TO: Valued New Engineering Employee
FROM: *ChopShop* Engineering team
RE: Design Problem #2: Chop Saw Blade Shaft Design
Due by 11:59 pm, 10 November 2023

While the senior engineers are (still) reviewing your pivot arm and pin design, your next job is to design the shaft and connecting hardware for for the saw blade.

A side view of the general layout is shown in Figure 1 below. The **front and back walls** of the **support box** provide support to the **blade shaft** via sealed **bearings**, which fit against **shoulders** in the walls. The shaft passes through both housing walls, connecting the **blade** at the back to the **pulley** at the front. The marketing team wants us to consider a blade that is connected to the shaft by a **pin** through its central **hub** (their idea is that it would speed replacement and that we could also sell the special saw blades as another product line). Axial motion of the shaft is resisted from the blade side by a **spacer**, confined between the pinned blade hub and the bearing in the back wall, and by use of a **retaining ring** at the pulley side. The shaft transmits torque to the pulley via a **key**. Because the belt nominally acts perpendicular to the shaft, the relatively small axial loads on the pulley are resisted via a **set screw**.

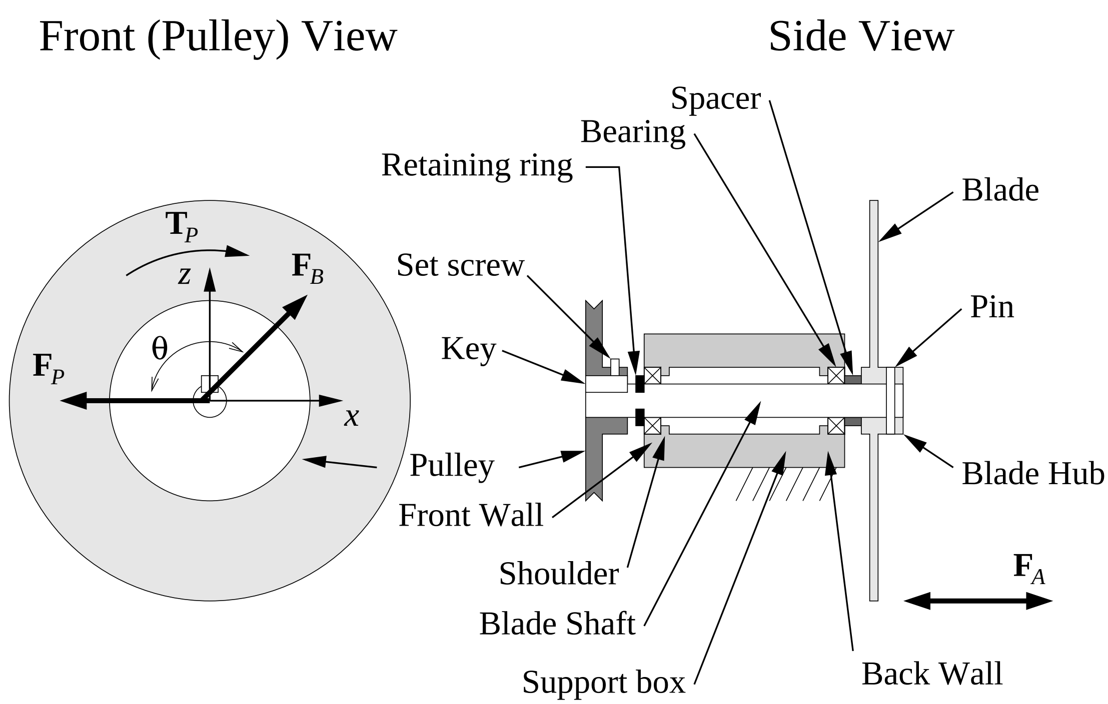

Figure 1: Chop Saw Blade Shaft Layout and Loading(Not to scale)

The dimensions (in millimeters, unless otherwise specified) are shown in Figure 2 below. At the front end of the shaft, there is a pulley with a 3" pitch diameter. The shaft extends far enough from the front wall that the pulley can be installed flush with the back end of the shaft. Based on the loads calculated in your previous design, combined with the weight of the pulley, the total load of the pulley on the shaft when operating at the rated speed of 4,600 RPM is $\mathbf{F}_P = 130.7$ N. In addition to this force, the belt drive system imparts a torque on the pulley (as you calculated in your previous design) of $\mathbf{T}_P = 1.548$ Nm. At the back end of the shaft (the blade side), the blade provides an equal and opposite torque to the shaft of $\mathbf{T}_\text{B} = 1.548$ Nm, as well as a total force of $\mathbf{F}_B = 42.8$ N, acting at a relative angle of $\theta = 111.4°$ with respect to the pulley force direction, as shown in Figure 1. We would also like you to consider the possibility that the blade might be slightly misaligned, causing a $\mathbf{F}_A = \pm 10$ N axial load at the bottom of the blade (8" diameter, as in your previous design work).

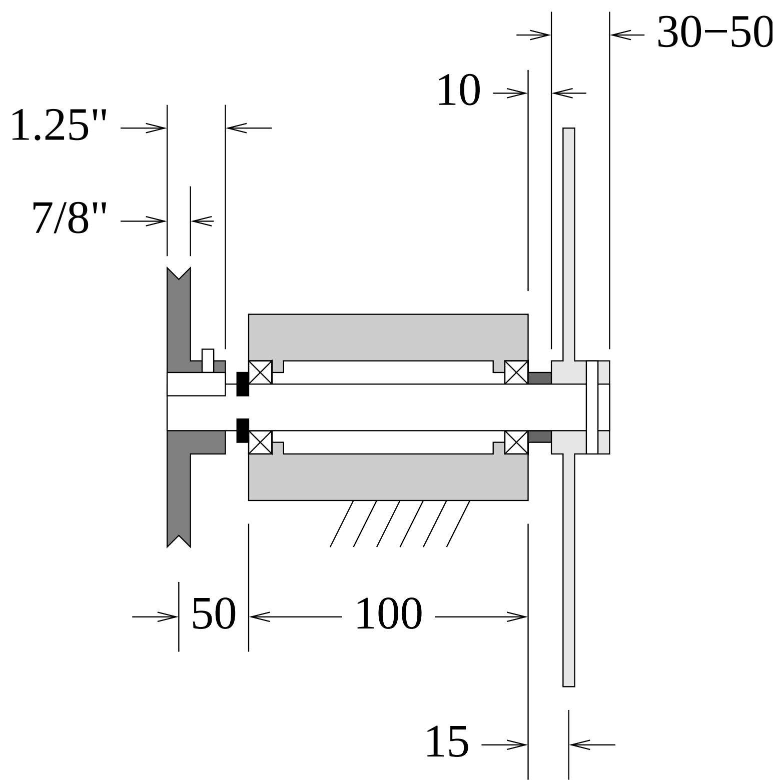

Figure 2: Dimension Sketch (not to scale)

Requirements

The initial requirements, in no particular order, are given below. Additional clarifications, if needed, will be posted on *Canvas* and/or *Piazza*. You are responsible for any updates posted, so please make sure to review these frequently.

1. You must design the **shaft** and its **connection components** (key, set screw, pin, and retaining ring).
2. To allow for overloads, assume a minimum factor of safety of 1.5 for the shaft and 1.2 for the key, set screw, retaining ring, and pins.
3. The shaft must be designed for infinite life.
4. To provide a consistent supplier and cost basis across all designs, all components and material must be sourced from McMaster-Carr. All cost estimates for the shaft will be based on the cost per length of the **longest standard available length** to make the shaft from the part number you provide. All standard components (*e.g.*, keys, screws, etc.) will be pro-rated to a per item cost.
5. Material requirements: The shaft must be selected from the available precision (rotary) shafts, in either steel or stainless steel. Other raw materials are not acceptable. If the shaft material is steel, the pins, key, set screw, and retaining ring may be either steel or stainless. However, if the shaft material is stainless, only steel connection components are acceptable.
6. Since all designs will have to have the hole for the pin connection to the blade hub, the grooves for the retaining ring, and the keyway for connection to the pulley, you do not have to include any machining charges for those features in your cost.
7. The blade hub is expected to extend a total of 30–50 mm along the shaft. You must choose a length that is sufficient to provide appropriate spacing between the pin hole and the end of the shaft.
8. While we haven't yet designed the bearings, the senior engineers are confident that their width (the dimension along the shaft axis) will be no more than 1/2" (13 mm). the shaft.

Design the Blade Shaft and Attachments

Show your design calculations. **In all cases, state all of your assumptions and include the calculations necessary to justify your result.** You will also have to enter the basic numerical information into a *Canvas* summary quiz.

IMPORTANT: Each section must be presented in a series of consecutive pages you must identify them when you upload them to Gradescope. This will allow the review to proceed more quickly. Designs will be penalized if they do not meet this requirement.

Shaft Design Calculations (4 points)

1. Calculate and report the reaction loads at the bearings (all directions, using the coordinate system defined in Figure 1).
2. Including any stress concentration effects, where would you expect the highest stress in the shaft?
3. Determine the total bending moment and torque at the location of highest stress.
4. Design the shaft.

Shaft Connection Hardware Design Calculations (4 points)

5. Design/Select a rectangular key for transmitting torque to the pulley.
6. Design/Select an appropriate set screw for securing the pulley and the key axially.
7. Design/Select the pin for connecting the blade hub to the shaft.
8. Design/Select a retaining ring for securing the shaft axially.

Design Drawing and Bill of Materials (1 point)

9. Produce a CAD drawing of your final shaft design, including all features, dimensions and tolerances. **Do not provide drawings for the key, screw, pin, or retaining ring** because they are purchased parts. Produce this drawing as a separate PDF file, suitable for sending to a shop for quote or fabrication, and include it as part of your assembled submission.
10. Provide a Bill of Materials for the shaft, retaining ring, pin, and key, including part numbers and costs. *You will also be required to enter these into the separate Canvas quiz.*

Acceptable and Economically Viable Design (1 point)

If your design is acceptable in terms of the loads and lifetime requirements, you will earn 0.25 points. If the final cost is within 50% of the nominal design cost, you will earn an additional 0.25 points. Finally, if the cost is within 25% of the nominal design cost, you will earn the final 0.5 points.