[0. Title]

Biased Weight Alignment Procedure for Bent Axle Alignment

by Stan Pope, 4 August 2013

[1]
Hello, pinewood derby racers! I'm Stan Pope. For a lot of years, I've been helping youngsters and their mentors learn to build better pinewood derby cars. A couple decades ago, I published a procedure for aligning axles for “straight running” which utilized wheel movement in or out on the axles as an indicator of alignment state. The procedure was effective but quite tedious and mostly beyond the ability of an 8 year old. Besides, “STR8 is GR8” but “cambered and guided is better.” The measurement indicators for straight alignment don't apply well to cambered axles. Back to the drawing board!

[2]
During the last few years, I've been developing and using a method for aligning pinewood derby cars to have them more race ready when they first hit the track. The specific designs to which the alignment process applies are "rail guided three-wheel cars" (one lifted front wheel) with "cambered rear axles achieved by twisting bent axles." I'm opening my notebook for you now because of the many folks I hear say such things as "I spent hours trying to align our car and I don't know if I am even close!" and others who, having a full sized test track, ask “Is X.XXX seconds a good time?”

[3]
Why does this happen? First, there are multiple variables, and they all interact with each other. Second, there are multiple goals that must be achieved. If each of the possible settings of the variables were divided into only 10 different values, the number of possible combinations of those various settings would be in the thousands. And because they interact, you have to have them all at the right value at the same time. You can't simply adjust each in turn for minimum time and be done! I will show you how to deal with those variables in an orderly manner so that all of the goals are achieved!

[4]
One of the techniques I've learned as a student of science is to ISOLATE variables. By isolating them, we can measure them individually with respect to our goals AND we can adjust them with minimal impact on the other variables. But that doesn't happen by accident ... we must make it happen. That is the subject of this video!

[5. Pic (3): Text of Alignment Goals, (53 sec total)]
So first, lets list the goals involved in having the car well aligned:

1. The car runs as straight forward as it can so as to present the smallest cross section and so, moving the least amount of air out of the way.

2. The rear wheels of the car stay away from the rail so that those heavily loaded rear wheels don't have friction from rubbing on the rail.
3. The rear wheels go in the same direction so that they don't fight each other, because if they fight each other, one will drag the other on its own path.

[6. Clip: Alignment board showing both sides, (30 sec total)]
One of the easily constructed gauges that will be used is an “alignment board”. It consists of a flat, smooth board with a rail attached down the center of one side and smooth on the other side. The “smooth side” is used for setting dominant front wheel toe in. The “rail side” is used for aligning the rear wheels. A length of 2-1/2 to 3 feet is sufficient.

[7. Clip showing arranging minimum cross section as viewed from down track, (42 sec total)]
So, now lets begin to address these goals:
What will the car look like when it is running on the track to present the smallest cross section? Set the car on a test section of track. Place the dominant front wheel gently against the rail and against the car body. Then move the rear of the car left or right until the car is pointed straight down the track. Then slide the rear wheels out to the ends of the axles and check to be sure you haven't changed the car's orientation on the track.

[8. Pic of rear wheel on track, (44 sec total)]
Now, look at the rear wheel behind the dominant front wheel! How far from the rail is it? Make sure that it is no closer than about 1/16" nor further away than about 3/16". That distance is going to be our measurement criteria for each of the alignment adjustments. Every adjustment that we make will be to cause that rear wheel to move to and occupy that location. Lets call that rear wheel and its distance from the rail "the measurement goal." It helps if you can draw a line parallel to the rail and separated from the rail by that amount.

[9]
Now, how do we isolate each rear wheel so that we can see the effect of its adjustment on "the goal?"

[10]
Here is the next key concept: The dominant rear wheel is the one with the most control over "the goal." How does a rear wheel become dominant? By carrying more weight than the other wheel! (More correctly, a rear wheel becomes dominant by carrying enough more weight than the other rear wheel that its sliding friction overcomes the other's sliding friction. We will use the simpler expression.)

[11]

Most three-wheel cars naturally have one rear wheel which carries ½ to 1 ounce more than the other, which is enough to make it "the dominant rear wheel." This happens naturally as result of centering the added ballast (lead, pennies, tungsten, etc.) which causes the weight on the dominant front wheel side to be divided between two wheels while on the other side one wheel carries half the car's weight!

[12. Clip of bias weights, showing car prep and assembly, (72 sec total)
The next step is to apply two new tools to the process. I call them "bias weights". These are weight assemblies of about ½ to 1 ounce each which easily clip onto the rear of the car in a consistent manner. Each weight assembly is adjusted to produce a ½ to 1 ounce weight advantage to one of the rear wheels. The further the weight extends away from the car's center line, the more of the total weight is shifted to the rear wheel on that side. The best way I've found to accomplish quick change bias weights is to use "springy wire" with a "three-point hitch" bent on one end and a half ounce lead slug at the other. (A separate video shows the construction of these bias weights.) The "attachment points" on the car are small depressions on the sides and rear of the car, made by a hand-held drill bit which allow the bias weight to be reattached in exactly the same position.

[13]
When aligning, we only make adjustments to the then-dominant rear wheel, but we measure the result by what happens to wheel that follows "the measurement goal" line.

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For instance, if our car has its dominant front wheel on the right side and we have attached the left side bias weight, then we will adjust the left rear axle and observe the effect on the right rear wheel! To start the test run, the car is set on the gently sloping test board just as it was when we were deciding on where the car should run. Then observe whether the the rear wheel stays at the measurement goal or moves toward or away from the rail. (Also observe the dominant front wheel to assure that it stayed "on the rail" for the duration of the test run. If not, increase the toe-in and repeat the test run.)

[15]
A facet of adjustment that many of us have difficulty remembering is "which way do I twist the axle?" The procedure codifies that decision with a simple mnemonic so that corrections are always to the correct axle and always in the correct direction! You are responsible to learn from observation how much of an adjustment to make. You should learn quickly since the amount needed is proportional to the rate at which the wheel leaves the measurement goal line.

[16]

From your observation you see which way the rear of the car needs to move. For instance, if the rear wheel deviated from "the measurement goal" away from the rail, then the adjustment corrects by steering the car closer to the rail.

[17. Pics: text of 5 mnemonics (60 sec total)]
Here is the mnemonic:

1. Work from the side of the alignment board so that your dominant hand is "down track", ie. your dominant hand is toward the lower part of the board.
2. Make a test run and note whether the rear of the car needs to steer closer to you or further away.
3. Hold the car, right side up, across the rail with the dominant front wheel on the down track side.
4. If the dominant rear wheel is not on the down track side, roll the car onto its back so that the dominant rear wheel is on the down track side.
5. Adjust the down track rear wheel as follows: twist the axle so that the uppermost part of the axle head moves in the direction of the needed correction.

[18. Pics: text of 5 alignment steps (48 sec total)]
The overview of alignment is this:

1. Set some dominant front wheel toe-in so that the car guides on the rail.
2. Set the bias weights so that they produce a ½ to 1 ounce advantage to each wheel in turn.
3. Attach the bias weight so that the wheel which is opposite to the dominant front wheel becomes the dominant rear wheel.
4. Make test runs and adjustments until the rear wheel rides on the measurement goal line (see mnemonic above).
5. When no further adjustments are needed for that wheel, swap bias weights and repeat at 3.
6. When two successive "no adjustment needed" runs are made (one on each side) you are done aligning the rears!

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Once the rears are aligned, flip the alignment board over and set the dominant front wheel toe-in for the desired amount of drift. This will vary depending on the length of the board and the roughness of the track on which you will race. About an inch of drift toward the center rail is safe for most tracks if the alignment board is around 3' long.

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That is it. It will likely take you much longer to watch this video (or read the script) than it will take you to perform a successful alignment! My typical times for alignment are between 3 and 4 minutes!

[21. Pics: text if 2 on track steps (28 sec total)
If you have track access and a timer, you might be able to improve performance.

1. First tweak the dominant front wheel for best time.
2. Then tweak ONLY the least heavily loaded rear wheel (usually the wheel behind the dominant front wheel) for best time.

[22]
How does this method compared to other methods? Here is where two methods come up short:

1. The commonly used forward and reverse rolls and watching for the wheels to migrate to the ends of the axles loses sensitivity as the camber increases above 2-1/2 degrees.   The migrations may be difficult to detect if you run with tight clearance between hub and car body. And you still don't know if the rear wheels will stay off the rail.
2. The sometimes used "treadmill alignment" does not guide adjustment, but does accumulate wear on the wheel bores. When you finish on the treadmill, you don't know if the car will scrape the rail or not and, unless you measure string tension, you won't know if the rear wheel are running parallel.

[23]
Good racing!

[24. Trailer:
Script, Photography and Narration by Stan Pope
Script review by Terry Wall
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