ME 308
MACHINE ELEMENTS II

CHAPTER 5_0

POWER TRANSMISSION

5.01.POWER TRANSMISSION

We very often need to transmit power from the so called PRIME MOVER (mechanical power generator) to a working machine which consumes the energy and transfers it to useful work. Sometimes we transmit power to an element of a machine like the propeller of a ship or airplane. There are three basic stages for mechanical power to be converted to useful work as shown in Fig. 5.1.

Fig. 05.1. Power Transmission.

It is very rare that the speed and torque characteristics of a prime mover is exacly suitable for the working machine. A change of speed, torque and force must always be performed and this must be done during power transmission.

The need for power transmission is both dictated by the prime mover and the working machine. Angular velocity of the prime mover must be kept constant for economical reasons; whereas the speed of the working machine (e.g. drilling machine, lathe, vehicles etc.) must be changed frequently. This is an other reason why a separate transmission is required. When the speed of the prime mover is decreased, its torque capacity will also be reduced and under minimum speed no torque will be produced by the prime mover. It is possible to reduce the size of the prime mover by having high speed and low torque. Working machine requires high torque at low speeds which does not correspond to the conditions of the prime mover, but when a transmission is introduced which reduces the speed and thus increases the torque, we can have both conditions (high speed, low torque for the prime mover and low speed, high torque for the working machine) satisfied. In majority of cases the weight of the prime mover with adequate transmission will have smaller dimensions and will be lighter than a slow speed prime mover without any transmission.

Some times transmission is used only to bridge distances. The prime mover can be far apart from the working machine and the working machine can positioned awkwardly with respect to the prime mover due to the space limitations or some other reasons. In some othe cases the need for transmission is not to transmit power or torque but to change the velocity. For example, in mechanical computing mechanisms power is only used to overcome the friction between the relatively moving parts.

In mechanical engineering, mostly mechanical transmissions are used, but recently hydraulic, electric and pneumatic transmissions were introduced to transmit power. The reason for using such transmissions might be easy control, higher efficiency, high response or cheapness.

In electric power transmissions from the prime mover, electric power is generated and from there the power is carried by means of wires and switches and close to the working machine an electric motor is placed which converts the electric energy to mechanical power again. For example, such transmissions are used in Diesel electric locomotives. The power produced by the diesel engine rotates a big generator which is directly coupled. The electrical energy is sent to the motors close to the wheels.

In hydraulic transmission first, mechanical energy is used to turn the hydraulic pump. The compressed fluid is sent to the working machine through high pressure pipes or tubes. For example, the door mechanism, in most of the city buses operates with this principle. Another good example is the hydraulic press.

There are pneumatic portable drills which use compressed air to turn a turbine inside the drilling machine. Such tools can be economical if there is compressed air in the work shop already for some other use. There are impact tools and drilling tools used in construction and mining operated by pneumatic power transmission.

The possible purposes of power transmission can be summarized as follows:

1. To change the torque of prime mover,
2. To bridge distances,
3. To change the angular velocity.

5.02. PRIME MOVERS

The following prime movers are of interest, since almost all of the machines utilize one of these as an energy source.

1. Spark Ignition Engines

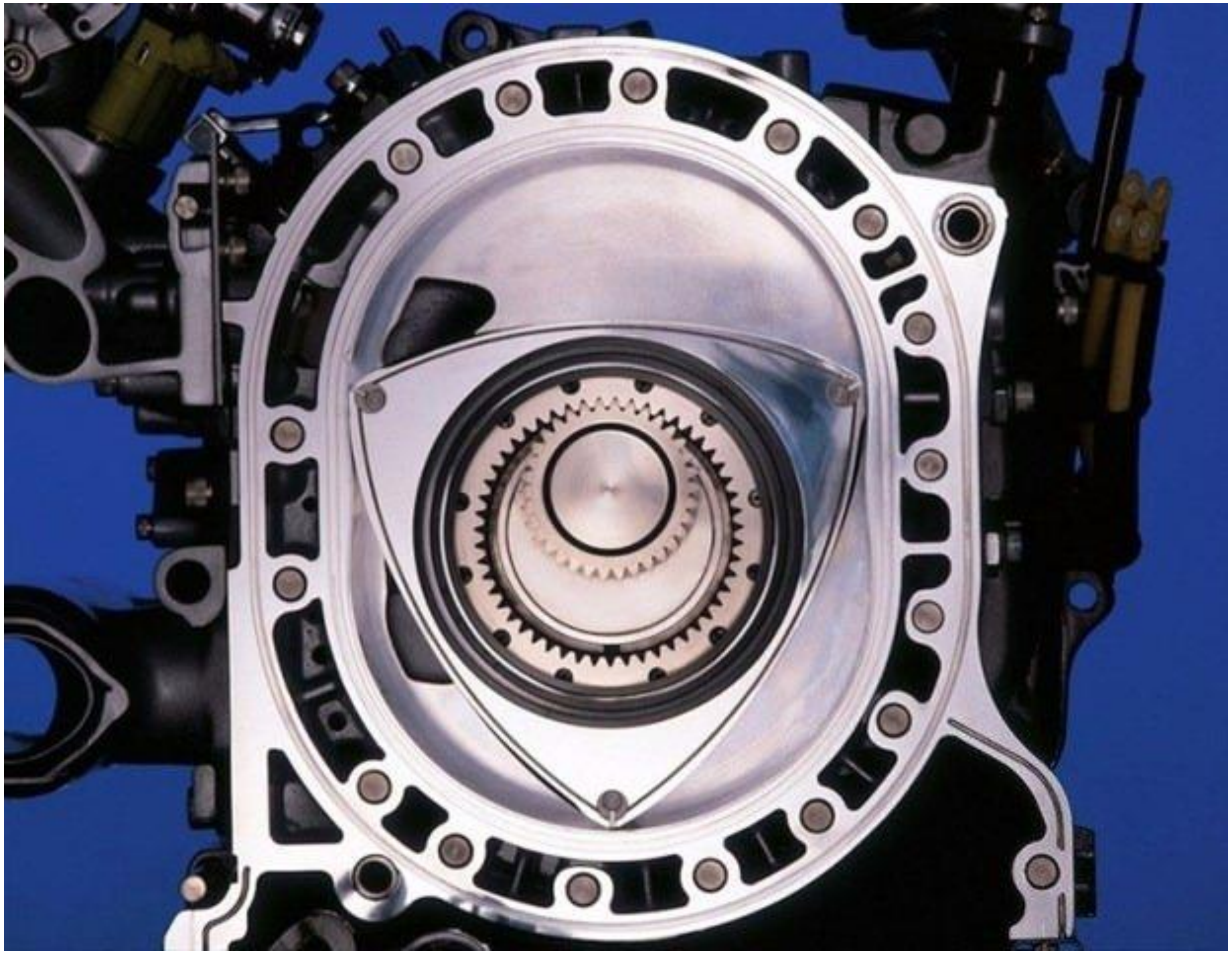
These usually run on carbureted mixtures of gasoline and air and is characterised by rapid burning (exploding) of mixture within each cylinder when ignited by a spark. The heated gasses that are created drive the piston until the exhaust valve openes. These engines are more flexible than other power sources and thus can be operated over a wide range of speed and low combinations. Almost all spark ignition engines are air cooled.

2. Diesel Engines

In this type of engine highly compressed heated air vaporized and ignites the fuel which is injected and mixed with the air in each cylinder (compression ignition). Diesels are built heavier than spark ignition engines in order to withstand the higher peak pressures which are accompanied by high load, bending stresses and deformations. Diesel engines are widely used where fuel economy and reliability are necessary as in busses, trucks and off-road equipments. Also they have a higher thermal efficiency.

3. Wankel Engine

Rotating combustion, or Wankel engines are relatively simple, small and smooth. Built with epitrochoidal combustion chambers and triangular rotors, the engines have about 40 % fewer parts about 1/3’rd the bulk and ½ the weight of reciprocating engines. Valveless Wankel have intake ports in the housing on both sides of a rotor. The fuel-air mixture is compressed as an internally geared rotor revolves around a stationary timing gear. One or two spark plugs ignite the mixture and the high pressure gases thus created drive the rotor.



4. Gas Turbine

Simplicity, reliability and a high power to weight ratio are chief factors that make gas turbines attractive for many industrial, marine and vehicular applications.

Intake, compression, ignition and exhaust events occur in a gas turbine as in a piston type internal combustion engine. However, the key moving parts in a gas turbine are a compressor, compressor turbine and a power turbine. Gas turbines operate at much higher speeds than other engines, therefore sufficient speed reduction must be utilized.

5. Stirling Engines

Clean, quite, smooth running stirling engines have long been regarded as too heavy, bulky, complex and costly. They have high efficiency and easy low temperature start.

6. Electric Motors

7. Other Prime Movers

5.03 POWER TRANSMISSION SYSTEMS

A machine consists of a power source and a power transmission system, which provides controlled application of the power. Merriam-Webster defines *transmission* as an assembly of parts including the speed-changing gears and the propeller shaft by which the power is transmitted from an engine to a live axle. Often **transmission** refers simply to the **gearbox** that uses gears and gear trains to provide speed and torque conversions from a rotating power source to another device.

In British English, the term transmission refers to the whole drive train, including clutch, gearbox, prop shaft (for rear-wheel drive), differential, and final drive shafts. In American English, however, a gearbox is any device that converts speed and torque, whereas a transmission is a type of gearbox that can be "shifted" to dynamically change the speed-torque ratio such as in a vehicle.

The most common use is in motor vehicles, where the transmission adapts the output of the internal combustion engine to the drive wheels. Such engines need to operate at a relatively high rotational speed, which is inappropriate for starting, stopping, and slower travel. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process. Transmissions are also used on pedal bicycles, fixed machines, and anywhere rotational speed and torque must be adapted.

Often, a transmission has multiple gear ratios (or simply "gears"), with the ability to switch between them as speed varies. This switching may be done manually (by the operator), or automatically. Directional (forward and reverse) control may also be provided. Single-ratio transmissions also exist, which simply change the speed and torque (and sometimes direction) of motor output.

In motor vehicles, the transmission generally is connected to the engine crankshaft. The output of the transmission is transmitted via driveshaft to one or more differentials, which in turn, drive the wheels. While a differential may also provide gear reduction, its primary purpose is to permit the wheels at either end of an axle to rotate at different speeds (essential to avoid wheel slippage on turns) as it changes the direction of rotation.

Conventional gear/belt transmissions are not the only mechanism for speed/torque adaptation. Alternative mechanisms include torque converters and power transformation (for example, diesel-electric transmission and hydraulic drive system). Hybrid configurations also exist.

5.04. MAIN FEATURES OF TRANSMISSION

In general the main fatures of any transmission are:

Description	Designation	Units Imp	SI
Power	*P*	hp	hp, kw
Torque	*T*	lb-in	kg-cm
Rotational speed	*N*	rpm	rpm
Rotational speed	*ω*	rad/sec	rad/sec

The relation between *N* (rpm) and *ω* (rad/sec) is as follows

$$\omega = \frac{2\pi}{60} N$$

The basic power equation in transmission is:

$$P = \frac{TN}{63000}$$

where: P: power, hp
T: torque, lb-in
N: rpm

$$P = \frac{TN}{71620}$$

where: P: power, hp
T: torque, kg-cm
N: rpm

Power may also be expressed in terms of kw. The relationship between hp and kw is:

$$1\,hp = 0.746\,kw = 746\,watts$$

Velocity Ratio, VR is defined as:

$$VR = \frac{N_{in}}{N_{out}} = \frac{\omega_{in}}{\omega_{out}}$$

where in. and out. refer to the input and output shaft respectively.

If VR > 1, transmission reduces the speed and increases the torque. Such transmissions are called speed reducers.
If VR < 1, transmission increases the speed and reduces the torque. Such transmissions are called speed multipliers.

Usually, transmissions have one fixed velocity ratio. If a compound train is used to give several output speeds (e.g. gearbox of a car), such transmissions are called fixed-step or multi-step transmission. If it is possible to vary the velocity ratio during operation within limits, such a transmission is called variable transmission.

Efficiency of a transmission η is defined as:

$$\eta = \frac{P_{out}}{P_{in}}$$

Output power is equal to the input power less the power loss due to the resistance during transmission.

$$\eta = \frac{P_{in} - P_{lost}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{lost}}$$

Losses are mostly transferred into heat. In some cases, where efficiency is low heat transfer becomes an important factor during transmission design. (e.g worm gears)

In cases of compound transmission, the total efficiency is the product of the efficiencies of each transmission stages.

$$\eta = \eta_1 \times \eta_2 \times \eta_3 \times ... \times \eta_n$$

For speed reducers torque ratio is important and can be obtained as:

$$\frac{T_{out}}{T_{in}} = \frac{P_{out}}{P_{in}} \times \frac{N_{in}}{N_{out}} = \eta \times VR$$

If the main task of the speed reducer is to increse the torque, high velocity is not the only important item, the efficiency must also be high. For examle worm gear and screw drives have the lowest efficiencies and they are the worst transmission elements with respect to torque increasing.