EML 2322L – MAE Design and Manufacturing Laboratory

Mechanical Power Transmission (Hub Design)

Hubs are used to transmit mechanical power from a drive motor by coupling it to an output device such as a wheel or an arm.

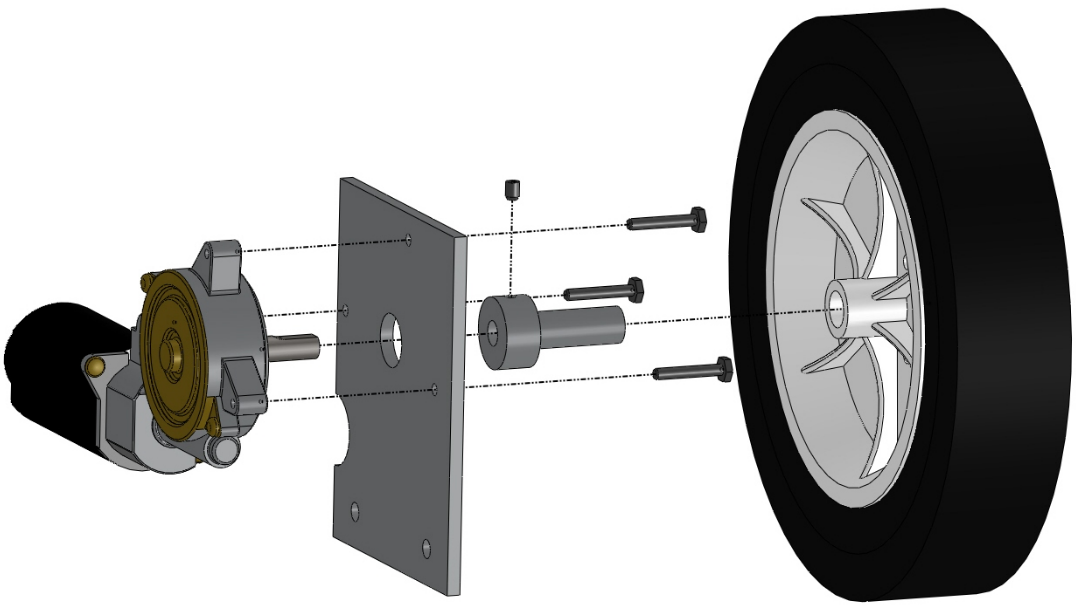

Figure 1. Exploded view of drive motor/hub/wheel assembly.

Figure 1 shows an exploded view of a typical motor/hub/wheel assembly. In this illustration the hub slides onto the output shaft of the drive motor and is secured using a set screw. The wheel is pressed onto the other end of the hub via an interference fit. Figure 2 shows a detailed picture of the wheel hub used in the above assembly.

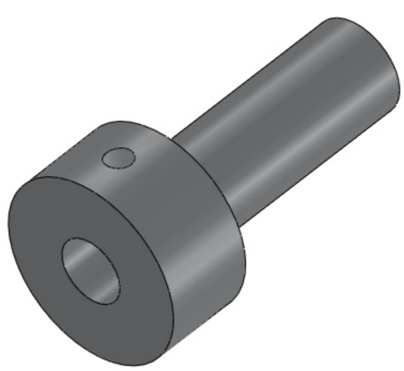

Figure 2. Example (wheel) hub.

Things to Consider When Designing Hubs:

1. Attaching the hub to the motor
2. Attaching the wheel or other power transmission device to the hub
3. Transmitting the power through the hub

1. Attaching the hub to the motor

The first step in designing a hub is to determine how it will attach to the drive motor. To accomplish this goal, the output shaft of the motor is measured and the hub is designed to properly mate with the shaft.

The hub shown previously is designed so the inside diameter of the bore is a very close clearance fit (i.e. +0.001 to +0.002″ total clearance) with respect to the outside diameter of the drive motor shaft; this allows the hub to slide freely onto the shaft of the motor while rotating concentrically with it.

2. Attaching the wheel or other power transmission device to the hub

The second step in designing a hub is to determine how it will attach to the wheel or other power transmission device. Wheels, for example, are attached by mating the hub to the center hole in the wheel (as shown on the previous page or on a bicycle) or by mating the hub to the face of the wheel (as seen on automotive wheels).

The hub shown previously is designed so it slides into the center hole of the wheel.

3. Transmitting the power through the hub

The four common ways power is transmitted from a motor into a hub are:

A. Press fits
B. Set screws
C. Keyways & Pin joints
D. Splines

3A. Press Fits

Press fits employ friction between surfaces to transmit power. As illustrated in figure 3, press fits rely on interference between mating components to transmit power. Due to the mechanical interference, press fits must be forced together to be assembled (thus the name). For example, the shaft on the wheel hub shown previously would be designed with a diameter slightly larger than the diameter of the hole in the center of the wheel so the two components can be pressed together. For a data point, a typical interference fit is 0.001″ per inch of bore or shaft diameter in a relatively soft metal like aluminum (that number would be smaller for press fits in steels and larger for press fits in plastics).

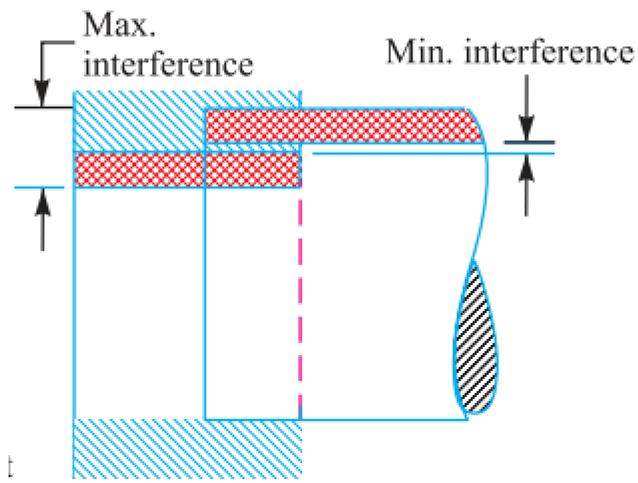

Figure 3. Illustration of press (i.e. interference) fit.

Pros: simple to design and fabricate; work well for permanent assemblies using strong/hard materials like steels

Cons: always slip when used with soft materials (like plastic) except where **very** low torque transfer is required; pressing parts together can damage electric motors or other precision components; press fits are also difficult to disassemble without damaging components

3B. Set Screws

As seen in figure 4, set screws are fully threaded fasteners which possess no external head projecting beyond the major diameter of the screw thread. Set screws are typically tightened or loosened via an internal-wrenching hexagonal drive which is engaged by hex keys (aka "Allen wrenches").

Figure 4. Examples of set screws with hex drives.

As shown in figure 5, set screws are often used to transmit torque through hubs because their headless design allows recessed installations with no protruding screw heads to contact anything near the rotating hub. In these examples set screws are used to apply radial forces on the motor shafts. Set screws rely on either friction or positive mechanical engagement to transmit torque; these two methods are explained in the next section.

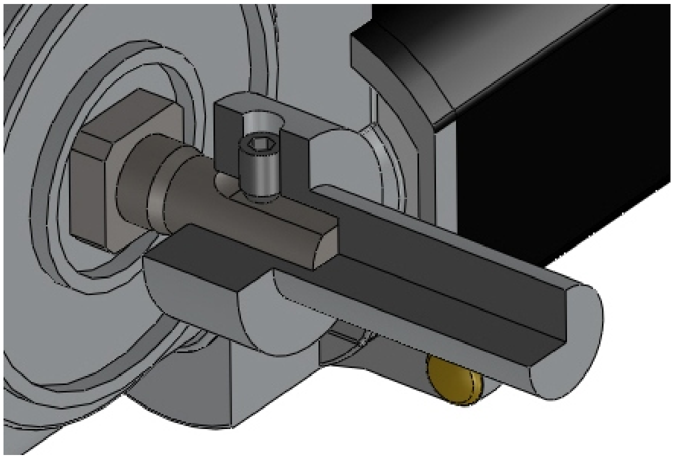

Figure 5. Illustration of set screw used to transmit torque using positive mechanical engagement.

Figure 6 illustrates the two methods of transmitting torque using set screws. The shaft and hub on the right use the set screw to create a friction interface with the shaft; this method is prone to slip except in very low torque transfer conditions. The shaft and hub on the left employ a flat machined into the shaft for positive mechanical engagement, which means the assembly does not solely rely on friction to transmit the torque, but rather mechanical engagement between the set screw and the flat on the motor shaft.

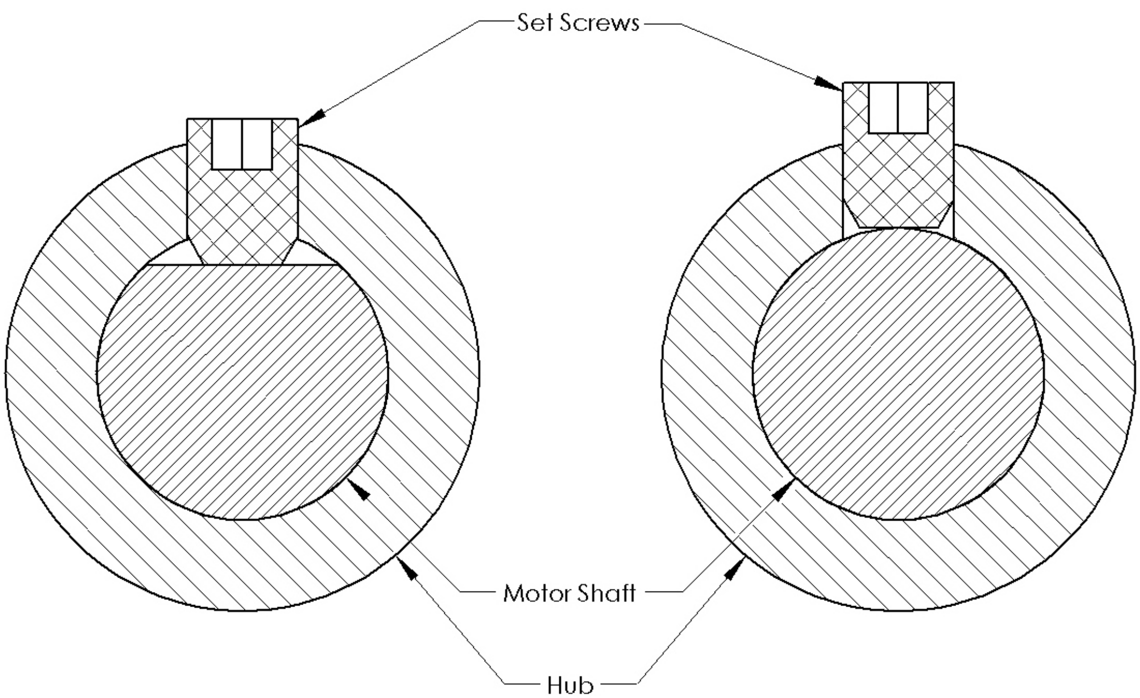

Figure 6. Illustration of set screw torque transmission methods.

Pros: easy to design, easy to machine, provides reliable power transmission in moderate torque applications when used with flatted shafts (i.e. positive mechanical engagement)

Cons: does not provide reliable power transmission when used purely as a friction interface with no machined flat or recess except where **very** low torque transfer is required

3C. Keyways & Pin Joints

As illustrated in figure 7 (from Joseph E. Shigley's *Mechanical Engineering Design* text), keyways and pin joints always provide positive mechanical engagement for torque transmission. The diagram shows six different keyway and pin joint arrangements. In each case the key or pin is placed in shear to transmit the power, which means a mechanical component would have to break (or shear) to fail, as opposed to only relying on friction.

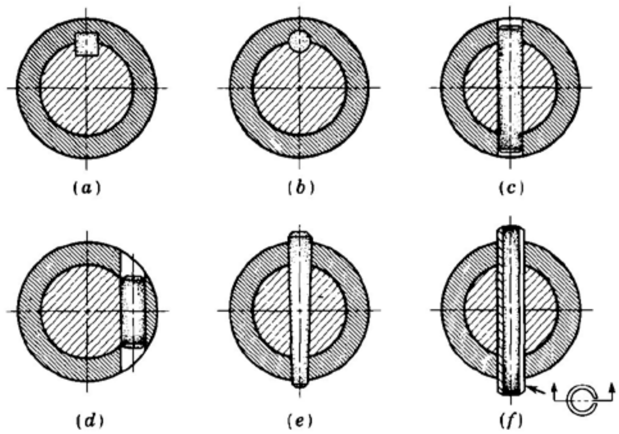

Fig. 7-27 (*a*) Square key; (*b*) round key; (*c*)–(*d*) round pins; (*e*) taper pin; (*f*) split tubular spring pin. The pins in (*e*) and (*f*) are shown longer than necessary to illustrate the chamfer on the ends; but their lengths should not exceed the hub diameters, to avoid injuries which might be caused by projections on rotating parts.

Figure 7. Common keyway and pin joint configurations.

Pros: provide positive mechanical engagement in all cases; pin joints are easy to design and machine (because they are cylindrical); keyways and pin joints allow disassembly without damaging components

Cons: keyways are a little more difficult and costly to machine than pin joints because they require additional equipment and tooling (beyond simple drills and reamers); both keyways and pin joints are permanent once machined into the (motor) shaft and hub

3D. Splines

Like keyways and pin joints, splines are used to provide positive mechanical engagement between two parts. Splines provide the strongest possible method of torque transmission, as well as easy assembly and disassembly. The downside to using splines is they cannot be easily or cheaply produced if they do not already exist on the (motor) shaft.

Below is a picture of a drive motor commonly found in the EML2322 laboratory. As shown in the zoomed inset, the motor shaft has small axial tapered splines (actually serrations which are just miniature splines).

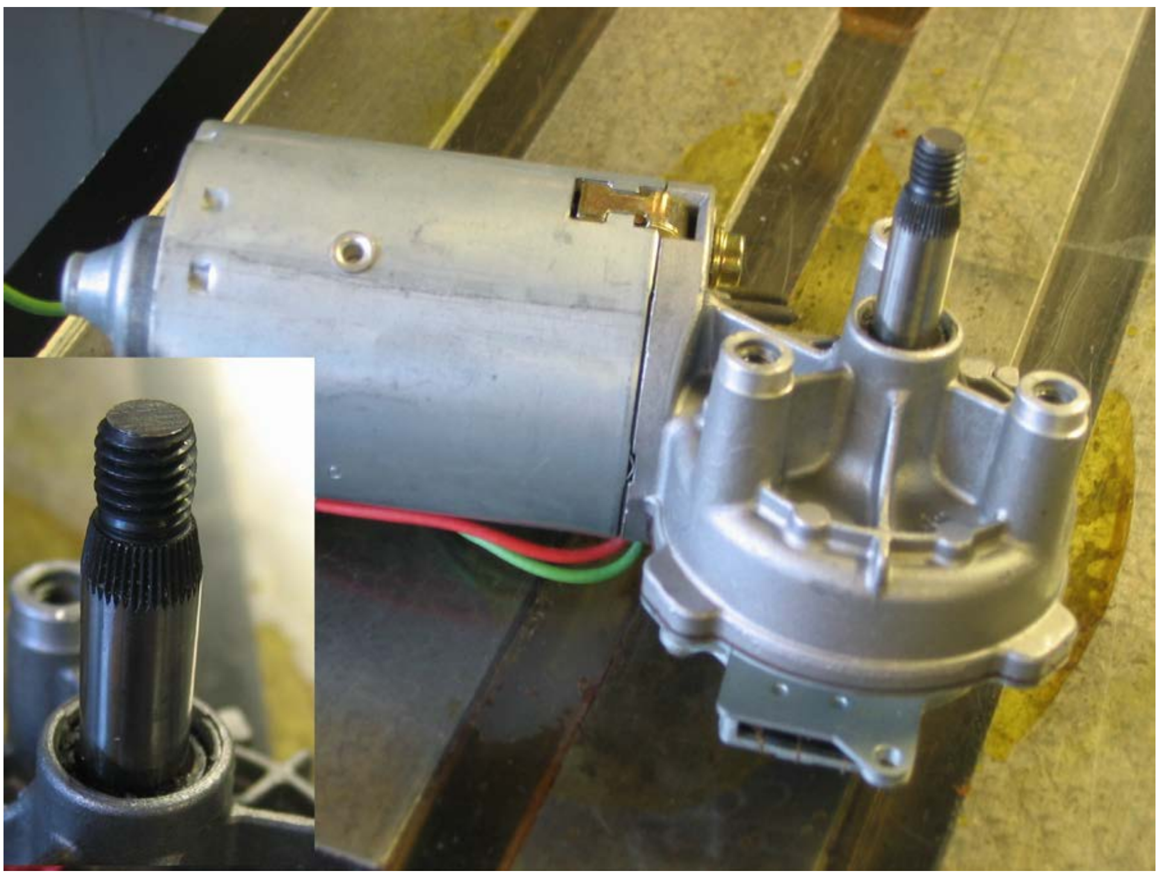

Figure 8. Example of motor shaft with splines.

The hub shown in figures 9 and 10 is a modified version of the one made during the beginning of the semester. As the retaining nut is tightened, the weaker / softer aluminum hub deforms around the stronger / harder steel splines on the motor shaft, providing positive mechanical engagement between the motor shaft and hub, providing reliable power transmission.

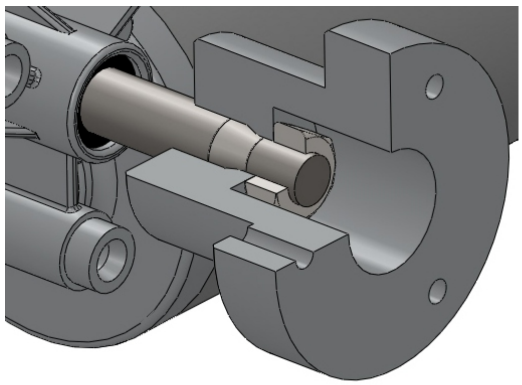

Figure 9. Wheel hub attached to motor shaft with tapered splines.

The cross sectional view shows the motor shaft is not of constant diameter. The splines are on the section of the shaft where the diameter decreases; this is where the aluminum hub deforms to engage with the shaft splines.

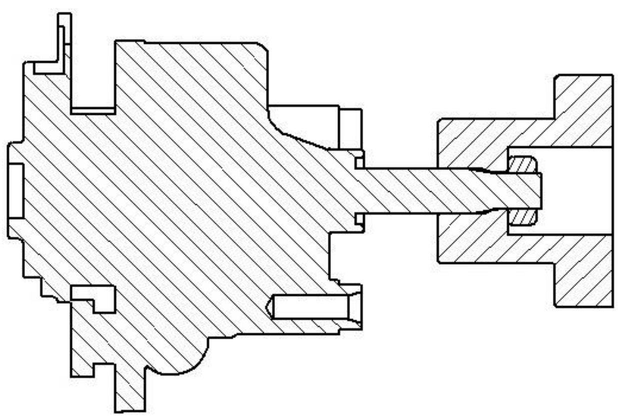

Figure 10. Cross sectional view of tapered spline engagement.

Pros: provides positive mechanical engagement and the most robust level of torque transmission; allows easy removal without damaging the motor shaft

Cons: unless the splines already exist on the (motor) shaft, they cannot be produced easily or cheaply