A Study Of The Vertical Forces On The Rear Axle In A Fairmont MT19A

by Bill Owen
in conjunction with
Mike Paul and Tom Norman

The Problem

The axle breakage problem in Fairmont MT19s is well known. Every year on our excursions several MT19 axles break while broken axles on other Fairmont cars such as the M19 (belt drive) or MT14 (chain drive) are much less common. A lot of good work has been done to try to understand and resolve this problem by Fairmont as well as several operators in our hobby.

Fairmont Service Data #411 recommended the center bearing and bearing support bracket be adjusted and maintained such that the axle does not bend more than 1/8" in the horizontal direction. Fairmont made available a service group package that relocated the center bearing and support bracket to the rear and discarded the center bearing spring. Tom Norman has worked on several aspects of this problem, including making high strength axles and improving the keyway. Mike Paul has arranged for analysis of broken axles that shows the failures are stress–related.

Most of the work on this problem has focused on properly adjusting and positioning the center bearing and support bracket. Several people have recommended that the center bearing spring should be removed to avoid the continuous downwards bending force it places on the rear axle. But MT19 cars have broken axles both with and without the spring.

Last year Tom Norman suggested it is important to make sure the axle is straight to avoid continuous bending forces a bent axle would see at the center arm. Mike Paul points out, however, that an axle that is bent significantly between the axle bearings will try to "orbit" at the center bearing, and end up destroying the center bearing.

So to this point, we had not identified a force on the axle large enough to cause the axles to break at such a high rate.

How Much Force Is Needed To Break An MT19 Axle?

Tom Norman has done a lot of work on this recently and has found that the .125" keyway with sharp corners in the standard Fairmont MT19 axle reduces the strength of the axle by more than a factor of 3. A 1045 steel bar has a yield point of 55,000 psi. If the Fairmont keyway reduces this strength by a factor of 3, then a stress greater than about 18,000 psi will exceed the strength of the axle at the keyway. Since we know the axles usually break near the edge of the sprocket next to center bearing, the force necessary to produce a stress of 18000 psi can be calculated. The distance from the left side of the sprocket to the inside of the left wheel bearing is 31.5" and to the inside of the right wheel bearing is 16". Using these distances, the calculated force needed to put a stress of 18,000 psi on the sprocket is about 240 pounds, and this force will bend the axle a little over 3/16".

The amount the axle bends as a result of force on the sprocket can be measured directly. Place wedges between the frame and wheel bearing blocks so the axle is held all the way down and cannot move; place scales under the sprocket and gently lower the car down on the scales. Measure the distance from the axle to the center frame member first with no weight and then with the weight of the car on the scales; the difference is directly the amount of bending resulting from the force of the weight of the car on the sprocket. On my MT19, the rear axle bent upwards about .25" with 300 pounds on the sprocket. This is about 75 pounds per 1/16" deflection which agrees well with the earlier calculations.

Where Can A Bending Force This Large Be Coming From?

The location and analysis of the breaks as well as the history of this problem give us some important clues. The M19 belt drive cars do not seem to have this problem. The problem appeared when Fairmont introduced the MT19 with a chain drive. This certainly suggests the conversion to chain drive contributed to the problem. Also, the breaks usually occur at the sprocket and are stress–related, again suggesting the chain drive has something to do with the problem. Looking at the path of the chain in the MT19, one notices that the chain comes off the top of the rear sprocket in a mostly horizonsprocket. I had to add three links to the original drive chain to accommodate the slightly longer path length of the dual idler drive chain. (Please see the picture of the dual idler installed in the MT19.) The chain is then tensioned by moving the lower idler sprocket forward in its elongated slot and then tightening the nut on the idler shaft securely to keep the shaft from slipping. Notice that with the dual idler installed, the chain can be tensioned so there is minimal slack. This is VERY different from the instructions for tightening the chain on a standard MT19. On the standard MT19 chain drive, it is very important to leave slack in the chain, even with the axle all the way down (no weight on the rear axle) to avoid putting additional vertical forces on the axle from the chain. This is another problem caused by having the chain come off the rear sprocket at a 45–degree angle instead of horizontally. As the axle moves up and down, the chain path length changes, which means the chain tension should be adjusted with all the weight off of the rear axle so the chain path length is at its maximum. If the chain is adjusted with the weight of the car on the rear axle, then the chain itself will bend the axle every time the car bounces up and weight on the rear axle is reduced. With the dual idler, the chain path length is nearly constant as the axle goes up and down, and since there are no vertical forces on the axle from the chain, the chain can be adjusted with minimal slack.

Tsubaki recommends chains that frequently change direction should be adjusted with a slack of about 2% of the span. The chain in a motorcar definitely changes direction frequently, constantly going between slight acceleration and deceleration on some grades. One way to set the chain tension is to put a three–foot straight edge on top of the chain and measure the amount the chain drops below the straight edge. Put the car up on jacks, take the brake off and put the transmission in neutral, so the chain is free to move. Make sure the upper chain guide does not touch the bottom of the chain. Adjust the tension such that the chain is about 3/8" below the straight edge just using the weight of the chain itself. Once the chain tension is set, adjust the upper chain guide so it is about 1/8" below the chain.

The Results

I installed the dual idler chain drive on my open MT19 and ran the car for about 48 miles at Folsom. Before this run, I doubled the sensitivity of the axle bending measurement system so each dot indicated 1/32" of bending of the rear axle. What I found on this run during normal operation is the axle bends both up and down about +/- 1/32" most of the time, and occasionally +/- 1/16". In 1st gear reverse acceleration up a slight grade (right at the limit of traction with two people in the car) there was no particular systematic bending. Again +/- 1/32" bend-

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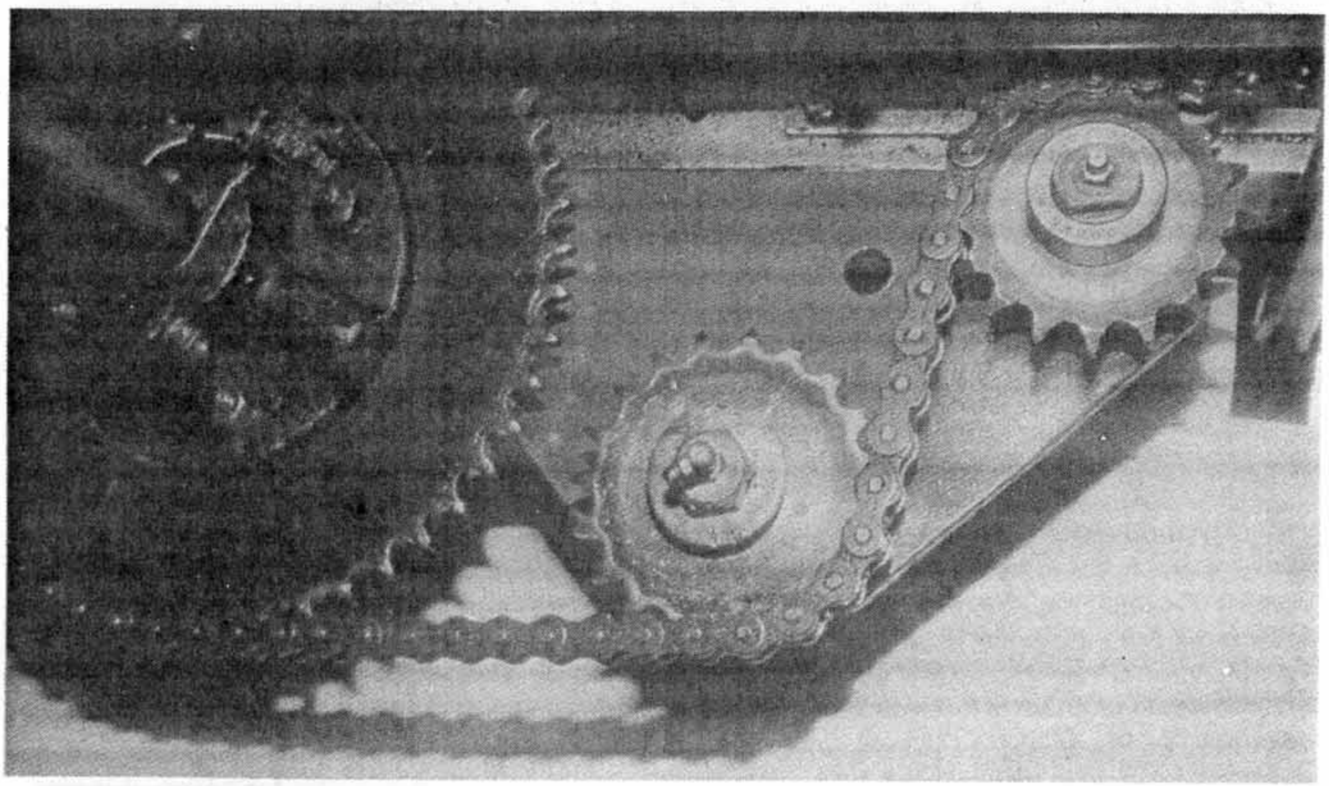
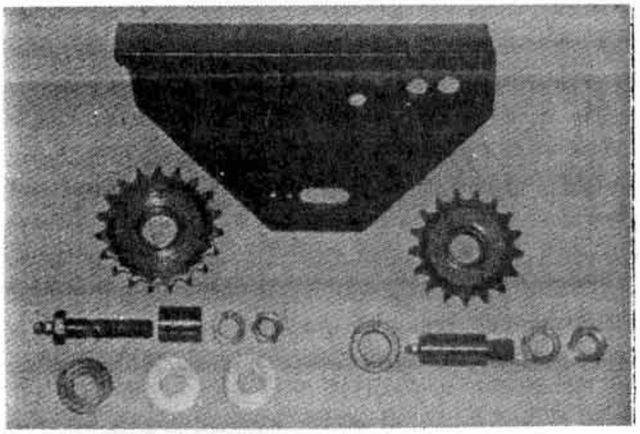
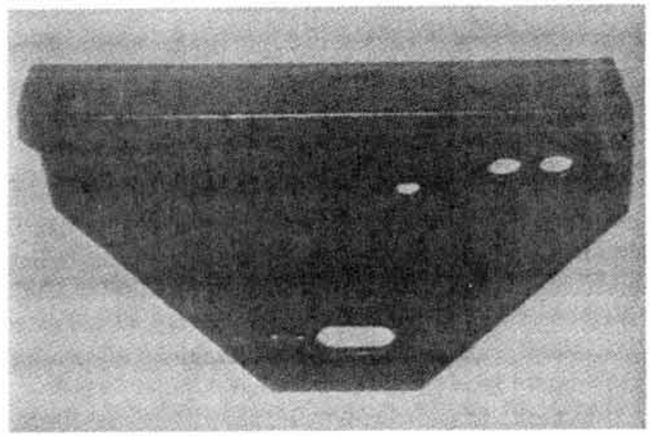


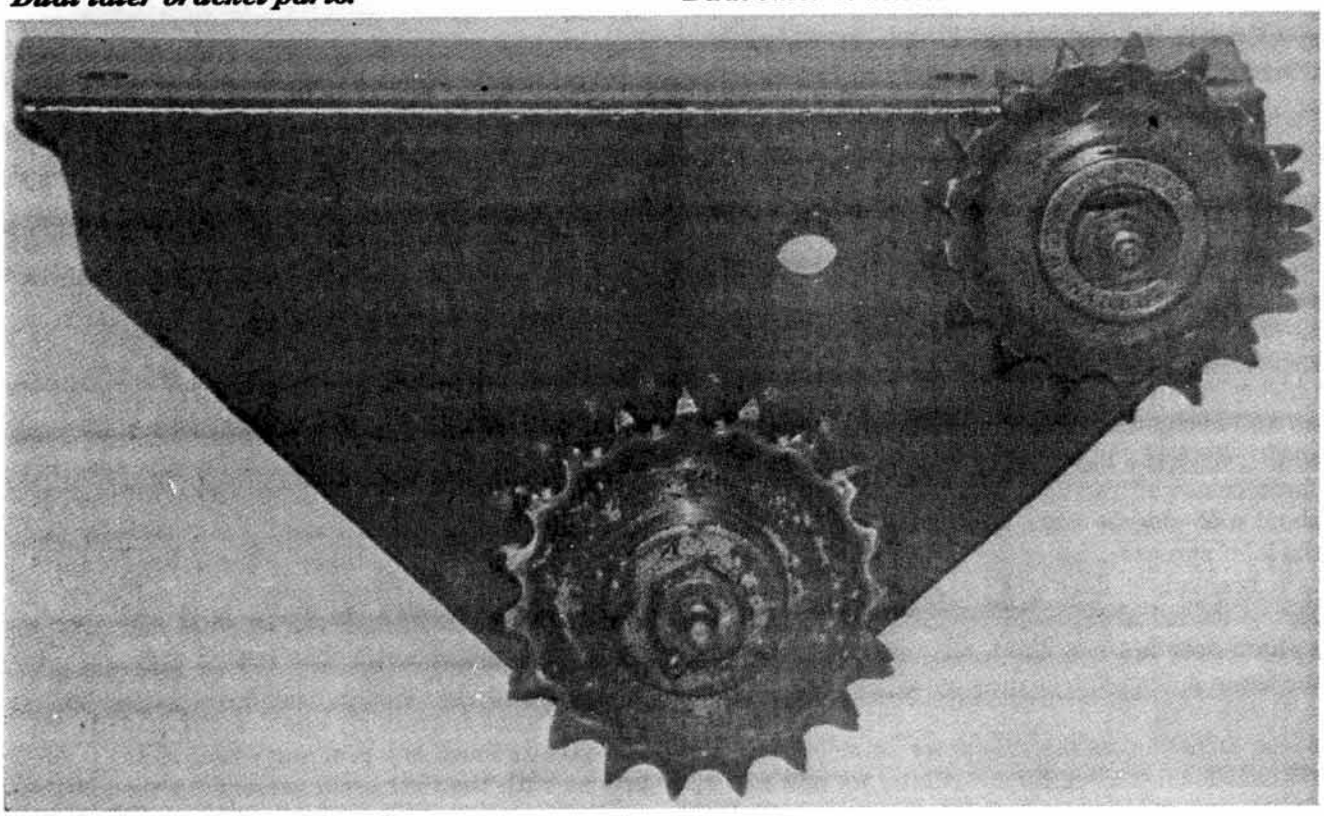
Dual idler Bracket assembly on MT19.



Dual idler bracket parts.



Dual idler bracket.



Assembled dual idler bracket.

lower idler slot with a heavy washer on both sides of the elongated slot along with a lock washer and nut to secure it. A new 3/4" Browning tightener shaft and a 17–tooth idler sprocket are installed in one of the two fixed mounting holes for the upper idler sprocket.

Mounting the Dual Idler Bracket

In order to mount this bracket on the MT19 frame member, it is necessary to move the center bearing support arm to the rear as recommended by Fairmont. This involves pulling the axle nearly half way out, so the center bearing arm can be slid off the axle and turned around and slid back onto the axle. Also, two new holes need to be drilled in the frame member behind the axle to support the center bearing arm. The front hole in the frame member that was used for the support arm can now be used for the dual idler bracket. To support the front of the dual idler bracket, a new hole needs to be drilled in the frame member—through the battery box bracket in some cars—near the front of the dual idler bracket. This bolt will see a vertical force when the lower chain is under tension, so if the hole is not drilled through the battery box bracket, a large washer should be placed on top of the frame member to spread out the force from the head of this bolt to the aluminum frame member. Once the bracket is mounted to the car with its two idler sprockets, the chain from the rear sprocket is routed under the lower sprocket and then up and over th pression spring is placed in the lever arm such that the lever arm pushes down on the axle with a steady force of about 50 pounds. This approximately counters the steady upward force on the rear axle due to pulling up the spring–loaded tensioner pulley. This design appears to work quite well, as we have quite a few restored M19s operating, and they don't seem to have any problems with rear axles breaking.

The MT19 Drivetrain

Several major changes in the drivetrain were made when Fairmont designed the MT19. The engine is a 2–cylinder, 20–HP Onan CCKB with a 2–speed transmission and forward/reverse gears. To transfer this extra power without slipping, a chain drive between the transmission and the rear axle is used. This new drivetrain allows the MT19 to operate quite well over a wider range of speeds and track conditions. The MT19 chain follows the same basic path as the belt—from a sprocket on the transmission to a sprocket on the rear axle and then from the bottom of the sprocket up and over a fixed idler sprocket on the lower side of the chain. The idler sprocket is located in about the same location as the tensioner pulley is on the M19 and holds the chain up and over a frame cross member and the brake shaft. With the idler sprocket in this location, the chain comes off the bottom of the rear sprocket at about a 45–degree angle in order to go up and over the idler sprocket. Since the idler sprocket is bolted to a bracket, it does not have any give like the spring–loaded tensioner pulley in the M19 has. Also, a chain does not slip like a belt, so any tension on the chain is transferred directly with very little loss to the rear sprocket. This is necessary to transfer power from the much more powerful engine and a geared–down transmission. But as we now know, any tension on the lower chain results in both forward and vertical forces on the rear axle. The center bearing and support arm counter the forward forces, but since the sprung axle has to be free to move in the vertical direction, the only way to counter the vertical forces is for the axle itself to bend.

The 20HP Onan in low gear has plenty of torque (which is multiplied about 2.9 times in low gear) which can bend the axle more than 5/16" in the vertical direction. This bending is the primary reason the MT19 axles break so often and so early in life.

Another important contributing factor to the axle breakage problem is the keyway in the MT19 axle. In order to handle the much higher torque on the rear sprocket, Fairmont increased the keyway depth to 0.125", compared to the M19 axle which uses a 0.0492" keyway depth. This deeper keyway reduces the strength of the axle, which further aggravates the breakage problem.

The Fix

Now we understand the primary cause of the MT19 axle breakage problem is the excessive bending of the axle due to vertical forces from the chain coming off the rear sprocket at a 45–degree angle. To fix this problem, an improved chain drive is proposed which eliminates these vertical forces by having the chain come off the rear sprocket in the forward or horizontal direction instead of at a 45–degree angle. By having the chain come off the rear sprocket in the horizontal direction, the vertical forces on the axle are eliminated. There are a couple of ways to do this on the MT19.

One way is to move the idler sprocket forward about two feet, mount it below the center cross–members, and run the chain under this sprocket up to the transmission sprocket. In this case, the chain runs for a some distance at about the same level as the bottom of the rear sprocket. If the chain is not kept fairly tight, the chain may even droop down below the level of the rear sprocket. In this position, it probably would pick up a lot more debris, especially in high ballast or in weeds, than the current chain path.

A second way is to add a second idler sprocket on a bracket such that the chain comes off the bottom of the rear sprocket nearly horizontally and travels a very short distance to the lower sprocket. The chain then goes up and over the upper sprocket and follows pretty much the original path to the transmission sprocket. The second arrangement keeps the chain at or above the bottom level of the rear sprocket for a fairly short distance so it will not have as much of a problem with picking up debris as with the first arrangement. Although the second arrangement requires a second idler sprocket, it looks like it is the best choice because it minimizes the amount of chain below the frame of the car.

The Dual Idler Bracket

To test this idea out, I made a bracket for the dual idler sprocket arrangement using 3" by 6" by 5/16" angle iron. (Please see the picture of this bracket with the idler sprockets mounted on it.) In order to adjust for chain wear, the lower sprocket hole is elongated by 1", and for the upper sprocket there are two spaced holes 1" apart. (Please see the scale drawing and the picture of the bracket.) The original idler sprocket on my MT19 has 19 teeth, and the threaded portion of the 5/8" diameter shaft is nearly 2" long. This idler shaft is installed in the

Analysis of the Results

These measurements show the axle does not bend significantly on rough track as theorized. The fact that no vertical bending was measured when the car was on rough track suggests the axle is quite rigid, and its strength–to–weight ratio is such that the center of the axle, including the mass of the sprocket, is not bending measurably over bumps. Also, even though the lower chain is under steady tension while operating in reverse, there still is very little change in the amount of bending on rough track.

But what we discovered instead is even more interesting. The 1/4" and 5/16" vertical bending on this axle during engine braking in the forward direction or during acceleration in the reverse direction is very large. This is definitely enough to exceed the stress limit of 18000 psi on the 1045 steel Fairmont axle with a .125" keyway with sharp corners. The fact that this occurs only during forward engine braking or reverse acceleration shows this excessive vertical force on the axle is a result of the lower chain being under tension which puts both a vertical and horizontal force on the rear sprocket. This simply indicates the 20–HP Onan CCKB engine has more than enough torque in low gear to bend the axle excessively in the MT19.

Conclusions and Recommendations

Fortunately this only occurs in first gear during forward engine braking or reverse acceleration—which does not occur frequently. But in heavier cars with more traction, the bending may be even greater. This may explain why heavier MT19 cars such as cars with enclosed cabs, turntables, or extra heavy loads have more problems with axle breakage. An open MT19 has less traction which would tend to reduce the axle bending problem.

Based on this information, one thing an operator can do right away to reduce this problem is to avoid heavy forward engine braking and reverse acceleration in low gear. Also, there are several modifications to the MT19 rear axle and chain drive that can be done that will significantly reduce or nearly eliminate this problem. That will be the topic of the next article on this subject.

Acknowledgments

I want to express my appreciation for the work Tom Norman has done on this problem in the past, and for the all the force/bending/stress calculations he did for this work. Also my thanks to Mike Paul for his many good suggestions and encouragement and for enticing his employer's metallurgist into examining failed axles to determine why they were failing from an engineering viewpoint.

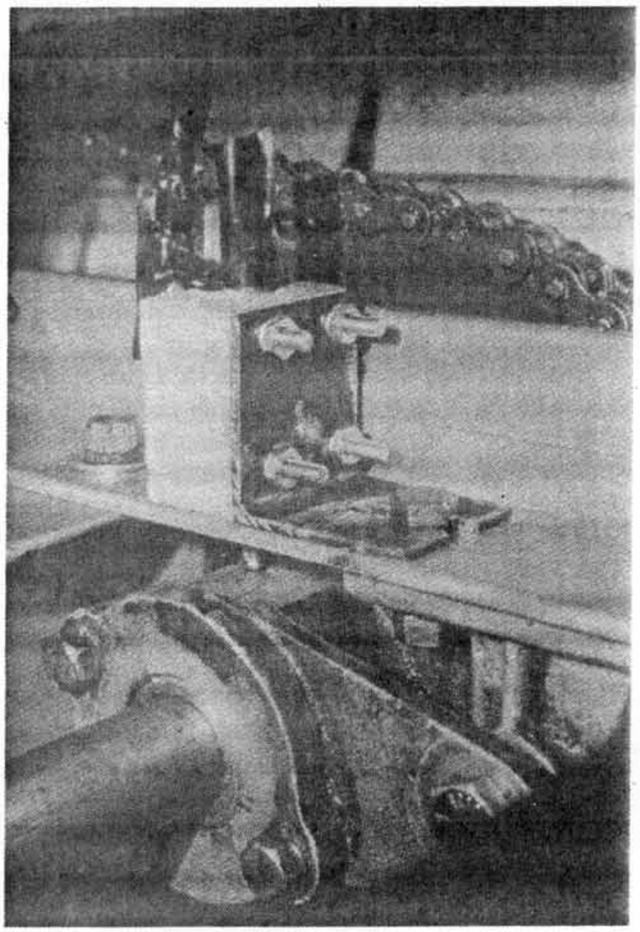
An Improved Chain Drive For The Fairmont MT19

by Bill Owen

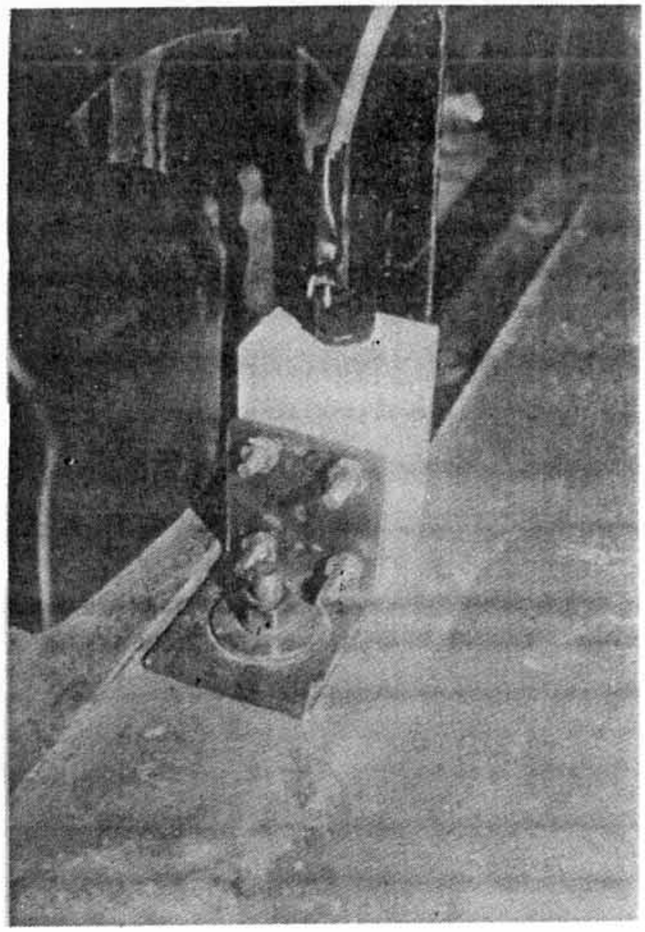
The study of the vertical forces on the rear axle of a MT19 showed very large vertical bending forces on the axle during heavy forward engine braking or rapid reverse acceleration in first gear. These forces are a result of the chain coming off the bottom of the rear sprocket at about a 45–degree angle in order to go up and over the idler sprocket. In order to understand why the chain follows such a path, one needs to know some of the history of Fairmont's M19 and MT19 motorcars.

The M19 Drivetrain

This series of inspection cars started with the M19, which is a belt–drive with a 2–cycle, 8 to 15–HP engine. The belt runs directly over a pulley on the engine shaft to a pulley on the rear axle, and a spring–loaded tensioner pulley is located on the bottom side of the belt. In order to operate in reverse, the engine is reversed. The belt slips on the engine pulley until the spring–loaded tensioner pulley is pulled upwards, tightening the belt around both the rear pulley and the engine pulley. Once underway, only a small amount of upwards tension on the spring–loaded tensioner pulley is needed to prevent the belt from slipping and to maintain speed on most grades. The M19 is a sprung car, which means the cars weight is supported by springs on each of the axle–bearing blocks, and the axles are free to move up and down a little over 1/2". To counter the forward bending forces on the rear axle coming from the belt drive, a center bearing supported by a lever arm is positioned on the rear axle right next to the pulley. The levered support arm allows the axle to move up and down freely but prevents the rear axle from bending in the forward direction. A small com-



Center bearing position sensor.



Left wheel bearing block position sensor.

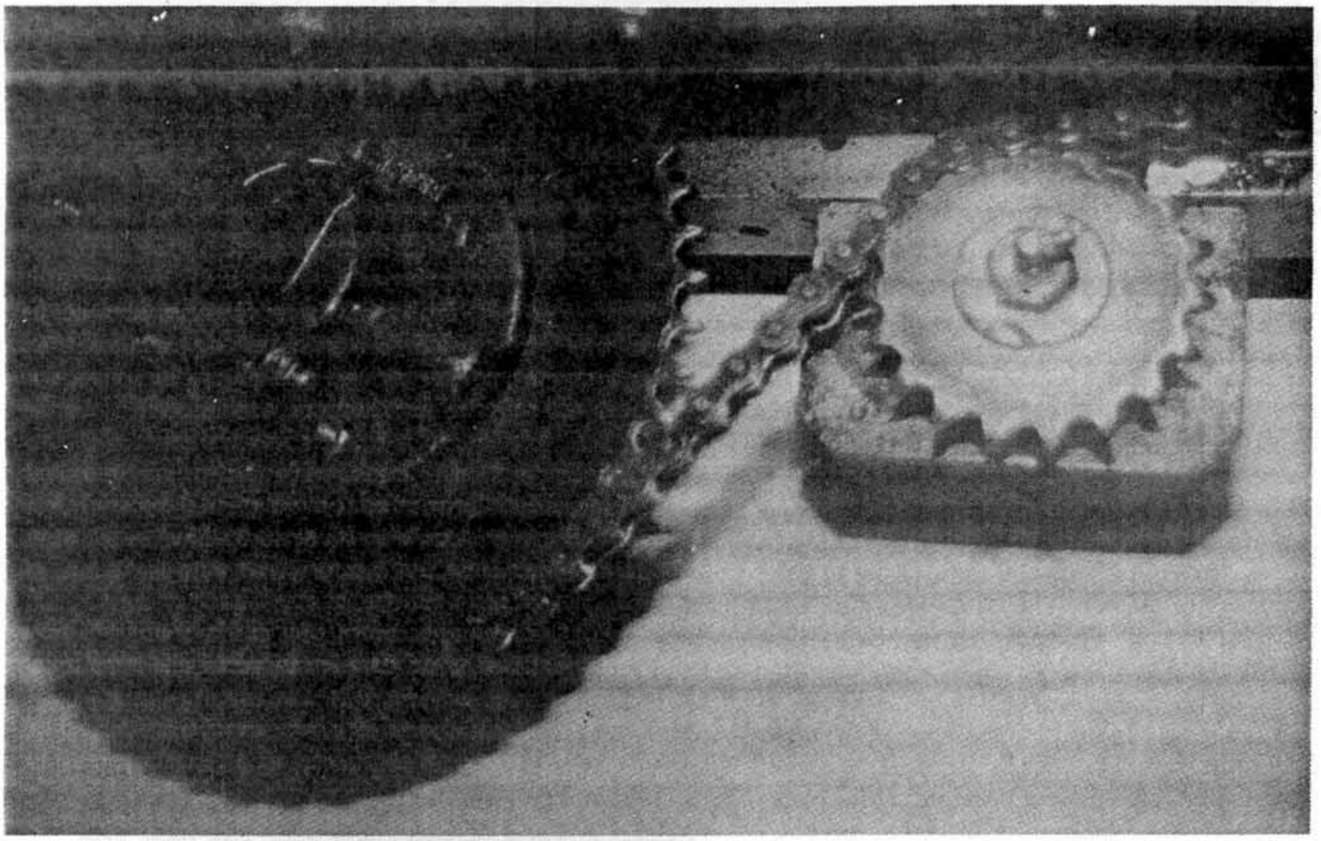
actual position measured by the center sensor. This difference voltage represents the amount of vertical bending in the axle. This difference voltage drives a bar graph display, so the bending is easily visible as the car is operated. The response time of the linear position sensors, the analog computer, and the LED display is very fast, so it is easy to see even a very brief bending event if it occurs. The circuit board and display are suspended with rubber bands inside a box to reduce vibration and shock. (If you are interested in more information on this system, please contact me, and I'll be glad to discuss it with you in more detail.)

Measurement Results

The axle bending measurement system was installed in my open MT19. The center bearing arm in this car is mounted in the original position in front of the rear axle, and the spring was removed. The measurement system was calibrated such that each dot on the display indicates 1/16" of bending. I ran the car at Niles Canyon, which is a good test track since the car runs forward slightly downhill for seven miles and then has to back up—uphill—for seven miles. Remarkably, the axle bending measurement system worked very reliably. This is what I learned:

1. In the forward direction, no bending was observed in either low or hi gear. Even over rough track and joints there was no indication of bending.
2. Engine braking in high gear bends the axle about 1/16" to 1/8".
3. Engine braking in low gear bends the axle up to 1/4" !
4. Reverse operation in low gear bends the axle up to 5/16" !
5. Reverse operation in high gear bends the axle 1/16" to 1/8".

The maximum amount of bending depended directly on how much traction we had. On the first run in the morning the track may have still been a little damp from the morning fog, and it only deflected about 3/16" in low gear in reverse before the wheels broke loose, which immediately decreased the amount of bending. On the second run in the morning, the track was dry, and I saw up to 5/16" bending as I accelerated in reverse in low gear.



Original Fairmont idler sprocket on MT19.

tal direction. Off the bottom of the rear sprocket, however, the chain is routed up and over the idler sprocket, which causes the chain to come off the bottom of the rear sprocket at about a 45-degree angle upwards. (Please see the picture of the MT19 chain drive taken under the right side of the car.) This means whenever the bottom of the chain is under tension, the axle sees both a forward horizontal force and an upwards vertical force. Since the angle is about 45 degrees, these forces are nearly equal. A properly adjusted center bearing and support bracket, which is located right next to the sprocket, very effectively counters the forward horizontal force. This prevents any significant bending of the axle in the forward direction.

However, the axles in a MT19 are sprung and supported vertically only by the bearings next to the wheels. This means any vertical force on the rear axle has to be countered by bending of the axle itself between the wheel bearings. Realizing this, we clearly needed to measure the vertical forces on the axle in a MT19 under actual operating conditions to see what was really going on. One theory was that a high vertical force occurred on the axle whenever the lower chain was under tension and the car went over a sharp bump such as a bad rail joint. The strong springs would force the axle to move down, but the lower chain (which is under tension and cannot stretch or give) would prevent the center of the axle from moving down instantly. This would cause a brief, high vertical force on the axle. In order to measure this kind of a force in a MT19, a system was needed that could measure the amount of bending of the axle with reasonably fast response time.

A Real Time, Axle Bending, Measurement System

To make these measurements while operating under actual conditions on the rails, I installed an electrical measurement system on my MT19A. Three linear position sensors were mounted directly above the three bearings on the rear axle—one over each wheel bearing and one over the center bearing. (Please see the pictures of the sensors mounted over the left bearing block and the center bearing block.) A linear position sensor is just a linear resistor with the wiper connected to a pin. The pin rides on top of a bearing block and tracks the vertical position of the axle. (This pin is visible in the picture showing the center sensor.) Each sensor produces a voltage directly proportional to the vertical position of the axle at that location. I designed and built a tiny analog computer which electrically calculates the unbent position of the center bearing based on the inputs from the left and right position sensors. It then electrically subtracts this from the

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ing was all the measurement system indicated. The same lack of bending was found during repeated tests of rapid deceleration in first gear. There is no question this dual idler chain drive eliminates the excessive vertical bending force on the MT19 rear axle.

Other Benefits

A nice surprise with the dual idler is the noticeable improvement in handling. Even my wife Kathleen noticed the difference! I'm very accustomed to the sloppy behavior of the MT19 due to the loose chain between acceleration and deceleration. The engine always hunts a bit, and the CCKB engine with a loose chain is often somewhat jerky in this in–between range. With the dual idler the chain can be adjusted with much less slack, and the amount of slack does not change as the axle moves up and down. So the chain whip is gone, and the resulting hunting and jerking between acceleration and deceleration is gone too.

Another important improvement with the dual idler setup is the lower chain no longer rubs on the brake shaft. The top of my brake shaft has two worn slots due to many years of the loose lower chain rubbing on it. With the dual idler, the chain runs nearly 2" above this shaft at all times, so it doesn't even get close to rubbing it.