ME3180, Design Problem #1
Pump Support Structure Static Design

Due (on Canvas) by 11:59 pm, 2 October 2020

Welcome to PumpCo! You've got the money and we've got pumps!™

We're glad to finally have another mechanical engineer on staff. While your senior colleague will be able to give some top-level guidance, we've really been needing someone to handle the design and calculations of the mechanical elements while they work on the impeller design.

Following flooding events near rivers and coastal areas, an important part of the clean-up is to pump water out of low areas. Our proposed system for a small-capacity new entry into this market is shown in Figure 1. In this concept, a centrifugal **pump head** is mounted to a **support structure** that is mounted into or close to the water. The pump head is driven by an **engine or motor** via a **belt and pulley** system.

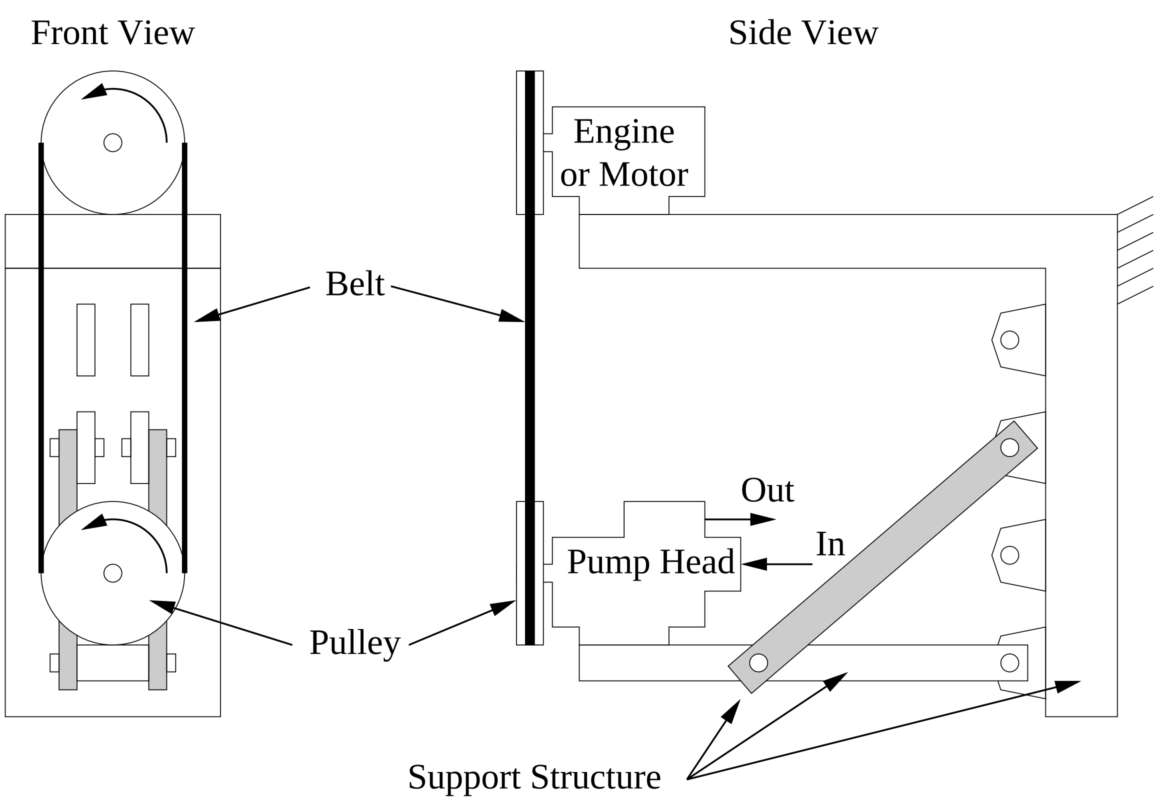

Figure 1: System Layout

To mount to our structure at different heights, we need to you design a **pump platform** and **support arms** as shown in Figure 2. The pump platform connects via easily-removable pins (one on each side) to a mounting point on the structure. The two identical support arms connect to the next connection up (also via pins), on the structure and to the sides of the platform at the location shown.

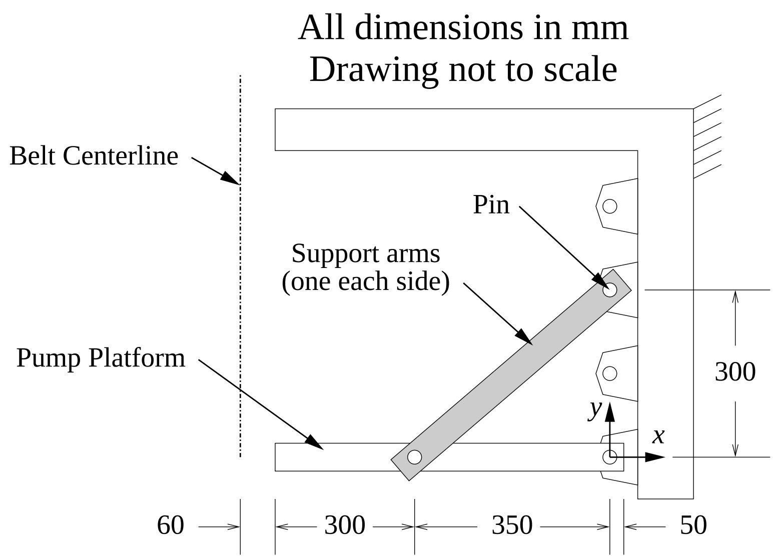

Figure 2: Platform Layout and Dimensions (lengths in mm)

Requirements

The initial requirements, in no particular order, are given below. Additional clarifications, if needed, will be posted on *Canvas*. **You are responsible for any changes posted there.**

1. The pump must deliver 150 GPM to a height of 60'.
2. The design team working on the impeller for the pump says you can expect a pump efficiency of 65% at this required flow rate and pressure head when the input shaft is driven at 1800 RPM.
3. The pump platform must be made from a single beam of a stock size available on McMaster-Carr. The top and sides must be planar and must be perpendicular to each other (to work with the planned layout for the pump mounting and pin connection).

4. Since this platform must also be consistent with an existing model of pump head, there is a required hole pattern of 3" by 4.5", as shown in Figure 3. These hole centers must be at least 12 mm from the sides of the platform.

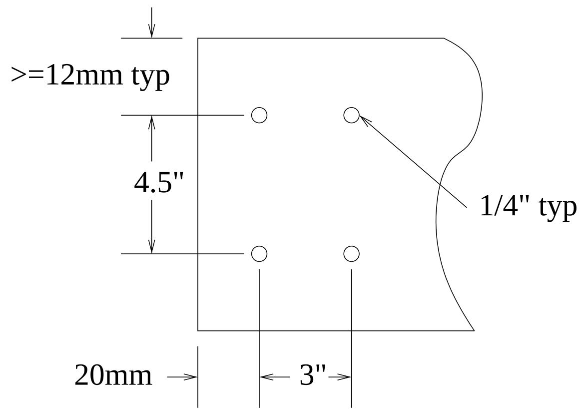

Figure 3: Hole Pattern Dimensions

5. The pump is expected to weigh 150 N, centered in the mounting hole pattern.
6. The pulley centerline is located 60 mm from the end of the platform.
7. The belt alignment is expected to be close enough that you may treat those forces as vertical.
8. The pre-load in the belt drive system will be such that the side of the belt system under the **least** load will have a tension of 150 N under operating conditions.
9. The support arms are connected by removable pins to the mounting lugs on the support structure at one end and to the pump platform at the other end. There will be an identical support arm on each side of the platform. The minimum spacing between any free edge and the center of the mounting pin hole must be at least two times the diameter of the pin.
10. The bending deflection at the end of the platform must be $\leq$0.5 mm. For this calculation, you may ignore any deflection of the support arms.
11. The pitch diameters of the pulley on the pump and on the system driving it are both assumed to be 8" (203 mm). The pump pulley spins counterclockwise seen in the front view of Figure 1.
12. Your design must have a factor of safety of at least two (2) with respect to the yield strength of the material and for any buckling loads.
13. Since everything will be near water, materials with some corrosion resistance or surface protection are preferred.

Design the Pump Support Structure

Determine the Loads (3 points)

1. What is the fluid power required by these specifications?
2. What is the mechanical power must be supplied to the rotating shaft of the pump head to deliver the required fluid power?
3. What are the forces/moments acting on the platform due to the pump weight and the belt loads? If the coordinates are as shown in Figure 2, with the '0' in the z direction at the centerline of the platform, where is each force located?
4. What is the load in each support arm? Assume that the supports react out all of the torsion load along the long axis of the platform. That is, the y components of the pins connecting the platform to the fixed structure are equal.
5. What are the loads at each of the pins in this design?
6. What is the magnitude of the peak bending moment in the platform, and where does it occur?

Provide your Design of the Pins (2 points)

1. Select an appropriate clevis pin that would be suitable for use at all of the pinned connections. Provide a McMaster-Carr part number.
2. Specify the hole diameter tolerance you require for these pins.

Provide your Design of the Support Arms (2 points)

1. The support arms must be simple rectangular bars with holes at the appropriate locations for the pins. Design the support arms, choosing your cross section to meet the requirements. Clearly state your selected width and height.
2. Show calculations to justify the performance in terms of the local stresses at the pin connections (including any stress concentration effects), the overall axial strength, and the resistance to buckling.
3. Produce a CAD drawing, including dimensions and tolerances, suitable for fabrication and official documentation.
4. Provide a McMaster-Carr part number and cost for the material.

Provide your Design of the Pump Platform (2 points)

1. Design the pump platform beam, choosing your cross section to meet the requirements.
2. Show calculations to justify the performance in terms of the local stresses at the pin connections the overall bending strength, and the approximate stresses due to the

torque on the pulley. **NOTE:** as a new employee, it is unlikely that you ever studied torsion in non-circular beams. You are expected to use your resources to figure this out and to cite your sources.

3. Show calculations to justify the performance in terms of the deflection of the end of the centerline of the pump platform (you may ignore torque for this part).
4. Produce a CAD drawing, including dimensions and tolerances, suitable for fabrication and official documentation.
5. Provide a McMaster-Carr part number and cost for the smallest standard amount of the material sufficient to build the platform.

Economically Competitive Design (1 point)

1. Provide a summary table for your bill of materials, including the total cost of materials for the pump platform, the two support arms, and the pins. Since everyone will have to drill the nearly the same holes, you do not have to provide a machining estimate.

If your final procurement cost is within 20% of the cost of the best acceptable design (either my solution or the best practical design produced by the class, **whichever is better**), you will receive one (1) point for this section.

If your final design is within 50% of the cost of the best acceptable design, you will receive a half (0.5) point for this section.

Designs outside this price range and designs that do not meet specification will receive no points for this section.