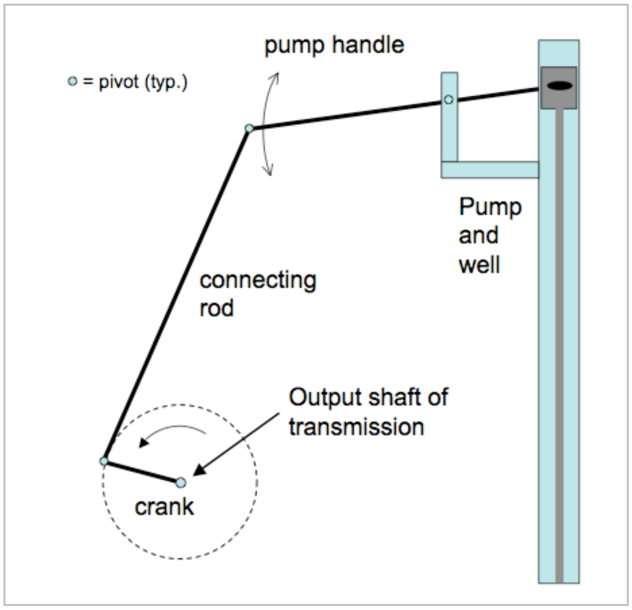
Lets use Matlab or Python to work through a gear design problem inspired by Design for Extreme Affordabilty…

You are designing a system for pumping water in the 3rd world. The pump is a deep-well pump (like you sometimes see at campgrounds in the US). Your project involves setting up an engine and transmission to power a rocker-crank linkage to pump the handle up and down. After considering various possibilities, you decide on a small steam engine, mainly because it can burn almost any liquid fuel from biodiesel to ethanol. The steam could even be generated partly by a thermal solar collector. Also, with care, it can have efficiency comparable to an internal combustion engines.[1]



Given:
The engine produces 120 inch lbf of torque at 1000 rpm (slow for a motor but good a steam engine). You require 60 lbf at the end of the crank, which is 12 inches long, which comes to at least 720 inch lbf of torque at the output of the transmission. Assuming some losses to friction, we should ask for at least 750 inch lbf.

Part I: Basic parameters and Lewis/AGMA bending stresses

1. Getting started:

- What sort of gear ratio do we need? Think about torque requirement. Also think about what would give a reasonable pumping speed of 1-2 strokes/second.
- Roughly what size (pitch, number of teeth, face width) gears might be appropriate?
- Given the gear sizes and ratio, does it seem like we want a single stage or a two-stage (compound) transmission?

2. Look at the AGMA application factors and assumptions

- What sort of overload factor, Ko, would be appropriate in this application?
- How about the mounting factor, Km?
- What sort of AGMA gear quality are we working with?
- What is the pressure angle of these gears?

[1] http://en.wikipedia.org/wiki/Modern_steam

3. Compute various intermediate values

To compute the Lewis/AGMA bending stresses we'll need some intermediate values. Some of these are computed by the script, others we need to look up. Note that the script is written to handle a two-stage transmission. For a single stage, we can ignore some of it.

Given the motor torque and the Pitch diameters, we can compute the tangential forces F_t = Ftan, and velocities, Vtan, for each gear.
The velocity factor, Kv, is computed using the AGMA factors A and B from Qv, and the equation in the class handout notes Kv = [(A + sqrt(V))/A]^B.

The Lewis tooth geometry factors, J, are looked up in Figure 15.23 from the given numbers of teeth and the pressure angle.

- Can we assume load sharing (more than one tooth in contact)? What would this depend on?

Before going any further, we should look at the various Lewis/AGMA bending stresses and compare those with the ultimate stress for steel, which is about 94250 psi. For a long lifetime, they should all be less than ½ of this value. If not, try bigger gears (more teeth, bigger face width, or coarser Pitch for the same number of teeth) before going further.

Part II: Allowable lifetime stresses

The ultimate tensile stress for steel (not cast iron) gears is Sult = 94250 psi, which we can get from the gear catalog.

- What is a good value for the reliability factor, Kr? (It is fairly sensitive – think carefully about needed reliability.)
- What is the mean stress factor, Kms, for these gears?
- What is a reasonable surface factor, Cs?
- What sort of lifetime (in cycles) should we expect for the pump? Is this an "infinite-life" application?

The script then helps you compute the fatigue stress, Sn', based on Sult and the adjusted allowable maximum stress Sn = Sn'*C_L*C_G*Cs*Kr*Kt*Kms where Kr, Kms and Cs are given above. C_L is just 1 for gears and C_G is also 1 for gears with a pitch of P=5 or higher. Kt is also 1 since we are not working at high temperature. (See class notes.)

Part III: Check contact ratios

Using the formulas in the Week 1 class notes (Gear Kinematics), we should check the contact ratio for each gear pair. The Lewis J factors depend strongly on whether we can assume "load sharing" among more than one pair of teeth. The contact ratio formula is encoded in the script.

- How does it look for each stage?
- If the contact ratio is on the low side (<1.5) what can we do to improve it?

Part IV. Check surface stresses

We should also check for surface stresses and wear. Recall that stresses are always higher on the smaller of two mating gears. The script encodes the AGMA version of the Hertz contact stresses from class notes, assuming both gears have the same material.

- How do the surface stresses look compared to allowable surface stresses, σ_z, for these gears?

Conclusions

- How do the gears all look? If one or two are a bit marginal what can we do?
- Don’t forget that when you try new gears you will have to look up and enter new Lewis J values for them.
- Parameters like face width, Pitch, quality, etc. might also change.