**Design Note: P48 Dome Drive Parameter and Calculations**

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The desired performance parameters for the P48 dome derived from the ZTF science requirements and agreed to in Aug. 6, 2015 meeting with R. Smith, E Bellm, E. Ofek, J. Henning, J. Zolkower are:

* ***Rotation cruising speed* = 5°/sec**
* ***Acceleration/deceleration* = ±1°/sec² = ±0.0175 rad/sec²**

Planned parameters for motor, reducer, and tire:

* ***Motor:*** **5 HP @** **1750 RPM** (=> **15 lb-ft** full load **torque @ 13.4 Amps**)
* ***Reducer:*** **60:1** ratio; **efficiency** = 98% / stage; 3 stage helical = > 0.98³ = **0.94**
* ***Tire:*** 16.25" outside diameter = **8.125" radius**; **Coefficient of Friction (CoF) = 0.7**

Dome parameters:

* Dome drive band = 42' diameter =  504" diameter = 252" radius
* Dome mass = 95000 lb
* Dome radius = 22 ft
* ***Dome inertia (I)*** = 2/3\*mr² = 2/3\*95000\*(22)² = 30.7e6 lb-ft²;
* 30.7e6 / g = 30.7e6 / 32 = 0.958e6 lb-ft-sec², round to I = **1.0e6 lb-ft-sec²**
* Measured rolling friction = 320 lb at dome perimeter (assumed constant over speed range)
* ***Dome frictional torque*** = F\*r = 320 lb \* 21 ft = **6720 lb-ft**

Speed and torque calculations:

* ***Dome:tire ratio***= 252"/8.125" = **31:1**
* ***Dome speed @ 1750 RPM motor*** = 1750 RPM/60/31 = 0.94 RPM = **5.64°/sec**
* Acceleration inertial torque: τ = Iα = 1.0e6 lb-ft-sec² \* 0.0175 rad/sec² = 17500 lb-ft
* Deceleration inertial torque (-1°/sec²) = -Acceleration = -17500 lb-ft
* Torque to accelerate/decelerate dome = Inertial torque + frictional torque
* ***Dome torque during acceleration****:* 17500 lb-ft + 6720 lb-ft = **24220 lb-ft**
* ***Dome torque during deceleration****:* -17500 lb-ft + 6720 lb-ft = **-10780 lb-ft**
* With 31:1 dome:tire ratio (assumed 100% efficient) =>
* ***Reducer accel torque*** = 24220/31 = 781 lb-ft = **9375 lb-in** (typical vendor units)
* ***Reducer decel torque*** = -10780/31 = -348 lb-ft = **-4173 lb-in** (over-running)
* ***Reducer cruising torque*** = 6720/31 = 217 lb-ft  = **2600 lb-in**
* ***Worst-case motor torque*** = reducer output torque/ratio/efficiency = 781 lb-ft/60/0.94 = **13.8 lb-ft**

Overhung load (OHL):

* Tire torque = reducer output shaft torque = 9375 lb-in worst-case
* ***Tire tractive force at contact***= τ/r = 9375 lb-in / 8.125" = **1154 lb**
* ***Required tire contact force*** = tractive force / CoF = 1154 lb / 0.7 = **1650 lb**
* Tractive force of tire generates a reaction force at shaft normal to contact force
* ***Net radial shaft force*** = √ (x²+y²) = √ (1650² + 1154²) = **2014 lb**
* Center of contact force: tire is assumed to wear such that force remains distributed over the entire tread width with its center in the middle of of the tread, which is 3" from the edge of the press-on flange.  This flange can be aligned with the base of the shaft best-case, so average overhang (or cantilever) would be 3", though instantaneously this could move farther out due to variations in dome drive band straightness; worst-case would be 5.5".
* Reducer manufacturers consider two factors: bearing life and shaft strength, and generally provide tables and/or formulas to calculate acceptable OHL from radial force and distance.

Motor & VFD notes:

* From above points, worst-case motor load torque (13.8 lb-ft) is less than rated full load torque of our motor (15 lb-ft), so the motor should always run between synchronous speed and full-load speed (97% of synchronous speed, since 1750 RPM / 1800 RPM = 97%).
* The VFD will control motor speed by varying its output frequency (0 - 60 Hz).  The motor can run at less than 60 Hz indefinitely if less than 5.6°/sec dome cruising speed is required.
* Motor current should always be less than rated full-load current (13.4A for 230VAC operation).
* The proposed ***3.7kW Yaskawa G7 VFD*** is rated **18A continuous**, with brief overloads permitted, so it should have plenty of capacity for the application. This same model drives the HA and Dec slew motors at P200, and we have a spare.
* Speed and acceleration parameters can be programmed into the drive, so run/stop contacts can provide motion control; or else pulse-stream, ±10Vdc analog, or Modbus serial commands can provide speed control.