Motor Sizing Unusual Loads

Don Labriola

One of the fun parts of the motion industry is involvement in popular movies! Motor specifications can be a bit rough: "I need to spin a 120-pound actor (and chair) 180 degrees in one-half second. He will be sitting upright. This was the requirements for rotation portion of the half human, half CGI android bartender in "Passengers".

So how do you go about calculating what is needed? My daughter had laughed that her Physics Professor used to say — oh, you need to model a cow, a sphere should be close enough for most applications. Sometimes you can get a bit closer. I decided that a 120 lb cylinder about 14 inches in diameter would be a reasonable first order approximation. And of course, I automatically went to metric for the calculations! So mass is 54.4 kg, Diameter is .356 meters, inertia calculates to .86 kg-m^2 (½ m*r^2).

Now, for a .5 second motion with smooth transitions, splitting the motion into ramping time and slew time. A normal starting point is ⅓ accelerating, ⅓ slewing, ⅓ deceleration. The average slewing rate can be calculated as distance/(total time — ramp time) = ½ revolution/(.5–.1667) seconds. Radians are more useful here, so ½ revolution is pi radians. Peak velocity is distance divided by the "average time" which is total time minus one ramp time. Peak rotational velocity = pi radians/ .333 sec = 3 pi radians/sec = 9.425 rad/sec.

Now we need the acceleration. Assuming a trapezoidal shape, this is peak velocity/ramp time: Rotational Acceleration = maximum rotational velocity/ramp time = 9.425/0.1667) = 56.54 rad/sec^2

Peak power will be torque × angular velocity = Acceleration × inertia × peak velocity = 56.54 × .859 × 9.425 (Nm × rad/sec) = 458W (Note that 1 Nm × 1 radian/sec = 1 W)

Looking at our range of motors, the 34HC-2 can provide that power level with some to spare at about 700 rpm. The nearest a pully ratio was 8:1 which moves the peak speed to 716 rpm.

Checking the inertia levels, the motor inertia is 2.7e-4 kg-m^2. This appears to the load to be 64 times larger due to the 8:1 pulley ratio, corresponding to 1.73 e-2 kg-m^2. This is a factor of ~50 less than the "load". 50:1 is normally fairly easily tuned by our control system.

The chair was assembled, with the belt drive, big pulley on the chair, and a person wearing a back brace so they would not be thrown if they got off balance. Testing showed they were able to get the motion down to about 300 ms, so we had some margin. The final motions were smoothed and coordinated together for the shoot using a CANopen stage controller. The actual motion was closer to the original .5 second. We were told that the director liked the deep sound of the servo motor — it was a "new" sound for an android of the future — and so they recorded it separately and combined it back into the final soundtrack! **PTE**

Note: *www.youtube.com/watch?v=eUevWgyQ0kQ&vl=en* "Behind the scenes on Passengers" — about 1:50 into the video shows the mechanism and how they blended it in.

Questions or comments regarding this article? Contact Don Labriola at *don_labriola@quicksilvercontrols.com*.

Donald P. Labriola II, president and founder of QuickSilver Controls, Inc., specializes in servo controllers and motors, with a special focus on cost-effective motion control. He has been granted eleven US patents as well as numerous international patents. His background includes over 40 years of motion control including 20 years in medical instrument design. He enjoys gardening, camping and Ham radio - and motion control!