MAE 325 Wind-up Car

Rowin Andruscavage, Sara Purdy, Kevin Ring, & Kevin Scharpenberg

October 5, 1998

Tuesday Group 4

1 Legend

1.1 Geometry of vehicle

Parameter	Definition
$M_c = 0.0285kg * 6$	minimum mass of cargo
$M_b \sim M_c$	dry mass of vehicle
$H = 0.3m$	height that mass drops; length of string available
$R_w = 7.5cm$	maximal radius of car wheel
$R_s = 3.87cm$	radius of string sprocket
$R_t = 1.29cm$	radius of tension spring sprocket
$K = 10.05N$	constant force spring constant

1.2 Assumptions

-

$\eta = 0.5$: efficiency is guessed to be about half. A prototype will help us get a better estimate of this parameter.

$g = 9.8\frac{m}{s^2}$: acceleration due to gravity.

$H\frac{R_t}{R_s} \sim 10cm$: maximum extention of spring.

1.3 Energy Analysis

We begin with the total available energy $Et = 2M_cgH$. Extracted from that is the spring potential energy $E_p = force * distance$, which is E_t minus any residual kinetic energy of the falling mass and the spinning ramp pulley. E_l is the additional frictional loss in the ramp pulley :

$$Ep = KH\frac{R_t}{R_s} = E_t - \frac{1}{2}I\omega^2 - M_cV^2 - E_l \qquad (1)$$

The useful energy put into raising height of cargo h_c is the spring energy minus losses due to raising the height of the empty vehicle $E_b = M_b g h_c$ and frictional losses E_{l2} :

$$E_u = M_c g h_c$$

$$= E_p - E_b - E_{l3} = KH\frac{R_t}{R_s} - M_b g h_c - E_{l2}$$

solving for h_c gives us an expression for the maximum height the transporter can go given the energy stored in the spring

$$h_c = \frac{\left(KH\frac{R_t}{R_s} - E_{l2}\right)}{g\left(M_c + M_b\right)} \tag{2}$$

Now solve for h_c in terms the distance D that the wheels would have to cover to completely exhaust the stored spring energy. Since the car will not travel the full distance due to frictional losses, express the height of the cargo in terms of efficiency $\eta = \frac{E_u}{E_t}$. The actual distance the car travels turns out to be

$$\eta D = H\frac{R_t}{R_s}\left(\frac{R_w}{R_t}\right) = H\frac{R_w}{R_s}$$

η swallows up all of the energy loss terms. Translating $D = \frac{h_c}{\sin\theta}$ gives us

$$\eta h_c = H\frac{R_w}{R_s}\sin\theta$$

Comparing this equation with equation (2), we find an expression for the ratio of the wheel to the spring sprocket radii :

$$\frac{R_t}{R_w} = \frac{g\left(M_c + M_b\right)\sin\theta}{\eta K} \tag{3}$$

Now that η has swallowed all of our losses, we can compute K from equation (1) as simply

$$K = 2M_c g\frac{R_s}{R_t}$$

and solve for the remaining variable R_t using equation (3).

2 Static Analysis

The force on the car due to gravity should at least be balanced by the force of the spring.

$$\frac{R_w}{R_t} g\,(M_c + M_b)\sin\theta < K = 2M_c g \frac{R_s}{R_t}$$

$$R_w\,(M_c + M_b)\sin\theta < 2M_c R_s$$

For our assumed values, the spring force comes out to roughly twice as much $\left(\frac{1}{\eta}\right)$ as the force of gravity on the car.