CAREER AVENUES

Aim for
excellence in
Engineering

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Farm Machinery

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Power

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SOURCES OF POWER

FARM POWER

Various types of agricultural operations performed on a farm can be broadly classified as:

- Tractive work – such as seed bed preparation, cultivation, harvesting and transportation.
- Stationary work- such as silage cutting, feed grinding, threshing, winnowing and lifting of irrigation water.

These operations are done by different sources of power, namely human, animal, mechanical power (oil engines and tractors), electrical power and renewable energy (solar energy, biogas, biomass and wind energy).

HUMAN POWER

Human beings are the main sources of power for operating small tools and implements at the farm. They are also employed for doing stationary work like threshing, winnowing, chaff cutting and lifting irrigation water. Of the total rural population in India, only 30% is available for doing farm work. The indications are that the decline in number of labourers employed for agriculture. On an average, a man develops nearly 0.1 horse power (hp).

- Advantages: Easily available and used for all types of work.
- Disadvantages: Costliest power compared to all other farms of power, very low efficiency, requires full maintenance when not in use and affected by weather condition and seasons.

ANIMAL POWER

The most important source of power on the farm all over the world and particularly in India is animal. It is estimated that, nearly 80% of the total draft power used in agriculture throughout the World is still provided by animals. India is having 22.68 crore cattle, which is the highest in the World. Mainly, bullocks and buffaloes happen to be the principle sources of animal power on Indian farms. However, camels, horses, donkeys and elephants are also used for the farm work. The average force a bullock can exert is nearly equal to one tenth of its body weight. Power developed by an average pair of bullocks is about 1 hp for usual farm work.

Advantages:

- Easily available.
- Used for all types of work.

- Low initial investment.
- Supplies manure to the field and fuels to farmers.
- Live on farm produce.

Disadvantages

- Not very efficient.
- Seasons and weather affect the efficiency.
- Cannot work at a stretch.
- Require full maintenance when there is no farm work.
- Creates unhealthy and dirty atmosphere near the residence.
- Very slow in doing work.

MECHANICAL POWER

It is available through tractors, power tillers and oil engines. The oil engine is a highly efficient device for converting fuel into useful work. The efficiency of diesel engine varies between 32 and 38%, whereas that of the carburetor engine (Petrol engine) is in the range of 25 and 32%. In recent years, diesel engines, tractors and power tillers have gained considerable popularity in agricultural operations. It is estimated that, about one million tractors of 25 hp range are in use for various agricultural operations in India. Similarly, total number of oil engines of 5 hp for stationery work is 60 lakhs. Normally, stationery diesel engines are used for pumping water, flour mills, oil ghanis, cotton gins, chaff cutter, sugarcane crusher, threshers and winnowers etc.,

- Advantages: Efficiency is high; not affected by weather; cannot run at a stretch; requires less space and cheaper form of power.
- Disadvantages: Initial capital investment is high; fuel is costly and repairs and maintenance needs technical knowledge.

ELECTRICAL POWER

Now-a- day’s electricity has become a very important source of power on farms in various states of the country. Electrical power is used mostly for running electrical motors for pumping water, dairy industry, cold storage, farm product processing, and cattle feed grinding. It is clean source of power and smooth running. The operating cost remains almost constant throughout its life. Its maintenance and operation need less attention and care. On an average, about 1/10th of the total electrical power generated in India, is consumed for the farm work, approximately it is 4600 megawatt.

- Advantages: Very cheap form of power; high efficiency; can work at a stretch; maintenance and operating cost is very low and not affected by weather conditions.
- Disadvantages: Initial capital investment is high; require good amount of technical knowledge and it causes great danger, if handled without care,

RENEWABLE ENERGY

It is the energy mainly obtained from biomass; biogas, solar and wind are mainly used in agriculture for power generation and various agricultural processing operations. It can b used for lighting, power generation, water heating, drying, greenhouse heating, water distillation, refrigeration and diesel engine operation. This type of energy is inexhaustible in nature. The availability of wind energy for farm work is quite limited. Where the wind velocity is more than 32 kmph, wind mills can be used for lifting water. Main limitation for this source is uncertainty. Average capacity of a wind mill would be about 0.5 hp. There are about 2540 windmills in India. It is the cheapest sources of farm power available in India.

IC ENGINE CYCLES - INTRODUCTION

A cycle is defined as sequence of processes which end in the same final state of the substance as the initial. The heat engines are devices which produce work by using heat from a reservoir and rejecting heat to another constant temperature reservoir called heat sink. Perhaps in earlier days some heat engines were developed which directly used the heat from sun, hitherto all engines have been using heat produced from combustion of fuel. Apart from heat source the engine has to have some working fluid that will absorb and reject heat and undergo such processes as expansion and compression. For theoretical study of cycles for engines it is assumed that some working fluid remains in the machine and undergoes different processes over and over again. A number of standard cycles, consisting of well known processes have been developed.

CARNOT CYCLE

Carnot was the first to study the performance of heat engine. Here, we describe the cycle as shown in Figure 1.1. The engine is made of a piston in a cylinder again shown in the same Figure. The cycle consists of four processes.

- 1-2-isothermal expansion
- 2-3-adiabatic expansion
- 3-4-isothermal compression
- 4-1-adiabatic compression

During 1-2 and 2-3, work is performed by gas (air) on the piston, whereas during 3-4 and 4-1, work is performed on the gas by the piston. At 1, a volume of air equal to V1 is contained in confined space between the piston and cylinder walls. Also assume the mass of the air is m = 1 kg. During isothermal expansion 1-2, a heat source (reservoir) is brought in contact with the cylinder end and since expansion is at constant temperature, entire heat transferred from hot body to the air is converted into work without any change in the internal energy. Thus,

$$W_{12} = Q_{12} = p_1 V_1 \ln \frac{V_2}{V_1} = RT_1 \ln \frac{V_2}{V_1}$$

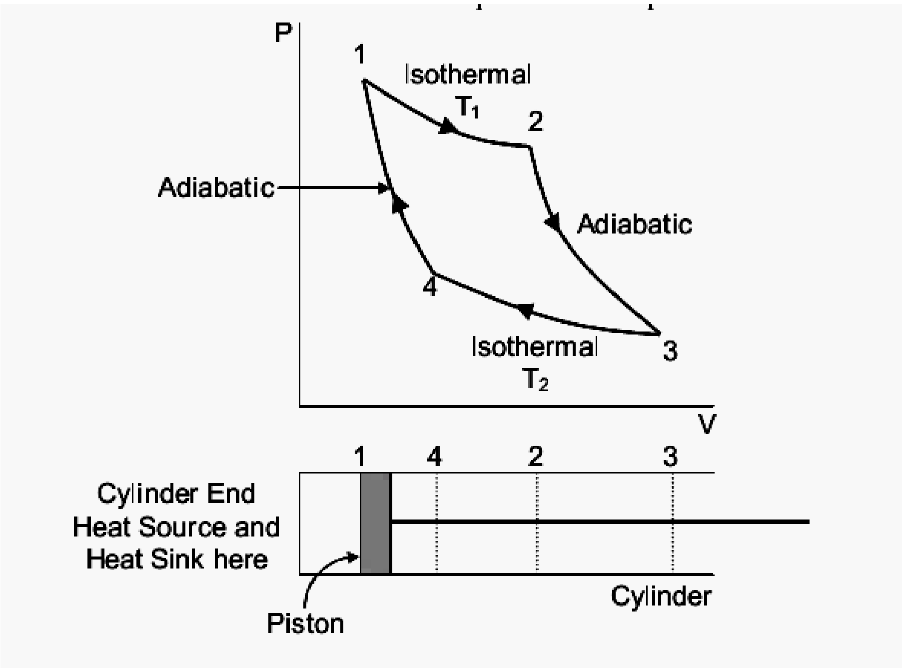

Figure 1 : Carnot Cycle

The efficiency of the engine is defined as the ratio of work obtained to heat supplied

From thermodynamics, per unit mass of charge

$$\text{Heat supplied from point 1 to 2} = p_2 v_2 \ln \frac{v_3}{v_2} \qquad (5)$$

$$\text{Heat rejected from point 3 to 4} = p_4 v_4 \ln \frac{v_1}{v_4} \qquad (6)$$

$$\text{Now } p_2 v_2 = RT_{max} \qquad (7)$$

$$\text{And } p_4 v_4 = RT_{min} \qquad (8)$$

Since Work done, per unit mass of charge, W = heat supplied – heat rejected

$$W = RT_{max} \ln \frac{v_3}{v_2} - RT_{min} \ln \frac{v_1}{v_4}$$

$$= R \ln(r)(T_{max} - T_{min}) \qquad (9)$$

We have assumed that the compression and expansion ratios are equal, that is

$$\frac{v_3}{v_2} = \frac{v_1}{v_4} \qquad (10)$$

Heat supplied $Q_s = R\ T_{max} \ln(r)$ (10)

Hence, the thermal efficiency of the cycle is given by

$$\eta_{th} = \frac{R \ln(r)(T_{max} - T_{min})}{R \ln(r) T_{max}}$$

$$= \frac{T_{max} - T_{min}}{T_{max}} \qquad (11)$$

Here T1 is the temperature of hot reservoir and T3 is the temperature of cold reservoir of heat. Heat is abstracted by the engine from hot reservoir and rejected to cold reservoir. The efficiency of the Carnot cycle is highest.

OTTO CYCLE

The most practical air cycle on which petrol engines work is the Otto cycle comprising four processes, viz.

- 1-2 Adiabatic expansion
- 2-3 Constant volume heat rejection
- 3-4 Adiabatic compression
- 4-1 Constant volume heat addition (Figure 1.2).

Apparently no work is done on the piston or by the piston during constant volume processes. Assume mass of air in the engine is 1 kg. Heat rejected by the air in the engine during the process 2-3

$$Q_{23} = C_v (T_2 - T_3)$$

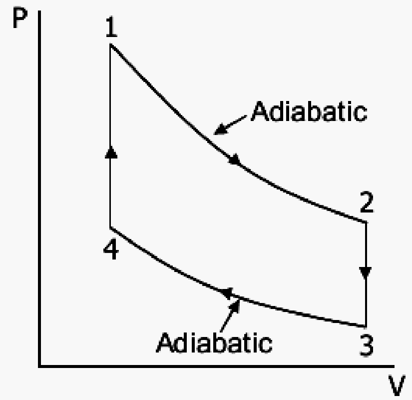

Figure 1.2 : Otto Cycle

Heat received during the process 4-1

$$Q_{41} = C_v (T_1 - T_4)$$

Heat rejection during the process 2-3

$$Q_{23} = C_v (T_2 - T_3)$$

$$\therefore \quad W = Q_{41} - Q_{23}$$

$$\therefore \quad \eta = \frac{Q_{41} - Q_{23}}{Q_{41}} = \frac{T_1 - T_4 - T_2 + T_3}{T_1 - T_4} = 1 - \frac{T_2 - T_3}{T_1 - T_4}$$

Note that, $\frac{V_2}{V_1} = \frac{V_3}{V_4} = r$ where r is called compression ratio. It may also be pointed out here that V1 = V4 is called the clearance volume

$\frac{p_1 V_1}{p_2 V_2} = \frac{T_1}{T_2}$ ……from gas equation

Also for adiabatic expansion,

$$\frac{p_1}{p_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

$$\therefore \quad \frac{T_1}{T_2} = \left(\frac{V_1}{V_2}\right)^{1-\gamma} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = (r)^{\gamma-1}$$

Similarly,

$$\frac{T_4}{T_3} = (r)^{\gamma-1}$$

$$\frac{T_1}{T_2} = \frac{T_4}{T_3}$$

or,

$$\frac{T_1}{T_4} = \frac{T_2}{T_3}$$

Thus,

$$\eta_{th} = 1 - \frac{T_1}{T_2} = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

or,

$$\eta = 1 - \frac{1}{(r)^{\gamma-1}}$$

From above expression it can be concluded that efficiency of Otto cycle increases with compression ratio r. A compression ratio in the vicinity of 7-8 is commonly used in petrol engines.

DIESEL CYCLE

This cycle is shown in Figure 1.3. Diesel engines using diesel fuel work on this cycle. The main difference lies in the fact that at the end of compression process sufficiently high temperature is obtained and fuel which is injected at this point ignites without any aid. In case of Otto cycle, a spark is needed to cause ignition of the fuel which is present during process of compression. In this cycle, the heat is transferred to fuel during constant pressure process when fuel is injected. The fuel burns during constant pressure process only. The gas (air) then expands adiabatically followed by heat rejection which occurs at constant volume. The air is then compressed adiabatically.

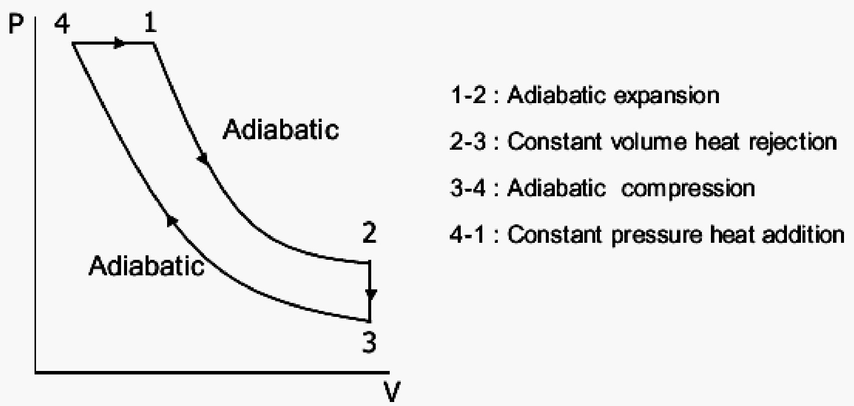

Figure 1.3 : Diesel Cycle

Efficiency of the cycle,

$$\eta = \frac{\text{Work done}}{\text{Heat added}} = \frac{\text{Head added} - \text{Heat rejected}}{\text{Heat added}}$$

$$\eta = \frac{Q_{41} - Q_{23}}{Q_{41}}$$

$$= \frac{C_p\,(T_1 - T_4) - C_v\,(T_2 - T_3)}{C_p\,(T_1 - T_4)}$$

$$= 1 - \frac{C_v\,(T_2 - T_3)}{C_p\,(T_1 - T_4)} = 1 - \frac{T_3\left(\frac{T_2}{T_3} - 1\right)}{\gamma\,T_4\left(\frac{T_1}{T_4} - 1\right)}$$

It may be noted that in case of diesel cycle the compression ratio is greater than expansion ratio. For adiabatic compression,

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma - 1}$$

For adiabatic expansion,

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma - 1}$$

Calling $V_4 = 1$, $V_1 = r$, the cut off ratio and $V_2 = V_3 = r$ = compression ratio

$$\frac{V_3}{V_4} = r, \quad \frac{V_2}{V_1} = \left(\frac{r}{\rho}\right)$$

For constant pressure process 4-1, $p_4 = p_1$

$$\therefore \quad \frac{p_1 V_1}{T_1} = \frac{p_4 V_4}{T_4}$$

$$\text{or} \quad \frac{\rho}{T_1} = \frac{1}{T_4}$$

$$\text{or} \quad \frac{T_1}{T_4} = \rho$$

For constant volume process, 2-3

$$\frac{p_2 V_2}{T_2} = \frac{p_3 V_3}{T_3}$$

$$\text{or} \quad \frac{p_2}{p_3} = \frac{T_2}{T_3}$$

For adiabatic process 1-2,

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{r}{\rho}\right)^{\gamma-1}$$

For adiabatic process 3-4,

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = (r)^{\gamma-1}$$

The thermal efficiency is,

$$\eta = 1 - \frac{1}{\gamma (r)^{\gamma-1}} \times \frac{\rho^{\gamma} - 1}{\rho - 1}$$

Diesel cycle normally has much higher compression ratio. For same compression ratio the efficiency decreases for increasing cut off ratio.

Problem 1: Calculate efficiencies of a Carnot cycle for compression ratios of 7, 8, 9 and 10 for air as working fluid.

Solution: Use g = 1.4 for air,

$$\eta = 1 - \frac{1}{(r)^{\gamma - 1}}$$

r	$r^{\gamma-1}$	$1/(r)^{\gamma-1}$	$\eta = 1 - 1/(r)^{\gamma-1}$
7	2.18	0.46	0.54
8	2.30	0.435	0.565
9	2.41	0.415	0.584
10	2.51	0.400	0.600

Problem 2 : Calculate the efficiency of a diesel cycle for which compression ratio is 14 and cut off ratio is 2. What will be the efficiency if cut off ratio is increased to 3.
Given ¥ = 1.4

Solution :

Use r = 14 and r = 2 with ¥ = 1.4 in following equation,

$$\eta = 1 - \frac{1}{\gamma (r)^{\gamma - 1}} \times \frac{\rho^{\gamma} - 1}{\rho - 1}$$

$$\eta = 1 - \frac{1}{1.4\,(14)^{0.4}} \times \frac{2^{1.4} - 1}{2 - 1}$$

$$= 1 - \frac{1}{4.02} \times \frac{1.64}{1} = 0.59$$

$$\eta = 59\%.$$

Now use r = 14 and r = 3 with ¥ = 1.4,

$$\eta = 1 - \frac{1}{1.4\,(14)^{0.4}} \frac{3^{1.4} - 1}{3 - 1}$$

$$= 1 - \frac{1}{4.02} \times \frac{3.655}{2} = 0.545$$

$$\eta = 54.5\ \%$$