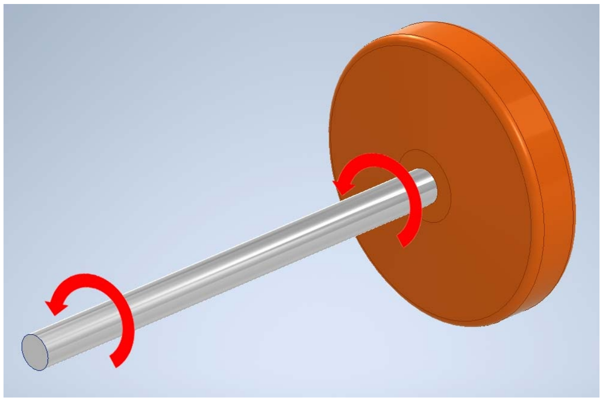
8 - Shafts

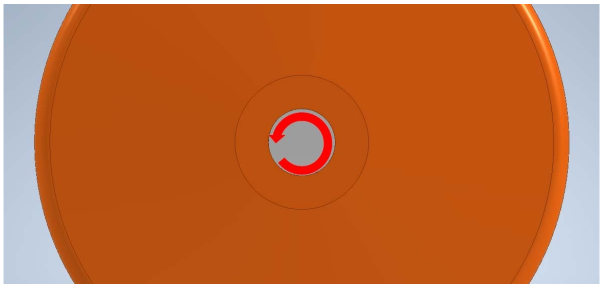
Because motors are the most common way to drive a robot and its mechanisms, rotational motion is everywhere in robotics. It covers everything from spinning wheels to propel the robot across the ground, pivoting an arm to score a game piece, rotating a winch to retract a climbing hook, and dozens of other things. To make something spin, you need to give it something to spin on and something to provide the motion, and for this we usually use shafts.

8.1 - Hex Shafts

First consider a cylindrical shaft, driven at one end and with a wheel at the other end, as shown below. If we apply a torque, a rotational force, at one end, we can expect the whole shaft to rotate with it. But, will the wheel rotate? It won't, because on a cylindrical shaft, there is nothing to transfer the torque from the shaft to the wheel.



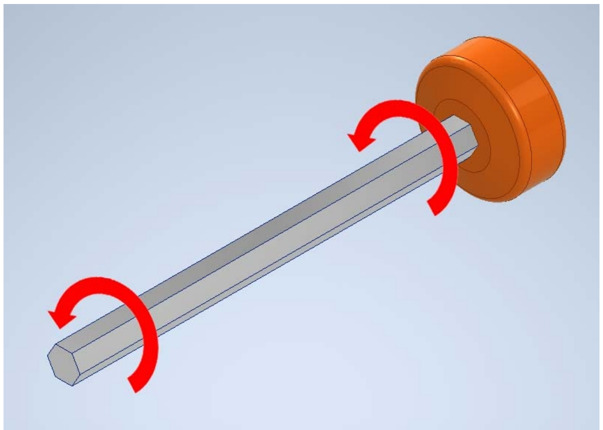
A wheel is connected to the shaft. As it rotates at one end, the other end of the shaft rotates, too.



However, the wheel does not rotate because the cylindrical shaft is loose in the cylindrical bore of the wheel.

Figure 1: Rotation with a round shaft

There are many ways to work around this. The most common in FRC is to use a hexagonal shaft, often just called a "hex" shaft, which works by having matching hexagonal shapes on the shaft and the wheel. The corners of the hexagon on the shaft bump into those on the wheel, preventing the two parts from slipping relative to each other.



Here, the wheel and the shaft are connected in the same way, but with a hex shaft.

As the hex shaft rotates, the wheel rotates with it.

Figure 2: Rotation with a hexagonal shaft

In FRC, 0.5" hex has become the standard size for nearly all shafts. FRC suppliers offer dozens of wheels, pulleys, sprockets, and many more items with 0.5" hex bores. Because of how common COTS parts are for 0.5" hex shafts, there is rarely a reason to use anything else.

ThunderHex is a special type of hex shaft customized for FRC applications and sold by VexPro. It features a hole through the center which can be used as either a tap hole or a clearance hole, so the shaft can easily have bolts thread into it or pass through it. Additionally, the corners of the hexagon are rounded to a circle so that the shaft can pass through round bearings. ThunderHex is widely versatile and can be used in most applications, and it is available in 0.500" and 0.375" hex sizes.

Figure 3: ThunderHex shaft
(Image from VexRobotics.com)

8.2 - Other Torque Transfer Methods

Another way to transfer torque on shafts is through interference fits. In such a connection, the hole on the wheel (or pulley, gear, etc.) is slightly smaller than the shaft, so that when the parts are assembled, friction binds them together. In fact, they are held together so tightly that they behave as a single part, and in most cases they can never be disassembled. These connections are typically used to connect pinions or pulleys to motor output shafts, where the shaft is too small to use any other method.

Figure 4: 775Pro motor with a pinion connected by an interference fit
(Image from VexRobotics.com)

Another method of transferring torque is to use a key. This is a small piece of metal, usually steel, which fits into matching slots on both the shaft and the gear (or other part, but they are common only on gears) to make the parts spin together. This is most often used to connect pinions to motors, namely the CIM, MiniCIM, and Neo. Keys are not ideal for custom parts, however, simply because we do not have the tools necessary to machine them.

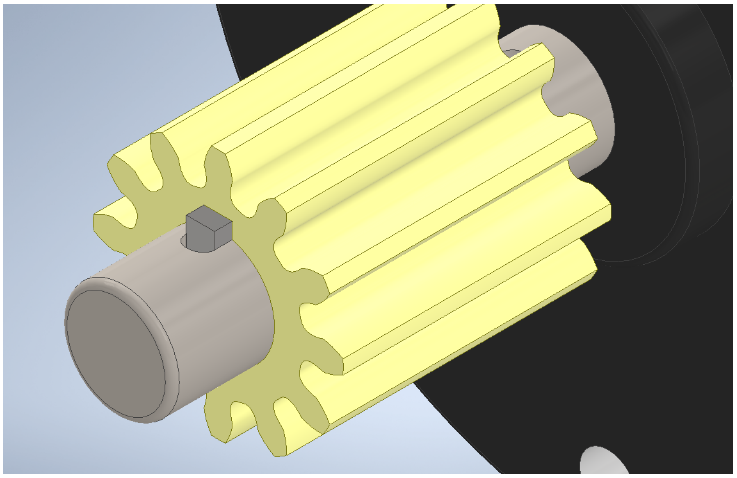


Figure 5: A pinion connected to a motor by a key, the small darker-colored part between the gear and the shaft

8.3 - Axial Retention

Whenever you use a shaft, you must also hold the components onto the shaft in the axial direction (i.e., along the length of the shaft) so that they do not slide off the ends. As with most elements of design, there are several ways to do this.

Shaft collars work by clamping onto the sides of a shaft and holding on with friction. They are especially easy to install and require no extra machining, and because they clamp onto the sides of the shaft, the shaft does not have to be cut to a terribly precise length. They can even be used in the center of a shaft, as well. However, they are weaker than other retention methods and have been known to fall off in high-vibration situations such as on drivetrain wheels.

Figure 6: A 0.5" hex shaft collar
(Image from VexRobotics.com)

Large-headed bolts are another common way to secure components on shafts. This method works by threading a bolt into the end of a shaft and having the bolt head, which must be larger than the diameter of the shaft, hold the components in place. ThunderHex is particularly useful for this because the center hole works as a tap hole. On Team 1732, we use sidewalk bolts, a special type with an especially large head, for this application, although other types of bolts could work, too. Even a standard bolt with a large washer could work, but using a single large bolt is easier to assemble.

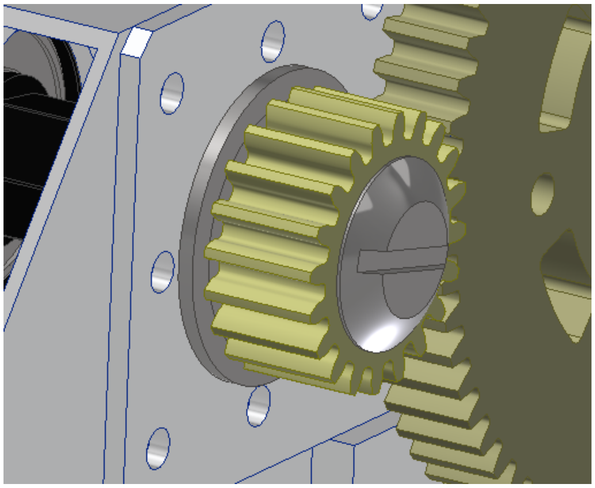


Figure 7: Sidewalk bolt in use on the 2018 robot

Finally, external retaining rings are another axial retention method. These are small rings that fit into grooves in shafts, and they come in a few varieties: snap rings, E-clips, and C-clips. Because they require precise sizes of grooves, the shafts must be machined on the lathe, which takes more time than other methods. However, retaining rings are lighter, smaller, and cheaper than shaft collars or sidewalk bolts, so they are superior in those ways.

Figure 8: Snap ring
(Image from Grainger.com)

Figure 9: E clip
(Image from HomeDepot.com)

Figure 9: C clip
(Image from HomeDepot.com)