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BIKE TECH

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COMPONENTS

The Next Unfair Advantage

The Browning Bicycle Transmission

Angel Rodriguez

I remember the first lesson I learned with my new ten-speed many years ago. "You have to ease up on the power to make the shift," the shop man kept saying. But I couldn't. I was shifting because I was slowing down to go uphill, and if I slowed down any more I wouldn't be going forward, and then shifting would be impossible. I finally mastered that paradox, but it took some mental anticipation and physical coordination. The shifting usually took only a fraction of a second, and if I made the shift in time, everything was fine. But heaven help me if I missed the shift.

Eventually I tried racing. And I quickly discovered the difficulty of shifting while riding uphill in a pack. I didn't have even a fraction of a second for a shift. If I sat down to let off the power, it was all over, and if I didn't shift it was all over too. What a deal. I often wished for something that would allow me to shift whenever I wanted, under full power, and with no possibility of missing a shift. What a dream.

The derailleur system, the most widely used transmission on today's bikes, is the source of these shifting problems. After all, pushing the chain off one chainwheel, in hopes that it lands on another, is a primitive, brute-force approach. Derailleurs were first conceived in France around 1934, and have remained virtually unchanged ever since. Their disadvantages are well known. A recent *Bike Tech* article stated: "conventional

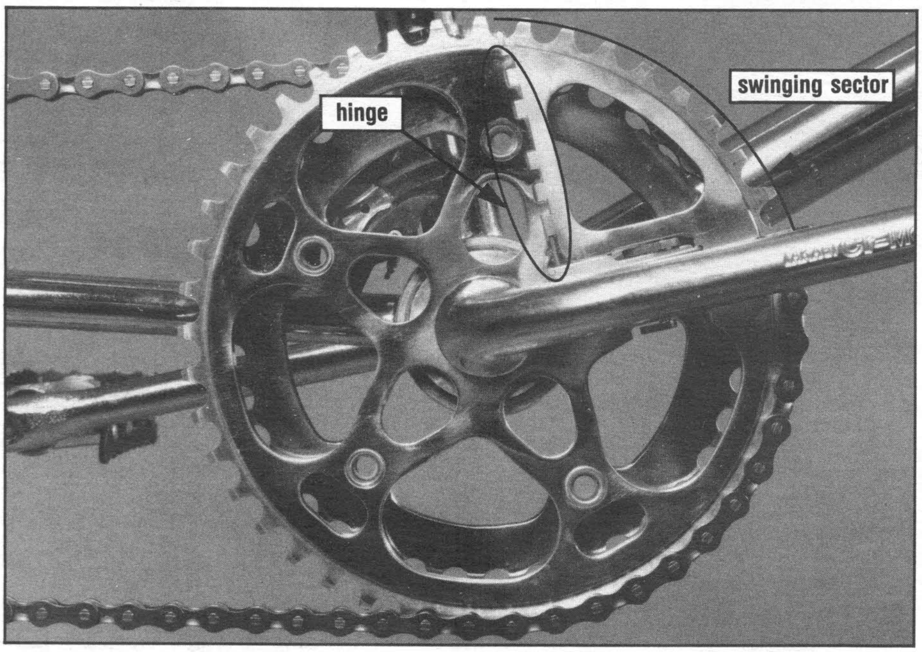

Figure 1: The Browning two-speed transmission, shown here in the middle of a downshift. Note chain engaged on both large and small rings simultaneously. The "ring cassette" assembly is comprised of two chainrings, hinge, and swinging sector.

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Note: Due to space limitations, the test report on bicycle headlights, originally scheduled for this issue, has been postponed to the next issue.

shifting components impose demands on the rider . . . the need to ease the pedaling force during the shift and the need for precision in moving the control lever."* The article reports that an incredible 20-plus kilograms (44 pounds, approximately) of cable tension was needed to shift the Campagnolo Super Record front derailleur while the bike was pedaled at what seems like an unrealistically low torque of 26 inch-lbs at the rear axle.

The second most common bike transmission is the internally-geared three-speed hub. This system uses planetary gears, which allow one to upshift and downshift by a certain ratio. The geared hub may be easy to use and reliable, but because it provides only three gear ratios (or five gears on some models), it is not suitable for modern touring and racing. And like the derailleur system, the internally-geared hub must not be under load at the moment of shifting.

The Browning Transmission promises to make these problems a thing of the past. The Browning system, which replaces the conventional front chainwheels and front derailleur, manages to shift the chain while keeping it *fully engaged on the cogs at all times*. How this is achieved is the subject of this article. The end result, in any case, is totally reliable shifting under even the heaviest pedaling loads, with negligibly small force (about 2 grams) on the shift lever.

"Biomechanics of Shifting Performance: Design of the Shimano New Dura-Ace Shifting System," by Shinpei Okajima, Bike Tech, *April 1985.*

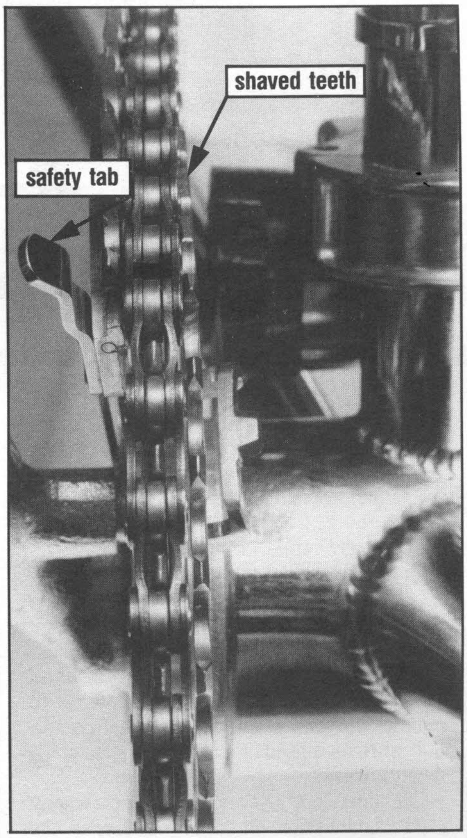

Figure 2: Front view of ring cassette, during the same downshift sequence shown in Fig. 1. Swing sector is swung *out* (away from small chainring), allowing chain to pass over shaved teeth (at arrow) onto small chainring.

Bruce W. Browning and his sons invented the transmission more than ten years ago (see sidebar), and refined it through extensive development and testing since then. A two-speed model for BMX machines is now commercially available, with a three-speed model for touring and all-terrain bikes (ATB's) scheduled for production soon. If the BMXers' enthusiasm for the Browning system is any indication, the conventional front derailleur may soon become extinct.

BMX racers have no use for derailleurs, finding them simply too unreliable. So when Darrell Young, a pro BMX rider, won the 1984 ABA Nationals on a Browning-equipped bike, the word was out. Here is the next unfair advantage; it's only a matter of time before the rest of the cycling world catches on.

Naming of the Parts

The Browning transmission has two basic components: a set of chainrings, called the *ring cassette* (see Figures 1 and 2), and a *selector assembly*, which mounts on the seat tube in place of a front derailleur (see Figure 3). (All photographs in this article show the *two-speed* BMX model **except figure 10*. I will explain later how the three-speed ATB model differs.)

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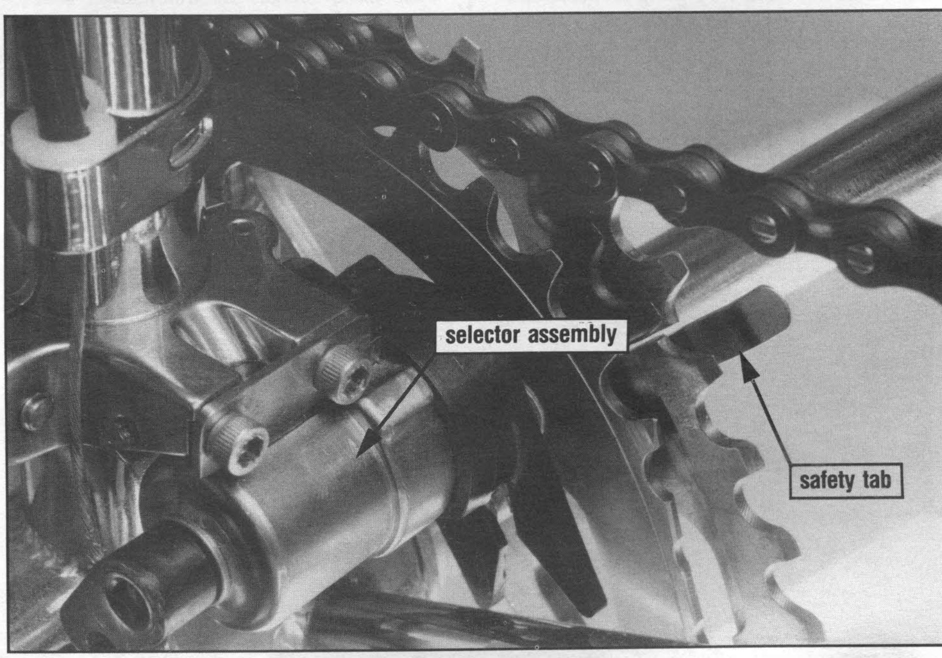

Figure 3: Selector assembly (at arrow) mounted on seat tube in place of front derailleur. Two cap screws allow for lateral adjustment. Note shift control cable at left, and shaved teeth on inner chainring at right. Also note safety tab on swing sector, needed to prevent another upshift when chain is on the large ring and an upshift is selected by the control lever.

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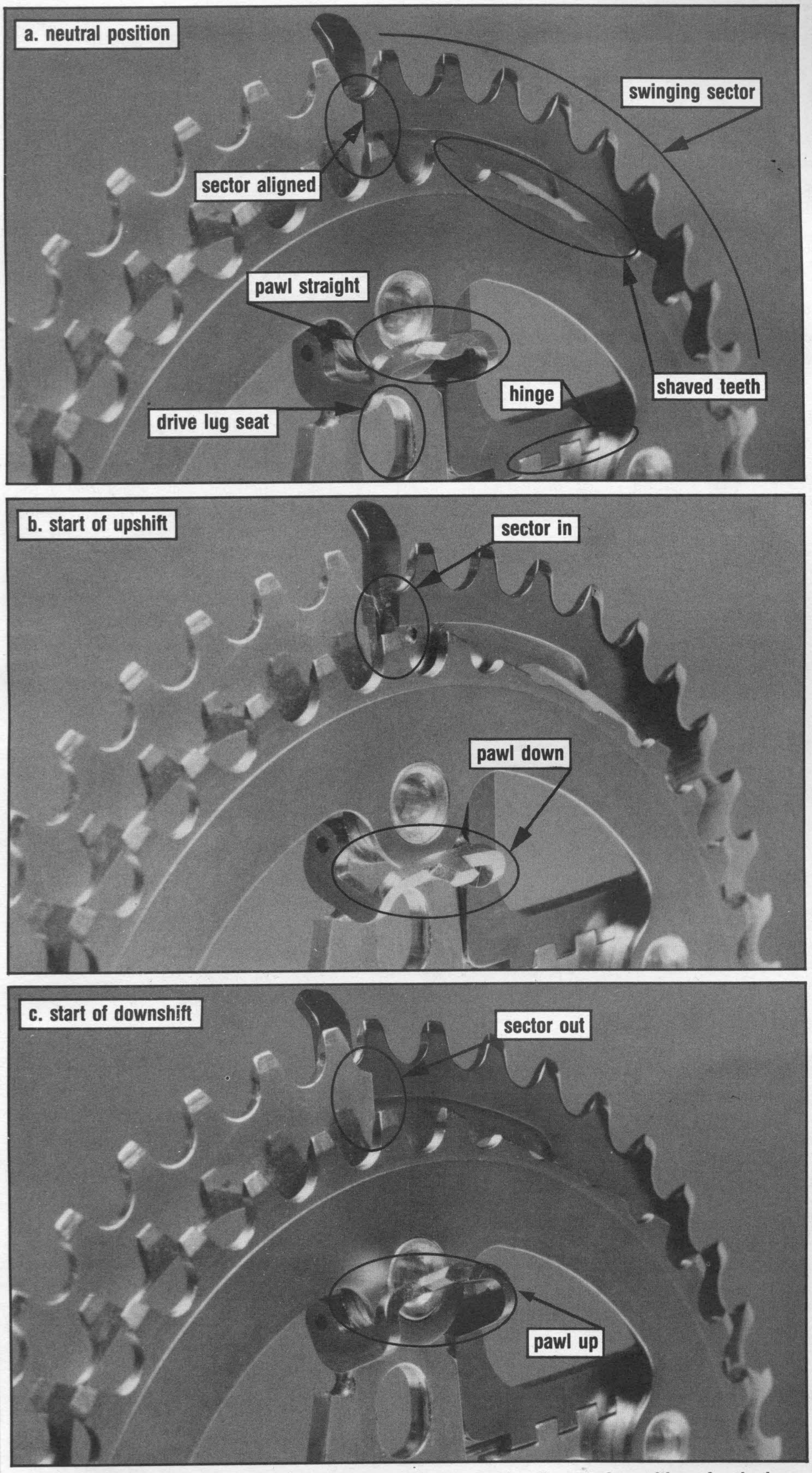


Figure 4: Position of hinged pawl (either straight, up, or down) controls position of swinging sector.

Continued from page 2

The two rings in the cassette are riveted together for reliability. The inner chainring is identical to a conventional one except that, for reasons to be explained, some of the gear teeth are cut away (see Figure 3). The outer chainring is unconventional: it has a pie-shaped *swinging sector* mounted on a hinge, allowing it limited freedom to swing from side to side. This swinging sector maintains control of the chain position at all times during both upshifts and downshifts.

Movement of the swinging sector is controlled by what's called the *chainring pawl.* The pawl is hinged onto one of the spider arms of the outer chainring (see Figure 4). When the pawl is moved radially outward ("up" in Figure 4), the swing sector moves "out" (away from the small chainring); when the pawl is moved radially inward ("down"), the swing sector moves "in" (towards the small chainring). After either of these motions, the pawl is returned to the center position, under force of a spring, and the swing sector moves to the neutral position (i.e., lined up in the plane of the outer chainring). This whole sequence of events is explained more fully below.

The position of the chainring pawl is controlled by the selector assembly. As the crank rotates, the pawl passes through two *cams* in the selector assembly (see Figures 5 and 7). The cams are moveable (in response to the shift control lever) and, depending on their position, route the pawl either up or down, and thus cause the swing sector to execute either a downshift or upshift (see Figure 7).

The two-cam setup provides an *interlock,* via the internal mechanics of the selector assembly, that eliminates the possibility of jumping the chain in case the rider backpedals during a shift. (Conventional derailleurs are all too vulnerable to this chain-jumping problem.)

Any conventional shifting lever and cable can be used to control the selector assembly. Some BMX riders like to use spring-loaded "twist grips" (such as Sturmey Archer #HSJ-763) for this purpose. Since BMX bikes have no rear derailleurs, a chain tensioner (such as Shimano #54801010) must be installed at the rear dropout, to take up the chain slack that occurs when shifting the front.

Gearing on the BMX model is 38T/44T, and the Browning BMX ring cassette can be mounted on any standard BMX axle (i.e., any one-piece crankset using a drive lug).

The three-speed ATB model works on the same principle as the BMX model. Of course, there are *three* chainwheels on the ring cassette, the larger *two* of which are made with a swinging sector as shown here. These two swinging sectors move *in unison* under the control of a *single* pawl and a single selector assembly. This triple cassette is geared 28T/38T/48T, making it useful for both mountain riding and touring. The triple cassette will mount on a standard (tapered end) cotterless crank axle, and the dimensions have been selected to allow the widest range of interchangeability with existing axles. Thus, the Browning system can be used with conventional bottom bracket components (bearings, axles, cups, retainers, etc.).

Solid Engagement

How exactly does the Browning transmission work? The explanation is deceptively simple. The important point to remember is that *the transmission is always engaged*. During a shift, the chain is seated momentarily on two gears at the same time. This is why the chain can carry a full pedaling load at all times during shifting. Of course, conventional front derailleurs keep the chain constantly engaged during a *downshift*. The Browning system achieves this constant engagement on *both* an upshift and downshift.

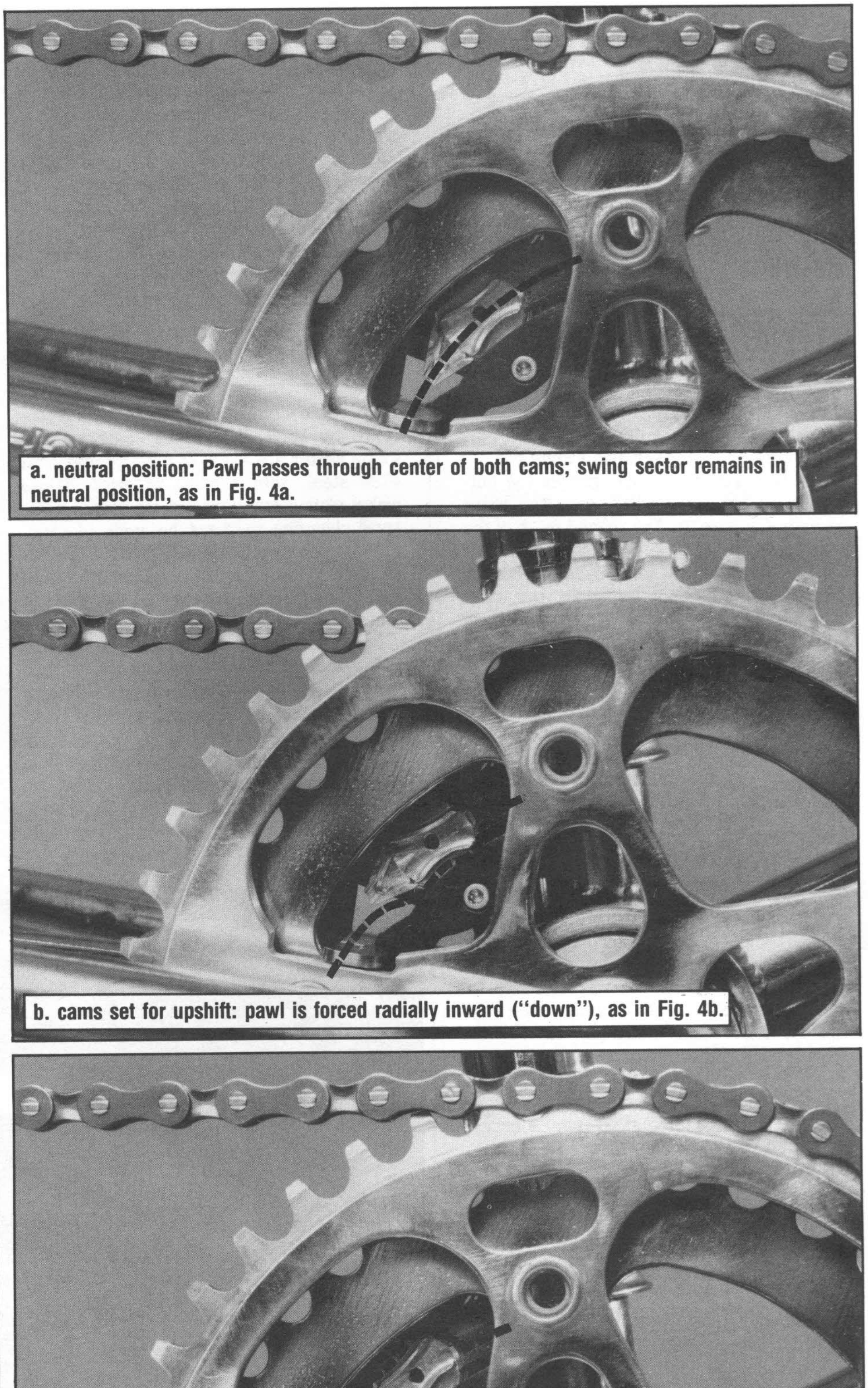
Think of how a railroad switch works. A train can be (momentarily) on two sets of tracks at the same time, with the process controlled by the switch. The switch moves a short set of tracks into (or out of) the train's way, in much the same way that the transmission's chainwheel pawl moves the swinging sector into (or out of) the chain's way. (Imagine if the railroads tried to make a train switch tracks by pushing it sideways with a big front derailleur cage!)

The swinging sector serves the same function as the moveable tracks in a railroad switch. During upshifting, the swing sector provides an essentially *spiral* path of teeth that lifts the chain off the small chainring onto the large one. During downshifting, it simply swings out of the way, allowing the chain to drop onto the small chainring by its own force. Here's a step by step look at these two processes.

The Up Switch

We'll start with the right crankarm at 9:00 and the chain on the small ring. At this point, the swing sector is between 6:00 and 8:30, and the pawl is in line with the crank at 9:00. As the crank reaches 10:00 (see Figure 8a), the chainring pawl meets the triangular cam which was set for an upshift by the selector (Figure 5b). The pawl is forced *down*, pulling the swinging sector inward toward the bike frame (Figure 4b) and into the line of the approaching chain. Shortly thereafter, the chainring pawl reaches the forward bottom curve of the reset cam, forcing this cam up and thus returning the triangular cam to its neutral position (Figure 5a).

When the crank reaches 11:00, the leading tooth of the swing sector begins to engage the chain (see Figure 8b). At 12:00, the swing sector has started to lift the chain off of the small ring, and the rider is now aware he is pedaling in a higher gear. By 2:00, the chain is well-seated on the swing sector, but is still engaged on the small chainring. When



a. neutral position: Pawl passes through center of both cams; swing sector remains in neutral position, as in Fig. 4a.

b. cams set for upshift: pawl is forced radially inward ("down"), as in Fig. 4b.

c. cams set for downshift: pawl is forced radially outward ("up"), as in Fig. 4c.

Figure 5: Operation of cams in selector assembly. Dashed lines show path of pawl.

the crank reaches 7:00, the transfer is complete and the swing sector springs back to its neutral (in-line) position.

The Down Switch

We'll start again with the crankarm at 9:00, but now the chain is on the large ring. When the crank reaches 10:00, the pawl meets the triangular cam (which is pointing down, see Figure 5c). As the pawl slides over the triangular cam, it is pushed upward, which moves the swinging sector out of the path of the approaching chain (Figures 4c and 5). At 10:30, the pawl has passed the triangular cam and reaches the forward (upswung) end of the reset cam, pushing it down into the neutral position (Figure 5a). The swinging sector remains swung out.

At about 12:00 the chain misses the outswung sector and "falls" onto the inner chainring (Figure 2). The shaved teeth of the inner ring provide the necessary clearance for the chain to move into position properly. If the teeth were not cut away, the chain would wedge between the two chainrings, as often happens when trying to upshift under load with a conventional derailleur.

While the crank is between 12:00 and 3:00, the chain is actually on both chainrings (Figure 1), like a train on two tracks at the same time. The switch is complete when the crank has reached approximately 3:00, and the chain is fully engaged by the small ring.

Shifting Loads

Because the chain is engaged at all times, the Browning transmission can carry full pedaling force during shifting. No conventional derailleur system has this capability. In tests conducted by Octo Company (see Figure 9), a Browning BMX unit showed no missed shifts after more than 64,000 up/down shift cycles under a constant load of one horsepower (this corresponds to constant 100 lb pedal force at 90 rpm cadence). By comparison, recent tests on Shimano, Sun-Tour, and Campagnolo front derailleurs were done at only 1/25 horsepower, which, under the reported test conditions, corresponds to pedal forces in the range of 7 to 15 lb. at 25 to 57 rpm (reference Figures 7 and 8 on page 4 of April 1985 *Bike Tech*).

Octo Company also performed destructive tests to see which component in the drivetrain fails first under outrageously large forces. These tests simulate the heaviest imaginable rider climbing a steep hill with loaded panniers. They calculated that a constant pedal force of 300 lb. represents this situation, allowing for a BMX rider capable of applying 330 lb. peak pedal force or a tourist using toe clips applying 500 lb. peak force. Under these loads, the Browning transmission showed no damage and continued to shift even while teeth were being sheared off the freewheel.

How much effort is required to shift? Since the shift is initiated when the swing sector is *not engaged* with the chain, a force of only 2.5 grams on the shifting cable is needed. In comparison, the Shimano New Dura-Ace front derailleur requires about 4,800 times more force to shift, i.e., 12,000 grams cable tension is needed (reference Figure 7 on page 4 of April 1985 *Bike Tech*). The 2.5 grams needed to shift the Browning transmission could be supplied by a battery-powered motor or solenoid, thus making fully automated shifting possible.

Production Methods

The Octo Company machines their prototypes by hand. The small chainring and swing sector are made of heat-treated AISI 4130 steel, with a finish of electrodeless nickel plating for corrosion resistance. The small chainring need not be made of steel, but it was chosen for the 38T/44T BMX application so that the 38T ring could be thinner, and thus placed closer to the 44T. In other applications, aluminum may be used.

For volume production, the chainrings and swing sector are made by a process called fine-blanking. This is a precision stamping operation, developed in Germany and Switzerland, using dies that are "deadly accurate" (a BMX term). Fine-blanking is one of the few mass production methods that can hold the close tolerances (plus or minus one thousandth inch) needed to make the hinge on the swing sector work properly.

The outer chainring (except swing sector) is made of 2024-T3 aluminum alloy by the fine-blanking process. It is then heat-treated to T8 temper, which results in properties close to those of 7075-T6. The 7075 alloy is not used in the first place because it is very hard on the fine-blanking dies.

Despite the extensive use of steel, the Browning system weighs about the same as a conventional chainwheel/derailleur setup.

In the BMX model the chainrings are assembled by a process called orbital riveting (see Figure 5). The designer felt that regular nuts and bolts were not reliable enough for the BMX market. In the ATB/touring model, the traditional threaded bolt system may be used for easy interchangeability.

ATB/Touring Model

Design of the BMX model was simplified by the fact that BMX bikes have only one gear in the back. With a multi-gear freewheel, the Brownings found that the wide angles of the chain caused it to derail off the swinging sector, especially when the chain was on the large rear cog during an upshift under heavy load. Consequently, the swing sector on the ATB/touring model is *bowed* in the following way: the teeth on the sector at the leading edge march in an arc away from the centerline of the bike, and at the same time lean into the bike's center line. The net effect is that all teeth help carry the chain laterally as opposed to only the last few teeth on the BMX model. The ATB model will

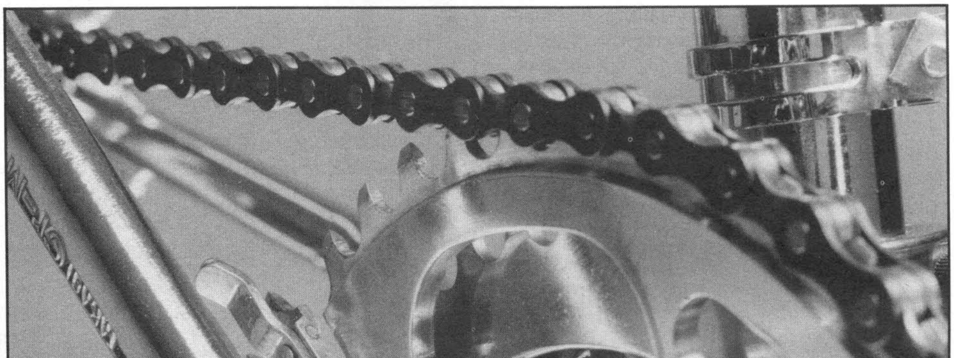


Figure 6: Chainring pawl (at arrow) shown passing through the control cams in the selector assembly.

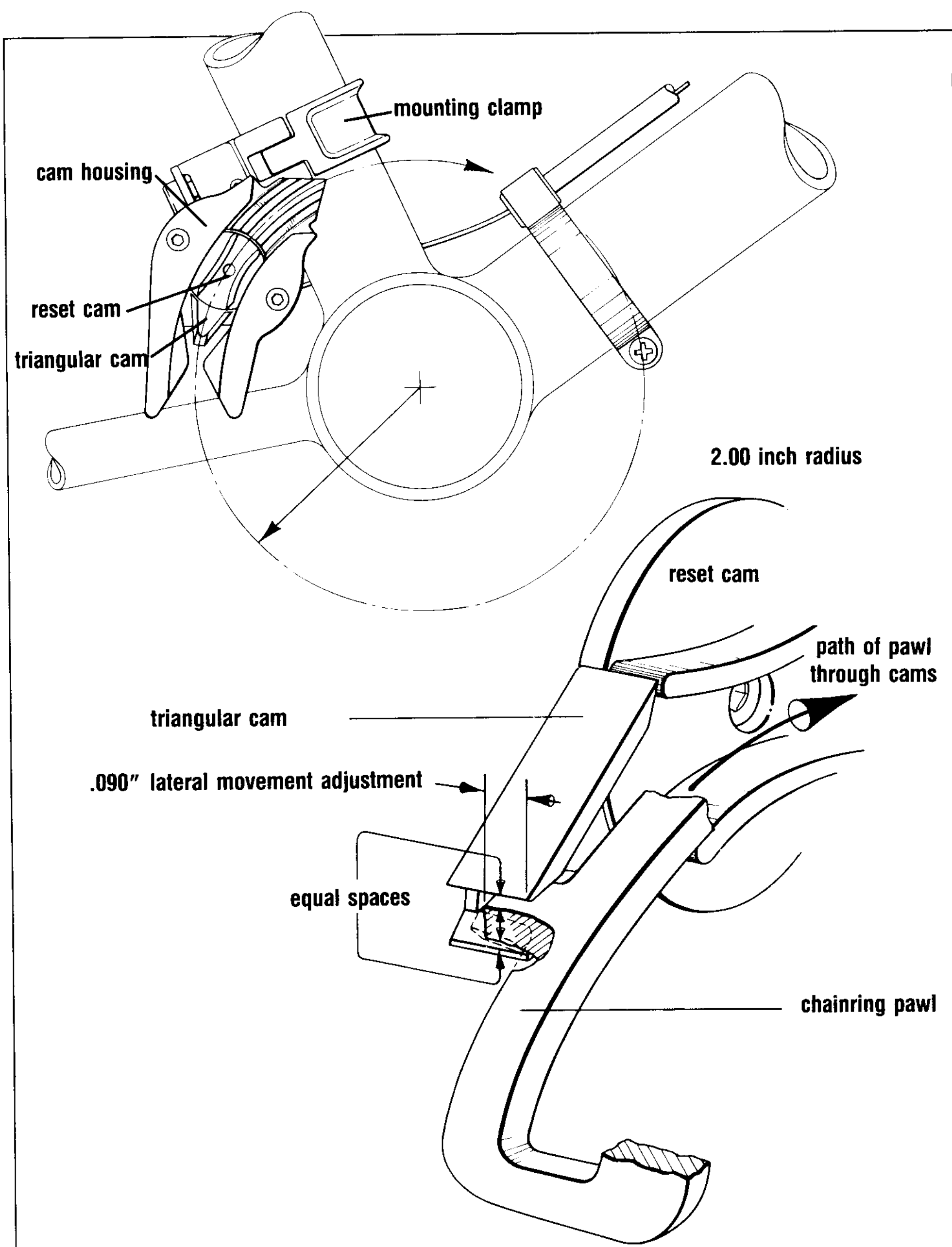


Figure 7: Selector assembly in position on seat tube (upper drawing). Triangular cam and reset cam control the path of the pawl. Lower drawing shows critical alignment between pawl and cams.

handle freewheels that fit in 121 mm rear spacing, giving the rider 15 or 18 speeds.

The shift lever for the three-speed ATB model works differently than a conventional front shifter. It has three positions (center, forward, and back), but the two outermost positions (forward and back) are *momentary*, i.e., a spring returns the lever to center position when the rider lets go. For example, moving the lever forward for an instant and then letting go is the signal to "call for a downshift." The transmission responds as follows: if in high gear, it switches to middle gear; if in middle gear, it switches to low; if already in low, nothing happens. Upshifting is similar. Thus, to call for an upshift, the rider pulls the lever back for an instant and lets go. If the transmission is in low gear, it switches to middle gear; if in middle gear, it switches to high; and if already in high, nothing happens. The benefit to this type of shifting control is that the rider wastes no time making fine adjustments to the lever position, as is often needed when shifting into the middle gear with a conventional front derailleur. The rider simply hits the lever "into the stops," and the shift happens automatically.

Dealer Support

The marketing plan for the Browning transmission was based directly on the successful approach of the Browning Arms Company. A group of well-trained, active dealers is the key. Browning transmissions are available to customers only through qualified bicycle dealers and shops.

Initially, only dealers are allowed to install and adjust the units; consumers will not be able to buy the units "loose" to install themselves. The reason is that the selector assembly must be aligned perfectly when it's first installed. If the chainring pawl does not go precisely into the triangular cam every time, serious damage could result to either the pawl or cams. Fortunately, this critical alignment process needs to be done only once.

The selector assembly is designed to snap off the mounting bracket for easy replacement. (Position of the fixed mounting bracket preserves the critical alignment discussed above.) If a selector ever needs service, the dealer simply installs a new selector from stock on the customer's bike, and returns the bad selector to Browning. Browning then ships a new selector to replenish the dealer's stock. The net result is that the dealer never faces the problem of opening up the selector, with its more than twenty small parts, for repairs.

Why BMX First?

Many would doubt the wisdom of trying to sell a new transmission into a market where, historically, shifting systems are distrusted. Besides, the first BMX unit carries a retail price of $250—quite expensive for what might be perceived as "nothing but two chainrings."

Despite these drawbacks, the Brownings saw BMX as the ideal challenge. If the new product could take the jumping, bumping, and dirt crashes, it could take anything. In short, the Brownings realized that their transmission could survive in any market if it survived BMX. Other factors also swayed the decision. The BMX market is not as tradition-bound as the mainstream racing/recreational market. And since there are no competing transmissions in BMX, defensive reactions from the derailleur manufacturers were not likely. Finally, if the Browning transmission failed to thrill the BMXers, this would not necessarily jeopardize its success in other cycling markets. So the Brownings decided to offer prize money to any BMX rider who wins a national event with their products and to pay for personal endorsements.

Now that a pro BMX rider won the 1984 ABA Nationals using a Browning transmission, other markets are in the Browning sights. The all-terrain bike seemed like the next roughest market, with the serious tourist in line shortly after that. As of this writing, prototypes of the ATB/touring model are going out for dealer evaluation.

The largest cycling market, recreational/sport riders, may be the slowest to accept the Browning transmission. After all, the average price for a department store bike last year was $89.

How Does it Ride?

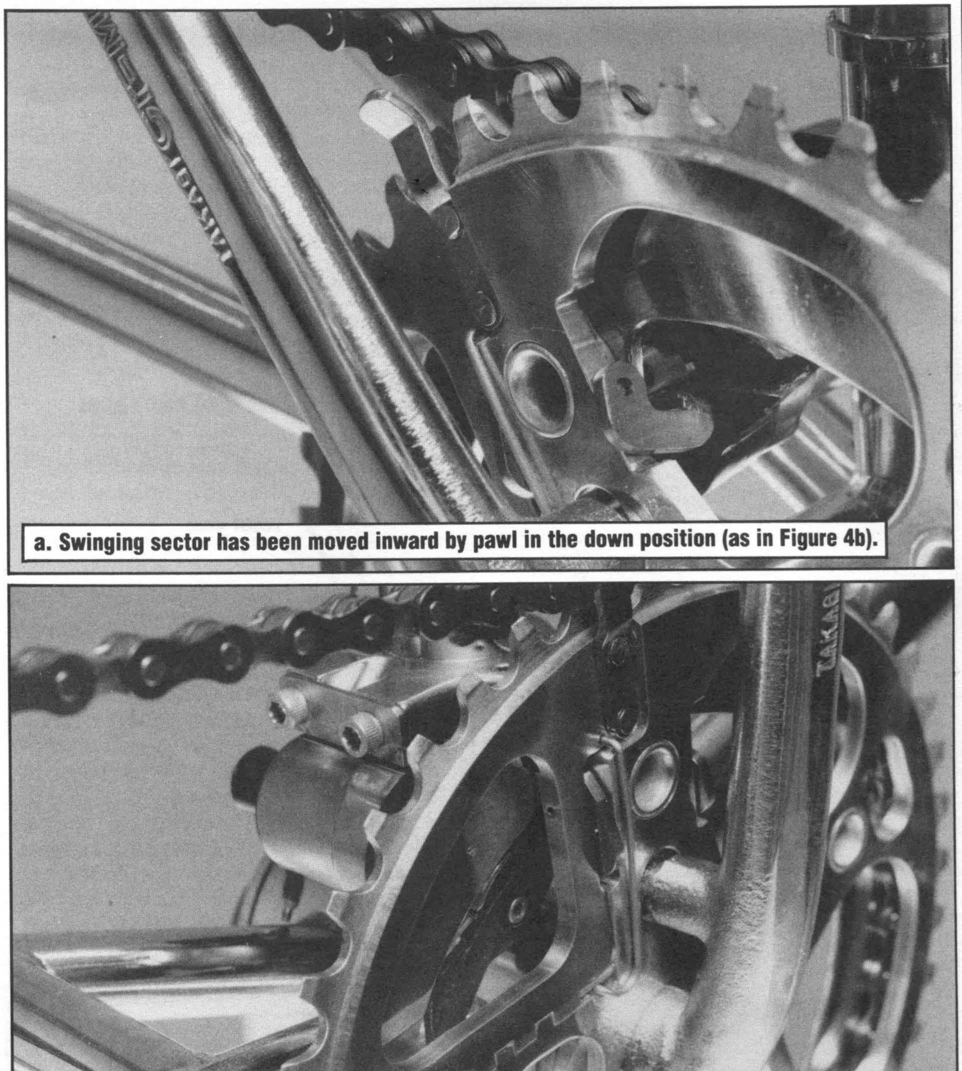
The way it works on the road is the very thing that got me interested in the Browning project. I have been going to trade shows for about 14 years and have tried all sorts of bike gizmos. For the most part, they are easy to discard for one reason or another: too heavy, too ugly, unreliable, etc.

The day I first rode the Browning transmission, my attitude was "I'll be polite and take it up the block." Well, that's all it took. I was sure these folks had something. The first time I shifted, I wasn't sure that the chain really moved. I was standing on the pedals when I tried that first shift, and I was sure that nothing was happening, so I tried it again, and got off the bike to confirm that the chain was in fact on the other chainring. At that point all I could do was smile, and try it again to make sure that it wasn't a fluke.

After a few minutes I could tell when the shift was happening and began adjusting to the new feel. Since the swing sector always picks up the chain at the same place, there can be a delay of almost a full revolution (a second and a half at slow pedaling rpm's) until the cranks come around. I had been expecting the instant rasping and grinding (generously called "feedback" in the April 1985 *Bike Tech*) that tell you the front derailleur is at work. Instead, I was disconcerted by the silence. Like switching to a new electronic typewriter that does not make the letter in immediate response to the key stroke, the small delay can be distracting for a while. Once you're used to that, it's great! Now I can't wait to get a Browning transmission for my personal tandem; no more trying to communicate and coordinate that difficult downshift while going uphill!

Angel Rodriguez started work as a bike shop mechanic in 1971. In 1973 he opened his own shop, R+E Cycles, and a year later studied framebuilding in England. He has received several bicycle-related patents. Nowadays he is best known for building the Rodriguez Tandems. Angel has been a consultant to the Brownings on the transmission project since 1980.

This article was written in cooperation with the Octo Company research team and the Browning Automatic Transmission Company. Inquiries concerning the transmission may be sent to Browning Automatic Transmission Company, 105 West 2950 South, Salt Lake City, UT 84115.



a. Swinging sector has been moved inward by pawl in the down position (as in Figure 4b).

b. First tooth of swing sector engages the chain.

c. Chain is now seated on the swing sector, but still engaged on the small ring.

Figure 8: Upshifting sequence: upshift was started when selector moved cams into position as shown in Figure 5b.

Figure 9: Two views of the main test machine at Octo Company. The fixture holds the bike upright and applies a load at the seat. A hydraulic motor drives the crank axle from the left side through universal joints. A friction brake attached to one of the rear rollers applies resistance. By measuring rotational speed and torque at the friction brake, power through the transmission is calculated.

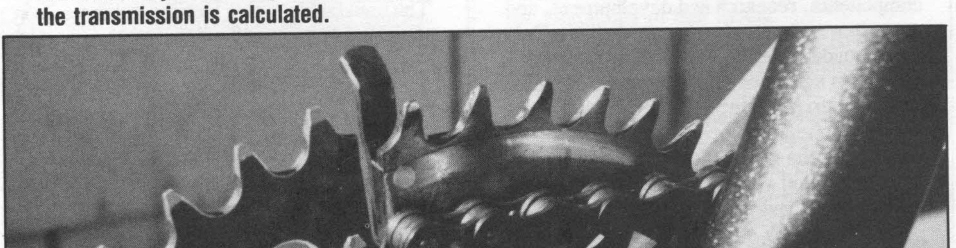


Figure 10: Bowed teeth on the swing sector for the ATB/touring model are needed to accomodate wide chain angles due to shifting on the multi-gear freewheel.