

REAR STAGGER

HOW DOES IT WORK?

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In this article we're going to look at rear stagger, what it is, what it does, why we run it, what factors affect it and how we can understand what we should be running. Over the course of our discussions hopefully we can delve a bit further into rear stagger and the physics that it brings about so that you can be better educated in knowing what you need to run and how you need to adjust it from track to track.

First, what is rear stagger? Answer: the difference in circumference of the LR and RR. Because we turn left it is always the circumference of the RR minus the circumference of the LR. So then, if we run our RR at 34" and our LR at 33" then we have one inch of rear stagger. The next obvious question is why do we run rear stagger – what are we trying to accomplish? The simple answer is that in a corner the left and right side tires follow two different corner radii

– the radius that the LR follows being the radius of the RR minus the track width (which is the measurement from the centerline of the RR to the centerline of the LR). For example, our kart is on a flat track where the RR travels along a corner with a 75 foot radius and we

have a 39.25" rear tread width on the kart. To convert the tread width to the track width we'll need to subtract half of the width of the LR and RR from the tread width which gives us a track width of 32.25". Going back to our RR corner radius of 75' and

subtracting the track width we get a corner radius for the LR of 72'3.75". If we calculate the actual distance that the LR and RR must travel in one corner we end up with the following:



The amount of banking has an effect on rear stagger



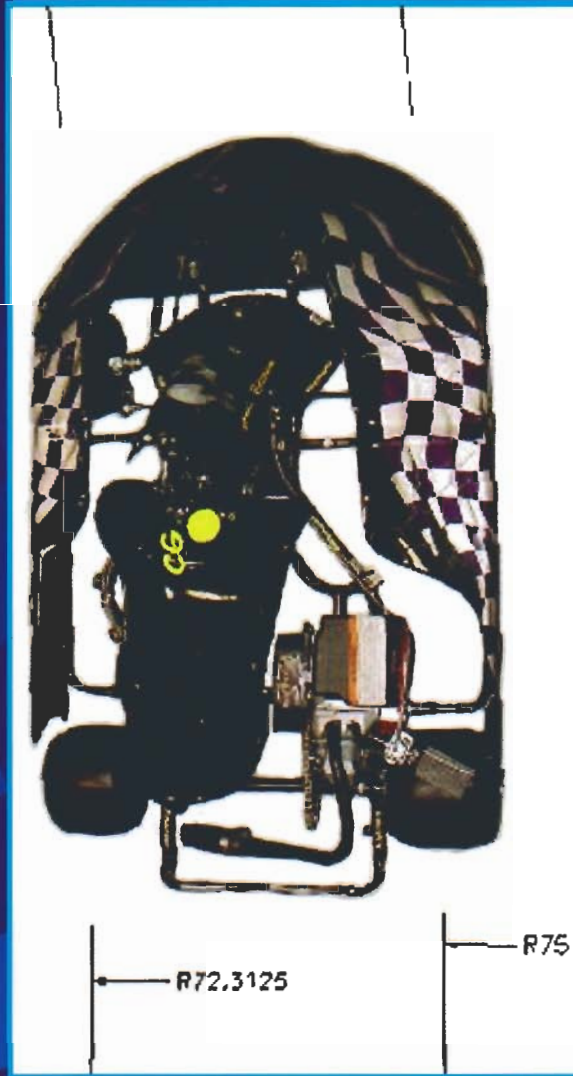
$$D_{LR} = \pi * r_{LR} = 3.1416 * 72'3.75'' = 2726 \text{ inches}$$

$$D_{RR} = \pi * r_{RR} = 3.1416 * 75' = 2827 \text{ inches}$$

From this we can see that the RR has to travel a bit further around the corner than the LR but the LR and RR are attached to a solid rear axle which forces them to turn at the same RPM. So then, if we want the back of the kart to roll through the corner without scrubbing one or both of the two tires then the LR is going to need to be smaller than the RR. Calculating this out gives us 1.218" of rear stagger. What about the affects of track banking? Using a bit of trigonometry we can include the effects of the banking. We won't go through the math but what we see is that at the relatively low bank angles that we see in most all forms of racing, the banking's effect on the "ideal" rear stagger is minimal – in our example of a 75' radius corner if we switch from a flat corner to one with 17° of banking the "ideal" stagger goes to 1.167"; or slightly more than 1/16" difference. According to this then, we rarely need to compensate for bank angle in the amount of rear stagger we run based purely on what we would call the "ideal" stagger.

If we look at the actual "ideal" rear stagger given for either of the bank angles we immediately see that we don't ever run that much on a track with that large of corner radius. If we don't run "ideal" stagger then there must be some other factors which must be considered in our rear stagger selection; what are they? At the end of one straightaway we're heading in one direction and at the end of the corner it's traveling in a direction 180° from the one it was traveling when it entered the corner. What is required to make it turn the 180°? Torque. The primary sources of torque on our karts are: LF and RF camber thrust, LF and RF steer angles, and rear stagger. If these sources combine to produce enough torque then the kart will turn and rotate and not push. If we have too little torque then the kart pushes; too much and it is

loose – in concept it really is this simple. There are many factors which go into how much force is actually required to turn the kart; they include: the corner radius, the kart and its setup, the track banking, the moment of inertia of the kart (the kart has rotational inertia just like the engine's flywheel and the rear axle), etc.



We now know that rear stagger helps the kart turn in the corner and also helps keep the rear tires from scrubbing so much in the corners but we really haven't look at its effects elsewhere. Based on what we've seen thus far we might assume that we need to calculate the amount or rear stagger that would yield the "ideal" stagger and run it like that. Unfortunately there are other considerations which make things a bit more complex. One of the problems is that we have to navigate the straightaways in addition to the corners. On the straight that same turning force which comes from rear stagger which helps the kart turn in the corner is also causing it to turn on the straight. Due to the rear stagger (and other forces), in order to keep the kart traveling straight we're going to have to turn the steering wheel to the right. This right steer angle will cause scrub of its own and will hurt the straight line speed of the kart. At this point we know that

for cornering we might want lots of rear stagger and for straightaways we might want no rear stagger so we might assume that it is a simple compromise between these two which drives what stagger we actually run but this isn't really the case either.

A paragraph or two above we learned that the kart had to rotate 180° in the corner and that in order to get it to rotate we had to apply a torque on the kart which we generate from several different sources. At this point we'll look a bit more in depth in those sources of turning torque and explain how rear stagger fits into the total picture to help a kart perform like it needs to. The first source of turning force we're going to look at is camber thrust. This is a lateral force which comes from



the two front tires which comes from the fact that they are leaning towards the inside of the corner. Generally speaking, the more inward lean (positive LF camber and negative RF camber), the more camber thrust we will get. This said, the truth is that camber affects quite a number of things on the kart and the camber thrust is a relatively small piece of the total picture. For this reason we don't really set camber based on the input of camber thrust into the turning force of the kart.



If we're not using camber thrust as a primary turning force generator then we are left with two areas that we can go to in order to generate more or less turning force: steer angle and rear stagger. There are a few nuisances associated with steer angle and how we use it to help the kart turn so lets look at those now. As we input steer angle the tires start making drag and in the corners this drag becomes significant. So then, one reason we have for running rear stagger other than for not scrubbing the rear tires in the corner is to help reduce the load on the front tires which will reduce steer angles on the front tires and thus the total rolling resistance of the kart. As we run more and more rear stagger the rear tires will create more and more turning force requiring the front tires to make less and less. Another reason that we cannot rely completely on steer angle to create the right amount of turning force is that different chassis have different balance characteristics, and more or less steering input doesn't always fix the problem. You know that if your kart is pushing then turning the wheel more doesn't always cause the push to go away and if the kart is loose, turning the wheel less isn't the common solution.

Given these truths there must be some inherent balance of turning force from steer angle and rear stagger that every chassis/driver/setup combination has and any given track will require. It is this combination which most often has the dominant effect on our choice of rear stagger. Of these two let's start by looking at

the inherent balance in the kart/driver/setup. Most of us have heard that a given kart will have a given tendency to push or be loose when it's not working.

One kart may tend to the push side more often and another of a different make might tend to the loose side more often. What we are seeing is the chassis' designed in tendencies. An common example of this tendency can be seen in most of the last two generations of karts
– Generations 3 and 4. When

a generation 3 chassis wasn't working quite right most tended to get pushy, whereas when many of the generation 4 chassis aren't quite right they'll tend to be loose. The reason for this is very simply that the

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generation 4 chassis are designed to make more grip than their generation 3 counterparts. Every chassis produced, no matter by whom will tend to exhibit a consistent tendency towards loose or push when it's not working properly.

To use real numbers, on a 1/5 mile track many generation 3 chassis tended to run 1" of rear stagger whereas many generation 4 chassis on those same tracks will run closer to 3/4" - this is an adjustment in stagger from one to the other to better match up with the kart's overall turning power. So then, we can say that one thing that will affect our choice of rear stagger has to do with how much rear turning power we need to match up with the kart's front turning power.

Now, on to the track itself. The first thing we'll look at is obvious: the smaller the corners and/or tighter the track the more rear stagger we will tend to have to run. On 1/5 mile tracks it's fairly common to run 3/4 to 1" of rear stagger and on 1/8 or 1/10 mile tracks it's not uncommon to be on 1.25 or so rear stagger or sometimes more. In addition to the track's size effects is the track's bite effects on rear stagger. Probably the biggest example I've seen of this is that I know those who have run very well on one 1/10 mile bullring on

1" of rear stagger and have run very well on a different 1/10 mile track with 2" of rear stagger. Wait! That's a 1" difference on the same track size - how is this possible? Here's why: on the small track where the 1" of stagger was run the track wasn't making much bite. The result is that when enough turning power was put into the front of the kart to start the rotation and keep it turning the back end struggled to keep up and the kart would get loose. In order to settle the back end we drop our rear stagger (in this case by quite a bit) which removes the rear steer in the kart and helps it balance and be fast. On the other track the difference was that it was making more bite. In this case we needed the extra rear turning power to help the front tires and because of the added bite the rear didn't have the tendency to be loose like on the slicker track. In the same way, larger tracks with lots of bite can, at times, require a bit more rear stagger than those with less bite although the difference will be much less dramatic because of the lower overall turning power requirements and lower steer angles (hence, most don't change stagger as bite goes up on the larger tracks). It is in the discussion of bite that track banking begins to creep back into the picture as well. Although the banking doesn't have much effect on the geometric requirement of rear stagger it does create additional loading on all four

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tires making the kart feel heavier and also allowing it to make more overall grip. This additional grip can actually cause the kart to want a bit more rear stagger than on a flat track at times. I want to be careful with this one because the truth is that whether to run more or less will depend on the dynamic balance of grip from the left side tires to the right. Generally the banking will load the left side tires more which might require more stagger but at the same time the additional loading will often yield more cornering forces which will tend to unload the left side tires more and may cause the kart to be able to be fast with less rear stagger. Most of the time the two effects tend to cancel out each other so that very similar rear stagger is run on banked tracks as flat tracks similarly configured.



dramatic difference on the kart and which many things go into to create an optimal setting. Hopefully by this point we've helped you to better understand the what and why of rear stagger so that you can optimize your setup, go faster, run better, and have more fun.

For more information on chassis evolution and generations 3 and 4 see the January 2006 issue of Oval Kart. For more information on baseline setups and their importance see the April 2006 issue of Oval Kart.

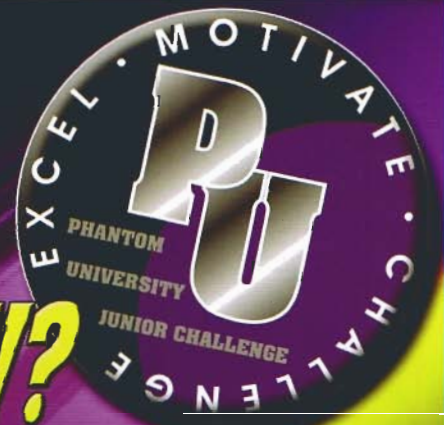
Todd Godwin is a contributing writer to Oval Kart Magazine. His tech articles can be frequently found in the pages of OKM or you can purchase his book Dynamics of Speed though his website at www.dynamicsofspeed.com.



In the end the amount of rear stagger we choose will depend on a combination of the track's corner's sizes and bite and the kart's natural tendencies. The result is that most people tend to run within a very narrow range of rear stagger. For example, on my kart on the tracks I run I most often run 3/4" across the back regardless of whether I'm on a 1000 ft. track or a 1400 ft. track. There is one track that I go to that has tight corners, makes good bite and which I know has a tendency to make a kart push; when I go to that track I always bump up to 1.25. I don't really adjust rear stagger even at that track, I just raise it and run it there. This seems to best compliment my kart and tracks. I find this same tendency with the people I work with via email on a week to week basis. We determine what rear stagger on which they need to start based on their kart, track and track bite. Then, after they've raced a few weekends we'll look for any tendencies in the heats and especially features for the kart to have a balance problem. If we see a consistent tendency for the kart to push or maybe to be loose from week to week and we know we're on a good baseline setup (see last month's article) then we might make a rear stagger change of 1/8" to 1/4" to better balance the chassis. Once we've identified a rear stagger setup that's working we rarely change it.

Rear stagger is an adjustment which can make a fairly

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