the Henry Ford®

work, energy and power
in Automobile Racing

Question for Analysis

How is energy transformed from one type to another in automobile racing?

Key Concepts

Acceleration The rate at which an object's velocity changes; a = Δ v / Δ t.

Aerodynamics The way the shape of an object affects the flow of air over, under or around it.

Electrical energy Energy derived from electricity.

Frame of reference The coordinate system for specifying the precise location of an object, or the point or frame to which motion is compared.

Horsepower A unit for measuring the power of engines and motors based on the average rate at which a horse can do a certain amount of work; 1 hp (horsepower) is equal to 746 watts of power.

Joule The unit of measurement for energy; 1 joule = 1 kilogram * meter^2/second^2.

Kinetic energy Energy of motion; kinetic energy = ½ mass * velocity^2, or KE = ½ m * v^2.

Momentum The combined mass and velocity of an object. Momentum = mass * velocity, or p = m v.

Potential energy Energy due to position; stored energy, or the ability to do work.

Power Rate of doing work, or work divided by the time.

Relative motion The comparison of the movement of one object with the movement of another object.

Thermal energy Heat energy.

Watt A measurement of power. One watt is 1 joule of work per 1 second.

Work The force on an object times the distance through which the object moves as the work is converted to either potential energy or kinetic energy; work = force * distance, or W = F d.

Work and Kinetic Energy

In order to move an object such as a race car, something or someone must apply a force through a distance, so that work is accomplished. The energy from the work is thus transformed into kinetic energy, or energy of motion.

Transforming Energy

Remember that energy cannot be created or destroyed. Energy can only be changed from one type into another. If a person does work by providing a force on a car, such as a push, then the energy of work comes from the calories in the food the person has eaten. The food energy is transformed into work energy and then into kinetic energy, or energy of motion as the person pushes the car, and the car gains kinetic energy as it moves. The kinetic energy of the car will then be transformed into heat energy, or thermal energy, in the friction of the brakes or the tires against the track.

Performing Work

One way of doing work to provide kinetic energy is by simply pushing an object such as a car. In both NASCAR and Indy-style races, when the cars are in the pit or the shop area, for safety reasons they need to be pushed by hand since these areas are crowded both with spectators and with people working on the cars.

How much work does it take to push a race car through the shop area? Look at the digitized image of the pit crew pushing a race car [Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328]. If a force of 2,000 Newtons is provided for a distance of 20 meters, how much work is done?

Work = Force * distance; $W = F * d = 2{,}000N * 20\ m = 40{,}000$ joules

This work will be transferred to the kinetic energy of motion, $KE = ½\ m * v^2$. In theory, the kinetic energy will be a measure of the work done. Thus, 40,000 joules of work = 40,000 joules of kinetic energy.

If the kinetic energy is known, the velocity can be calculated. Assume the mass of the car is 3,400 pounds = 1,545 kilograms.

$KE = 40{,}000\ j = 40{,}000\ \text{kilogram-meters}^2/\text{second}^2 =$

$½\ m * v^2 = ½ * 1{,}545\ kg * v^2$

$½ * 1{,}545\ kg * v^2 = 40{,}000\ \text{kilogram-meters}^2/\text{second}^2$

$v^2 = 40{,}000\ \text{kilogram-meters}^2/\text{second}^2/\ (½ * 1{,}545\ kg)$

$v^2 = 51.8\ m^2/sec^2$

$v = 7.2$ meters/second

Even though in theory the work could provide as much kinetic energy as 40,000 joules, in reality much of the energy from pushing will be lost due to friction. The real numbers for kinetic energy and velocity will be a lot lower.

Converting Energies

Cars that are actually racing go through several energy changes and are subject to many different forces. Their energy begins as chemical energy in fuel. The engine converts the chemical energy into thermal energy. Look at the digitized image of the race car engine of the Ford Thunderbird #9 race car [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)]. The thermal energy is converted to mechanical energy to the crankshaft and then the mechanical energy is transferred to the wheels, which move the car, giving it kinetic energy.

Race car engineering begins with the engine. The more efficiently energy can be converted from chemical to thermal to mechanical to kinetic, the faster the race car can move.

Analyzing Work and Energy

As a car comes out of the pits, the driver accelerates rapidly over a short distance, with the car's engine providing the force. As the engine force pushes the car through the distance, the race car gains kinetic energy.

If a car comes out of the pit area and increases its speed from 60 mph to 200 mph over a distance of 150 meters, how much work will be done by the engine and what will be car's gain in kinetic energy? The car has a weight (or mass) of 3,400 pounds, and 3,400 pounds * 1 kilogram/2.2 pounds = 1,545 kilograms. Note that in order to calculate kinetic energy, mass must be in kilograms and velocity must be in meters/second.

For the car exiting the pit at 60 mph, first calculate its initial kinetic energy then its final kinetic energy, and then its gain in kinetic energy. Note that 1 mile/hour = .447 meters/second, or m/sec.

Conversions

60 mi/hr * $\frac{.447 \text{ m/sec}}{1 \text{ mi/hr}}$ = 26.8 m/sec

200 mi/hr * $\frac{.447 \text{ m/sec}}{1 \text{ mi/hr}}$ = 89.4 m/sec

KE (initial) = ½ m * v^2 = ½ * 1545 kg * $(26.8 \text{ m/sec})^2$ = 5.55 x 105 joules

KE (final) = ½ m * v^2 = ½ * 1545 kg * $(89.4 \text{ m/sec})^2$ = 6.17 x 10^6 joules

KE (gained) = KE (f) - KE (i) = 6.17 x 10^6 j – 5.55 x 10^5 = 5.62 x 10^6 joules

To calculate the force of the engine

work = F * d = KE (gained)

F * 150 m = 5.62 x 106 j

Force = 5.62 * 10^6 joules /150 meters = 37,400 Newtons

Theoretical Situations vs. Real Situations

In a real situation, there is a great amount of friction, so the actual numbers would be substantially different from the results of theoretical calculations. However, for a general understanding, we can ignore the friction and still gain an understanding of the concepts and necessary calculations.

Horsepower and Watts

Work is defined as a force applied through a distance, or

W = f d

Power is defined as work per time or energy per time, or

P = W / t

Another way to think of power is how rapidly work is completed. Power is measured in watts. One watt = 1 joule/second.

In automobiles in general, and in automobile racing, the amount of work an engine can exert is measured in horsepower (hp). The concept of horsepower was developed by James Watt (1736-1819). Watt was looking for a way to measure power, so he devised a method of having a horse lift a weight (of 33,000 lbs) through a height (1 ft) in a period of time (1 min). He called the rate of 33,000 foot-pounds/minute 1 horsepower. One horsepower is equivalent to 746 watts, or 746 joules /second.

All of these terms and concepts can be used to explain the work and energy involved in automobile racing.

Equations

1 horsepower = 746 watts

P = W * t

W = F * d

Work = Energy / time

Work = Δ KE

KE = ½ m * v^2

Conversions

1 mile = 1,610 meters

1 mile/hour = 1 mph = .447 meters/second

1 hour = 3,600 seconds