Copy of Bike Crank - Pre-Analysis & Start-Up

Author: Rajesh Bhaskaran, Cornell University

Pre-Analysis & Start-Up

Pre-Analysis

In the pre-analysis step, we review the:

- Mathematical model
- Numerical solution strategy
- Hand calculations of expected results

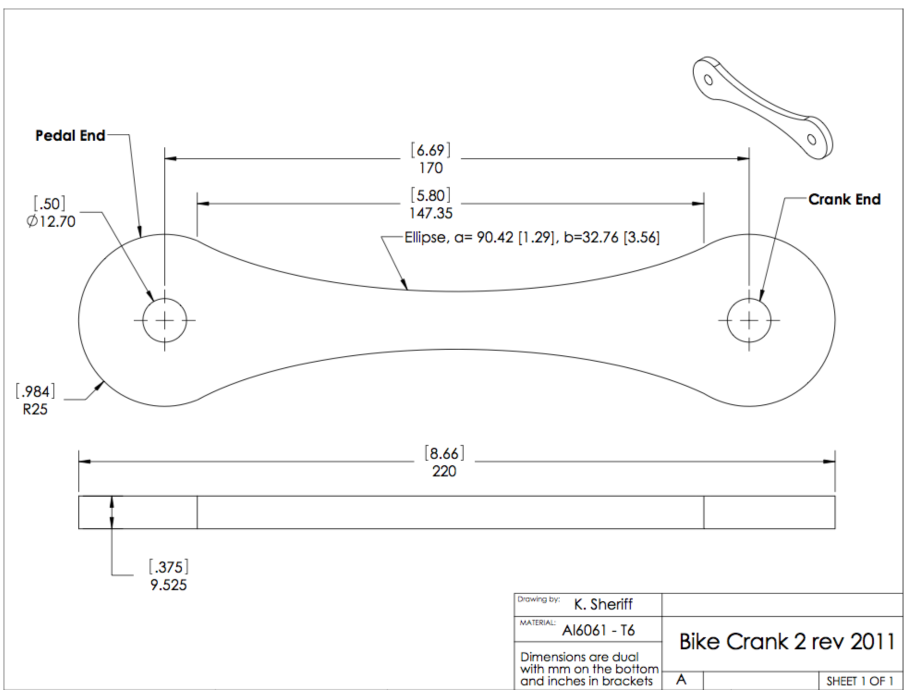
Total Deformation

The first back-of-the envelope blah blah calculation that we will make is for the total deformation of the crank under the specified applied load. A list of different cantilevered beam loading cases along with their closed-form maximum deflections formulas can be accessed on this website. Because our beam is loaded at the second hole instead of at the tip, our loading is best represented by the case 2 presented (i.e for a cantilevered beam with a concentrated load, P, at any point). The appropriate formula for the maximum deflection is therefore

$$\delta_{max} = -\frac{Pa^2}{6EI}(3L - a)$$

where "P" is the load, "a" is the distance from the support to the load, "L" is the distance from the support to the end of the beam, "E" is Young's Modulus and "I" is the moment of inertia.

Using the dimensions provided below, we can determine "a" to be 6.69 in and "L" to be 7.674 in.



We also know that "P" is 100 lbs and "E" is 10,000 ksi. The tricky part is to determine the moment of inertia. Recall that for a rectangular cross-section of height h and depth b,

$$I = \frac{1}{12}bh^3$$

where "h" is the height and "b" is the depth. In this case we know that the depth is 0.375 in but what should we do about this varying height? Since height varies as a function of x, the moment of inertia also varies with x. Finding the maximum deflection for a varying moment of inertia is actually very complex. The goal here is not necessarily to get the exact answer but to get a reasonable idea of what we should expect our ANSYS solution to be.

One simplified approach is to estimate a reasonable average beam height in order to proceed with the moment of inertia calculation. From the diagram above, the maximum height is 2*0.984 = 1.968 in. The minimum height can be approximated as 2*(1.29-0.984) = 0.612 in if one subtracts the radius of the left circle from the ellipse (the ellipse makes the curvature). From the maximum and minimum heights, we find that the average beam height is 1.29 in. But you and I know that greater deflection arises from the thinner part of the crank and so using the average beam height will likely undershoot the actual maximum deflection. So let us take a value for h that is slightly below the average beam height, say 1 in.

We now have all variables needed to find the maximum deflection. Using the equations above, we estimate the maximum deflection to be 0.039 inches.

σ_x

along the height of the cross-section

Now we wish to do hand-calculations to predict the stress in the x-component across the height of the cross-section at the thinnest part of the crank (i.e the middle). Because

σ_x

is linear along the height of the cross-section, and because from symmetry, the value at the top of the cross-section is the same as the value at the bottom of the cross-section, one can simply calculate the

σ_x

at the top to compare with ANSYS. This value is the only real unknown because stress at other heights are directly dependent on that value and can be found quite easily by interpolation. So let's calculate

σ_x

at the top of the cross section. Dividing the minimum height found above by two, we find the coordinate of this point to be (3.345", 0.306") with the origin at the left hole center.

$$M = -P*(L - x) = -(100)*(6.69 - 3.345) = -334.5 lb*inches$$

$$I = \frac{1}{12}bh^3 = \frac{1}{12}(0.375)(0.612)^3 = 0.00716 in^4$$

$$\sigma_x = \frac{M*y}{I} = \frac{-334.5*0.306}{0.00716} = -14295.7 psi$$

We now have a good idea of what to expect from our ANSYS results. We will come back to these hand-calculation results in the verification and validation step. Let's now solve this problem using ANSYS!

Start-Up

The following video shows how to launch ANSYS Workbench and choose the appropriate analysis system (which, under the hood, sets the governing equations that one will be solving). The video also shows how to add a new material to the material list for this project. We'll later assign our material to the model in the Physics Setup step.

Go to Step 2: Geometry

Go to all ANSYS Learning Modules