

## Wheel Hub Design

This document explains how to design wheel hubs (and other parts) for the course design project. The top priority for part design is function; above all else, the part must function properly without failing. Beyond that, *good* designers are concerned with designing parts that can be made quickly and cost effectively; this means [keeping parts simple, material use low and manufacturing processes to a minimum](#). The following points discuss these topics.

### Objectives

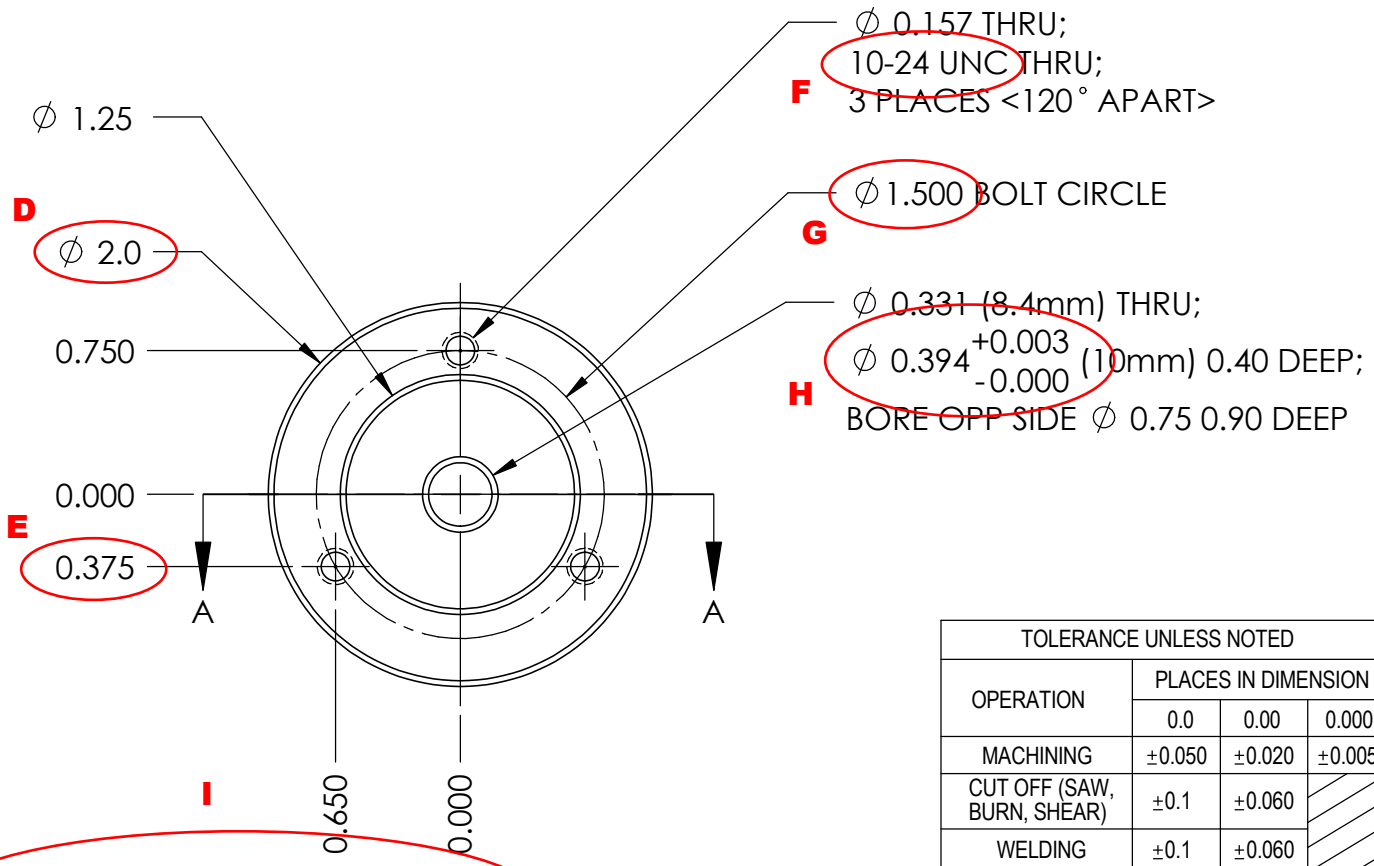
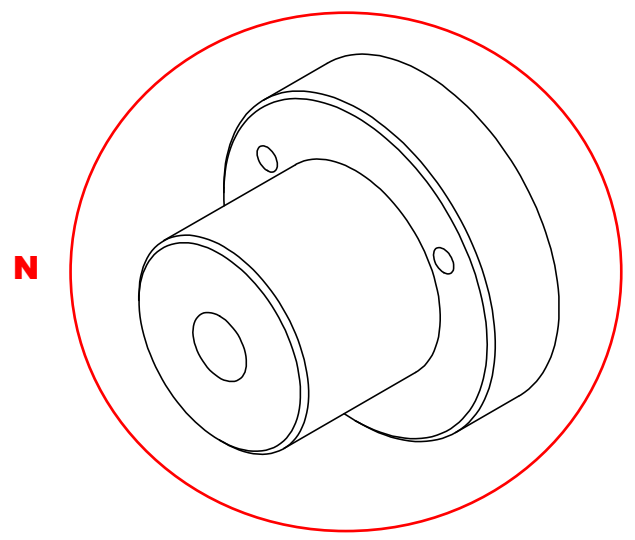
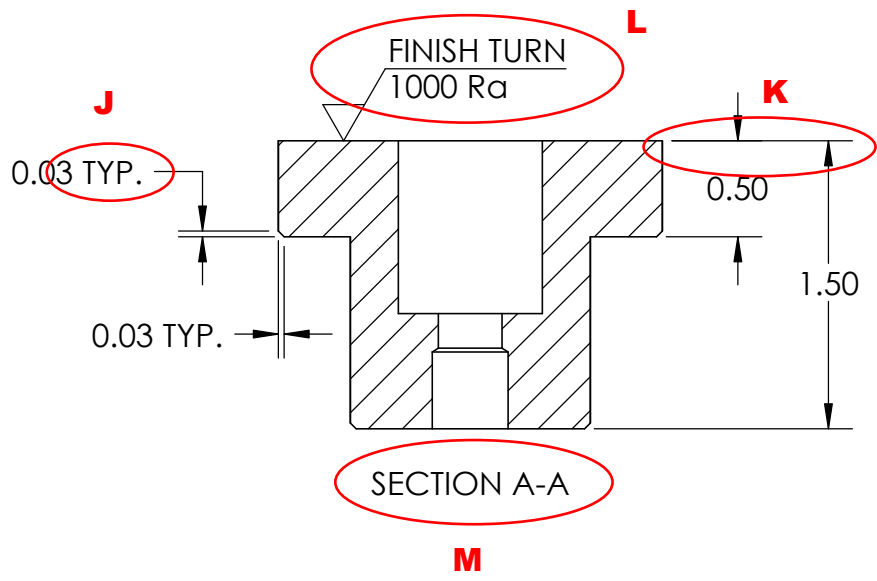
1. **Function.** As shown in [the 3D example](#), the purpose of a wheel hub is to attach a wheel to a motor shaft. Hubs are also used to attach lifting arms, release doors and pulleys to motor shafts.
2. **Attachment method (to wheel).** Wheels are typically attached to hubs via the wheel's face or its center. Fasteners are usually the most suitable method for attaching the wheel to the hub because they provide good strength and can be easily removed for storage or servicing.
3. **Attachment method (to motor).** Hubs are typically attached to motors by closely sliding over and locking into engagement with their shafts. Fasteners are usually the most suitable method for attaching hubs to motors because they provide good strength and can be easily removed.
4. **Transmitting the power through the hub.** While deciding how to attach the hub to the wheel and motor, one must also select an appropriate method of reliably transferring torque from the motor, through the hub and to the wheel. As discussed in the [mechanical power transmission notes](#) for this course, the four common methods of torque transmission are press fits, set screws, keyways / pin joints and splines. The course notes list the pros and cons of each method.
5. **Mechanical properties.** The hub must be capable of rigidly supporting its share of the robot's weight without failure during its expected life span. If the hub geometry and material selection are inadequate, the hub can break completely or bend so much that the motor can not effectively accomplish its task.

### Wheel Hub Design Tips

1. **General shape.** Use simple shapes you have experience producing using the manual machines in the lab. Stated another way, *never design part features you don't know how to make*. It is much easier (i.e. quicker and cheaper) to design a simple round wheel hub cut to size from a piece of longer round bar using the bandsaw as opposed to a fancy part with features that would require a CNC machine to produce (and the necessary part programming and debugging time).
2. **Keep it small.** A shorter or smaller hub has a lower material cost. A shorter hub is also stiffer (if all other geometry is identical). *Therefore, a shorter hub is cheaper and more rigid compared to a longer part, so make sure you can justify why your hubs cannot be made any shorter or smaller*. From a functional standpoint, one end of the hub must attach to one of the wheels in the lab which all have common bolt patterns for #10 fasteners on a 1-1/2" diameter bolt circle. If the center of the bolt pattern lies on a 1-1/2" diameter bolt circle, the part must be larger in diameter to provide enough material to drill and thread. Since the next larger nominal size is 2.0", this is what we will use.

3. **Material specification.** Most of the robots built in the course weigh around 35 pounds (including the control box). When deciding on material type and size, it's instructional to grab a piece of material off the material rack and physically apply the force it will see by hand to decide if it's a wise choice. ***Round aluminum bar stock is generally a good choice for hubs.*** Select a material possessing good manufacturability and adequate strength. If weight is important, consider different materials' strength-to-density ratios. Manufacturing time and thus part cost are typically proportional to material strength; knowing this, ***always select the weakest material that is strong enough for the design*** to ensure the cheapest material and lowest part cost.
4. **Surface finish & appearance.** Based on [the wheel hub previously manufactured on the lathes in lab](#), raw extruded aluminum round bar possesses approximately 0.010" roundness error from the supplier. ***Since only one surface on this part affects its function, explicitly instruct the manufacturer to leave all other surfaces unfinished.*** It is NOT necessary to finish machine any other external surfaces of the part, as its function only depends on the perpendicular relationship between the wheel mounting face and the shaft bore axis. If the wheel mounting surface is not perpendicular to the shaft axis, the hub will wobble when rotating on the motor shaft (which could adversely affect controllability). Notice none of the objectives listed above mention appearance of the wheel hub, so a rough finish is just fine for this part (as for most) to reduce manufacturing time.
5. **Coarse versus fine threads for fasteners.** ***Since the wheel hub is specified as aluminum (a relatively soft material) it should use coarse threaded fasteners as opposed to fine; therefore the threads are specified as 10-24 versus 10-32.*** Always use the industry standard tap drill sizes listed on [the tap and clearance drill chart](#), which in this case is  $\text{Ø}0.157$ ".
6. **Design parts to take advantage of nominal raw material sizes.** Students entering this course cannot understand this important point, but after making parts on the mills and lathes, this tip should make sense. ***It's important to design parts around nominal raw material stock sizes.*** When a piece of 2" round bar is ordered to make a hub, it will measure between 1.995" and 2.005" in "raw" stock size (which typically varies  $\pm 0.005$ " for aluminum extrusions). During class it was necessary to remove as much as 0.020" off the hub's outside diameter (OD) to make it "perfectly" cylindrical. That means the OD of our example workpiece is now between 1.975" and 1.985". If the OD is specified as  $2.000 \pm 0.005$ " with a finished surface, this target will never be achieved; but if the OD is specified as  $1.980 \pm 0.005$ ", it can be easily achieved. ***For the hub manufactured in lab, the exact OD has absolutely no effect on the function of the part, so if the designer was smart, he/she would specify it as:  $2.000 \pm 0.020$  (or even  $\pm 0.050$ ) and place a note on the drawing that it does NOT need to be a finished surface.*** Therefore, any 2" round raw stock would work and the person making the part would not waste time and money finishing surfaces that don't improve the part's function. On the other hand, if the OD of the part was important, the designer could wisely specify the OD as  $1.980 \pm 0.001$ ". This specification would allow the part to be cut to final size in one pass, whereas specifying the OD as  $2.000 \pm 0.001$ " would require the purchase of the next larger raw material stock size (~2.5"), as well as the time to cut it down to the final 2.000" size.

**The next page shows a drawing of a wheel hub design used with the [Entstort 44 rpm right angle gear motor](#) found in the lab. The drawing provides a good example of how to apply the previous concepts to design a wheel hub. The drawing is heavily commented to explain the design choices made for each portion of the part; the comments are printed on the final page of this handout. More practical tips for designing for cost and manufacturability can be found [in the excellent DFM Examples handout](#).**



- NOTES:**
1. QTY: 2 **A**
  2. ALL DIMS IN INCHES
  3. MATL: ALUMINUM
  4. FINISH NOTED SURFACE(S) **B**
  5. BREAK ALL EDGES

TOLERANCE UNLESS NOTED				TITLE:	
OPERATION	PLACES IN DIMENSION			ENTSTORT WHEEL HUB	
	0.0	0.00	0.000	DRAWN	M. BRADDOCK
MACHINING	$\pm 0.050$	$\pm 0.020$	$\pm 0.005$	DESIGNED	J. KOCH
CUT OFF (SAW, BURN, SHEAR)	$\pm 0.1$	$\pm 0.060$		SIZE	DWG. NO.
WELDING	$\pm 0.1$	$\pm 0.060$		<b>A</b>	EML2322L-022
ANGULAR DIMS	$\pm 5$	$\pm 2$	$\pm 0.5$	SCALE: 1:1	REV <b>B</b>
				SHEET 1 OF 1	

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## Explanation of Design Parameters for Wheel Hub

- A. This hub is designed to fit the left and right side drive motors, which offers two advantages: first, I only need to create and proof one part model and detail drawing; second, I don't have to worry about checking which part goes where on the robot, since they are now universal.
- B. Finishing surfaces takes time. Unless a finished surface is required for function or appearance, clearly indicate no surface finish is required. Since only one surface on this part affects its function, I explicitly instruct the manufacturer to leave all other surfaces unfinished. Note it is NOT necessary to finish machine any other surfaces of the part, as its function only depends on the perpendicular relationship between the wheel mounting surface and the shaft bore axis.
- C. This drawing is a revision to the original drawing made during the first part of the semester in the laboratory. Consequently, it is denoted as "*Revision B*" so the two cannot be confused.
- D. The outside diameter of this part does not affect part function (unless it's WAY too small), so I specify a very large/liberal tolerance ( $\pm 0.050$ ") to reduce cost.
- E. Hole dimensions for attaching the wheel to the hub should be precisely located to match the holes in the wheel, thus the  $\pm 0.005$ " locational tolerances.
- F. Since the material in which threads are to be created is soft, coarse threads should always be used; therefore specify 10-24 UNC threads (as opposed to 10-32 UNF threads).
- G. Note the tolerance on the bolt circle diameter matches the tolerances on the Cartesian coordinates listed for the individual holes. Otherwise, the manufacturer would not know which to follow.
- H. The purpose of this feature is to precisely slide over the motor shaft and allow the splines to engage the tapered step in the bottom of the bore. Typically, a shaft bore is toleranced as a VERY close clearance fit. In other words, it must be larger than the precision shaft size (0.3937" in this case), but not much larger. In this case, the 0.394" plus 0.003" minus 0.000" forces there to be between 0.0003" and 0.0033" of clearance. The 8.4mm thru hole ensures 0.010" of clearance for the threaded portion of the motor shaft and the 0.75" bore allows access for a socket wrench to manipulate (i.e. tighten or loosen) the M8x1.25 nut on the Entstort motor shaft.
- I. If watermarks are present in your version of SolidWorks, always print drawings using a PDF printer (rather than performing a save-as PDF command) to move the watermark to the page border (as shown). Newer SW versions don't print watermarks, eliminating the problem.
- J. *TYP.* is the abbreviation for "typical", which means any features of similar size on the drawing will use these dimensions. Chamfers increase manufacturing time and are often unnecessary, so these could be removed to further reduce part cost. The remaining sharp edges must be removed to satisfy the "*BREAK ALL EDGES*" note, so I suggest removing the chamfers altogether.
- K. Whenever possible, minimize the number of part datums to make manufacturing easier and cheaper since an edge finder must be used each time a new datum is specified. Note there is only one X, one Y and one Z datum for all features on this part. (Of course, function must take precedence over cost, so if you must specify additional datums to achieve the required function, then by all means do so.)

## Explanation of Design Parameters for Wheel Hub (cont)

- L. This is the ONLY functional surface on the entire part requiring a surface finish specification, since this is the surface the wheel mounts against. If this is not a finished surface that is perpendicular to the shaft axis, the hub will wobble when rotating on the motor shaft, which could adversely affect controllability.

The *FINISH TURN* specification alone is adequate for this course to denote the surface should be fully machined (turned on the lathe) using a finish pass. In other words, for the wheel hubs you are designing, if you denote the finished surface(s) using the FINISH TURN notation, a team member or TA should be able to understand your design intention, and therefore that would be perfectly acceptable on your project drawings.

In industry, however, more information is required, as provided in the rest of the surface finish note. *Ra* (*average roughness*) is the arithmetic average deviation of the surface profile from the mean, or in this case, the datum plane. Specifically, the *1000 Ra* finish specification means 1000 micro-inches ( $\mu$ -in), which is  $1000 \times 10^{-6}$  in, or 0.001 in. In other words, the 1000 Ra spec means the designer is requiring a peak-to-valley average deviation of 0.001" over this part face, which is the practical limit of what is achievable with a turned finish on a typical lathe. A5000 Ra finish would be perfectly acceptable for the intended use of this wheel hub, but more than that would result in the previously mentioned wobble that we want to avoid.

- M. The only way to show the detail of the center of the part without dimensioning to hidden lines (which should NEVER be done) is to include a broken section view of the part.
- N. Always include an isometric part view to clearly communicate the part's shape. Suppress hidden lines and NEVER include dimensions in the isometric view. Always show the most complex side of the part in the isometric view.