TORQUE

In physics, torque can be thought of informally as "rotational force". Torque is measured in units of newton metres, and its symbol is τ. The concept of torque, also called moment or couple, originated with the work of Archimedes on levers. The rotational analogues of force, mass and acceleration are torque, inertia and angular acceleration respectively. The force applied to a lever, multiplied by its distance from the lever's fulcrum, is the torque. For example, a force of three newtons applied two metres from the fulcrum exerts the same torque as one newton applied six metres from the fulcrum. This assumes the force is in a direction at right to the straight lever. More generally, one may define torque as the cross product:

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$$

where

F is the vector of force.

r is the vector from the axis of rotation to the point on which the force is acting.

Units

Torque has dimensions of force times distance and the SI units of torque are stated as "newton-metres". Even though the order of "newton" and "metre" are mathematically interchangeable, the BIPM (Bureau International des Poids et Mesures) specifies that the order should be N•m not m•N[1].

The joule, the SI unit for energy or work, is also defined as 1 N•m, but this unit is not used for torque. Since energy can be thought of as the result of "force dot distance", energy is always a scalar whereas torque is "force cross distance" and so is a (pseudo) vector-valued quantity. Of course, the dimensional equivalence of these units is not simply a coincidence; a torque of 1 N·m applied through a full revolution will require anenergy of exactly 2π joules. Mathematically,

$$E = \tau\theta$$

where

E is the energy

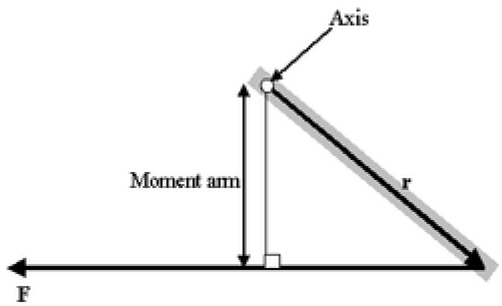
τ is torque

θ is the angle moved, in radians.

Other non-SI units of torque include "pound-force-feet" or "foot-pounds-force" or "ounce-force-inches or meter-kilograms-force.

Special cases and other facts

Moment arm formula



Moment arm diagram

A very useful special case, often given as the definition of torque in fields other than physics, is as follows:

$$\boldsymbol{\tau} = (\text{moment arm}) \times \text{force}$$

The construction of the "moment arm" is shown in the figure below, along with the vectors r and F mentioned above. The problem with this definition is that it does not give the direction of the torque but only the magnitude, and hence it is difficult to use in three-dimensional cases. If the force is perpendicular to the displacement vector r, the moment arm will be equal to the distance to the centre, and torque will be a maximum for the given force. The equation for the magnitude of a torque arising from a perpendicular force:

$$\boldsymbol{T} = (\text{distance to centre}) \times \text{force}$$

For example, if a person places a force of 10 N on a spanner which is 0.5m long, the torque will be 5 N·m, assuming that the person pulls the spanner in the direction best suited to turning bolts.

Force at an angle

If a force of magnitude F is at an angle θ from the displacement arm of length r (and within the plane perpendicular to the rotation axis), then from the definition of cross product, the magnitude of the torque arising is:

$$\boldsymbol{\tau} = rF\sin\theta$$

Static equilibrium

For an object to be at static equilibrium, not only must the sum of the forces be zero, but also the sum of the torques (moments) about any point. For a two-dimensional situation with horizontal and vertical forces, the sum of the forces requirement is two equations: ΣH = 0 and ΣV = 0, and the torque a third equation: Στ = 0. That is, to solve statically determinate equilibrium problems in two-dimensions, we use three equations.

Torque as a function of time

Torque is the time-derivative of angular momentum, just as force is the time derivative of linear momentum. For multiple torques acting simultaneously:

$$\sum \boldsymbol{\tau} = \frac{d\mathbf{L}}{dt}$$

where L is angular momentum.

Angular momentum on a rigid body can be written in terms of its moment of inertia $\boldsymbol{I}$ and its angular velocity $\boldsymbol{\omega}$:

$$\mathbf{L} = I\,\boldsymbol{\omega}$$

so if $\boldsymbol{I}$ is constant,

$$\boldsymbol{\tau} = I\frac{d\boldsymbol{\omega}}{dt} = I\boldsymbol{\alpha}$$

where α is angular acceleration, a quantity usually measured in rad/s²

Machine torque

Torque is part of the basic specification of an engine: the power output of an engine is expressed as its torque multiplied by its rotational speed. Internal-combustion engines produce useful torque only over a limited range of rotational speeds (typically from around 1,000–6,000 rpm for a small car). The varying torque output over that range can be measured with a dynamometer, and shown as a torque curve. The peak of that torque curve usually occurs somewhat below the overall power peak. The torque peak cannot, by definition, appear at higher rpm than the power peak.

Understanding the relationship between torque, power and engine speed is vital in automotive engineering, concerned as it is with transmitting power from the engine through the drive train to the wheels. The gearing of the drive train must be chosen appropriately to make the most of the motor's torque characteristics.

Steam engines and electric motors tend to produce maximum torque at or around zero rpm, with the torque diminishing as rotational speed rises (due to increasing friction and other constraints). Therefore, these types of engines usually have quite different types of drivetrains from internal combustion engines.

Torque is also the easiest way to explain mechanical advantage in just about every simple machine.

Source: http://engineering.wikia.com/wiki/Torque