EM120, Engineering Statics
Project 2007

Objective:
Your team is to design a link which will secure a rotating blade while minimizing the weight of the link. Assume that a novel helicopter rotor blade has been developed which requires the blade to be offset from a radial line that passes through the center of rotation of the rotor. The concept for holding the blade in place has been developed and is shown in Figure 1.

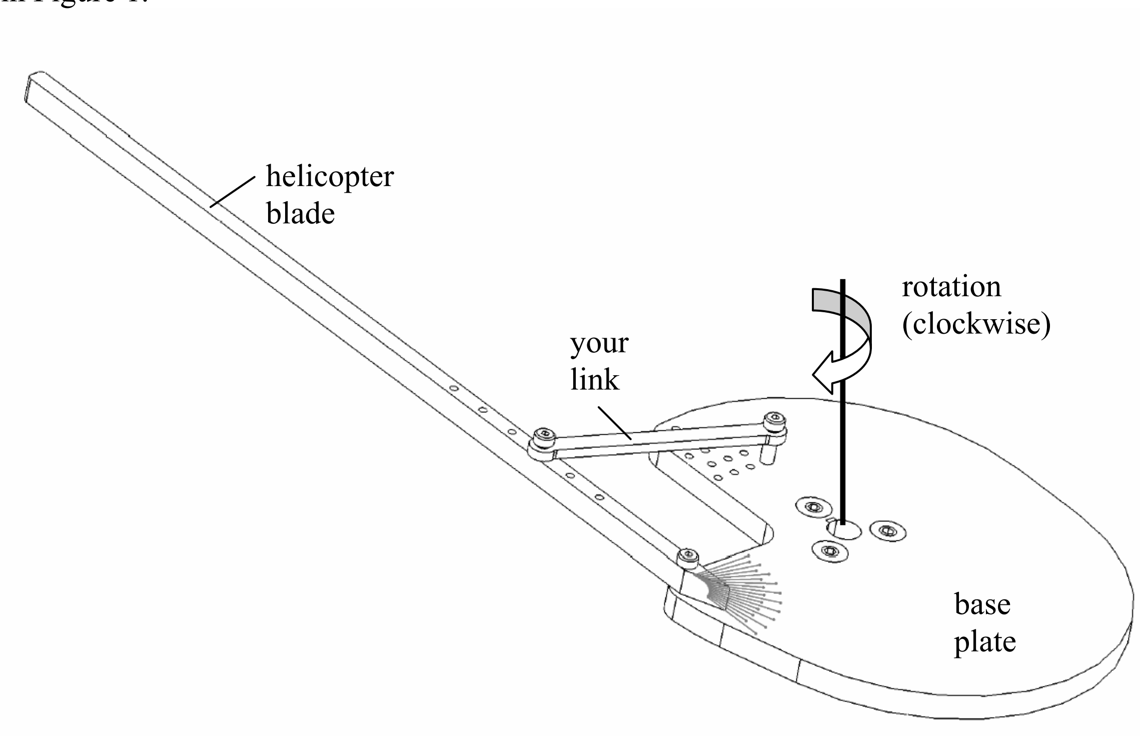

Figure 1
Isometric View of Rotor and Blade Assembly

Your link must hold the blade in place without excessive deflection up to a rotational speed of 1300 rpm. To determine if there is excessive deflection or failure of the link, a small paper doll will be placed at a distance of 19 inches from the center of rotation of the rotor, which is just outside the circle traced by the spinning blade. If the doll is not damaged after the blade reaches 1300 rpm the deflection of the link will be judged acceptable.

Link Material:
The material that you will use to create the link is Nylon 6/6. The Young's Modulus of the Nylon is reported in a handbook as 470,000 psi. The available thicknesses and the associated ultimate tensile strengths (obtained by your instructors) are shown in Table 1.

Thickness	Ultimate Tensile Strength
0.065 in	7.9 ksi
0.094 in	9.3 ksi
0.124 in	10.3 ksi
0.192 in	9.4 ksi

Table 1. Available Thicknesses and Ultimate Strengths

Fabrication:
Your link will be fabricated using a computer controlled laser cutter. You will select the thickness of the material and then have the laser cut the outside perimeter of your link. The cutting accuracy of the machine is approximately ± 0.004 inches. You will draw your link using SolidEdge software. Make a solid model, then create a drawing of the solid model, and save this drawing and submit it as a *.dxf file (sectionxx_teamname.dxf).

Rotor Description:
A portion of a dimensioned drawing of the rotor assembly is shown in Figure 2. The dimensions shown in the figure are in inches. The overall length of the blade is 17.64 inches. The blade material is aluminum. One end of your link will be joined to the blade by a shoulder bolt at one of the holes that are spaced 0.79 inches apart. You are free to select which of these holes you use. The other end of your link will be joined to the rotor by a shoulder bolt at the holes that have the 0.39 inch spacing as shown on Fig. 2. You are free to select which of these holes you use. The shoulder diameter of the shoulder bolts that will hold the link is 0.250 inches. The height of the blade is 0.500 inches and the width of the blade is 0.375 inches. The mechanism can be found in DL201 near the machine shop. You are encouraged to visit the shop and view the mechanism. However, *don't turn the rotor mechanism on* and remember to wear safety glasses and closed-toe shoes while you are in the shop.

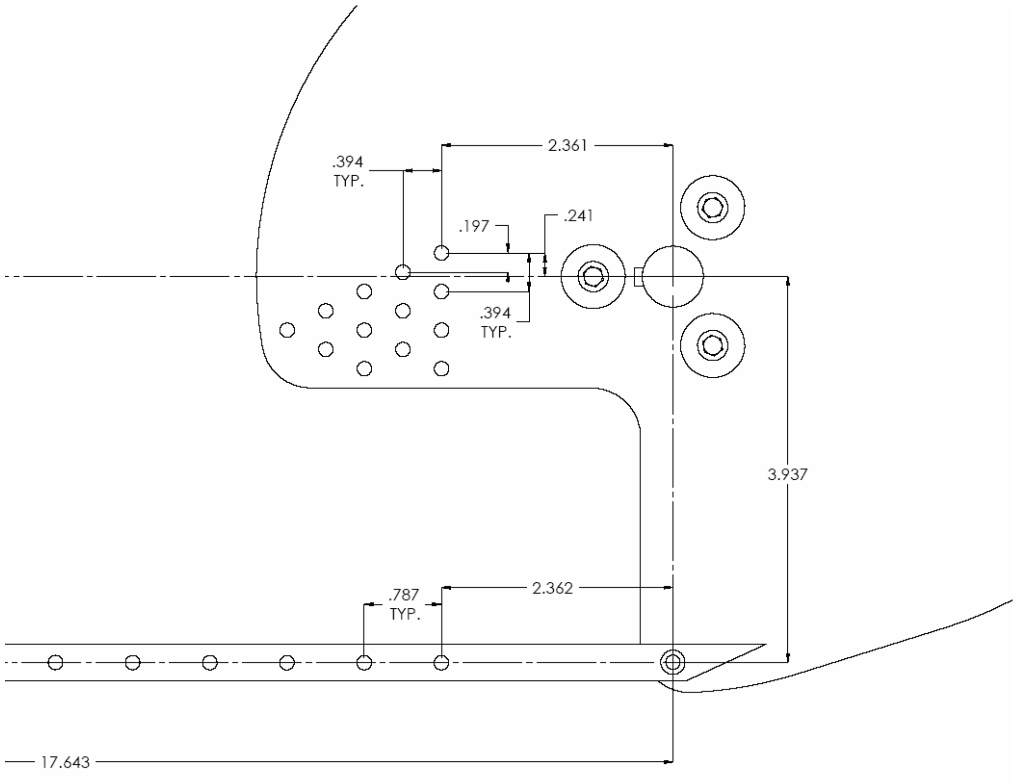

Figure 2
Dimensioned Drawing of Rotor Assembly

Important Project Dates:

- Monday, 4/16: receive project assignment and begin work
- Friday, 4/20: classtime to work on project
- Friday, 4/27: classtime to work on project
- Friday, 5/4: classtime to work on project, submit final drawing file
- Friday, 5/11: final check and submission of actual link
- Monday-Friday, 5/14-5/19: testing by section in Meyers Presentation Room (M137). When your section is not testing you may view the other tests or you may work on your web pages.

Deliverables:

- Link drawing file (Due 5/4 at the end of class)
  - The file should be a *.dxf file.
  - The file should be in inches.
  - The file should contain only the 2-D drawing of the link. Do not include dimensions or a titleblock. There is a sample file on the webpages for the course (under "Labs")
  - The file should be named sectionxx_teamname.dxf. This is the only way we have to identify your file so get this right!

- Turn in your file by copying and pasting it to the AFS drive
  T:\me\EM 120 Statics\Section xx Link Drawings
  (T is the class drive)
- Doll (Due Friday, 5/11 at start of class)
  - The doll should be a rolled piece of plain white copier paper with a diameter of 1.5 inches and a height of 2.5 inches.
  - Feel free to decorate your doll. Do not fill the doll with red paint or anything similar, as amusing as that might initially seem.
  - Your doll must have your team name and section written on it.
- Link (Due Friday, 5/11 at the end of class)
  - On Friday, 5/11, you will receive your link during class. You will not be able to fabricate a second link.
  - When you have inspected your link and are ready to turn it in, you will also fill out a link turn-in form indicating which set of mounting holes should be used for your link. This form will also be used to record the official weight of your link, which will be determined by contest officials before the contest itself.
- Webpage (Due Saturday, 5/20 at 5pm)
  - Your webpage should provide the following information in a well organized manner:
    - Project Objective
    - Predicted performance (weight and safety factor)
    - Design process
    - External Load Calculations
    - Link Load Calculations: (must include free body diagram)
    - Team information
  - You will receive more information on the webpage specifications later.

Grading:

Webpage Documentation: 75%

Performance 25%

Does it Function? (at 1300 rpm is your doll uninjured?)

- No: your performance score is 55.
- Yes: your performance is based on the weight of your link (light is good)
  - Top in section: 100
  - Top third in section: 95
  - 2^{nd} third in section : 85
  - Bottom third in section: 75

Frequently Asked Questions: These will be posted on the "Labs" page of the course website as they are accumulated.

Additional Design Information:
We can reasonably expect there to be at least two kinds of external forces acting on the blade, which will have to be carried by the link and the pivot. The first kind of force would simply be due to the angular acceleration of the aluminum blade. The second kind of force would be due to air drag on the blade.

To calculate the forces due to the angular acceleration of the blade, you would find the centroid (!) of the part of the blade past the pivot point, and then the resulting forces would act there, pointing radially outward from the center of rotation. You should be able to figure out the forces by using material you learned in physics.

For the forces due to air drag, we will need some new information. The air drag on any small slice of the blade at these speeds is proportional to the square of the air velocity on that small slice.

$$dF = kV^2\,dx$$

Hence, the distributed force on the blade goes like the square of the distance from the center of rotation, much like the distributed loads on beams that we covered just before break. The constant of proportionality is

$$k = \frac{1}{2}\rho\, h\, C_D$$

where

ρ	=	Air density
h	=	Height of the blade, 0.5”. (This is the cross-sectional area of bar per unit length.)
C_D	=	Coefficient of drag, typically 1.0 for bluff bodies such as our blade.