedals are a hybrid that combines features from quill-type road pedals and Shimano's own experiments with off-road platform pedals like the DX. The heavy-duty cage sports large, blunt teeth for a secure grip that's augmented by stainless steel pins pressed into the massive pedal body.

Seen from the side, the pedal cage has a parallelogram section that greatly aids foot placement on the pedal—just press down on the pedal. The forward cant of the front and rear cage plate sections will flip the pedal up against the underside of your foot, without the need for an easily damaged kick tab. To make it easier to mount toeclips on the slanted plates, Shimano offers an angled shim plate, and there are toe-strap slots in the cage and the body arms.

Ground clearance for the 3-cm-deep XT pedal is good, but if you do stick one in the mud, the open design sheds it easily. In addition to typical Shimano labyrinth seals, a thick, pliable contact seal also guards the Conrad-type ball bearings and chrome-moly spindle.

Brakes

It's a long way (8.8-cm straight line) from the cable anchor to the pivot point of the new rear New Deore XT U-brake. That distance translates into substantial leverage and stopping power: enough to literally lock up the rear wheel on a paved, 35-mph descent. It's power with control. Once the brakes are applied, subtle modulations in braking force can be made. But stopping power isn't the reason you'll love your U-brake. The first time you slog your way through mud wet enough to totally clog up a chainstay-mounted roller cam brake, you'll be delighted to find you still have a rear brake that stops braking when you want it to. The 10-ounce U-brake offers plenty of clearance between the caliper arms and the tire, as well.

The simplicity of the U-brake design—two hefty brake arms mounted on two pivot points—implies reliability and low maintenance. The calipers' return springs are enclosed at the pivot point, and the pivot bushing is sealed. The return-spring tension can be fine-tuned with a 2.5-mm allen set screw—major adjustments are accomplished by resetting the return-spring position. The U-brake's extra-firm, low-profile brake pads worked well in both wet and dry conditions.

Like many centerpulls, the U-brake does not have a quick-release mechanism, per se. Instead, you simply pull a tab located at one end of the transverse cable, squeeze the pads against the rim, and slip the end of the cable out of its slot. An even faster quick-release can be achieved by freeing the wheel, then forcing the tire forward against the upper segment of the brake arms. That squeezes the arms together, releasing the tension on the transverse cable. That's often sufficient to free the cable end automatically. If not, flick it loose with your free hand. To put in a new wheel, position it between the chainstays and jam it against the upper arms again, then fasten the end of the transverse cable with your free hand. Just don't forget to secure your rear wheel in the dropouts!

The front cantilevers that are standard with the New Deore XT package are more than a match for the U-brake. "The U-brake is more powerful than last year's cantilever, but this year's cantilever is more powerful than both!" reports Uhte. The longer, more upswept arms of the new cantilevers orient the transverse cable close to a 90 degree angle with a line from the pivot point to the cable end of the cantilever, for the best mechanical efficiency.

Besides stopping your ATB with smooth authority, the New Deore XT cantilever is also a lot easier to center and synchronize. The most obvious feature dealing with these typical cantilever problems is the special cable anchor (or "carrier," as Shimano dubs it). One leg of what appears to be a standard transverse cable is actually a short, separate cable with end buttons at each end. The other leg of the "transverse cable" is the extension of the brake cable, which is clamped as it bends through the cable anchor and then proceeds to the end of one of the cantilever arms, where it is secured. This means the position of the cable anchor is adjustable, and secured as well.

Making the individual cantilevers touch the rim in unison is an easier task, thanks to another spring-adjusting, 2.5-mm setscrew like the one found on the U-brake. And you'll receive another, unexpected benefit from that adjuster.

■ *The reach adjusting screw shows on the underside of one brake lever, just clean, strong lines on the top of the other. The U-brake is simple and solid, with lots of clearance.*

The usual method of synchronizing cantilevers requires pulling one or both of the brake pad studs some distance out of their holder, thereby decreasing mechanical advantage while increasing stud bending. Because the Shimano spring adjuster accomplishes synchronization without having to pull out the pad studs, you're more likely to enjoy the maximum braking power of the Shimano system.

Depending on the configuration of your current bike, you should be able to purchase the XT group with two pairs of cantilevers, 2 U-brakes, or one of each.

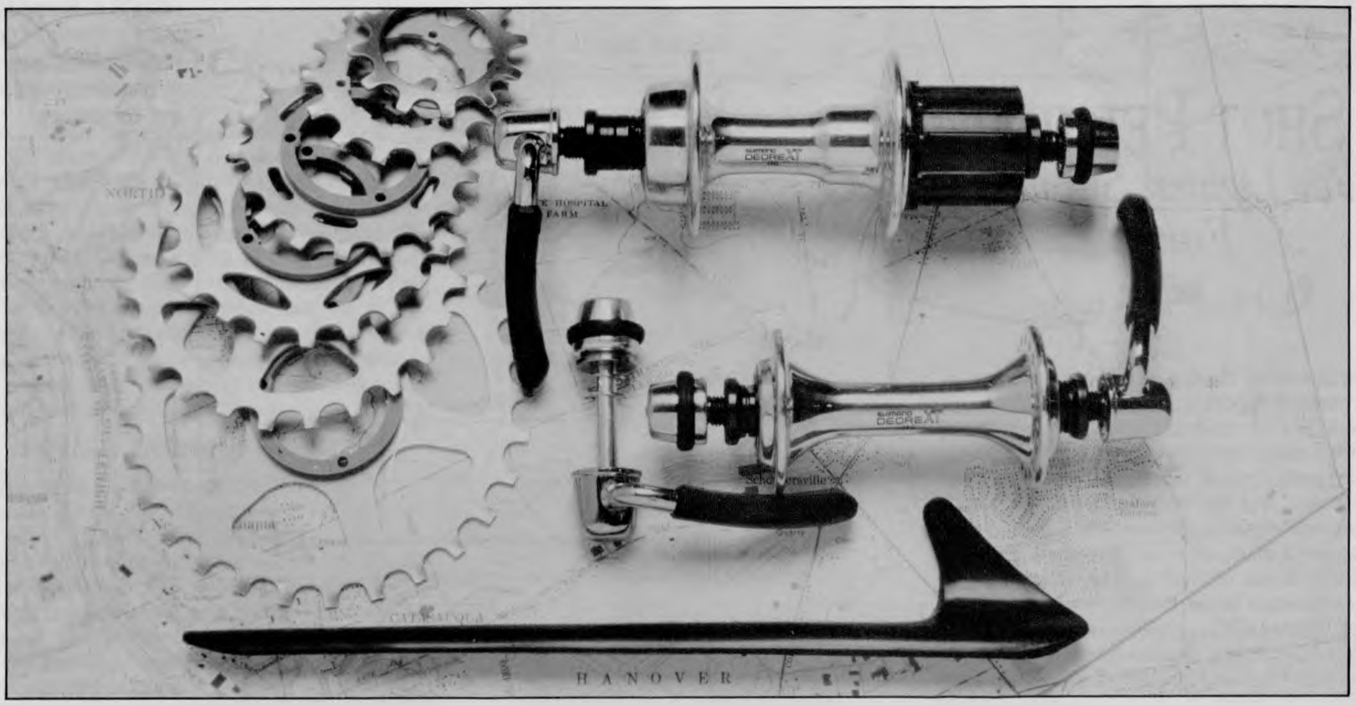
Rounding out this excellent brake package are the new New Deore XT brake levers. One of our favorite features is the 4-position lever reach adjustment. Even a coin fits into the wide-slot screw head, which can be easily turned to change the lever-to-grip distance. This permits the levers to be adapted quickly to four hand sizes.

The levers are sleekly contoured and comfortable in the hand. They have a smooth, even action and come with rubber hoods, which shield the hinge area from dirt. The levers can accommodate a variety of cables and casings, up to the 6-mm casing and stout 2-mm cable which come standard.

Hubs

At first glance, the New Deore XT freehub appears similar to the same road cassette hub familiar to us for several years. That's to be expected; using Dura-Ace cassette freehubs for "bullet-proof" off-road wheels has been an insider's trick for a while. It would be hard to imagine better proof for Shimano's contention that the freehub design almost totally eliminates bent rear axles.

Closer inspection of the XT freehub, however, reveals some adaptations for off-road use. More material has been left in the hubshell than with the Dura-Ace model for added strength, and the lower-friction, labyrinth-type seals used in the Dura-Ace hubs have been buttressed with the addition of better-sealing, full-contact seals. Lubrication ports in the dust caps can be opened with a simple twist, allowing you to



■ *Black gum rubber covers adorn the quick-release levers of Shimano's latest designer dirt group. The "sharkfin" chainstay guard eliminates chain jamming between the chainstay and the rear tire. The trusty freehub has been reinforced for off-road abuse.*

use a hypodermic-type grease injector to lube the hub bearings without disassembly.

At this time, the XT hubs are only available drilled for 36 14-gauge spokes, but with a choice of nutted or quick-release axles. Ours came with the new quick release, complete with rubber-covered handles and a full-size rear skewer specifically designed for a 130-mm hub.

Freewheel

The XT freewheel is an integral part of the freehub unit—the freewheel inner body is actually bolted to the hub and supports the right side axle bearing out near the end of the axle, instead of an inch or more in from the end like a regular hub/freewheel combination. The New Deore XT version has gone a step beyond earlier Shimano road freehub models by using a large, hollow allen bolt (10-mm hex wrench size!) to secure the freewheel to the hub body, for greater strength and easier disassembly and maintenance.

All the cogs except the screw-on outermost are identically splined and interchangeable with 600 and Dura-Ace cogs, and the spacers are a uniform dimension. This makes fine tuning your gearing a snap with two chain whips and a variety of cogs. Cog sizes available include 12T-26T, 28T, 30T, and 32T. Shimano makes a 34T freehub cog, but they don't guarantee SIS performance above 32T.

Other Goodies

What's the perfect complement to your seat post Hite-Rite adjuster spring? A seat post quick-release that has a handle which stays in position even when loosened. According to Shimano, you'll find the New Deore XT quick-release lever in the same position every time you reach for it, thanks to a built-in spring pre-load device. It didn't work that well on our test bike, but the XT quick-release was designed to work with a quick-release seat lug boss, according to Uhte, not the threaded, bolt-type on our test bike.

Shimano's knack for finding good names for components lives on. "Sharkfin" is the memorable moniker of the New Deore XT's chainguard. Besides protecting the finish on the top side of the chainstay, the fin section prevents the chain from bouncing down and jamming itself between the tire and the chainstay.

The only items absent that you would normally expect in a component group are a headset and seatpost. According to Shimano's Wayne Stetina, "Headsets are becoming as expendable as chains. So far, we haven't come up with a headset that's radically different from what's available, but we're working on it." For now Shimano recommends either the 600 or Dura-Ace headset for off-road use. Stetina also reports that Shimano doesn't have an existing seatpost that's long enough for ATB use.

CONCLUSION

We think the New Deore XT will inspire other component manufacturers to assemble top-line ATB component groups that are more of a match for the high-quality framesets that are part and parcel of the mountain bike experience.

In the meantime, Shimano isn't wasting any time trickling down New Deore XT features to their (you guessed it) New Deore line of components. They lack some of the finish and convenience features of XT, but also sport a lower price tag in return for much of the same XT performance. No group price has been set for New Deore, so check your local shop for individual component prices. ▪

SHOT PEENING
For Lighter, Stronger Frames

Morton S. Schaffer

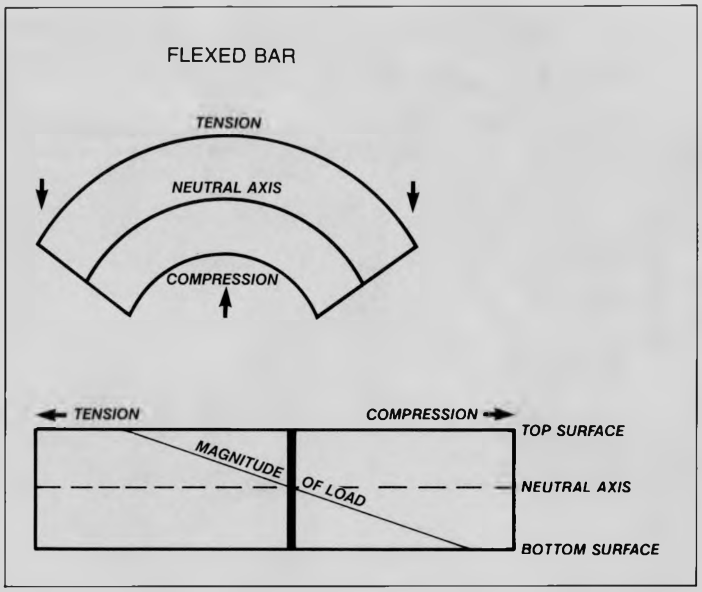


FIGURE 1: Flexed bar and corresponding graph showing comparative magnitudes of tensile and compressive loading.

Designers of bicycles and airplanes share at least one all-important concern, fatigue failure. Both types of machines operate in situations where a minor part failure can result in tragedy. As a result, bicycle manufacturers often base the section size and/or wall thickness of frame tubing on fatigue endurance limits rather than maximum loading or even, in some instances, desirable levels of rigidity. This is particularly true with some of the lower-strength aluminum alloys such as 6061, etc. The immediate consequences are frames that are heavier, and sometimes more rigid and therefore less comfortable, than they need be.

The residual stress present in the vicinity of welded joints can also be a source of fatigue problems. This is particularly true because of the ever-increasing popularity of TIG-welded framesets, which have gained great acceptance in the ATB field. Once again, increased weight, as well as added stiffness, is a consequence of the thicker tubing butts or mechanical reinforcements (internal sleeving or gussets) used to compensate for this problem.

Shot peening offers a low-cost, easy means of increasing fatigue limits in both of these examples. The benefits to the cyclist could include lighter, more comfortable bicycles.

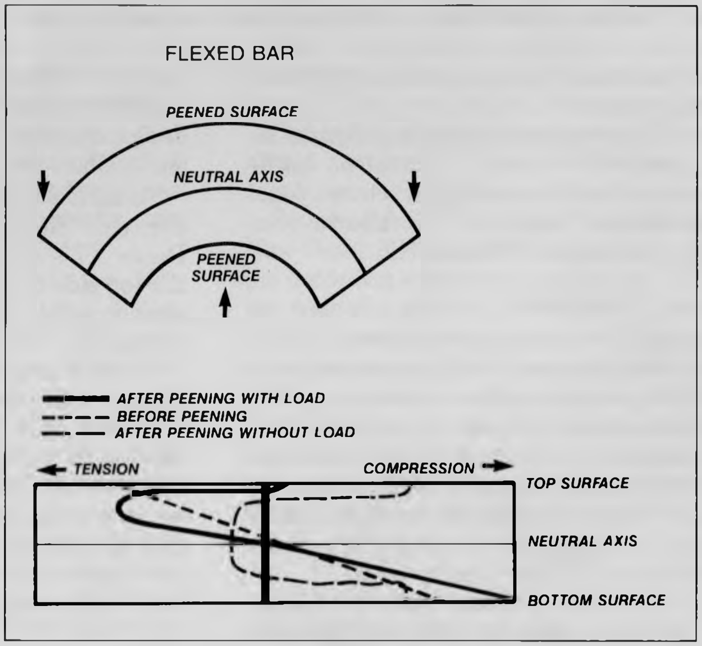


FIGURE 2: Flexed bar after peening with graph showing comparative magnitudes of tensile and compressive loading.

THE PROCESS- HOW AND WHY

Since its inception in the 1940s, shot peening has been an effective tool in prolonging fatigue life of various materials. Some aluminum alloys have experienced fatigue strength increases of up to 34%, while some steel alloys have shown increases up to 87%[1]. The actual improvements in specific applications and with specific alloys can vary widely and depend on properly researched procedure. Typical S/N (fatigue failure) curves for 4140 steel and 7075 aluminum both before and after shot peening are shown in FIGURES 3 and 4.

In shot peening, round shot of uniform size (typically .0049″-0.1870″) is projected at high velocity at the target area to be peened. Shot is usually propelled pneumatically through a nozzle or mechanically by a spinning wheel. When hand-applied, the process resembles sand blasting.

As a direct result of the controlled, mechanical working of the surface by the shot, a thin, *compressive* layer of the base material is formed on the outside of the part. Even though the depth is quite shallow, the magnitude of compression is relatively high. To understand how the layer of compressed material inhibits fatigue failure, let's briefly review the actual mechanism of failure from cyclic loading.

Fatigue failure occurs under repeated fluctuating loads where the maximum loading is less than the tensile yield strength of the material. Imagine a bar that is in a flexed mode (FIGURE 1). We know intuitively, and can easily prove both mathematically and empirically, that in the tension mode the layer of material furthest from the neutral axis experiences the greatest degree of elongation, and therefore the highest level of stress. This is conceptualized in the graph in FIGURE 1. Because higher levels of stress are almost always associated with a faster rate of failure, it's no surprise that fatigue cracking al-

---

Morton S. Schaffer is a Registered Professional Engineer with a B.S. in Metallurgical Engineering (Lafayette College). He has worked for J&L Steel, Airco Industrial Gases, and Metal Improvement Co., a finishing contractor that offers commercial shot peening services.

most always begins on outermost surfaces.

The effect of peening that outermost layer is shown in FIGURE 2. Note that without load, the skin of the peened material has residual *compressive* stress. When tensile forces are applied, the net result in the outermost layer of material (algebraic sum of tensile and compressive forces) could be slightly compressive, but will in any event result in lower levels of tensile stress compared to the unpeened material. This would, of course, tend to suppress crack initiation and increase the fatigue life of the part.

OTHER FAILURE SOURCES

Any type of discontinuity in the tension surface, such as a nick, will aggravate the tendency to failure by concentrating tensile forces. This can locally increase stress above the tensile yield strength of the material. Improper filing during finishing might be a typical source of this type of surface imperfection. The typical result is the formation of a minute crack. Upon each subsequent load application, this crack will increase by small increments until eventually there is insufficient uncracked material to sustain the load.

The effects of the cyclic forces which cause fatigue failure can also be exacerbated by residual tensile forces. A common source of high residual forces is welding. The stresses result from the thermal gradients associated with this process. The uneven heating and cooling induces internal stress, not only from uneven thermal expansion and contraction, but also from metallurgical changes in the structure of the metal.

Shot peening has shown itself very effective in countering nicks and other surface imperfections, as well as welding-induced residual stress (FIGURE 5).

Peening does not, as yet, seem to be a commonly accepted practice in the manufacturing of bicycles. Those interested in the benefits of peening will need to take care that there is minimal finish damage to lug edges (where applicable) and that, conversely, peening is effective to a sufficient depth. A proper peening protocol could potentially allow weight reductions of 10-20 percent without compromising frame life, although rigidity would be decreased unless fundamental changes in tube diameter were made.

NOTES

[1]*Shot peening. In* ASM Handbook, 9th ed., *9:143. Metals Park, OH: American Society for Metals.*
[2]*From Vertol Aircraft Corp., Mr. K. T. Waters. Oct. 1959. Paper #75, presented to American Society of Testing and Materials.*
[3]*From Was, G. S. and Pellous, R. M. 1979. The effect of shot peening on the fatigue behavior of alloy 70075-T6.* AIME, *10A (May):3.*
[4]*Manson, S. S. 1971. Metal fatigue damage-mechanism, detection, avoidance, and repair with special reference to gas turbine components.* ASTM Publication STP-495. ▪

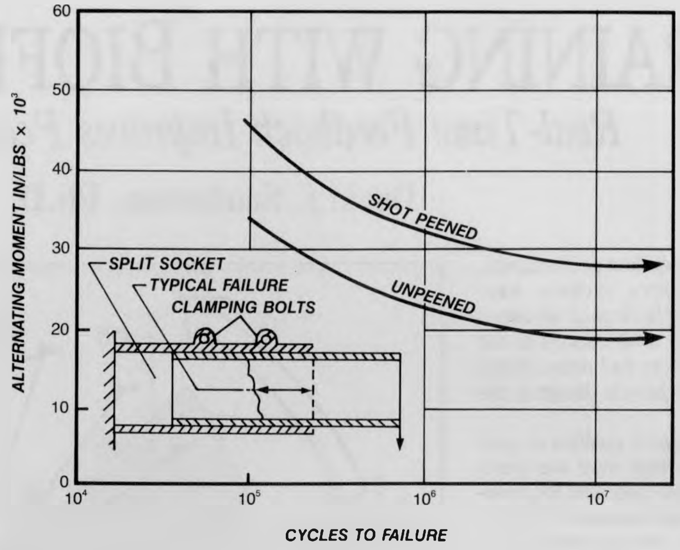


FIGURE 3: S/N curve for a 4140 steel clamped joint.[2]

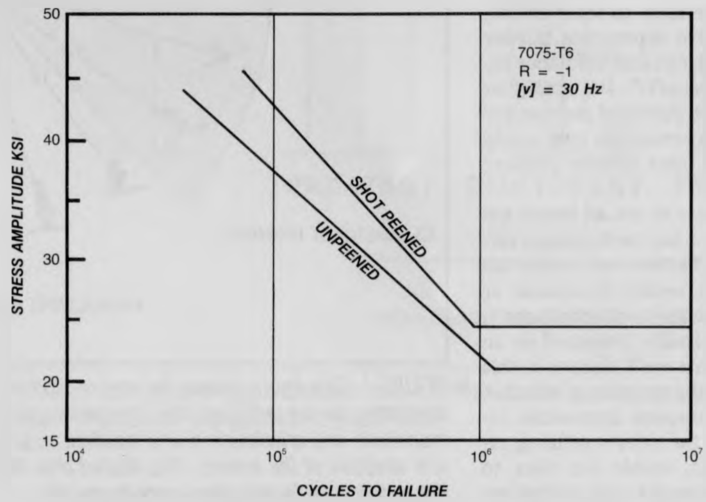


FIGURE 4: Reversed bending fatigue test on unpeened and peened specimens of 7075-T6 aluminum alloy.[3]

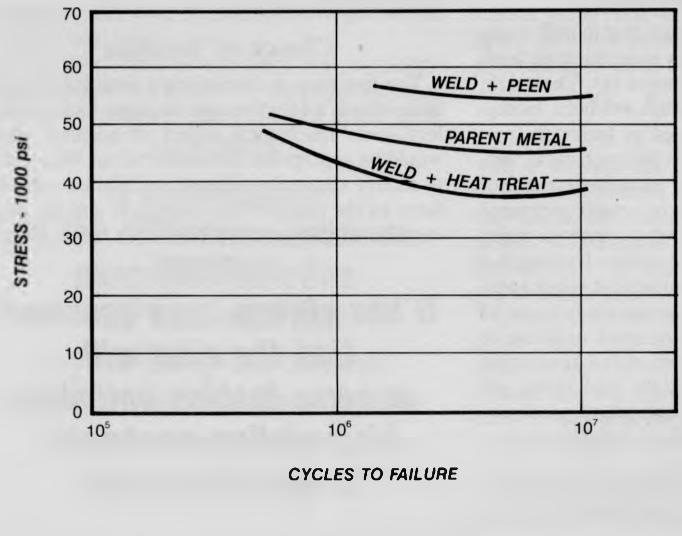


FIGURE 5: The effect of shot peening on welded A286 fatigue strength.[4]

TRAINING WITH BIOFEEDBACK

Real-Time Feedback Improves Pedaling Style

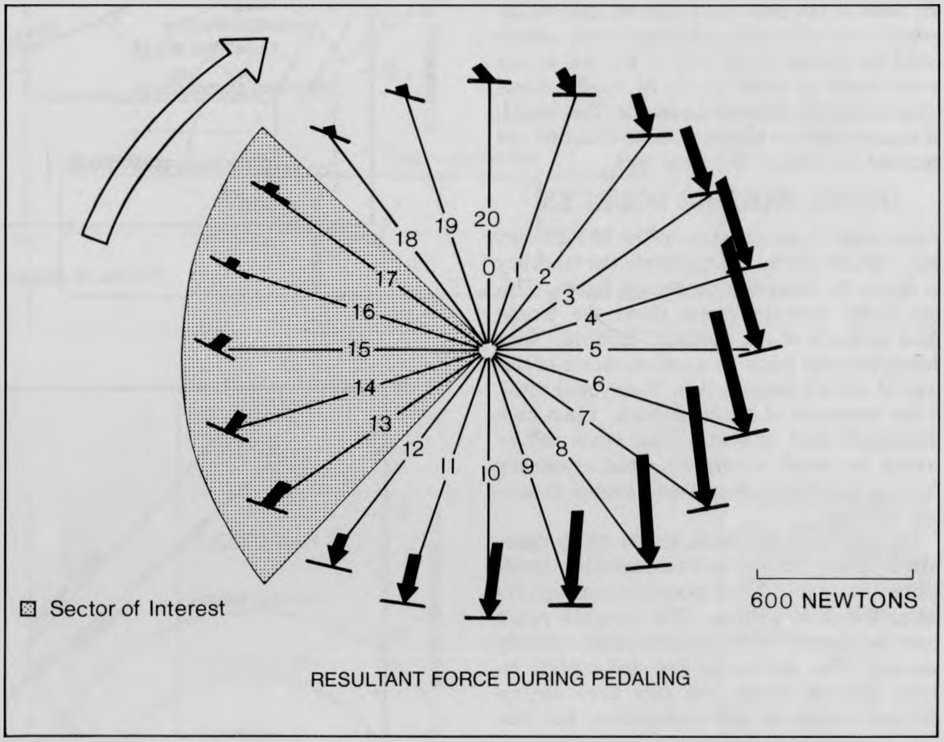
David J. Sanderson, Ph.D.

Recent improvements in cycling performance, especially among competitive cyclists, have arisen more often from technological advances in bicycle design than from modifications to the rider's style. Those advances had come slowly until the outburst of radical bicycle design in the last several years.

The relative lack of change in position or pedaling style of the bicycle rider over the years hopefully suggests the same potential for revolutionary gains in rider performance. Why? It has always been assumed, though not proved, that the rider will in some fashion optimize his pedaling mechanics to suit the bicycle.

While there is little doubt that people do optimize movement characteristics to some extent, there is also evidence that appropriate training with augmented feedback can lead to further improvements in performance(1)*. It's analogous to the difference between *perceived exertion* and *real exertion*—your body sensations may *not* be the best gauge of your most *effective* pedaling style.

Of course, effectiveness is not an innate human feeling, it's a bottom-line performance rating. More importantly, effectiveness usually can not be associated on a second-by-second or even a minute-by-minute basis with variations in a performed task—it's usually measured on an event basis. The research we'll discuss in this article seeks to answer the question of whether or not providing the heretofore impossible, *simultaneous* feedback of the rider's pedaling effectiveness, would: first, enable the rider to modify his pedaling style on the basis of that external feedback; and, second, aid in the permanent acquisition of those improved skills.



■ *FIGURE 1: This figure shows, for one revolution of the crank during steady-state riding: the crank orientation as the radiating lines; the pedal and its orientation as the short bold line; and the magnitude and orientation of the resultant pedaling force at each crank position by the length and direction of the arrows. The shaded area (the sector of interest) corresponds to the part of the pedaling cycle the riders were to modify.*

Skill Acquisition

It has been well established that in skill acquisition, knowledge of results or augmented feedback is an important component (4). There are, however, only a few examples where biomechanical data have been used as feedback.

To use the feedback of a biomechanical variable to modify a complex movement requires that the movement pattern be readily measured and controlled in the laboratory without major compromises to the actual event. Cycling is a good example of a skilled movement which satisfies these requirements, primarily because of the limited freedom of movement available to the cyclist and also because of the reasonable similarity between steady-rate road riding and riding in a laboratory. The equipment necessary to measure the biomechanical variable continuously as the individual performs is also a requirement for this research.

*The numbers in parentheses refer to the source list at the end of the article.

Choice of Variable

The first step in developing a protocol to test biofeedback's effectiveness requires that we select some mechanical aspect of pedaling that would be appropriate for modification. We chose to modify the manner in which the rider applies force to the pedals. The magnitude and the orientation of the applied forces each helps determine the amount of the force which provides useful propulsion. Successful modification of the rider's pedaling style should allow either greater propulsion for the same effort, or the same propulsion with less effort. All that is required is a system to record these forces and feed them back to the rider in some visual form.

It has always been assumed that the rider will in some fashion optimize his pedaling mechanics to suit the bicycle.

FIGURE 1 presents a typical pattern of force application for a rider who is cycling at a steady rate and intensity. It can be seen that the magnitude and direction of the applied forces vary through the pedaling cycle. Note specifically that during the recovery phase, or second 180 degrees of the crank revolution, the forces are applied in the opposite direction to crank rotation. This requires that some of the other leg's propulsive forces be used to overcome this retarding force.

The presence of this retarding force is contrary to the popular notion that good cyclists *pull up* on the crank during this phase of pedaling. Such may be the case in sprinting or hill climbing but not, even in our experience with Olympic-caliber cyclists, in steady-state cycling. Considering the magnitude of these negative torques, their reduction or elimination could have a very significant effect on cycling performance. We decided, therefore, to alter the pattern of force application by trying to reduce the forces applied during the recovery phase to zero. This would allow for an examination of the issue of pulling up as well as the efficacy of biomechanical feedback.

To test the hypothesis, we attempted to train a group of riders to modify their pattern of force application to the pedals while riding at a steady power output. This was to be achieved by recording the pedal forces in real time and using those forces to modify a graphic image. That graphics display was visible to the riders in an experimental group but not to the riders in a control group. The systematic reduction of the time during which the feedback was visible would test whether the task could be assimilated via kinesthetic learning (learned from the sensations of the movement by simple repetition) and retained after the feedback had been removed (a necessity for the modification to be effective in the actual sporting event).

Rather than attempt to modify the pedal stroke over the whole recovery phase, we limited the riders' efforts to a portion of the cycle (FIGURE 1). The sector of interest is 90 degrees of crank rotation, beginning at a crank angle of 225 degrees after TDC (top dead center) and continuing to 315 degrees after TDC. The subjects were instructed to reduce the forces applied to the pedals in this sector to zero.

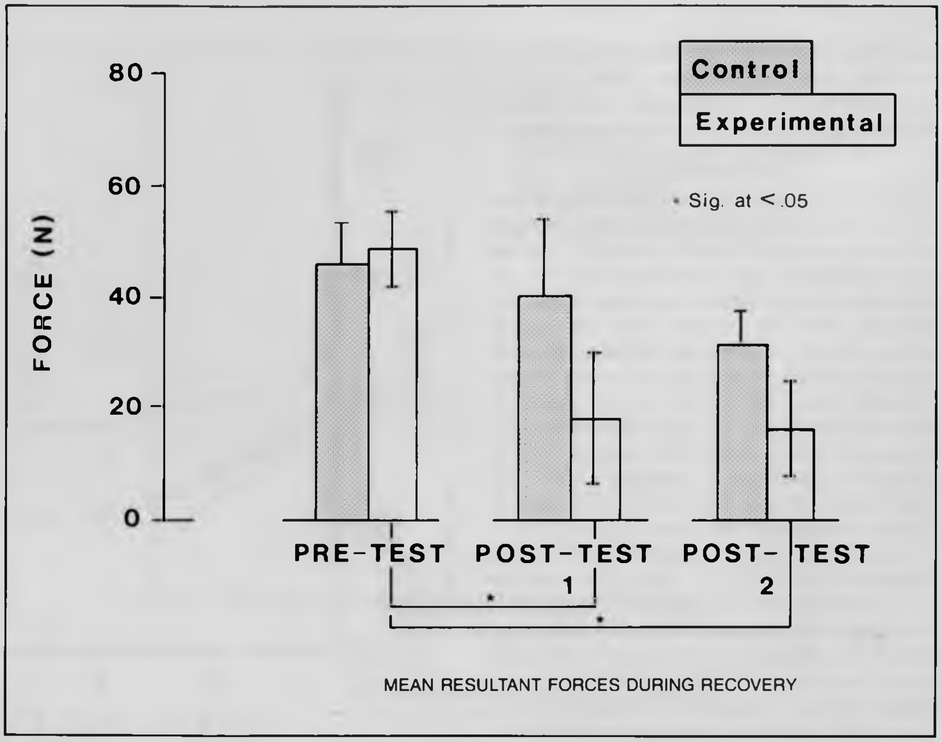


FIGURE 2: Histogram of mean resultant forces for the control and experimental groups from pre-test, post-test 1, and post-test 2 evaluations.

The Test Equipment

The apparatus used in this study was based on a 57.5-cm bicycle frame (Masi) mounted on a rigid platform. It was instrumented such that TDC for the right crank, as well as continuous crank position, could be recorded as an analog signal. Force measuring pedals were used to monitor left and right pedal angles relative to the crank, as well as left and right shear and normal components of the force applied to the pedals. The data were sampled by a 12-bit analog-to-digital converter at a sample rate of 100 Hz. During the "training" rides, the forces recorded in the sector of interest were used to manipulate an image on a Megatek 7000 graphics computer, which was positioned so that the experimental group could see it as they rode.

The visual feedback was in the shape of a vertical bar, which varied in height according to the amount of negative torque applied during the sector of interest. The force data were sampled for five consecutive cycles. During the sixth cycle the program computed the mean resultant force applied by each leg during the 90-degree sector of the recovery phase for all six cycles. The average of the left and right legs was then computed and used to modify the height of the vertical bar.

The object for the test riders was to modify their application of force to the pedal during a 90-degree sector of the recovery phase such that the vertical bar diminished to zero height. Successful learning would result in an unloaded pedal during this sector. Both groups were given the same instructions, but only the experimental group received the visual feedback. The pedal rate and power output were to remain constant at 60 RPM and 112 watts respectively.

It's analogous to the difference between perceived exertion and real exertion —your body sensations may not be the best gauge of your most effective pedaling style.

The Test Subjects

The subjects (n = 8) were volunteer males with an average age of 29 years. The subjects were inexperienced, recreational riders in that they had no competitive riding experience. Each subject was assigned randomly to one of two four-member groups: an experimental group and a control group.

Each cyclist rode in a pre-test at the beginning of the study. This was followed by the training sessions. Each of the training sessions lasted 32 minutes and was repeated daily for 10 days. Because it was important that the riders not become dependent upon the computer-generated feedback, the time during which the feedback was visible was gradually reduced according to a fixed schedule over the 10-day period. Immediately after the end of the 10th training ride, a post-test value was recorded. After a further seven-day interval, during which the subjects did no cycling, another post-test was conducted.

Test Results

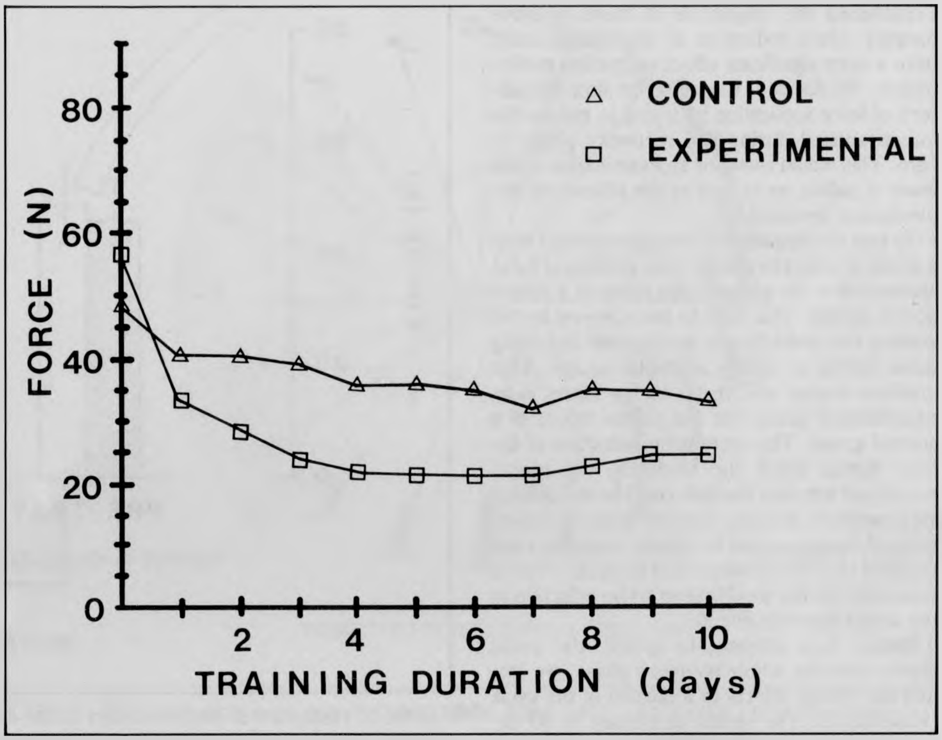
FIGURE 2 presents the mean resultant forces of the left and right leg for each group for the pre-test, post-test 1, and post-test 2 evaluations. Statistical analysis indicates that the experimental group reduced the pedal forces significantly over the 10 days while the control group showed no significant reduction in pedal force. However, because of the large variation in pedal forces *within* each group, statistical analysis showed that the large difference in the mean pedal forces *between* the groups was not statistically significant. A subsequent study with more riders will provide a more realistic test of the between-group differences.

These results indicate that the riders in the experimental group had successfully learned the new pattern of force application. That is, they were able to significantly reduce the mean force during the 90-degree recovery sector. Furthermore, they were able to maintain this new pedaling pattern in the post-test 1 evaluation without feedback and seven days later in post-test 2. Thus, the augmented feedback served to assist the experimental group in identifying kinesthetic variables that were used to control the new pattern of force application. The control group subjects were unable to identify the same variables.

FIGURE 3 shows the mean resultant force applied each day over the whole training period for the control and experimental groups. The pre-test evaluation occurred on Day 0. These data show the rate at which both groups reduced the pedal forces. By the end of the third day the experimental group had reduced the pedal forces to close to the final values. After that, the pedal forces remained nearly constant for the remainder of the 10 days. Even though the forces were reduced, the control group showed only a gradual change over the 10 days.

Previous research (1,2) has shown that kinematic changes (changes in displacement, velocity, and acceleration) resulting from the learning of a new motor skill occur within the first few trials. The present data agree very well with these findings. It would not be appropriate to conclude, however, that the riders' new pedaling pattern had been completely incorporated after only a few days, and that the subsequent days of training were totally unnecessary.

For the training procedures to have been considered successful, in biomechanical terms, it is necessary that the pattern of force application over the whole cycle be considered appropriate. In other words, it would not have been useful for the riders to develop some aberrant pedaling style simply to reduce the forces in one sector, the "sector of interest."



■ *FIGURE 3: Mean resultant forces in the recovery sector averaged over the left and right legs for the control and experimental group over the whole testing period. The pre-test scores are plotted as day 0.*

The data presented in FIGURE 4 show this was not the case. The control group showed that they were able to reduce the pedal forces to only a limited extent in the sector of interest. In fact, it would seem that the reduction was not at all confined to the desired area. The experimental group, on the other hand, showed a dramatic reduction of force within the sector of interest. It is evident, however, that the cyclists in the experimental group had a time lag in their pedal force reduction. It was not until almost 270 degrees after TDC that the largest drop in force was recorded. This suggests that the timing of pedal loading was important. Had specific feedback on the timing of the sector been provided, the reduction of pedaling force would have possibly been better defined and more complete within the limits of the sector of interest.

... the experimental group riders could now maintain the same power output with reduced pedal force.

Even so, the reduction in pedaling force during the recovery phase by the experimental group has important implications for rider performance.

It was one of the requirements of the experiment's protocol that the pedaling rate and power output remain constant throughout the test sessions. It follows directly that a general reduction in pedaling force during the recovery phase should, and in fact did, result in reduced pedaling force during the propulsive phase *at the same power output as before*. In short, the experimental group riders could now maintain the same power output with reduced pedal force. This improvement in the mechanics of cycling has important implications.

Conclusions

The data presented here show that in spite of the lack of specific information on the timing of their pedaling efforts, the visual feedback assisted the riders in the experimental group to focus on a region of interest, augmented their kinesthetic learning, and enabled them to retain their newly learned pedaling skills. We could probably say that the experimental group riders had acquired a more *effective* pedaling style.

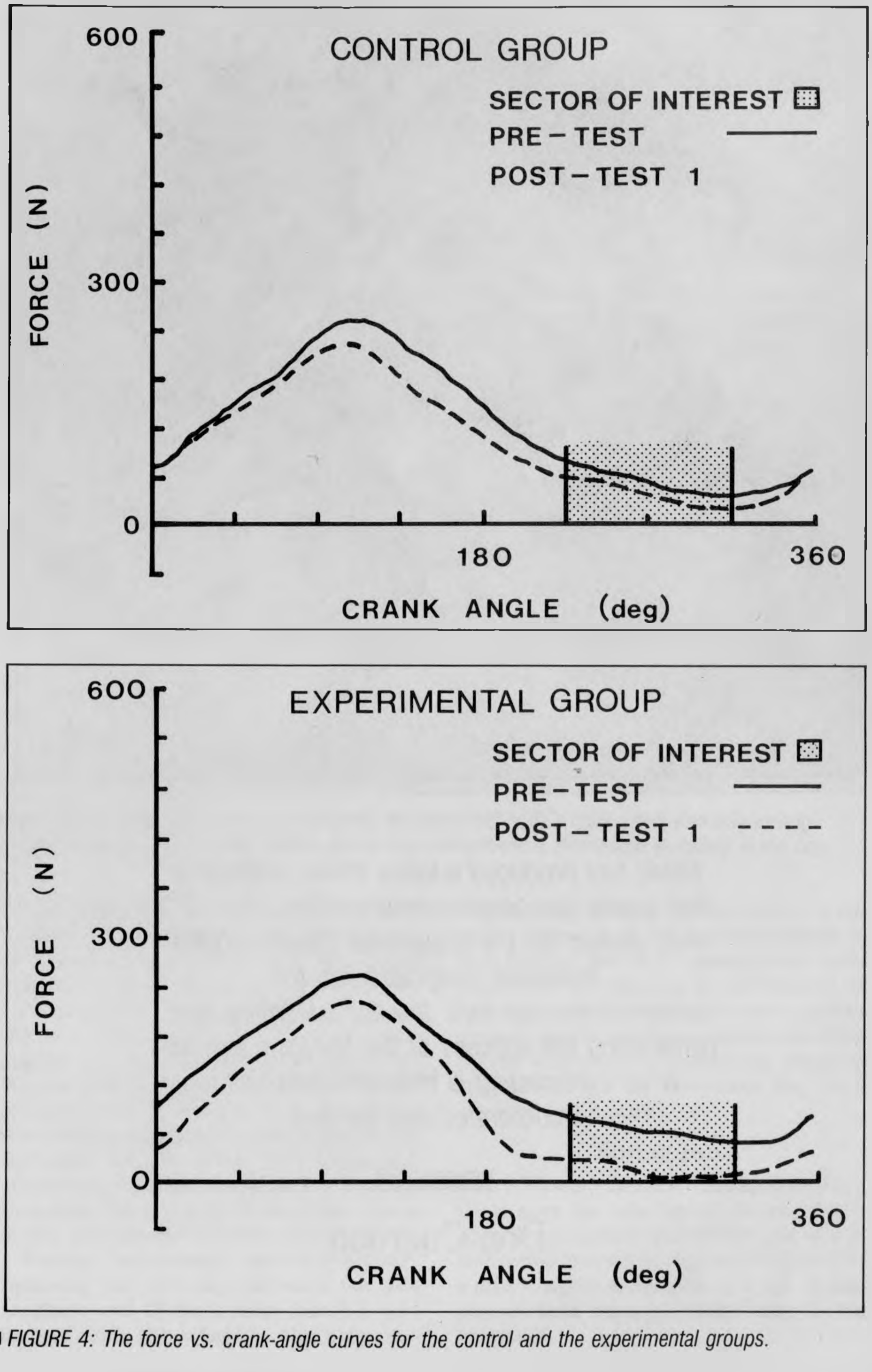
However, because the physiological cost of pedaling for each group was not monitored, the question of whether reduced pedal forces in the 90-degree sector of the recovery phase would truly result in better cycling *economy* remains unanswered. The effort required to fully, or even partially, unload the pedals during the recovery phase of pedaling may be greater than the resulting reduction in effort during the propulsion phase. Or, it may be that biofeedback of this type provides a relatively "painless" means to improve performance.

Regardless of the final determination, this project has provided a powerful training tool that can be used in the future to help design an experiment to examine this and other such questions quantitatively. ■

The data presented in these illustrations were derived from research done by Sanderson and Cavanagh at The Pennsylvania State University.

REFERENCES

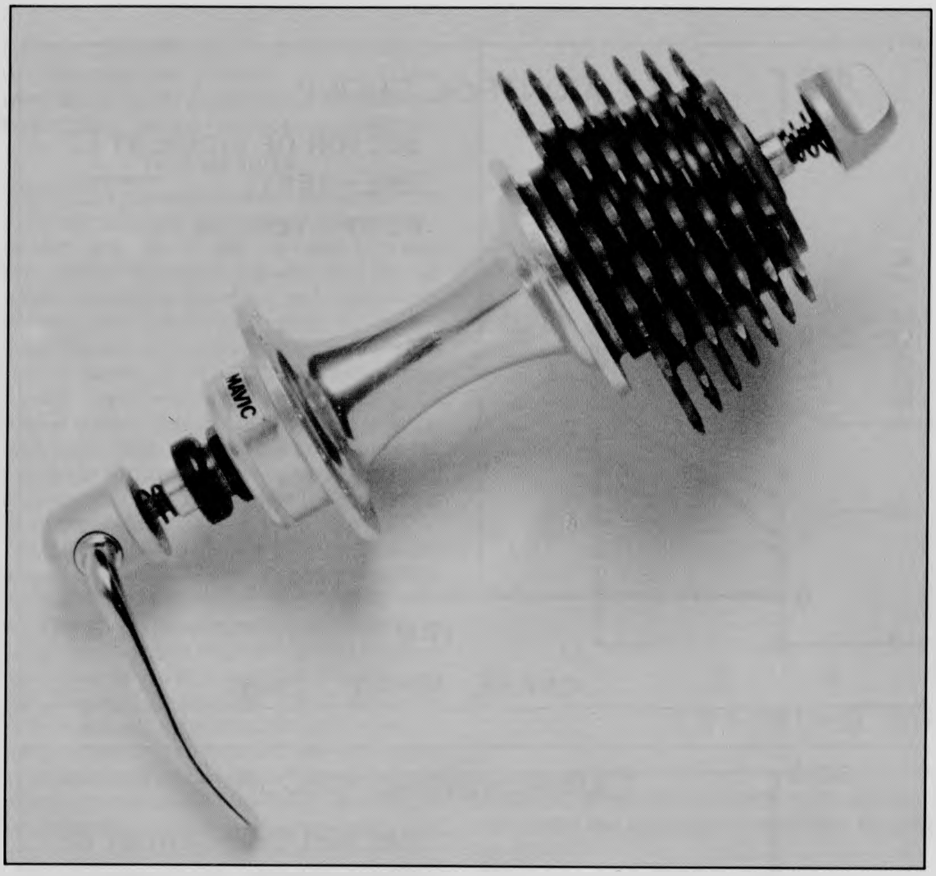
1. *Hatze, H. 1976. Biomechanical aspects of a successful motion optimization. In* Biomechanics VG, *ed. P. Komi. International Series on Sports Science, 2:5-12. Baltimore: University Park Press.*
2. *Hobart, J. R., and Vorro, D. J. 1974. Electromyographic analysis of intermittent modification during the acquisition of a novel throwing skill. In* Biomechanics IV, *ed. R. C. Nelson and C. A. Morehouse. International Series on Sports Science, 1:559-566. Baltimore, University Park Press.*
3. *Landa, J. 1979. Analysis of skill acquisition of a novel throwing task in terms of biomechanical factors.* Journal of Human Movement Studies, *5:52-60.*
4. *Newell, K. M., Morris, L. R. and Scully, D. M. 1985. Augmented information and the acquisition of skill in physical activity. In* Exercise and Sport Science Reviews, *ed. R. Terjung, 13:235-261. New York: Macmillan Pub. Co.*



■ *FIGURE 4: The force vs. crank-angle curves for the control and the experimental groups.*

MAVIC Z HUB

Quick-Change Alloy Cogs Plus Super Serviceability



Mavic has produced another clever addition to their highly functional component line. The "Z" hub, named for the trapezoidal threads on the freewheel integrated into the design of the rear hub. It's not a startling idea, considering the success of the Shimano freehub. What's interesting is how *the freewheel is incorporated into the hub.*

Don Cuerdon

The left side of the hub is similar to that of other cartridge bearing hubs in Mavic's line, with the addition of an extra ball bearing. The twin sealed Conrad-type bearings support the aluminum-alloy axle in such a way as to prevent side-loading the bearings when the quick release is tightened (all end loads are transmitted through the axle and the inner races of the axle bearings).

Because the freewheel unit does not screw onto the hub body, it is truncated at the right flange. A hollow steel tube which rotates with the hub body extends to the right, forming the *outer* race of a needle bearing that supports the middle of the aluminum axle, and the *inner* race of a larger needle bearing that supports the freewheel body. Like a Chinese puzzle box, it's a bearing within a bearing. Just in case that isn't enough precision balls and races to suit you, there's a fifth (that's right, count 'em) bearing located at the outboard end of the freewheel body to support the far right end of the axle. Roughly $1/3$ of the hub axle is supported by bearings!

This may appear to be an exercise in overdesign, but the extra support allows the use of an aluminum-alloy axle that won't bend twice a week, while keeping the weight per pair of hubs to 725 grams with alloy skewers and 12-18T cogs. Steel skewers raise the weight to 771 grams. For comparison, a pair of small-flange Campagnolo hubs and alloy freewheel total 698 grams.

The Freewheel

The freewheel body is also made from aluminum alloy. Three pawls mounted at 120-degree intervals on the bottom of the freewheel body drive the hub through a steel ratchet ring pressed into a cavity in the right hub flange. The freewheel slides easily onto the hub/bearing race extension, with the pawls slipping into the cavity and engaging the ratchet with a slight twist of the freewheel as it's pushed home. The three pawls engage simultaneously, providing a solid contact for driving the hub forward. A single circlip-like pawl spring is contained and aligned by splits in the pawls. Removing the spring and/or the pawls takes seconds, without the frustration of exploding parts scattering throughout the shop, or all over the ground if you're at a race.

Trapezoidal, Acme-type threads run the length of the freewheel body. The threads are of large proportion and allow the cogs to thread on securely without becoming jammed by grit. Thread diameter and pitch are identical for *all* cogs, creating a multitude of possible freewheel configurations.

The cogs are aluminum alloy and will be priced comparably with Campagnolo's alloy freewheel cogs. At this time, we haven't ridden the freewheel far enough to predict cog longevity. Mavic currently claims about a

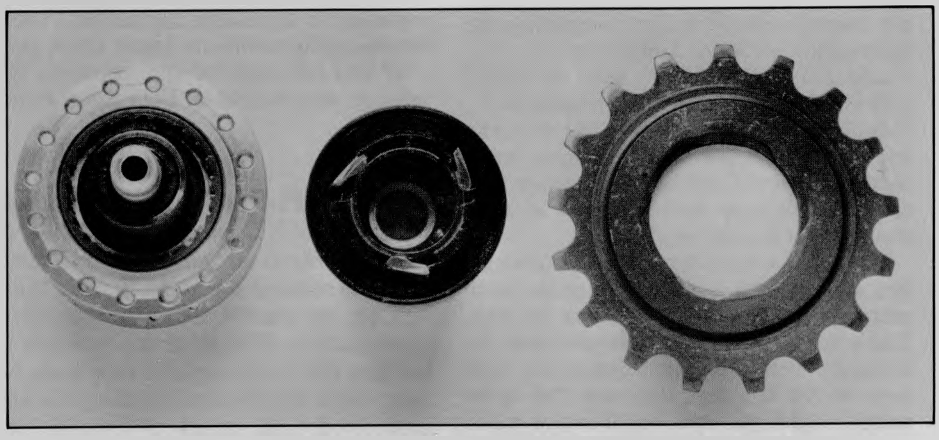
PHOTOGRA Y JIM REDCAY

7,000-mile lifespan for a 17-tooth cog in their own testing. That would be a breakthrough in longevity for aluminum freewheel cogs, if riding the cogs confirms the claim.

For quick changes between stage race events, separate freewheels can be assembled in advance and swapped with no tools at all, literally in seconds! And with a few spacers (each cog has an integral spacing boss on one side), the freewheel can sport as few as one cog or as many as seven. Build a 12-13-14-15T for flat time trialing or a 15-21T straight-block for the Junior Nationals on the same wheel. Mavic has a tool to hold the freewheel in place while removing the cogs with a chain whip.

Cogs will be offered from 12 to 28 teeth. With a 28-tooth largest cog, it probably won't be long before the Marin County boys try this one in the dirt.

■ *Two ball bearings support the left end of the alloy axle, while the large-diameter tube projecting from the hub is the outer race for the axle needle bearing, and the inner race for the freewheel needle bearing. A final outboard ball bearing in the outer end of the freewheel body supports the end of the axle. Bulletproof!*



■ *Note the steel ratchet ring in the hub body, the freewheel body's triple pawls and ball bearing visible at its far end, and the built-in spacer and sextuple-pitch, Acme-type threading in the cog.*

Driving A "Z"

The most noticeable aspect of the Z hub is the complete lack of freewheel wobble. The large needle bearing in the freewheel body dictates straight running cogs. With a Sedis Professional chain and Campagnolo Nuovo Record derailleur sporting SunTour sealed pulleys, shifting through the Z's cogs was remarkably concise. Although I haven't tried it yet, I would predict the system works admirably with the rigid pulleys of a Mavic rear derailleur. The Z hub seems destined for the 1000 SSC group.

Another feature worth mentioning on both hubs is the hub flange spacing. The left flange of the rear hub is closer to the hub center than on more traditional hubs. This position reduces the spoke tension necessary on the freewheel side to center the rim between the locknuts. Both flanges of the front hub have been moved toward the hub center as well, to reduce spoke angle and present a more aerodynamic profile. The only drawback we've found to this configuration involves mounting cycle computers designed to work on standard hubs. With a Mavic-hub front wheel, the spokes are too far away from the fork blade for the pickup to work properly. It takes a bit of ingenuity to jury-rig a suitable connection. If the narrower design becomes popular, the computer manufacturers will have to respond.

Serviceability +

The Z hub, like the other components Mavic produces, is designed to withstand the rigors of the European road racing season. This includes racing over cobblestones through rain, mud, and snow, in addition to thousands of miles in fair weather. Between rides, the components are expected to be serviced by a technician made surly by riding thousands of miles over cobblestones through rain, mud and snow in the back of the team car. Mavic tries to make service simple for this underpaid, overworked cyclophile.

The hubs are greased by blocking one end of the hollow hub axle and inserting a grease syringe with a rubber seal in the other end. Pressure forces the grease through a hole in the axle, filling the cavity between the axle and the hub shell. The grease is then forced into the back of the hub bearings, pushing the old grease out through the front. This can be done without fouling the needle bearing in the freewheel because it has been ingeniously quarantined from the rest of the hub bearings by a close-fitting sleeve. Wipe off the excess grease and consider the hubs repacked.

Bearing "adjustment" (you're really only removing the end play between the axle shoulders and all those inner races) is performed with the wheel in the dropouts. Tighten the adjusting nut 1/4 turn at a time with a 15-mm cone wrench to eliminate excess bearing play. If you suspect they're too tight, back the adjusting nut off 1/2 turn, remove the wheel and the quick-release skewer, tap the axle lightly beside the adjusting nut with a mallet, reinsert the wheel and start over. I like any component that can be adjusted with a mallet.

Spring Intro

Art Wester, General Manager of Mavic USA, says the hubs should be available by April (if not earlier) and will be sold as a set with seven freewheel cogs for $230 to $280, a price roughly comparable to a pair of Campagnolo hubs equipped with Campy's alloy freewheel. ▪

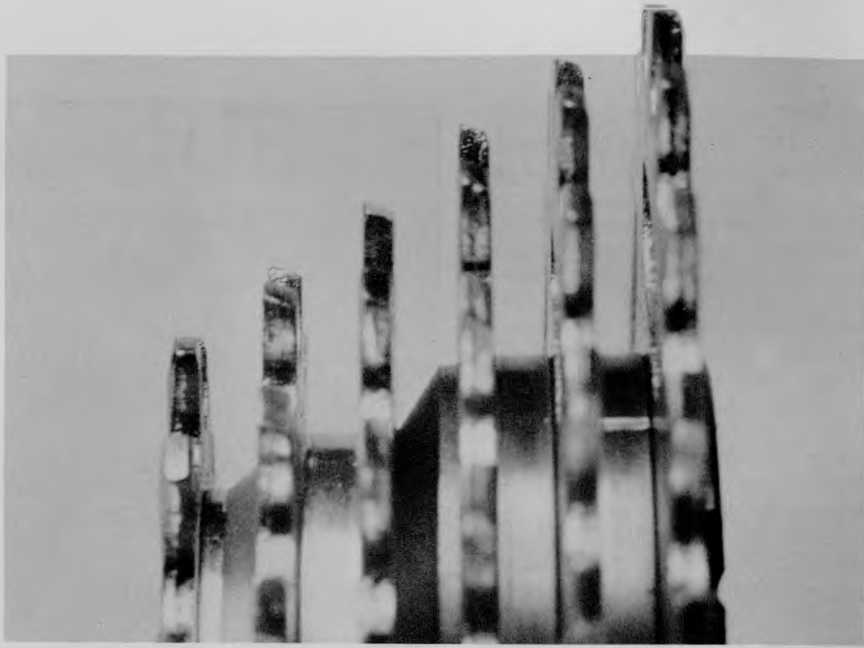
CAN'T SEE THE DERAILLEURS FOR THE DETENTS DEPT.: It must have been because we had already been testing it for almost a half-year. That's the only way I can explain forgetting that at IFMA in Cologne, SunTour's introduction of their AccuShift line of index-shifting derailleurs was probably the *biggest* flash of the show. AccuShift's "click" shifting capabilities extend from Superbe Pro all the way down to bikes retailing for $300 and even less. And, most importantly, what was shown in Cologne will be shipped on 1987 models, starting before the New Year.

OK, this is a major commitment with potential major market impact. But we only forgot *when* AccuShift was news—its importance never escaped us. AccuShift represents SunTour's attempt to match, in less than one year's time, the results of a multi-year commitment by Shimano to indexed rear shifting. Granted, SunTour had already given indexed shifting a serious tryout with its Trimec model, an inexpensive changer aimed at the low-end market. It didn't sell. Period. As recently as March, 1986, the president and driving force behind SunTour, Junzo Kawai, had scornfully confided to our staff that when it came down to indexed shifting, SunTour would stand aside and watch Shimano relive for themselves the unfortunate history of Trimec.

June changed the tune, however (along with some help from top-down marketing!). Shimano's SIS was successfully trickling down to 600 EX price points from its introduction on New Dura-Ace, and manufacturers were showing future interest in even lower-priced derailleurs.

The reaction from SunTour was amazingly fast, and we were privileged to see the initial prototypes, presented in person by SunTour's head of new-product development, K. Yamazaki. Real production prototypes have been slower to arrive, however, and we've waited to give you an in-depth review based on the same product you'll see in stores, rather than prototypes. So join us next issue, when we look over several AccuShift models.

THE BIG COMMITMENT to a titanium product line has finally come to pass for Kestrel Metalworks, a.k.a. Gary Helfrich and his band of merry cranksters (Gwin Jones and Mike Augsberger). Their initial intention was to market titanium forks and handlebars, but demand for complete ATB frames is pushing them toward that product first. We'll road-test one for you soon. In addition, look for *Bicycling*'s and Kestrel's (and *Bike Tech*'s!) joint-effort road-bike project a few issues from now. Would you believe a 3.5-pound frame-and-fork combination that's as stiff and fatigue-resistant as a chrome-moly frameset?



JIM REDCAY

THE INDEXED-SHIFTING BUS isn't going on the road without a full booking. Add Regina to the list of manufacturers that produce new products compatible with indexing, or, as Regina calls it,"pre-set"derailleurs. Their new Synchro freewheel, available in either Oro (gold) or silver finish, replaces the BX model—its cogs weren't spaced in accordance with the dictates of indexed shifters. (Regina's America freewheel *is* index-compatible, in both narrow and wide versions. The CX freewheel is also index-compatible.) The Synchro model, which features a sharply beveled tooth profile for faster chain pickup, will be available by the beginning of 1987 and will retail for approximately $23 in 6-speed configuration, with 5-speed versions also available. Both Synchro configurations are regular spacing only.

BOULDER-PROOF might be a more appropriate term for Pearl Izumi's new "bullet-proof" Kevlar-fabric shorts. At least that's the sentiment from the mountain-bike contingent, which has given the new concept an enthusiastic reception. The reason? You're much more likely to crash 'n' trash a set of shorts off-road than on, an expensive fact of the "dirt" life that better justifies these shorts' approximately $130 price tag. (All you Cat. 4s take note, too.) Two or 3 ripless landings and whatever else your body can stand is free! That thought must have occurred to Pearl Izumi, because this impervious second skin is padded with high-impact-resistant, closed-cell foam laminated between the Kevlar outer panels and their cotton lining. Inner panels are stitched from standard nylon/spandex fabric. If you're not much of a bruiser, you can forgo the padding and have your Kevlar for only $99. And don't worry about the "ironpants" look—unlike everything else Kevlar we've ever run across, *this* Kevlar has two-way stretch! All you have to do is wait until March.

NEXT ISSUE

- AccuShift—How does it stack up in the suddenly all-important world of indexing derailleurs? We'll give you the lowdown on SunTour's line-wide challenge to the market.
- Get in the training groove with OTC physiologist Peter Van Handel's comprehensive overview of periodicity. You'll learn how to achieve peak form in time for your season's major competitions.
- So you think carbon-fiber frames in the Tour de France is a recent phenomenon? Would you believe an American frameset ridden by Lucien Van Impe in 1973? Check out our road test of a 1975 Graphite USA, made by the same Southern California company that supplied Gitane with something "special" for super-climber Van Impe.
- *PLUS MORE!*