UUC motorwerks

How can we compare the effects of rotational weight at the flywheel versus fixed weight on a car? We will calculate the relative kinetic energies of a rotating flywheel versus a fixed mass. The rotational speed of the flywheel is directly proportional to the overall gear ratio between engine speed and the wheels (transmission gear ratio times final drive ratio). Since this overall ratio depends on the transmission ratio as well as the differential ratio, we will calculate the relative effects in each gear. Some of the values will drop out in the end which will result in a fairly simple equation.

M = the equivalent mass we are trying to find

V = the vehicle speed

ω = rotational speed of the flywheel

I = rotational moment of inertia of the flywheel

m_{fly} = flywheel mass

R_{fly} = flywheel radius

Diff = differential ratio (final drive ratio)

G_{trans} = transmission gear ratio

R_{tire} = tire radius

$I := \frac{1}{2} \cdot m_{fly} \cdot R_{fly}^{2}$

Moment of inertia of a flat disk
For simplicity, we assume that flywheel is a flat disk with its mass evenly distributed across its surface.

$G_{eff} := G_{trans} \cdot Diff$

Effective total gear ratio = trans ratio times diff ratio

$\omega_{wheel} := \frac{V}{R_{tire}}$

Rotational speed of the drive wheel

$\omega_{fly} := \omega_{wheel} \cdot G_{eff}$

Rotational speed of the flywheel

$K_e := \frac{1}{2} \cdot M \cdot V^2$

Kinetic energy of a moving object

$K_r := \frac{1}{2} \cdot I \cdot \omega_{fly}^{2}$

Kinetic energy of a rotating object

$K_e := K_r$

$$\frac{1}{2} \cdot M \cdot V^2 = \frac{1}{2} \cdot I \cdot \omega_{fly}^{2}$$

$$M := \frac{I \cdot {\omega_{fly}}^2}{V^2}$$

$$M := \frac{I \cdot \left(\omega_{wheel} \cdot G_{eff}\right)^2}{V^2}$$

$$M := \frac{I \cdot \left[\omega_{wheel} \cdot \left(G_{trans} \cdot Diff\right)\right]^2}{V^2}$$

$$M := \frac{\left(\frac{1}{2} \cdot m_{fly} \cdot {R_{fly}}^2\right) \cdot \left[\frac{V}{R_{tire}} \cdot \left(G_{trans} \cdot Diff\right)\right]^2}{V^2}$$

$$M := \frac{1}{2} \cdot m_{fly} \cdot \left(\frac{R_{fly}}{R_{tire}}\right)^2 \cdot \left(G_{trans} \cdot Diff\right)^2$$

$$M := \frac{1}{2} \cdot m_{fly} \cdot \left(\frac{R_{fly}}{R_{tire}} \cdot G_{trans} \cdot Diff\right)^2$$

Oops, we only accounted for the rotational effects of the flywheel. The flywheel is rotating AND translating along with the whole car so we have to include it's translational mass. Our new equivalent mass equation becomes:

$$M := m_{fly} + \frac{1}{2} \cdot m_{fly} \cdot \left(\frac{R_{fly}}{R_{tire}} \cdot G_{trans} \cdot Diff\right)^2$$

$$M := m_{fly} \cdot \left[1 + \frac{1}{2} \cdot \left(\frac{R_{fly}}{R_{tire}} \cdot G_{trans} \cdot Diff\right)^2\right]$$

Flywheel/clutch Info.
The mass indicated below is for the entire flywheel and clutch assembly.

$M_{st} := 40 \cdot lb$ $M_{st} = 18.144 \cdot kg$

$M_{al} := 23.5 \cdot lb$ $M_{al} = 10.659 \cdot kg$

$D_{fly} := 330 \cdot mm$

$R_{fly} := \frac{D_{fly}}{2}$

$R_{fly} = 0.165 \cdot m$

Final Drive Ratio

$Diff := 3.15$

$RPM := \frac{2 \cdot \pi \cdot rad}{60 \cdot sec}$

Transmission Ratios

$G_1 := 4.23$

$G_2 := 2.53$

$G_3 := 1.67$

$G_4 := 1.23$

$G_5 := 1.00$

$G_6 := 0.83$

Wheel and tire info

$D_{wheel} := 18 \cdot in$ $D_{wheel} = 0.457 \cdot m$

$Tread := 275 \cdot mm$

$AspectRatio := 35$

$D_{tire} := \left(2 \cdot Tread \cdot \frac{AspectRatio}{100}\right) + D_{wheel}$

$D_{tire} = 25.579 \cdot in$

$D_{tire} = 0.65 \cdot m$

$R_{tire} := \frac{D_{tire}}{2}$

$C_{tire} := \pi \cdot D_{tire}$

Using the derived equation and the numbers above, we can calculate the equivalent weight reduction in any gear when using a lightweight flywheel. Don't forget to keep your units consistent.

1st gear

$$M := \left(M_{st} - M_{al}\right)\cdot\left[1 + \frac{1}{2}\cdot\left(\frac{R_{fly}}{R_{tire}}\cdot G_1\cdot Diff\right)^2\right] \qquad M = 394.384\cdot lb$$

2nd gear

$$M := \left(M_{st} - M_{al}\right)\cdot\left[1 + \frac{1}{2}\cdot\left(\frac{R_{fly}}{R_{tire}}\cdot G_2\cdot Diff\right)^2\right] \qquad M = 151.682\cdot lb$$

3rd gear

$$M := \left(M_{st} - M_{al}\right)\cdot\left[1 + \frac{1}{2}\cdot\left(\frac{R_{fly}}{R_{tire}}\cdot G_3\cdot Diff\right)^2\right] \qquad M = 75.399\cdot lb$$

4th gear

$$M := \left(M_{st} - M_{al}\right)\cdot\left[1 + \frac{1}{2}\cdot\left(\frac{R_{fly}}{R_{tire}}\cdot G_4\cdot Diff\right)^2\right] \qquad M = 48.451\cdot lb$$

5th gear

$$M := \left(M_{st} - M_{al}\right)\cdot\left[1 + \frac{1}{2}\cdot\left(\frac{R_{fly}}{R_{tire}}\cdot G_5\cdot Diff\right)^2\right] \qquad M = 37.619\cdot lb$$

6th gear

$$M := \left(M_{st} - M_{al}\right)\cdot\left[1 + \frac{1}{2}\cdot\left(\frac{R_{fly}}{R_{tire}}\cdot G_6\cdot Diff\right)^2\right] \qquad M = 31.049\cdot lb$$