PUMP CO

You've got the money and we've got pumps!

TO: Mechanical Engineering Staff
FROM: David R. Smith
DATE: 19 October 2020
RE: Next task (due on *Canvas* by 11:59 pm, 30 October 2020)

While the senior engineers are reviewing your support design, your next job is to design the impeller shaft, the connecting hardware, and bearings for the pump.

A side view of the general layout is shown in Figure 1 below. The front and back **housing walls** provide support support to the **impeller shaft** via sealed rolling element **bearings**, which fit against **shoulders** in the walls. The impeller shaft passes through both housing walls and extends at the back end through a **seal plate** into the **pumping cavity**, where it is connected to the **impeller**. Axial motion of the shaft is resisted by use of **retaining rings** outside each bearing. The impeller is connected to the shaft by a **tapered pin**. At the front end, the shaft is driven by a **pulley**, which is driven by a belt (not shown). The pulley transmits torque to the shaft via a **key**. Because the belts act vertically, the relatively small axial loads on the pulley are resisted via a **set screw**.

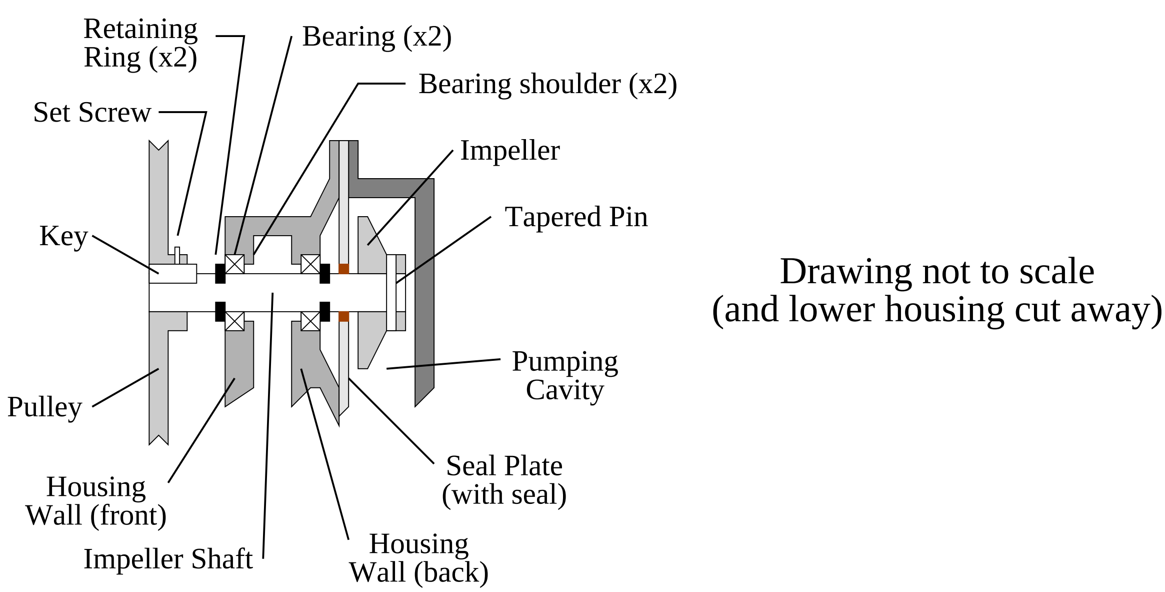

Figure 1: Impeller Shaft Layout

The dimensions and loading are shown in Figure 2 below. At the front end of the shaft, there is a pulley with an 8" pitch diameter. As you reported from your design of the support system, the belt applies parallel loads of 150 N on one side of the pulley and 286.4 N on the other when pumping water at the rated power. At the rear end of the shaft, the impeller reacts an equal and opposite torque, as well as an axial load of 200 N, as shown. The shaft extends 50 mm from the front housing wall so that the pulley can be installed flush with the end of the shaft.

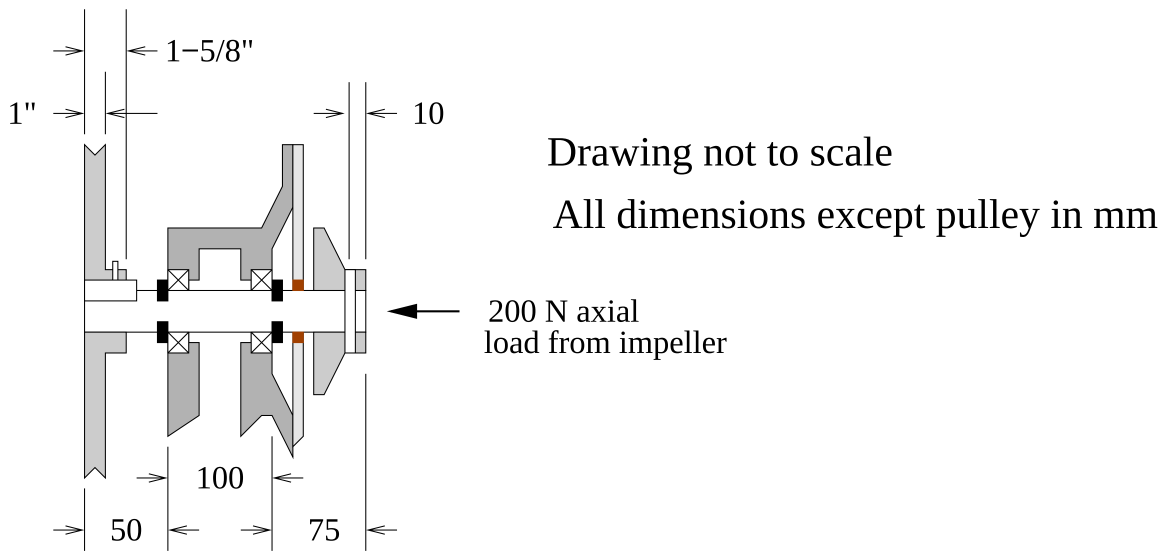

Figure 2: Dimensions

Requirements

The initial requirements, in no particular order, are given below. Additional clarifications, if needed, will be posted on *Canvas*.

1. You must design the **shaft**, its **connection components** (key, tapered pin, and retaining rings), and its supporting **bearings**. Additionally, you must provide the requirements for the minimum **housing wall thickness** and hole **sizes and tolerances**.
2. To allow for overloads, assume a factor of safety of 1.5 for the shaft and 1.2 for the keys, retaining rings, and pins.
3. The shaft must be designed for infinite life.
4. The bearings, which must be identical, are expected to operate for 10,000 hours. Since they are replaceable, it is sufficient for them to have 90% reliability at this life and there is no additional factor of safety required for these elements for this design. As stated in Design Problem #1, the pump runs at 1,800 RPM.
5. To provide a consistent supplier and cost basis across all designs, all components and material must be available at McMaster-Carr. All cost estimates will be based on the cost per length of the shortest available length that is sufficient to make the shaft from the part number you provide.
6. Material requirements: The shaft must be selected from the available precision shafts in either 303, 304, or 316 stainless steel. We want our tapered pin to be from 416 stainless (as discussed in class), but you may select from the 18-8 options in McMaster-Carr and assume that pins from 416 stainless would have comparable cost. The retaining rings should be steel, but with some corrosion resistance. The key may be any non-stainless steel material and the set screw may be any available part number sufficient for the design requirements.
7. You must specify the tolerance for the shaft, the bearing mounting hole, and the shoulder through hole.
8. Since all designs will have to have the tapered hole for connection to the impeller, the grooves for the retaining rings, and the keyway for connection to the pulley, you do not have to include those in your cost.

Design the Drive Shaft, Attachments, and Bearings

Show your design calculations for the following. **In all cases, state all of your assumptions and include the calculations necessary to justify your result.**

Shaft Design Calculations (3 points)

1. Calculate and report the reaction loads at the bearings.
2. Including any stress concentration effects, Where would you expect the highest stress in the shaft?
3. Determine the bending moment and torque at the location of highest stress.
4. Design the shaft.

Shaft Connection Hardware Design Calculations (3 points)

5. Design a rectangular key for transmitting the torque from the pulley to the shaft.
6. Choose an appropriate set screw for securing the pulley axially.
7. Design and select the tapered pin for transmitting the torque and axial load to the impeller.

Bearing Design Calculations (2 points)

8. Select a sealed bearing appropriate for the design.
9. State the minimum thickness for the housing walls and the hole sizes and tolerances for both the bearing and the through hole of the shoulder.

Design Drawing and Bill of Materials (1 points)

10. Produce a CAD drawing of your final shaft design, including dimensions and tolerances. You do not need to provide drawings for the key, screw, pin, or retaining rings. Produce this drawing as a separate PDF file, suitable for sending to a shop for quote.
11. Provide a Bill of Materials for the shaft, retaining rings, pins, key, and bearings, including part numbers and costs. *You will also be required to enter these into a separate Canvas quiz.*

Acceptable and Economically Viable Design (1 points)

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 20% of the nominal design cost, you will earn the final 0.5 points.