Energy analysis of ball launch

The following page of calculations is an energy analysis of the system which should provide an idea of how much torque is required to launch the balls given our design parameters.

Energy of ball at launch

$KE = \frac{1}{2} m V^2$

$m = 0.45 kg$ for Size 5 Soccer ball

$V = 100 \frac{km}{hr} \left(\frac{1hr}{3600 Sec}\right)\left(\frac{1000 m}{1 km}\right)$

$V = 27.7 m/s$

So $KE = \frac{1}{2} m V^2$

$= \frac{1}{2}(0.45 kg)(27.7 m/s)^2$

$KE = 172.64 J$

Rotational energy $RE = \frac{1}{2} I (w_1^2 - w_2^2)$

Where I is the rotational inertia of the wheel

For a hoop, $I = MR^2$

For a solid cylinder, $I = \frac{1}{2} MR^2$

So I figure that a tire is somewhere between a hoop and solid as there is air in the tire

So for now will assume something like: $I = \frac{3}{4} MR^2$

$= \frac{3}{4}(0.45 kg)(0.1016 m)^2$ (radius = 4")

$I = 0.003484 kgm^2$

So if the KE=172.64 for the ball, then half this number and set equal to rotational energy formula to solve for w_2 after ball has been launched

$172.64 J \cdot \frac{1}{2} = 86.32 J \longrightarrow$

$RE = \frac{1}{2} I (w_1^2 - w_2^2)$

$86.32 J = \frac{1}{2}(0.003484)(273.4 \, rad/sec^2 - w_2^2)$

$w_2 = 158.73 \, rad/sec$

So the wheels drop to this speed after shooting the ball. This doesn't account for the extra torque/energy required to compress ball.

$w = \frac{V}{r} = \frac{27.78 m/s}{0.1016 m}$

$w = 273.43 \, rad/sec$

Now the time that it takes for the motors to get back up to speed will depend on the torque of the motors:

$\tau = I\alpha \longrightarrow \tau = \frac{I w}{t} = \frac{(0.003484 kgm^2)(273.4 \, rad/sec)}{5 Sec}$ (5 Sec ← example)

$\alpha = w/t$

$\tau = 0.19 Nm$