9 - Bearings

The next thing to consider with shafts is how they are supported. Bearings are parts that support shafts and reduce the friction between them and the frame. They are necessary on any spinning shaft. Although other kinds exist, FRC design uses mostly ball bearings and bushings

9.1 - Ball Bearings

In a ball bearing, the inner and outer edges (called the inner race and the outer race) are separated by a ring of steel balls which spin loosely to allow the two races to rotate with very little friction. The shaft fits through the inner race, and the outer race fits into the frame.

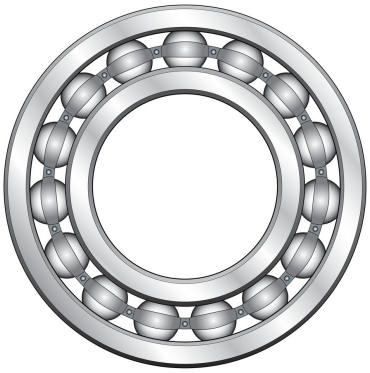


Figure 1: Diagram of a simple ball bearing

In FRC design, bearings are typically categorized by the shape of the inner race and whether or not they have a flange on their outer race. Below are the three common types.

Table 1: Bearing types

Type	Image	Notes
Flanged Hex Bearing		These have a hexagonal inner race in order to fit onto a hex shaft. 0.5" hex bearings are the most commonly used bearings.

Flanged Round Bearing		These are simple bearings with a round inner race, used for any round shaft.
Radial Bearing		These do not have a flange, and are instead held on by being press-fit into the frame. They are usually used on COTS gearboxes.

9.2 - Bushings

Bushings are a simple type of bearing which consist of a single, unmoving piece. They are made of a hollow cylinder, sometimes with a flange, where the inside of the cylinder fits on the shaft and the outside fits into the frame. Although bushings cannot handle as high of speeds as ball bearings, their simplicity, small size, and light weight makes them great candidates for low-speed or high-load applications.

Figure 2: Bronze bushings sold by VexPro

9.3 - Attaching Bearings to Frames

Attaching bearings to frames is rather straightforward. Usually, just a large hole in the aluminum is enough. The flange on a flanged bearing is very useful for this too, as it

keeps the bearing retained against the frame in one direction. The orientation of the flange is important to consider in order to best hold the shaft onto the frame. If this is done incorrectly, the bearing can slip out of its hole.

Bearing blocks are parts that provide support for a bearing on a frame piece. They are especially useful on drivetrains, where the bearings on the wheel axles need extra support to dissipate the forces of impacts, reversals, and other high loads while driving. In addition to this, the bearing blocks sold by VexPro can also act as chain or belt tensioners.

Figure 3: VersaBlock
(Image from VexRobotics.com)

Figure 4: WCP Side Bearing Block
(Image from VexRobotics.com)

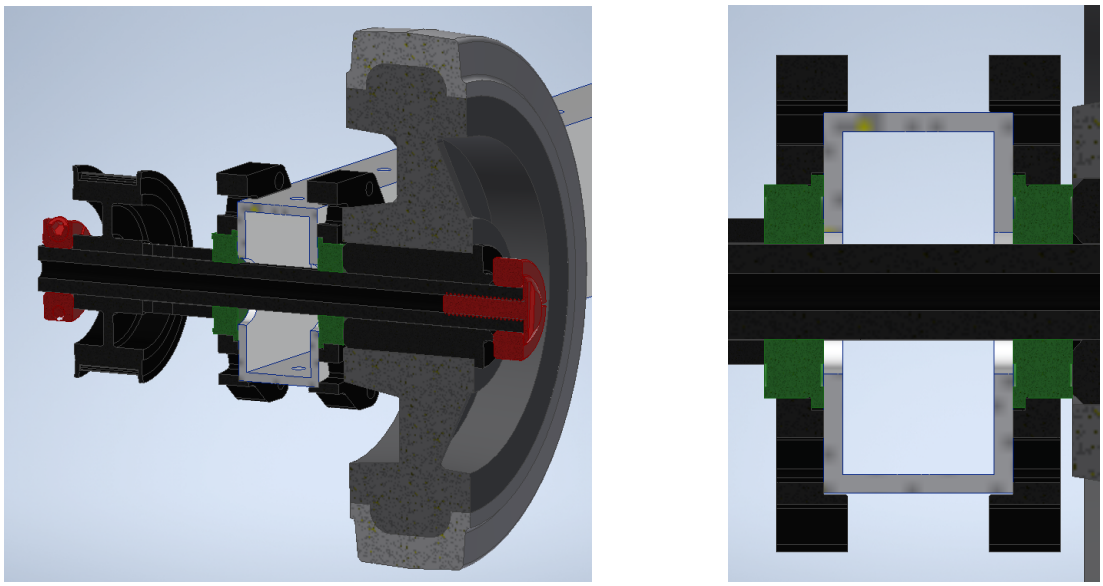


Figure 5: Section view of a drivetrain shaft assembly from the 2018 robot. In this case, the flanges of the bearings are constrained in both directions, held between the frame and the bearing blocks, the large black pieces on either side of the frame.

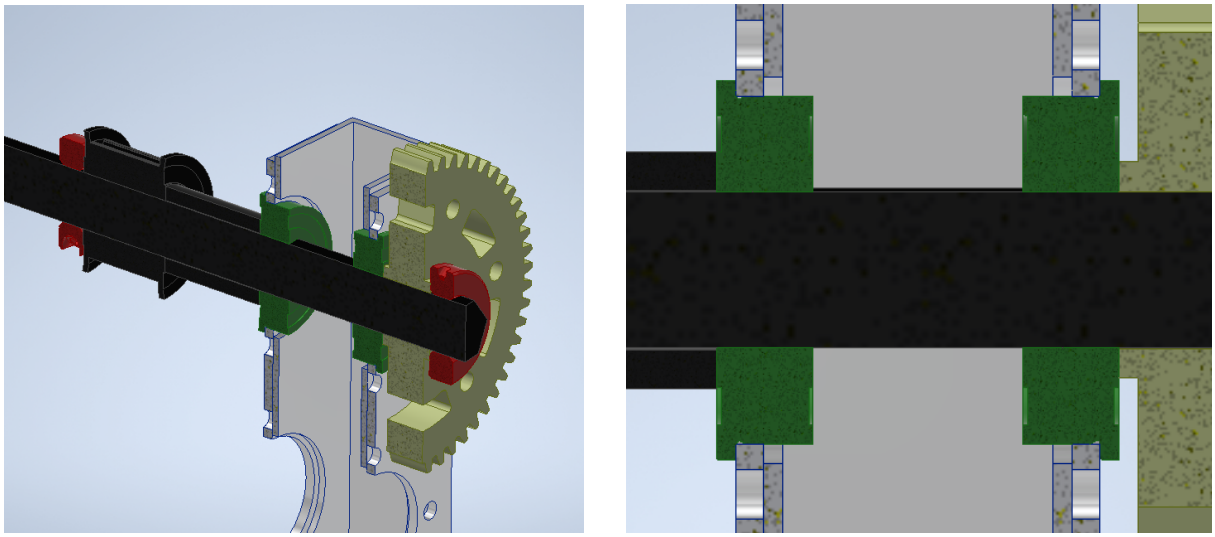
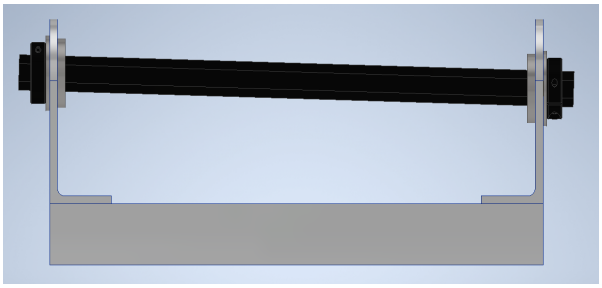
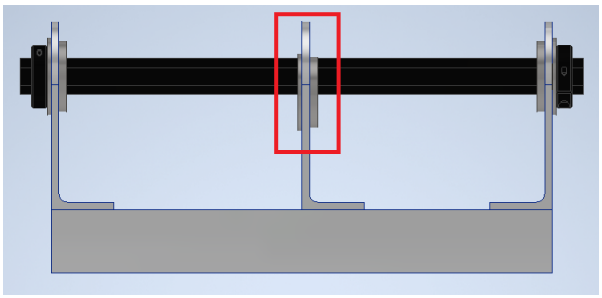
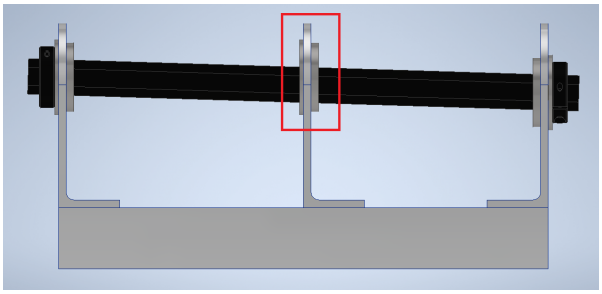


Figure 6: Section view of another shaft assembly from the 2018 robot. Here, the frame only supports the flanges in one direction, but the shaft collars on either end hold the whole assembly together so that the bearings do not slip out.

Another thing to consider when attaching shafts to frames is that, in most cases, a shaft should only have two bearings on it. This ensures that the shaft will assemble easily, essentially because it is easier to line up two bearings than it is to line up three or more.

 Figure 4a	When the bearings are lined up perfectly, the shaft fits through both easily.
 Figure 4b	If one bearing is out of position - perhaps because the angle plate it sits in was machined incorrectly - the shaft still fits through both bearings, although not as well.
 Figure 4c  Figure 4d	If there are three bearings on the shaft, it cannot fit through all three if even one of them is out of alignment.

These examples, of course, are exaggerated. The inaccuracies in bearing alignment may be on the order of hundredths or even thousandths of an inch, but it can make a difference in assembling shafts. The one major exception to this, however, is if a shaft has four bearings, in pairs a large distance from each other. Here, it is easy enough to line up the two bearings in each pair with each other, so they behave almost as one bearing.

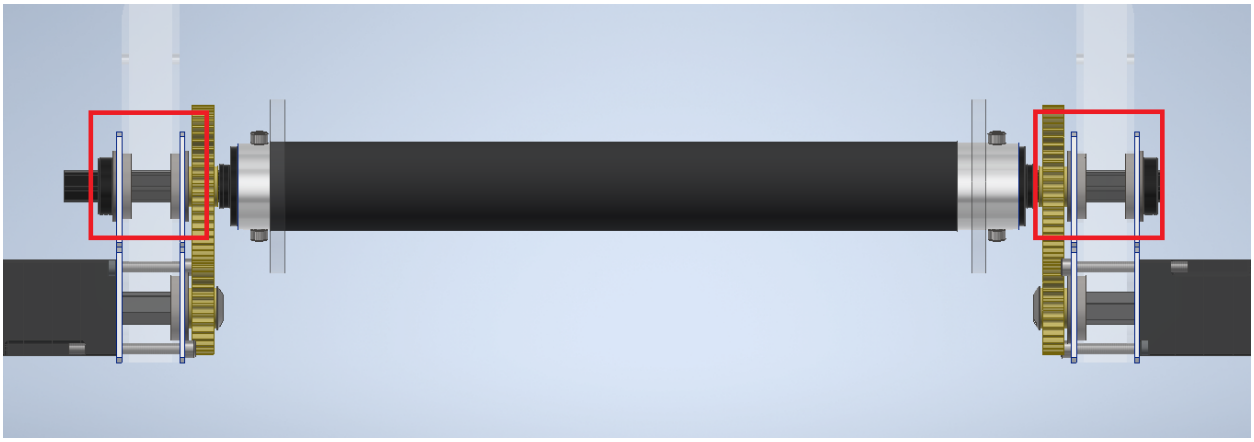


Figure 5: The climber mechanism from the 2017 robot, an example of a shaft which has more than two bearings. Here, the bearings are far enough apart that alignment is not a problem. Also, since this shaft must hold the weight of the robot, having more bearings helps distribute the weight of the robot to not put too much stress on any one bearing.