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Some thoughts on the ESP control system

Gene,

Here are a few preliminary thoughts on the ESP control problem we were discussing. It's probably premature to call these suggestions – let's leave them as just "thoughts". My guess is that I'm covering turf you've already been over, but if you happen to resonate with any of this, let me know and we can talk some more.

(1.) I would make sure that the wet weight of the profiler is "much greater than" 12% of the dry weight. I looked at the wave data you sent me, and (if I did it correctly) decided that the maximum acceleration of the surface was about $3.4 \frac{ft}{sec^2}$. That's about 12% of g.

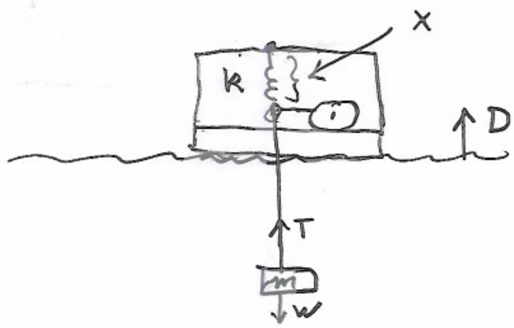
(2.) I would design a motor control system that responds to speed commands, i.e. how fast cable should be payed in/out. The bandwdith needs of this system needs to be "fast" with respect to the maximum speed command that will be issued. From the data you sent me, I think this is about $3.3 \frac{ft}{sec}$. Note, you only need this speed if you decide to implement either the feedforward or feedback terms below.

(3.) I would consider three components to a cable control system: (a) a low frequency loop that keeps the average cable length equal to the commanded profiler depth, (b) a feedforward command that attempts to "cancel" the wave action, and (c) a feedback control loop that regulates the cable tension. Of these, only the first loop (cable length) is absolutely required.

(a) For the cable length loop, I would implement an integral control loop that is simply $\dot{L} = -K_1 * (L - Lc)$. $\dot{L}$ is the commanded rate that you send to the motor control system. L is the cable length and L_c is the desired (average) length. The gain K_1 determines the bandwidth of this loop, and it should be kept small with respect to the characteristic wave frequencies.

(b) The goal of the feedforward term is to cancel the wave motion. I would recommend trying $\dot{L} = \frac{1}{s+a} \ddot{D}$. Here $\ddot{D}$ is the output of an accelerometer on board the surface component that measures vertical acceleration. (D for "disturbance.") The term $\frac{1}{s+a}$ is just a low pass filter with bandwidth a. At high frequencies $\frac{1}{s+a} \ddot{D}$ is a measurement of velocity. Hence, this term tries to pay out cable at a rate equal to the rate the surface is going up/down. There is no feedback at low frequencies. Note that I would also block the DC coming out of the accelerometer.

(c) To implement a feedback term, I would probably recommend that you install a "spring" in the system as shown below. From our previous conversation, it sounds like this is pretty common. Note, however, that I think a wide range of spring constants would be ok – if your plan is to use a feedback system.



Given this configuration, there are at least 3 options for a feedback control. All attempt to regulate the tension, or more correctly, try to keep the rate of change of tension equal to zero.

option #1: Use $\dot{L} = -K_2 * \dot{x}_{measured}$ where x is the displacement of the spring. To implement this, you'd need a measurement of $\dot{x}$. Note, this does exactly the same thing as a mechanical dashpot, so that's an alternative. Actually, using a mechanical spring and dashpot instead of any control for this stuff is probably my favorite choice.

option #2: Use $\dot{L} = -K_2 * \frac{as}{s+a} x_{measured}$. I'd do this if it was easier to measure x than its rate of change, $\dot{x}$. $\frac{as}{s+a}$ is a differentiator with some filtering.

option #3: Use $\dot{L} = -K_2 * \frac{as}{s+a}(\frac{T_{measured}}{k})$. In this case, T is your measurement of cable tension, and with the spring, $x = \frac{T}{k}$.

Does any of this make any sense? Let me know.