Dynamic Characteristics of Vehicles

There are several forces act on a vehicle while it is motion: air resistance, grade resistance, rolling resistance, and curve resistance. The extents to which these forces affect the operation of the vehicle are discussed in this section.

Air Resistance
A vehicle in motion has overcome the resistance of the air in front of it as well as the forces due to the fractional action of the air around it. The forces required to overcome these is known as the air resistance and is related to the cross-sectional area of the vehicle in a direction. As shown in the following equation:

\[ R_a = 0.5 \times (2.15 \times p \times C_D \times A \times v^2) / g \]

Where:
- \( R_a \) = air resistance force (ib).
- \( C_D \) = aerodynamic drag coefficient (0.4 for passenger car and from 0.5 to 0.8 for truck).
- \( A \) = frontal cross-sectional area (ft\(^2\)).
- \( v \) = vehicle speed mi/h).
- \( g \) = acceleration of gravity (3.2 ft/sec\(^2\)).

Grade Resistance
When a vehicle move up a grade, a component of the weight of the vehicle acts downward, along the plane of the highway. This creates a force acting in a direction opposite that of the motion. A vehicle traveling up a grade will therefore tend to lose speed unless an acceleration force is applied.

\[ R_g = (W \times G) / 100 \]

Where:
- \( R_g \) = grade resistance (lb).
- \( W \) = gross weight of vehicle (lb).
- \( G \) = percentage of grade (\%).

Rolling Resistance
This forces that offer resistance to motion. These forces are due mainly to fractional effect on movement parts of the vehicle, but also include the fractional slip between the pavement surface and the tire. The sum effect of the forces on motion is known as rolling resistance. It is depend on the speed of vehicle and the type of pavement.

Rolling resistance for passenger car:

\[ R_r = (C_a + 2.15 \times C_b \times v) \times W \]

Where:
- \( R_r \) = rolling resistance forces (lb).
- \( C_a \) = constant= 0.0012.
- \( C_b \) = (0.65 \times 10^{-6} \text{ sec}^2/\text{ft}^2).
v= vehicle speed (mi/h).
W= gross weight of vehicle (lb).

**The rolling resistance for truck:**

\[ R_r = (C_a + 1.47C_b v)W \]

\[ C_a = \text{(constant}= 0.02445 \]

\[ C_b = (0.00044 \text{ sec/ft}) \]

**Curve Resistance**

When a vehicle maneuvered to take a curve, external forces act the front wheels of the vehicle. These forces have component that have a retarding effect on the forward motion of the vehicle. The sum effect of these components continues the curve resistance. This resistance depends on the radius of the curve, the gross weight of the vehicle and the velocity at which the vehicle is moving and can be determined in the following equation:

\[ R_c = 0.5\left(\frac{2.15v^2W}{gR}\right) \]

Where:

\[ R_c = \text{curve resistance (lb).} \]

\[ v = \text{vehicle speed (mi/h).} \]

\[ g = \text{acceleration of gravity (32.2 ft/sec^2).} \]

\[ R = \text{radius of curvature (ft).} \]

**Power Requirements**

Power is the rate at which work is done. It is usually expressed in horsepower. Where 1 horsepower is 550 lb-ft/sec. the performance of vehicle is measured in term of the horsepower the engine can produce to overcome air, grade, curve and friction resistance forces.

\[ P = \frac{(1.47Rv)}{(550)} \]

\[ P = \text{horse power delivered.} \]

\[ R = \text{sum of resistance to motion.} \]

\[ v = \text{speed of vehicle (mi/h).} \]

The figure below showed the forces acting on a vehicle during up grade.
Example: Determine the horsepower produced by passenger car traveling at a speed of 65 mi/h on straight road of 5% grade with a smooth pavement. Assume the weight of the car is 4000 lb and the cross-sectional area of the car is 40 ft².

Solution:
Note that there is no curve resistance since the road is straight.

\[
R = (\text{air resistance}) + (\text{rolling resistance}) + (\text{grade resistance})
\]

\[
R_a = 0.5 \times (2.15 \times p \times C_D \times A \times v^2) / g
\]

\[
= 0.5 \times ((2.15 \times 0.0766 \times 0.4 \times 40 \times 65 \times 65) / 32.2)
\]

\[
= 172.9 \text{ lb.}
\]

\[
R_r = (C_a + 2.15 C_b v^2) \times W
\]

\[
= (0.012 + 2.15 \times 0.65 \times 10^{-6} \times 65)(4000)
\]

\[
= 72 \text{ lb.}
\]

\[
R_g = (W \times G) / 100
\]

\[
= (4000 \times 5) / 100
\]

\[
= 200 \text{ lb}
\]

\[
R = R_a + R_r + R_g
\]

\[
= 172.9 + 72 + 200
\]

\[
= 444.9 \text{ lb}
\]

To determine horsepower produced:

\[
P = (1.47 \times R \times v) / 550
\]

\[
= 77.3 \text{ hp}
\]