TO: Valued New Engineering Employee
FROM: Fandom Engineering team
RE: Design Problem #1: Fan Drive Support Structure Static Design
Due by 11:59 pm, 27 February 2026

We're glad to finally have another mechanical engineer join the staff at *Fandom*! We mean it when we say "Welcome to our fan-ily!"™ While your senior colleague can give some top-level guidance, we've really been needing someone to handle the design of the mechanical parts while they work on the fan blade manufacturing details.

We're developing our new design for a 1.8m diameter commercial warehouse exhaust fan. The current proposal is an easy-to-disassemble single-support-strut design to simplify field maintenance. Our concept is shown in Figure 1 and works as follows: The **motor** is mounted in the lower corner of the **fan shroud structure**. The **fan support box** is connected to a **vertical strut** using two **connecting pins**. The vertical strut can be easily attached to (or removed from) the fan shroud structure by a **mounting pin** connection to a **bracket** at each end. After installing the lower mounting pin, the **belt** is placed around the **drive pulley** and the **fan pulley**. Finally, the belt is properly tensioned by rotating the vertical strut into position and installing the upper mounting pin.

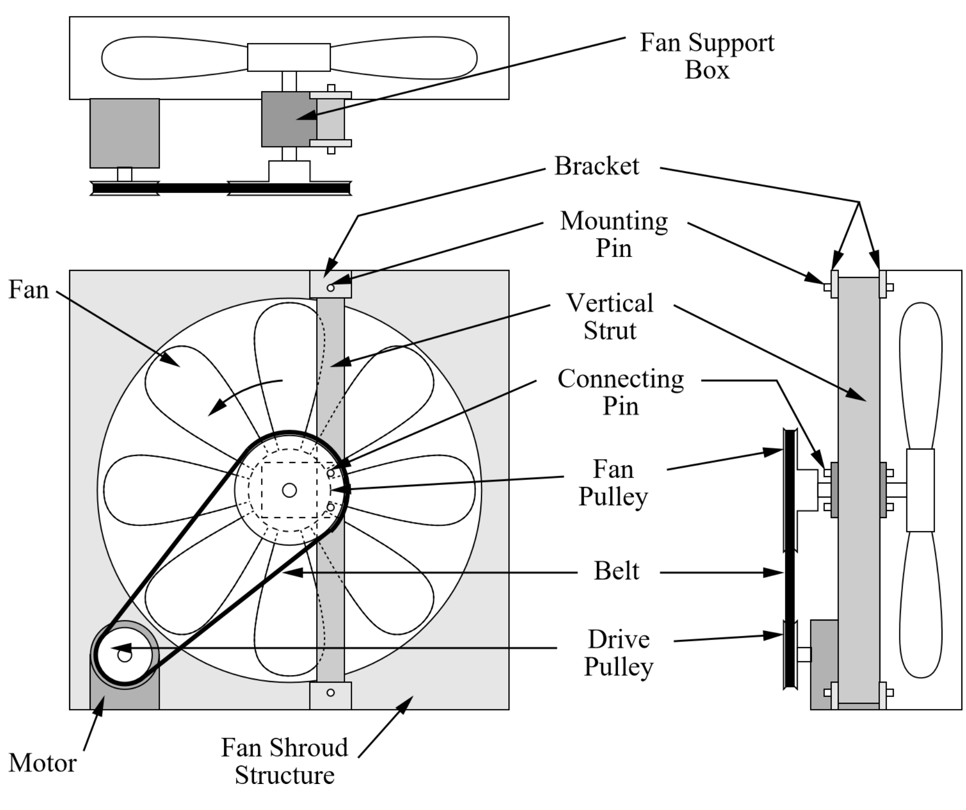

Figure 1: System Layout (not to scale)

We need you to design the **vertical strut** and the **pins**. To match the existing fan shroud structure design (from another product in our catalog), the fan centerline and the motor locations are specified, as shown in Figure 2. All pins must be on the strut centerline (x direction). For their positions along the strut, the connecting pins between the fan support box and the vertical strut must be centered vertically (y direction) and the pin centerlines must be separated by 3”. However, there is some allowable range in the location of the mounting pins at each end of the vertical strut. You may place those pin connections anywhere in the range shown. The center of gravity of the fan and its support box are on the rotation axis of the fan, and have the indicated position along the z axis.

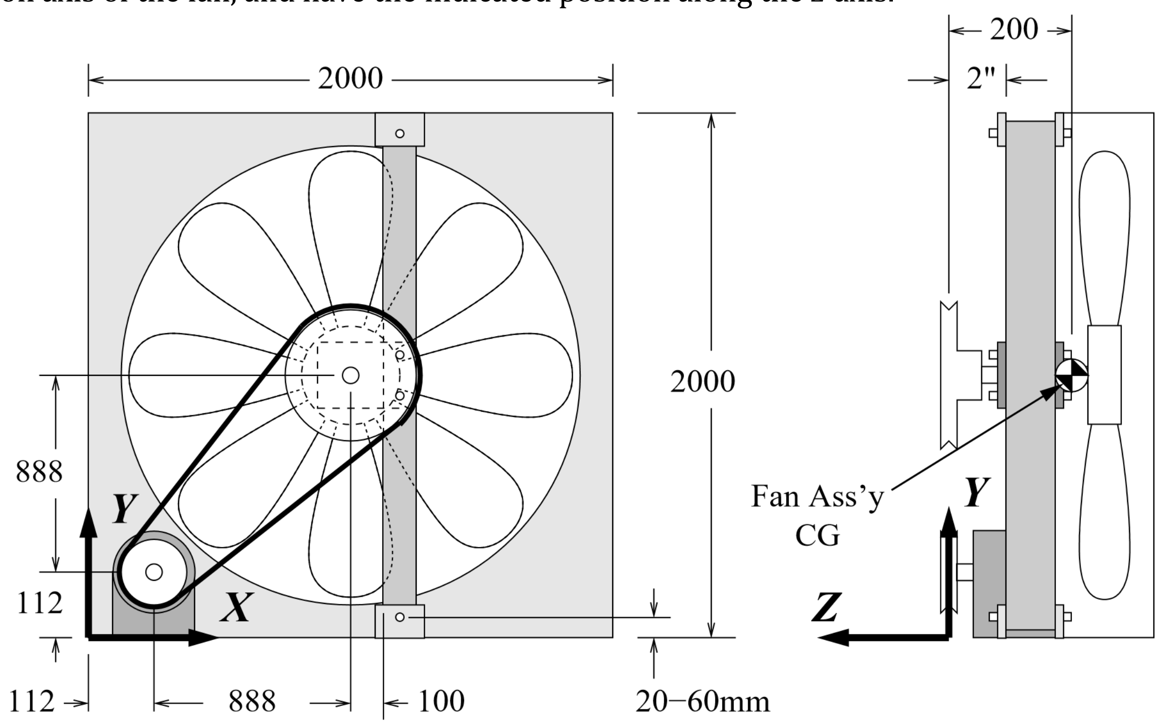

Figure 2: Layout and Dimensions (not to scale)

Requirements

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

1. The fan must deliver 30,000 CFM at a static pressure of 1/8” (inches of water) under normal operating conditions.
2. The fan design team expects an overall fan efficiency of 38% at this flow rate and pressure when the fan shaft is driven at its constant rated speed of 320 RPM.

3. The vertical strut must be made from a single piece of a stock size available from McMaster-Carr. In order to work with the layout for the mounting pins, the left, front, and rear (as shown in Figure 1) must be planar and the left must be perpendicular to the front and rear.
4. For this design, the pitch diameters of the pulleys are 15” at the fan and 4” at the motor (our standard motor turns at 1,200 RPM).
5. The fan pushes the air in the $-z$ direction at the indicated static pressure.
6. The belt drives the fan counterclockwise facing the pulley (Figure 1). The rotation axis is 100 mm from the left face of the vertical strut (Figure 2).
7. The pre-load in the belt drive system is 130 N. This is enough that the side of the belt under the **least** load will have a tension of 45 N under operating conditions.
8. The weight of the fan assembly (fan, shaft, and pulley) is 300 N. As shown in Figure 2, the center of gravity is centered on the rotation axis and is located 200 mm towards the fan, measured from the belt centerline.
9. The design is intended to be easy to service. As a result, the connections to the vertical strut are made by hand-removable pins: one at each end of the strut and two to connect the fan support box to the strut. Installation and removal of the pins must not require a hammer, press, or similar tool. For all pins, the minimum spacing between any free edge of the strut and the center of the mounting pin hole must be at least two times the diameter of the hole.
10. You may assume that the fan support box, the fan shroud support, and all connecting brackets don’t deform enough to worry about. All connecting brackets are 1/4” thick steel (yield strength 50 ksi). Because the support is symmetric, you may assume that the torsional and axial loads along the vertical strut are shared uniformly by the pins.
11. Your design must have a factor of safety of 1.75 with respect to the material strength.
12. The magnitude of the total deflection of the fan assembly center of gravity (including any motion due to twist of the vertical strut) must be ≤0.2 mm.
13. The total twist angle in torsion of the vertical strut must be ≤0.004°.

Fan Support Structure Design

Determine the Loads (3 points)

1. What is the fluid power required by these specifications?
2. What is the mechanical power that must be supplied to the fan shaft to deliver the required fluid power?
3. There are many forces, moments, and reactions acting on the vertical strut. Provide a table of the **locations** (coordinates) of all forces and moments on the system that affect the design of the vertical strut, along with the **vector components of the corresponding forces and moments**. Use the coordinate system shown in Figure 2.
4. What are the total reaction forces and moments acting at the centerline of the vertical strut at each pin location?
5. What are the loads at each side of each pin in this design? For each of the four pin locations, label the forces as 'Front' for the side of the pin closest to the pulley and 'Rear' for the side of the pin closest to the fan.
6. What is the magnitude of the peak axial load, the peak bending moment in each direction, and the peak torque on the vertical strut, and where does each occur?

Provide your Design of the Pins (2 points)

1. Select an appropriate pin that would be suitable for use at **all** of the pinned connections. That is, all of the pins must be identical. Justify your selection with appropriate calculations. Additionally, **you must be able to install them without cutting additional holes in the vertical strut aside from the pin holes.** Provide a McMaster-Carr part number and cost for the pins.
2. Specify the hole diameter and tolerance you require for these pins. **NOTE:** depending on your experience in your CAD class, you might need additional information on holes and tolerances. You are expected to use your resources to make an appropriate design choice and to cite your sources.

Provide your Design of the Vertical Strut (4 points)

1. Design the vertical strut, choosing your cross-section to meet the strength and deflection requirements. In your design, you may ignore any possible stiffening or strengthening effects on the strut due to the presence of the fan support box bracket.
2. Show calculations to justify the strength performance in terms of the local stresses at the pin connections and the overall axial, bending and torsional stresses. **NOTE:** as a new engineer, it is unlikely that you ever studied torsion in non-circular beams. You are expected to use your resources to make this calculation and to cite your sources.

3. Show calculations to justify the performance in terms of the deflection of the CG of the fan assembly and twist angle of the strut.
4. Produce a CAD drawing of the vertical strut, suitable for quote/fabrication and appropriate for official documentation.
5. Provide a McMaster-Carr part number for your selected cross-section. Your price should be for the **shortest** piece of stock that is long enough to use in making the vertical strut. Do not reduce the cost if your length is shorter than the stock piece.

Economically Competitive Design (1 point)

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

   For this section:

   If your design meets all specification and has a final procurement cost within 25% of the cost of the reference design (my solution), you will receive 1 point.

   If your design meets all specification and has a final procurement cost within 50% of the cost of the reference design (my solution), you will receive 0.5 points.

   If your design meets all specification, but is more expensive than the cases above, you will receive 0.25 points.

   Designs that fail to meet all of the specifications will receive no points.