Building a Faster Derby Car

for a Shape N Race Derby, Pinewood Derby, etc.

Shape N Race Derby, Pinewood Derby, Kub Kar Rally—whatever you call it, a derby is a lot of fun, and it's a great opportunity for learning and for making memories.
This document describes ways to make a derby car faster.

I must begin this document with a disclaimer: My experience building fast derby cars is limited. I typically invest most (if not all) of my effort in the appearance of my derby cars. However, I believe that my background in physics and engineering has enabled me to evaluate accurately the information I have accumulated from those who do have experience building fast derby cars.

No amount of work can guarantee a winning car; I have seen many carefully optimized cars that didn't do well on race day. On the other hand, I have seen derbies won by cars that were built haphazardly, so it seems that a minimal effort does not assure a losing car either.

With that said, here are some ways you may be able to improve the speed of your derby car.

Obey Your Derby's Rules!

This is the *most important* advice I can offer. If you break one of your derby's rules and your car is disqualified, it doesn't matter how fast it is. Some of the suggestions that follow are illegal in many derbies, including derbies that I have helped organize. Ignore *any*speed tips that violate the rules for your derby.

Make Sure Your Car Fits the Track

Two common sources of trouble are (1) wheels that are too close together, and (2) too little clearance under the car for the center guide rail. If its wheels pinch the center guide rail, or if its bottom drags on the center guide rail, then your car may not even reach the finish line. The original kit dimensions should fit the track; don't reduce them!

Unusual designs can encounter other track-fit problems. As a rule, if the basic shape of your design is unusual, check with whoever sponsors the race to see if it will work with the track's starting gate, finish gate, guide rail, etc.

Friction is Your Enemy

Yes, aerodynamics can make a difference. Yes, getting your car as close as possible to the weight limit can make a difference. Yes, other things can make a difference too. But friction is the most significant force slowing your car down, so reducing friction is the most important thing you can do if you want a faster car. Friction occurs between the wheels and axles, between the wheels and car body, and between the wheels and center guide rail. This is where you need to reduce friction.

Experiment Together

Don't forget that the derby is supposed to be a father–son (or adult–child) activity. Set up a long board on a slight incline and experiment together until the car rolls straight down the board as quickly and as smoothly as possible.

You can also test axle alignment this way. With perfect axle alignment, you can start the car with its wheels pushed in (against the car body) or with its wheels pushed out (against the axle heads) and they'll stay that way as the car rolls down the incline.

Keep Wheels & Axles Straight

Crooked axles will cause your car to ride the center guide rail, or will cause the wheels to slide in addition to rolling. In either case, the extra friction will slow your car down. Keeping your wheels and axles straight is probably the most important step in building a faster car.

The time to think about keeping your axles straight is before you start shaping your car. It is much easier to create straight holes for your axles when the sides of the block of wood are still square, than after you have shaped your car. Later, when you've finished shaping and painting your car, the axles will fit easily into these holes, and your wheels and axles will be straight.

One obvious technique for creating straight axle holes is to pre-drill them with a drill press. If you use a bit that is slightly smaller than the axle nails in your kit, then you may not need glue to hold your axles in place and you won't have to worry about the axles wobbling in oversized holes.

In our derby workshops, we use a variation of this technique. Instead of a drill bit, we use an axle nail with the head sawn off. *Without turning on the drill press,* lower the axle nail straight into the block of wood. If you don't have access to a drill press, you can clamp an axle nail in a pair of pressure pliars (e.g., Vice-Grips), and carefully insert the axle nail straight into the pre-cut axle slots.

Polish the Axles

This works best if two people work together. Lock an axle into the chuck of a hand drill, leaving the head of the axle plus about 1/2 inch of the axle itself sticking out. While one person holds the drill and turns it on, the other person should polish the exposed axle with a thin strip of wet emery paper. Polish both the axle shaft and the inside of the axle head. Keep the emery paper moving to avoid creating grooves in the axle. For an even better polish, you can use steel wool, metal polish, and/or jeweler's rouge after an initial polishing with emery paper.

Examine the axle closely (with a magnifying glass, if possible). It should be perfectly smooth. Test the axle by inserting it through a wheel and spinning the wheel with your finger. The wheel should spin smoothly and slow down very gradually.

Prepare the Wheels

When you get your wheels, they may have irregularities left over from the casting process (e.g., a peg-like sprue or paper-thin flash). You should remove these irregularities, and then carefully sand any remaining roughness with emery paper. Metal polish can restore the glossy finish to your wheels.

Commercially available mandrels allow you to spin your wheels with a hand drill (this is similar to the axle-polishing technique described previously). This can be a big help in removing fine irregularities, but be careful not to reshape or damage your wheels. Make sure the wheel is secure within the mandrel; if the wheel rotates on the mandrel you'll overheat and melt its plastic hub, completely ruining the wheel.

Be careful to **avoid reshaping your wheels** in any other way, or you may disqualify your car!

Lubricate the Wheels

Various lubricants are available from hobby shops. The standard derby lubricant is graphite powder, which is good, but can be messy (especially when used in excess). Penetrating oils (e.g., WD-40) can also work well. Some people recommend talcum powder (baby powder), or high-tech lubricants with Teflon, silicone, or molybdenum sulfide. Some liquid lubricants can get sticky though, so test them before using them on your car. Some derbies restrict which lubricants you can use, so check your derby's rules.

I've found that the best way to lubricate the wheels is to apply the lubricant to the inside of the wheel hub first. Once the wheel is lubricated, insert the axle through the hub and mount the it on the car. If the wheel is mounted first, it's very difficult to get lubricant between the wheel and the axle.

Avoid mixing lubricants, and especially do not mix dry lubricants with wet lubricants. The result is often a sticky mess.

Don't Bind the Wheels

If you push the axles in too far, the wheels will bind against the sides of the car. Leave a little room for the wheels to move sideways, along the length of the axle.

Paint Early, Paint Often

This sounds like an appearance suggestion, but it is also a speed suggestion. Paints and finishes that haven't cured completely tend to be slightly tacky, and then stick to the wheels and slow the car down. Leave yourself time to apply your final finish coat well in advance of the actual race, so that it will finish curing before you put your wheels on. Also, a single heavy coat will take longer to dry and cure, so be sure to apply several light coats instead.

Here are two other ways to create a low-friction contact surface where the wheels touch the car body.

- Keep the contact points of the car body completely clean. Before painting the car body, mask these locations. Use a circle of paper held in place by masking tape; the circle of paper protects the wood from picking up adhesive from the masking tape.
- Before mounting the wheels, rub graphite into the paint at the contact points. With reasonably well-cured paint, this technique replaces any residual tackiness with a dry lubricant. Be careful not to spoil the paint on the rest of the car though; graphite creates ugly black fingerprints.

Reduce Air Resistance

Fancy aerodynamic styling doesn't improve a car's speed significantly, but air resistance is still an important factor. To reduce air resistance, design your car low to the ground. A smaller cross section will create less air resistance.

Weight Your Car Well

Heavier cars are faster than lighter cars, so try to get your car as close to the maximum weight as possible. It's a good idea to plan for a way to adjust the weight on race day. That way you can add as much weight as possible, or you can remove excess weight without risking significant damage to your car. If you plan ahead, you can create a way to add small metal objects (e.g., screws, BBs, coins, fishing weights) to your car on race day.

Weight distribution matters, too. I believe that the front end of your car needs to move easily so it can correct its course easily when it hits the guide rail. Your car's weight distribution determines how easily its front end can move.

Make the unweighted car body as light as possible, and keep the lead weight as compact as possible. This reduces the rotational inertia of your car.

Put the lead weight just in front of the rear axles. If the weight is behind the rear axle, your car's front wheels will tend to bounce. This bouncing will slow your car down, and it might even cause your car to derail and leave the track.

The exception to this weight-to-the-rear design is if your race uses a track that gets steeper right after the starting gate. On such tracks, the weight should be forward (just behind the front axles) so your car will accellerate more quickly in the beginning.

Four Wheels Good, Three Wheels Better

It takes less energy to make three wheels roll, than it does to make all four wheels roll. Keep the center of gravity towards the rear, so you can leave one of the front wheels slightly higher than the other. Then your car will roll on three wheels (one front and two rear wheels) instead of rolling on all four wheels.

I've also heard of cars built so that they balance on two diagonally opposite wheels (e.g., left front and right rear). The two remaining wheels will occasionally touch the track, but the car's weight is carried primarily by two wheels. This may be a case of "Three Wheels Better, Two Wheels Best".

Lengthen the Wheel Base

If your derby rules allow it, lengthen the wheelbase as much as possible. In the races I've seen, long-wheelbase cars have done very well.

Reshape the Wheels

This suggestion is probably against the rules for your derby. In fact I've *never* heard of a derby that allowed reshaped wheels, although at least one hobby shop sells professionally reshaped wheels for BSA kits.
If reshaped wheels are legal for your derby, you can reshape your wheels using a commercially available mandrel that allows you to spin your wheels with a hand drill. This is like the wheel-preparation technique described previously for removing irregularities, only more severe. Make sure the wheel is secure within the mandrel; if the wheel rotates on the mandrel you'll overheat and melt its plastic hub, completely ruining the wheel.

So, how should you reshape the wheels? It turns out that almost anything you do will help some by reducing the mass of the wheels. Reducing the mass of the wheels will reduce the amount of energy required to rotate them. That leaves more energy for the forward motion of the car.

You should also reduce the amount of the wheel surface that contacts the track. Shape the running surface of the wheel so that it is angled, leaving a narrow edge that will contact the track.

Paint It the Right Color

It won't fool an electronic finish line, but I've heard that human judges tend to err in favor of red cars when the race is close. It can't hurt. . . .