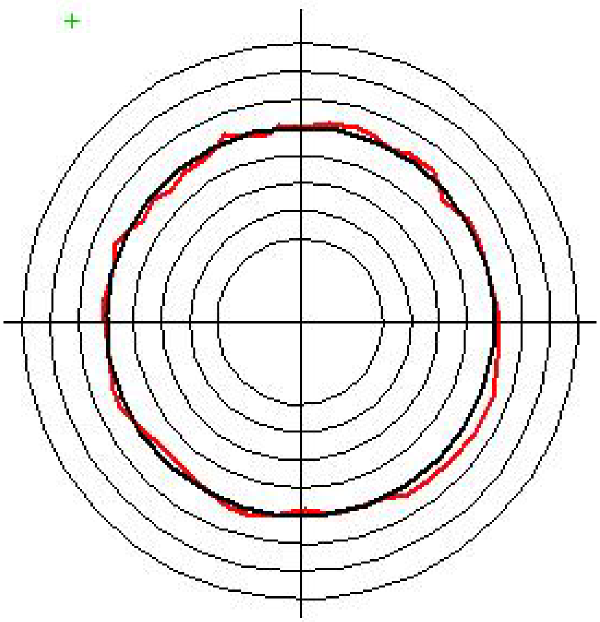
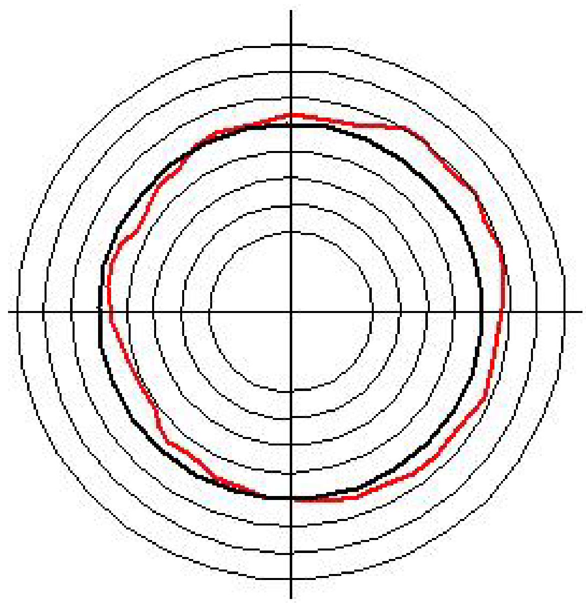
Zipp Speed Weaponry Ultra-Precision Bearing Design

One thing that has set the Zipp hub apart since the beginning has been the bearing design. Zipp is the only company in the world specifying Swiss made ball bearing cartridges, but these are not even standard Swiss made cartridges, they are highly specialized. Since most stock bearings of the size used in bicycle hubs come from the machine industry, they are invariably designed for higher rotational speeds and generally lower loading, and usually no shock loading. Working with a family owned Swiss bearing manufacturer, Zipp was able to define certain key criteria to bearing smoothness and long life, and develop the finest cartridge bearing every introduced into the cycling industry.

To start with, standard bicycle bearings are usually tolerance at 50 millionths of an inch. This is done by blowing them up a graduated tube with air, and guarantees that all balls are within 50 millionths of an inch of each other in diameter, and any individual ball is round within that same 50 millionths of an inch spread. High precision balls utilized in most company's high end products up this spec to 25 millionths of an inch to ensure better roundness of the balls, and ensure smoother rolling. Zipp ball bearings are specified to 10 millionths of an inch tolerance, guaranteeing that they are at least 2.5 times rounder and better matched than most company's 'high precision' balls, and more than 5 times tighter than most 'precision' balls. The measurement reports below show two 'round' items, the first measuring 10 millionths round, the second 20 millionths round.



10 Millionths of an Inch Runout

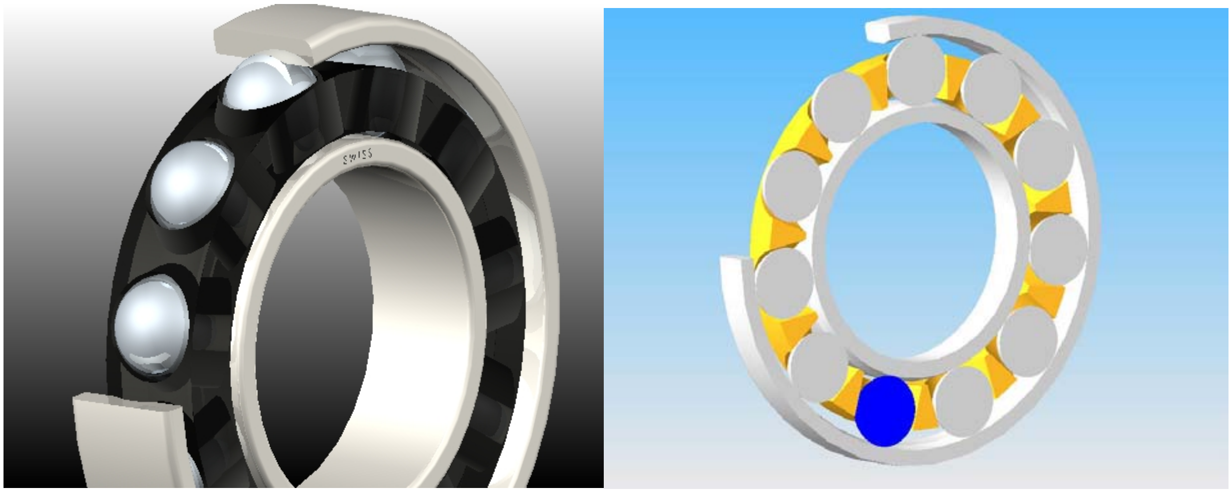


20 Millionths of an Inch Runout

As you can see in the charts, neither ball is exactly truly round when viewed at this scale, but the 10 millionths ball is considerably rounder and has much smoother surface at the microscopic level than the 20 millionths round ball. This contributes to smoother rolling with less friction, and increased lifespan of the bearing.

Teflon Ball Retainer

Zipp then specified Teflon impregnated plastic ball retainers instead of brass. Most bearings utilize a brass waffle retainer within the cartridge to ensure the balls remain evenly spaced throughout the cartridge, this also keeps the balls from rolling against each other, but it does introduce a point of wear, heat buildup, and friction, as the ball is forever rolling against a metallic element. Zipp was the first company to spec a plastic retainer made from Teflon so that each ball is properly located in the cartridge, but the balls never have any sliding contact with any metal components. This retainer concept is now being copied throughout the industry by numerous companies, and was originated first in the 202/84 hubsets introduced in 2000, and is the only design to utilize Teflon instead of traditional plastics. The end result of the plastic retainer is a 1 gram weight savings per cartridge, extended bearing life in the field, and smoother rolling with fewer frictional losses.

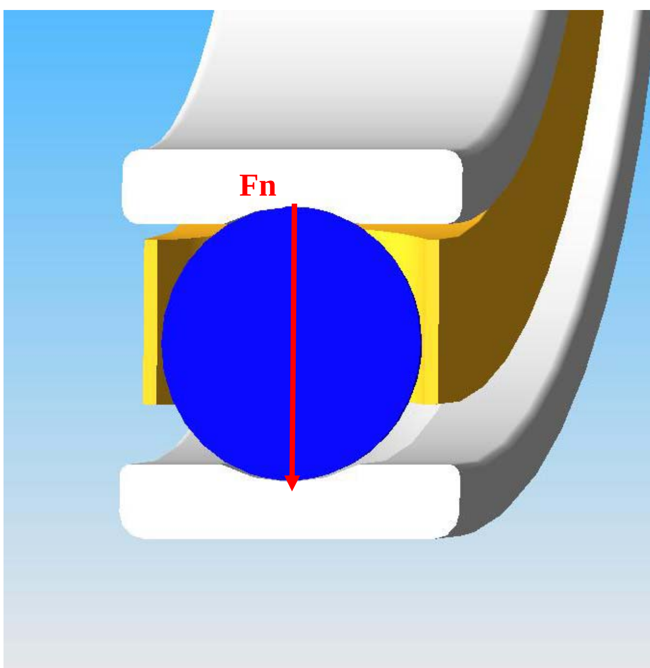


Zipp Cartridge Cutaway Views Showing Teflon Retainer

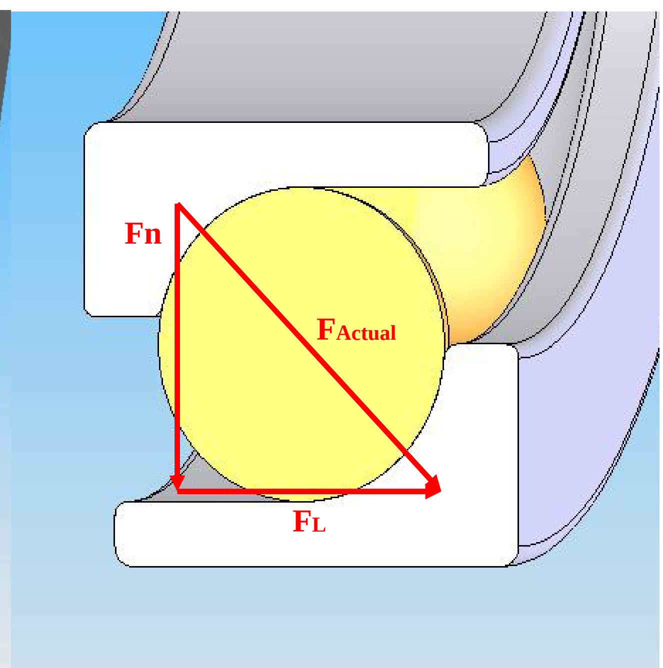
Radial Contact instead of Angular Contact

One area, which we feel strongly about is using non-preloaded radial contact bearings with 'Perfect' ball location. This means that we utilize deep groove cartridges, but confine their location to be optimal for friction and life, and do not allow them to be preloaded or adjusted by the consumer. Why are we so adamant about this design? And what does that mean for you, the consumer?

First, radial contact bearings much better handle the loads seen in a bicycle hub, and nearly ½ the manufacturers out there are using them. The radial ball loading better distributes the load fed into the hub, and can handle higher loading using lighter weight bearings that generally spin smoother than cup and cone type setups. Granted, that cup and cone bearings can be carefully adjusted to feel near perfect in your hands, but once the wheel is on the bike, the loading of the cup and cone bearing actually results in higher ball friction and reduced life. The graphics below demonstrate:



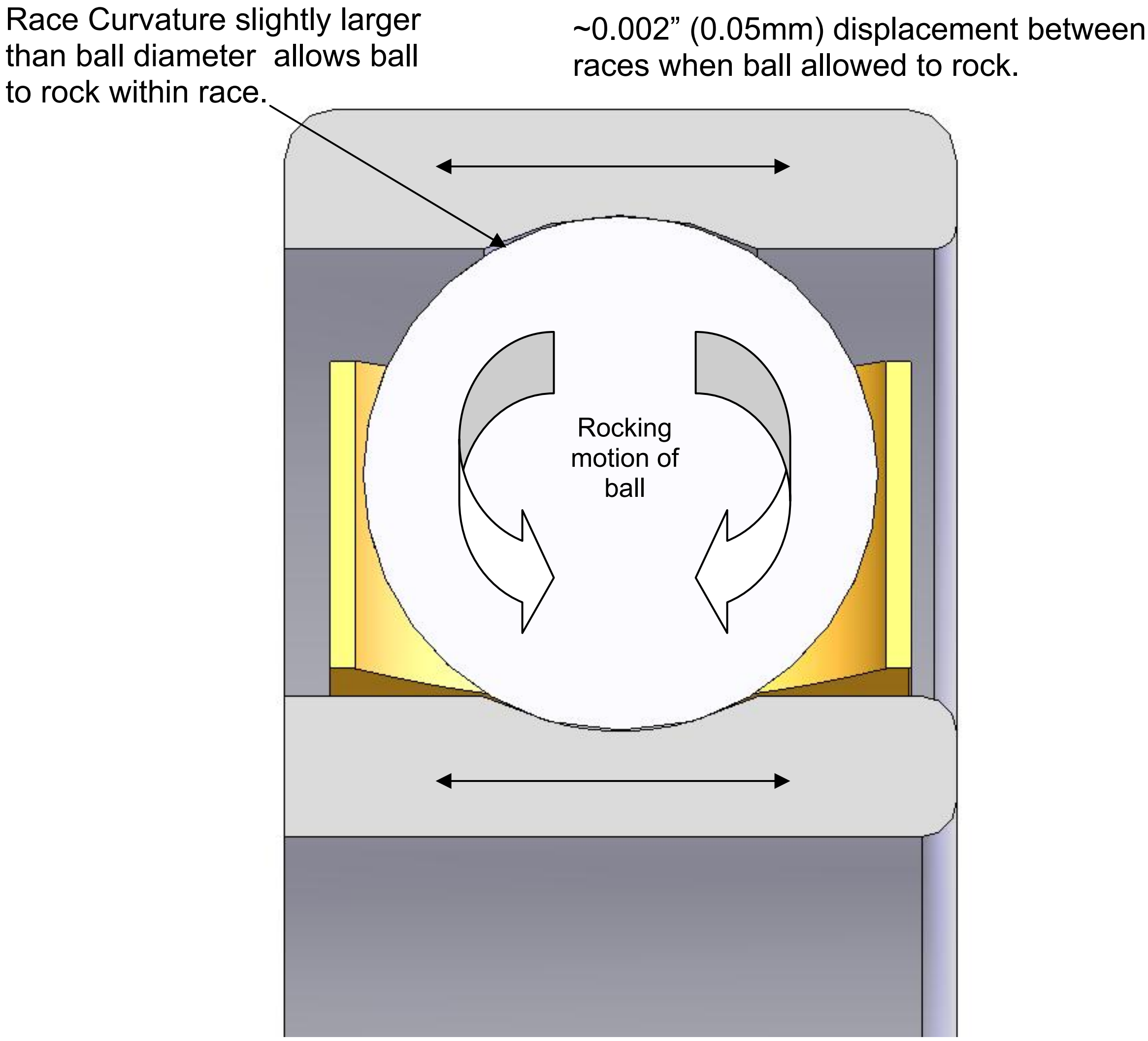
Radial Ball Bearing



45 Degree Angular Contact (Cup and Cone) Bearing

The key to notice in the Radial vs the Cup and Cone design is that the force Fn is the Normal (vertical) force fed to the bearing through the weight of the rider. In the radial bearing design, Fn is the same force resisted by the ball, but in the angular contact situation, the normal force is only one component of the ball force, since the ball contact line runs 45 degrees to the force line, the ball must generate √2 times more force (and a lateral force component represented by FL). This means that Factual is 1.41 times greater than Fn, so the ball in the cup and cone scenario sees 41% higher load than the radial ball bearing. This higher ball load results in higher friction, decreased ball and race life, and increased wear of the internal components meaning that the hub will have to be adjusted more frequently.

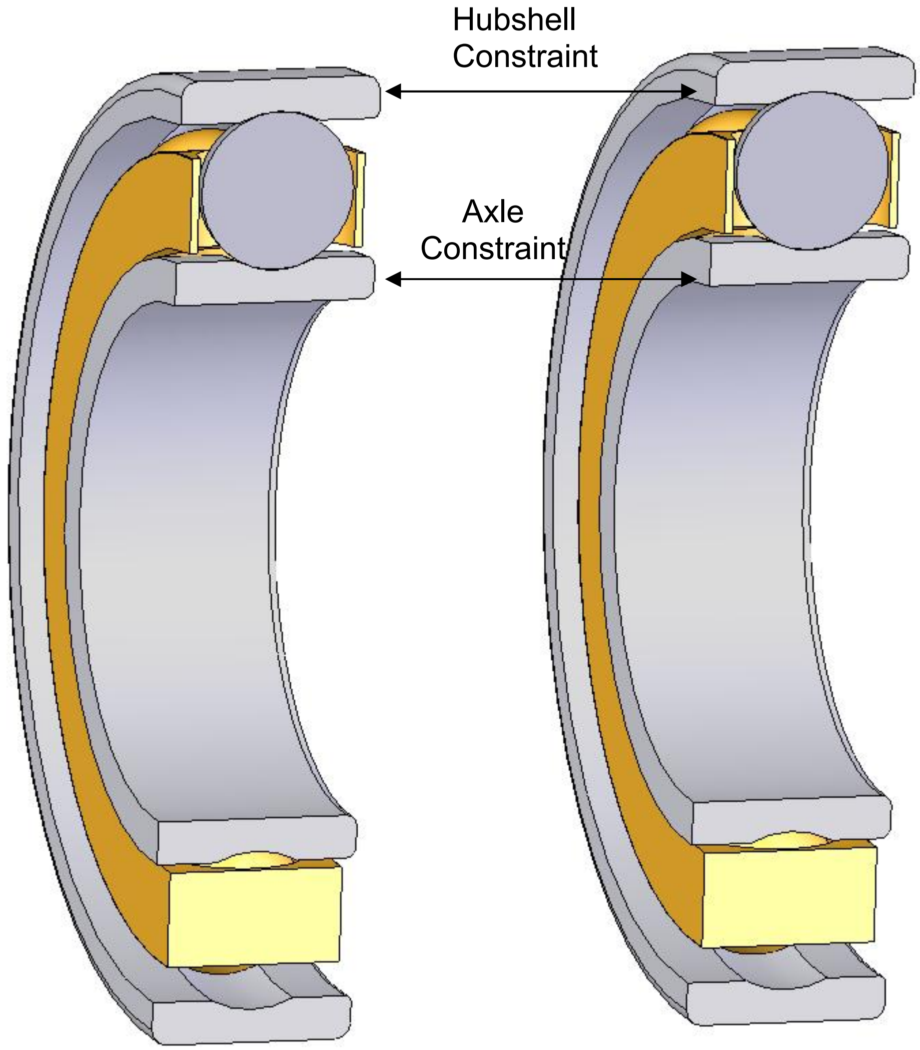
Perfect bearing alignment has a small amount of 'Play'



Closeup of bearing cross section showing play within individual bearing

The slightly larger curvature in the race relative to ball size allows the two races to move axially relative to each other in an unrestrained cartridge bearing. In most designs, tolerances between hubshells and axle spacers or other components generally removes this play when the hub is tightened and the races are misaligned relative to each other. The removal of play slightly increases friction and reduces ball life within the bearing.

The Zipp hub design uses ultra-high precision machining techniques to machine and them match components so that the bearing races can locate perfectly. The diagram below describes this location technique.



Relative location of bearing races determined by hubshell and axle components.

In the Zipp hub design, the total difference between the hubshell and axle lengths is only 0.001" where traditional designs utilize the entire 0.004" of axial play allowed in the bearings. This means that in traditional designs, the bearings can range from perfectly aligned, to the absolute limit of allowable sideload, but these differences can only be measured on very precise specialty equipment in terms of watts to spin, or bearing life. This also demonstrates the importance of proper torque specification during hub tightening or assembly as tightening pressure from an overtightened axle can compress the internal spacers within a hub nearly 0.002"!

Though this play can be felt when the hub is in a free state, when the hub is loaded during riding, the balls are pushed into the curvature of the races by the normal force illustrated above and the entire assembly is perfectly aligned and has no play. This slight amount of assembly 'play' is the sign that the Zipp hub is perfectly aligned and assembled, and the lack of friction and side loading of the bearings is what results in the improved efficiency as well as increased bearing life. This means that our hubs have no 'Break In Period' in which the bearings must deform or displace their races before they feel smooth. We receive many questions about this 'play' from consumers, bike shops, and pro-athletes alike since no other company is currently producing a hubset using this design philosophy or producing to tolerances this tight, and always confirm that our design is different for a reason, and that reason does in fact, make these hubs faster.

So if radial bearings are preferable and 'Perfect' bearing alignment is faster why isn't everybody doing it? Mainly, it is much less expensive to machine and assemble cup and cone assemblies and angular contact bearings assemblies since the components can be adjusted for preload by the consumer.

With cup and cone designs the bearing race diameters can have nearly twice the tolerance, and there is little to no need for axial tolerances in the assembly as any slop can be accounted for in the adjustment of the cone. Contrarily, the radial ball situation requires exact dimensional control of both bearing bore diameter, as well as axial length of both hubshell and center spacer, as well as requiring bearing planes to be exactly coplanar to each other. One design variant now becoming popular is to utilize radial cartridge bearings but to use an adjustable cone design, allowing for user adjustability for bearing preload, but this essentially negates the gains to be had in using radial cartridge bearings (other than the better seals) as the threads on the axle are far too coarse to allow for minute enough adjustments to achieve 'Perfect' alignment. The precision necessary for a perfect radial cartridge hub is on the order of +/- 0.0002" in 3 axes, this is simply unachievable in most production processes, and is not even achievable in most types of CNC equipment when run at production volumes, so it is very, very expensive to obtain. However, with proper machines and fixturing, the Zipp hub is manufactured to these exacting tolerances and specifications, the only hub in the world to do so. The result is a hub that spins with as much as 1 watt efficiency improvement over competing designs! What's 1 watt mean? Well, that's roughly 2-3 seconds in a 40k time trial, and it was all achieved through design and process control measures.