Velocity and Acceleration

INTRODUCTION

The concepts of velocity and acceleration are essential to the understanding of objects that are in motion, and of the relationships between forces which are applied to those objects and the motions that occur as a result of those forces. Velocity and acceleration provide the means to quantify and predict the changes in position of an object as a function of time, or as a function of some other reference variable such as the rotation of a shaft.

VELOCITY

Velocity is defined as the rate at which the position of a body changes with respect to some reference. Typically, the reference is time, and we are all familiar with everyday expressions of velocity (speed), such as miles-per hour, feet-per-second, revolutions per minute, furlongs-per-fortnight, etc.

In addition to *time*, another common reference variable is *rotation*, or angular position. For example, the change in the position of a piston with respect to the angular movement of the crankshaft is a convenient way to study piston motion. Similarly, the change in the position of a cam follower with respect to the angular position of the camshaft is a convenient way to study valvetrain motion.

The term ***velocity*** technically refers to a vector quantity, meaning that it has both magnitude and direction. The "speed" of an object is the measure of how fast the object is moving, without regard for the direction. Saying that a car is travelling 60 MPH is a statement of its *speed*, whereas saying it is travelling 60 MPH North defines its*velocity*.

However, velocity is sometimes stated in terms of magnitude only (speed), because often the direction is self-evident. Examples of that include the motion of a piston confined to move along the axis of a cylinder, or a poppet valve constrained to move along the axis of its guide. In other cases, the direction is irrelevant. For example, the direction component of the velocity of an automobile is assumed to be coincident with the direction of the road upon which it is travelling. (When the direction diverges from that of the road, usually some very rapid acceleration is soon to follow.) For the remainder of this discussion, we will be primarily discussing the magnitude portion of the *velocity* vector, and therefore will take the liberty to use the terms *speed* and *velocity* interchangeably.

Linear Velocity is the measure of the linear (straight-line) distance something moves in a specified amount of time. It is typically calculated as *distance* divided by *time*. That calculation produces what is called *average speed*. For example, if a car travelled exactly 60 miles in exactly one hour, it would be obvious that the average speed was 60 MPH. But that calculation does not take into account any changes in direction that occurred. Nor does it take into account the fact that over the course of that 60 mile journey, the instantaneous speed of the car will most certainly have been changing, under the influence of stop lights, slower drivers, passing cars, corners, freeway offramps, a wobbly right foot, etc.

Suppose it was necessary to produce a graph showing a better representation of the car's speed throughout the journey. In the absence of a data acquisition system, we could take time and distance measurements throughout the trip. The incremental distances and times would simply be the difference between two adjacent measurements. By dividing those incremental distances by the corresponding incremental times, we would have the average speed over that smaller portion of the trip.

By decreasing the size of the time increments at which the distance measurements were taken, we would be able to get ever closer to determining the instantaneous speed of the vehicle. In fact, that is precisely what the mathematical operation known as a *derivative* accomplishes. Therefore, speed is the first derivative of position with respect to time without regard to direction, and velocity is the first derivative of position with respect to time, taking both speed and direction into account.

Angular velocity is the measure of rotational distance something moves in a specified amount of time. It is typically expressed in units such as revolutions-per-minute (RPM) and degrees-per-second.

For many engineering calculations, it is necessary to express angular units as **radians** instead of degrees, and angular velocity in units of **radians-per-second**, rather than degrees-per-second or revolutions per minute (RPM). The explanation of "why" requires more math than is appropriate here, but suffice it to say that it is necessary in order to make the numbers work out right.

A **radian** is an angular measurement equal to approximately 57.3 degrees. It is defined as *the angle formed by an arc on the circumference of a circle, the length of which is equal to the radius of that circle*. Since the circumference of a circle is the radius times 2π, then obviously the value of a radian is the angle 360° divided by 2π, or 57.29578 degrees.

ACCELERATION

Acceleration is the measurement of how quickly the velocity of an object is changing, usually with respect to time. If you measure the velocity of an object at a particular time ($Time_1$), then again at a subsequent time ($Time_2$), then the average acceleration which the object has experienced will be:

Acceleration = ($Velocity_2$ - $Velocity_1$) / ($Time_2$-$Time_1$)

Clearly, the longer the period of time over which the measurements are taken, the more that value becomes an average, and the less will be known about the instantaneous acceleration of the object.

Acceleration is a critically important value for dynamic systems, because it is the instantaneous acceleration imposed on moving (dynamic) components, along with the mass of the components, which determines the actual forces raquired or applied in order to get components within the a system to change velocity from one value to another (Newton's second law), covered previously in **Force, Pressure and Friction**).

Linear acceleration is typically expressed in inches-per-second-per-second and feet-per-second-per-second(velocity per unit time). Common units of angular acceleration are degrees-per-second-per-second, radians-per-second-per-second and RPM-per-second.

However, acceleration (and velocity as well) need not be expressed with respect to time. For example, the acceleration value typically used in camshaft lobe design is inches-per-degree-per-degree or inches-per-degree^2 . This value is the acceleration which a cam lobe applies to the cam follower it is driving. In order to calculate the forces a cam applies to its mating components, the cam lobe angular velocity with respect to time must be known. Using that value, the lobe acceleration value can then be converted into inches-per-second-per-second, from which the forces are then calculated. In 2004, for some undiscernible, but most certainly *politically-correct*, reason, the cam design community apparently switched to metric units { velocity in mm/deg and lobe acceleration in mm/deg^2 }.

Source:

http://www.epi-eng.com/mechanical_engineering_basics/velocity_and_acceleration.htm