SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF AGRICULTURAL ENGINEERING

19AGT 202 –Machine Design

III YEAR V SEM

UNIT 4 – Fundamentals of Theory of Machines

TOPIC –Flywheel Fluctuation of speeds & Energy

INTRODUCTION:

A flywheel acts as an energy reservoir, which stores energy during the period when the supply of energy is more than the requirement and releases energy during the period when the requirement is more than the supply.

Components of Flywheel

Rotor

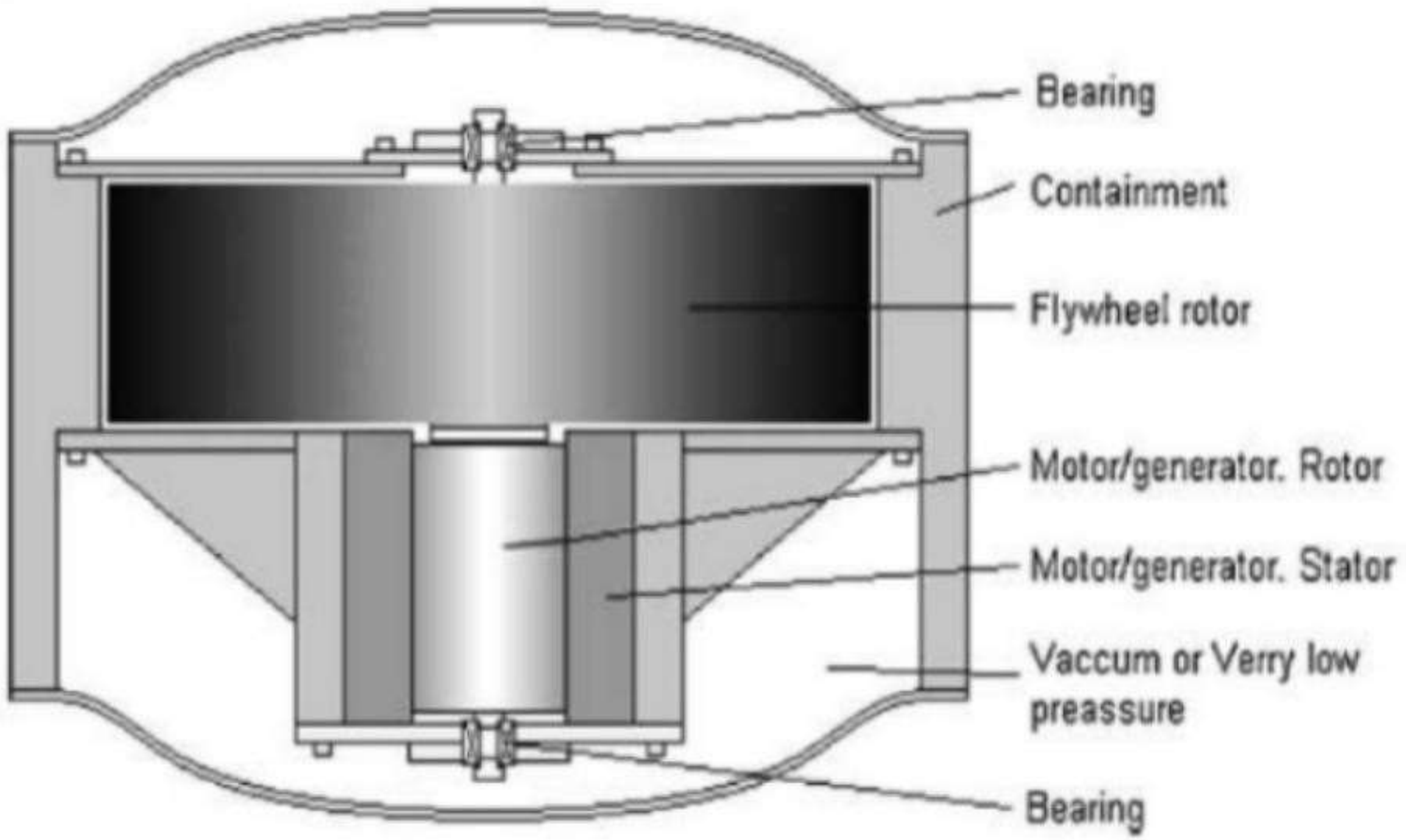
Bearing

Motor/Generator

Power Electronics

Control/Instrumentation

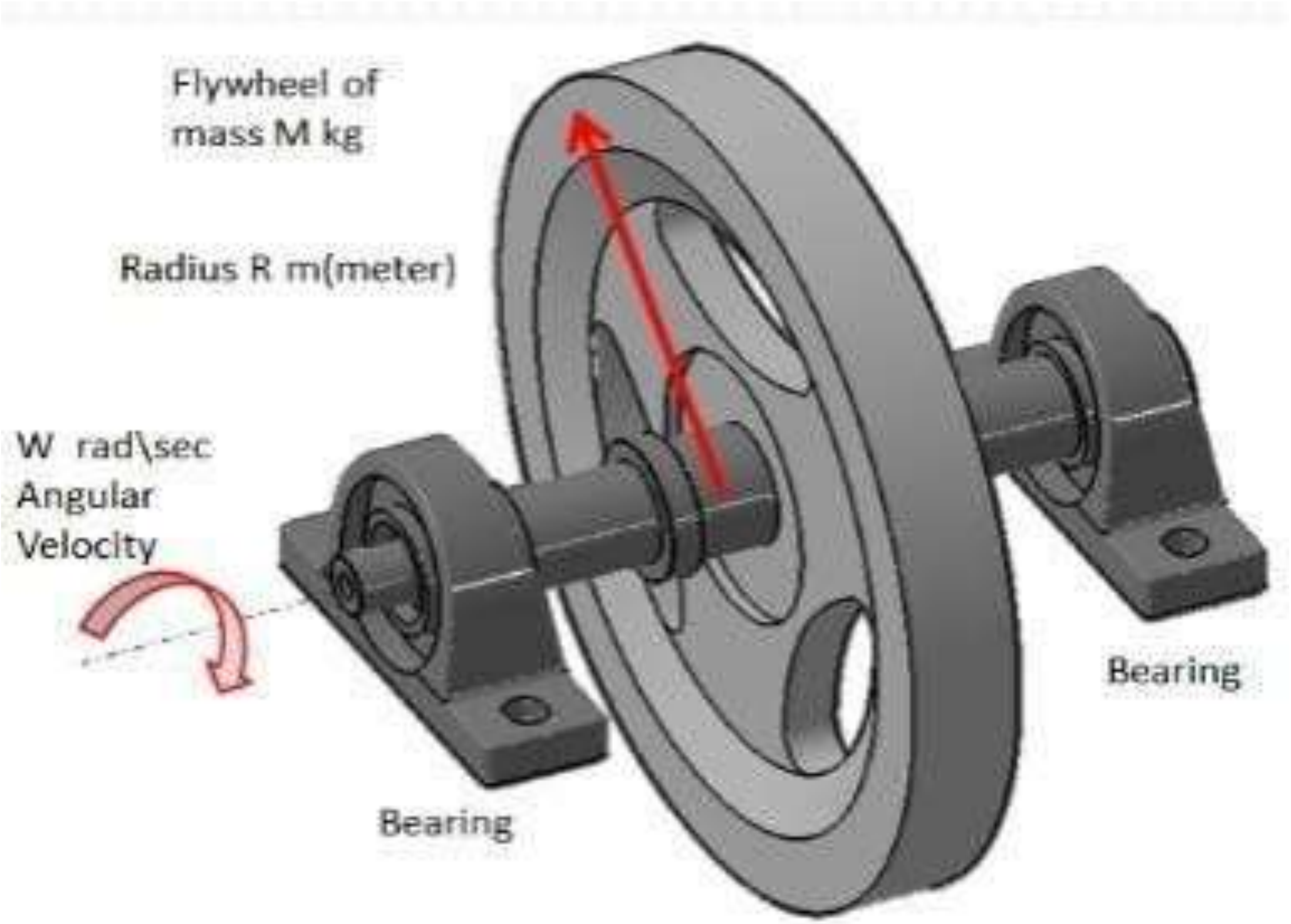
Housing



Material Selection

- Flywheels are made from many different materials; the application determines the choice of material.
- Cast iron flywheels are used in old steam engines.
- Flywheels used in car engines are made of cast or nodular iron, steel or aluminum.
- Flywheels made from high-strength steel or composites.

Design of a Flywheel



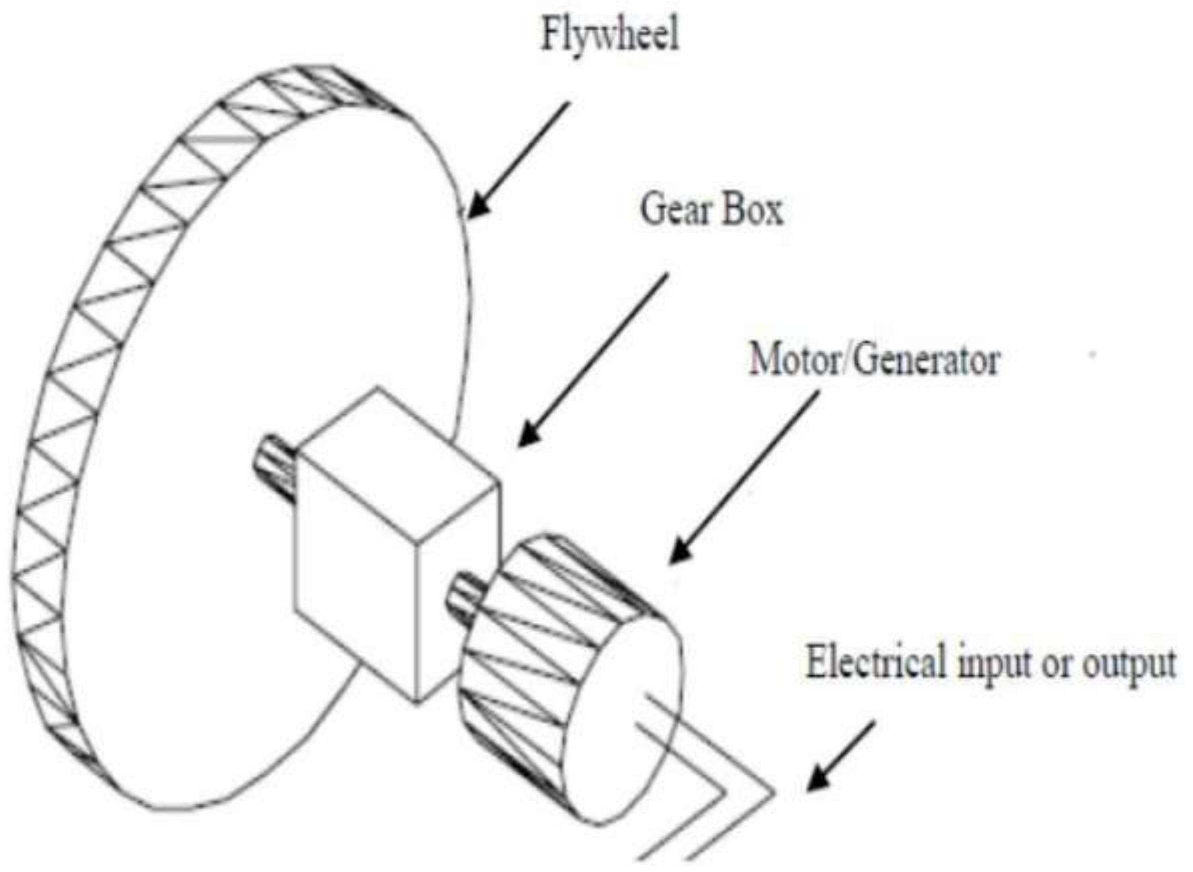
This design exercise deals with the design of a flywheel to bring the fluctuation of the engine speed to a required limit.

Working of Flywheel

Flywheel is essentially a mechanical battery consisting of a mass rotating around an axis.

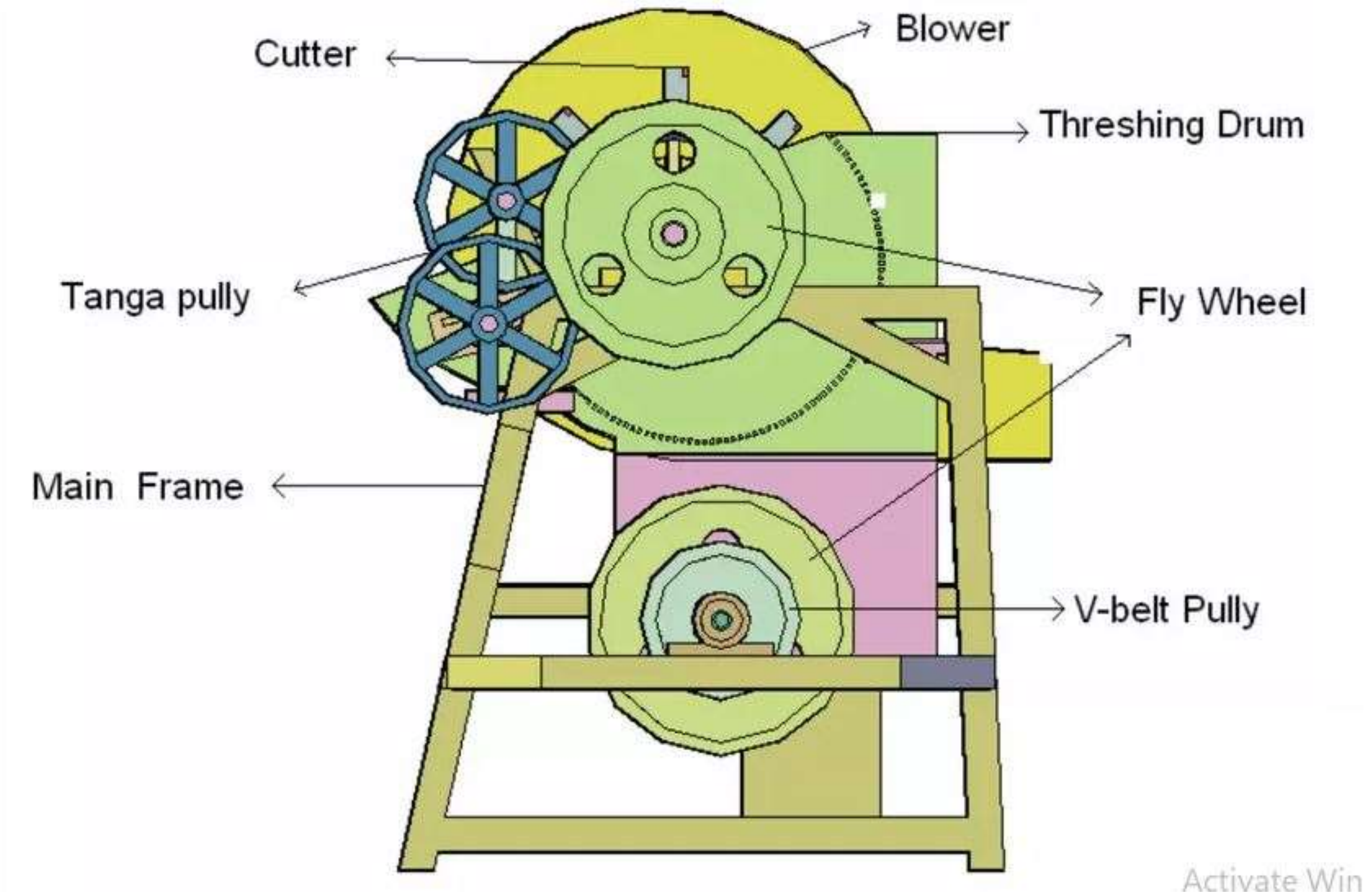
It stores energy in the form of kinetic energy and works by accelerating a rotor to very high speeds and maintaining the energy in the system as rotational energy.

Flywheel energy storage is a promising technology for replacing conventional lead acid batteries as energy storage systems.



EMPATHY

AGRICULTURAL APPLICATIONS OF FLYWHEEL



DEFINE & IDEATE

Design Procedure of Flywheel

- Selection of the engine.
- Data tables will be provided and select the problem based on the serial number.
- Calculation of Turning Moment.
- Calculation of torque due to inertia forces
- Obtain the turning moment and hence find the mean torque.
- Calculation of the Moment of Inertia of the flywheel to limit the speed fluctuation to given value.
- Design of the flywheel with the required Moment of Inertia.

Let m = Mass of the flywheel in kg,

k = Radius of gyration of the flywheel in metres,

I = Mass moment of inertia of the flywheel about the axis of rotation in kg-m^2 $= m.k^2$,

N_1 and N_2 = Maximum and minimum speeds during the cycle in r.p.m.,

ω_1 and ω_2 = Maximum and minimum angular speeds during the cycle in rad / s,

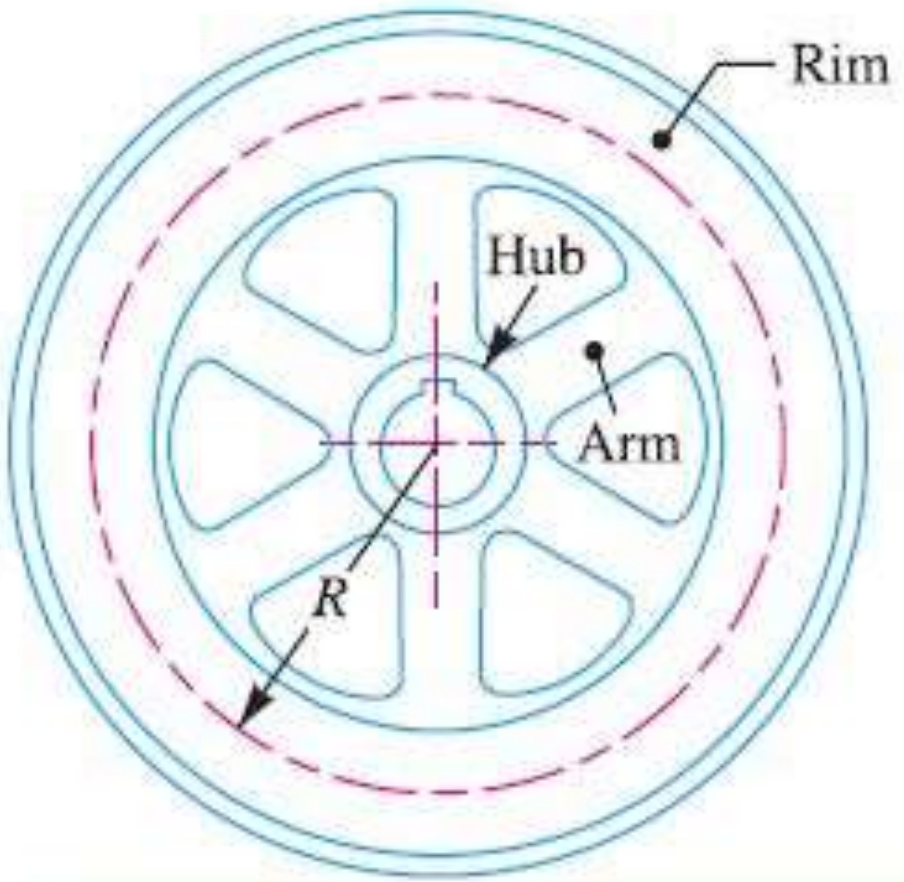


Fig. 22.5. Flywheel.

N = Mean speed during the cycle in r.p.m. $= \dfrac{N_1 + N_2}{2}$,

ω = Mean angular speed during the cycle in rad / s $= \dfrac{\omega_1 + \omega_2}{2}$

C_S = Coefficient of fluctuation of speed $= \dfrac{N_1 - N_2}{N}$ or $\dfrac{\omega_1 - \omega_2}{\omega}$

We know that mean kinetic energy of the flywheel,

$$E = \frac{1}{2} \times I.\omega^2 = \frac{1}{2} \times m.k^2.\omega^2 \text{ (in N-m or joules)}$$

As the speed of the flywheel changes from ω_1 to ω_2, the maximum fluctuation of energy,

$$\Delta E = \text{Maximum K.E.} - \text{Minimum K.E.} = \frac{1}{2} \times I(\omega_1)^2 - \frac{1}{2} \times I(\omega_2)^2$$

$$= \frac{1}{2} \times I \left[(\omega_1)^2 - (\omega_2)^2\right] = \frac{1}{2} \times I (\omega_1 + \omega_2)(\omega_1 - \omega_2)$$

$$= I.\omega (\omega_1 - \omega_2) \qquad \ldots\left(\because \omega = \frac{\omega_1 + \omega_2}{2}\right) \ldots (i)$$

$$= I.\omega^2 \left(\frac{\omega_1 - \omega_2}{\omega}\right) \qquad \ldots\text{[Multiplying and dividing by } \omega\text{]}$$

$$= I.\omega^2.C_S = m.k^2.\omega^2.C_S \qquad \ldots(\because I = m.k^2) \ldots (ii)$$

$$= 2\,E.C_S \qquad \ldots\left(\because E = \frac{1}{2} \times I.\omega^2\right) \ldots (iii)$$

The radius of gyration (k) may be taken equal to the mean radius of the rim (R), because the thickness of rim is very small as compared to the diameter of rim. Therefore substituting $k = R$ in equation (*ii*), we have

$$\Delta E = m.R^2.\omega^2.C_S = m.v^2.C_S \qquad \ldots(\because v = \omega.R)$$

From this expression, the mass of the flywheel rim may be determined.

Notes: 1. In the above expression, only the mass moment of inertia of the rim is considered and the mass moment of inertia of the hub and arms is neglected. This is due to the fact that the major portion of weight of the flywheel is in the rim and a small portion is in the hub and arms. Also the hub and arms are nearer to the axis of rotation, therefore the moment of inertia of the hub and arms is very small.

2. The density of cast iron may be taken as 7260 kg / m^3 and for cast steel, it may taken as 7800 kg / m^3.

3. The mass of the flywheel rim is given by

$$m = \text{Volume} \times \text{Density} = 2\,\pi\,R \times A \times \rho$$

From this expression, we may find the value of the cross-sectional area of the rim. Assuming the cross-section of the rim to be rectangular, then

$$A = b \times t$$

where b = Width of the rim, and

t = Thickness of the rim.

Knowing the ratio of b / t which is usually taken as 2, we may find the width and thickness of rim.

4. When the flywheel is to be used as a pulley, then the width of rim should be taken 20 to 40 mm greater than the width of belt.

Example 22.1. *The turning moment diagram for a petrol engine is drawn to the following scales:*

Turning moment, 1 mm = 5 N-m; Crank angle, 1 mm = 1°.

The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line, taken in order are 295, 685, 40, 340, 960, 270 mm^2.

Determine the mass of 300 mm diameter flywheel rim when the coefficient of fluctuation of speed is 0.3% and the engine runs at 1800 r.p.m. Also determine the cross-section of the rim when the width of the rim is twice of thickness. Assume density of rim material as 7250 kg / m^3.

Solution. Given : D = 300 mm or

R = 150 mm = 0.15 m ; C_S = 0.3% = 0.003 ; N = 1800 r.p.m. or $\omega = 2\pi \times 1800 / 60 = 188.5$ rad/s ; $\rho = 7250$ kg / m^3

Mass of the flywheel

Let m = Mass of the flywheel in kg.

First of all, let us find the maximum fluctuation of energy. The turning moment diagram is shown in Fig. 22.6.

Since the scale of turning moment is 1 mm = 5 N-m, and scale of the crank angle is 1 mm = 1° = π / 180 rad, therefore 1 mm^2 on the turning moment diagram.

$$= 5 \times \pi / 180 = 0.087 \text{ N-m}$$

Let the total energy at $A = E$. Therefore from Fig. 22.6, we find that

Energy at $B = E + 295$

Energy at $C = E + 295 - 685 = E - 390$

Energy at $D = E - 390 + 40 = E - 350$

Energy at $E = E - 350 - 340 = E - 690$

Energy at $F = E - 690 + 960 = E + 270$

Energy at $G = E + 270 - 270 = E$ = Energy at A

From above we see that the energy is maximum at B and minimum at E.

$\therefore$ Maximum energy $= E + 295$

and minimum energy $= E - 690$

We know that maximum fluctuation of energy,

$$\Delta E = \text{Maximum energy} - \text{Minimum energy}$$
$$= (E + 295) - (E - 690) = 985 \text{ mm}^2$$
$$= 985 \times 0.087 = 86 \text{ N-m}$$

We also know that maximum fluctuation of energy (ΔE),

$$86 = m.R^2.\omega^2.C_S = m\,(0.15)^2\,(188.5)^2\,(0.003) = 2.4\,m$$

$\therefore$ $m = 86 / 2.4 = 35.8$ kg **Ans.**

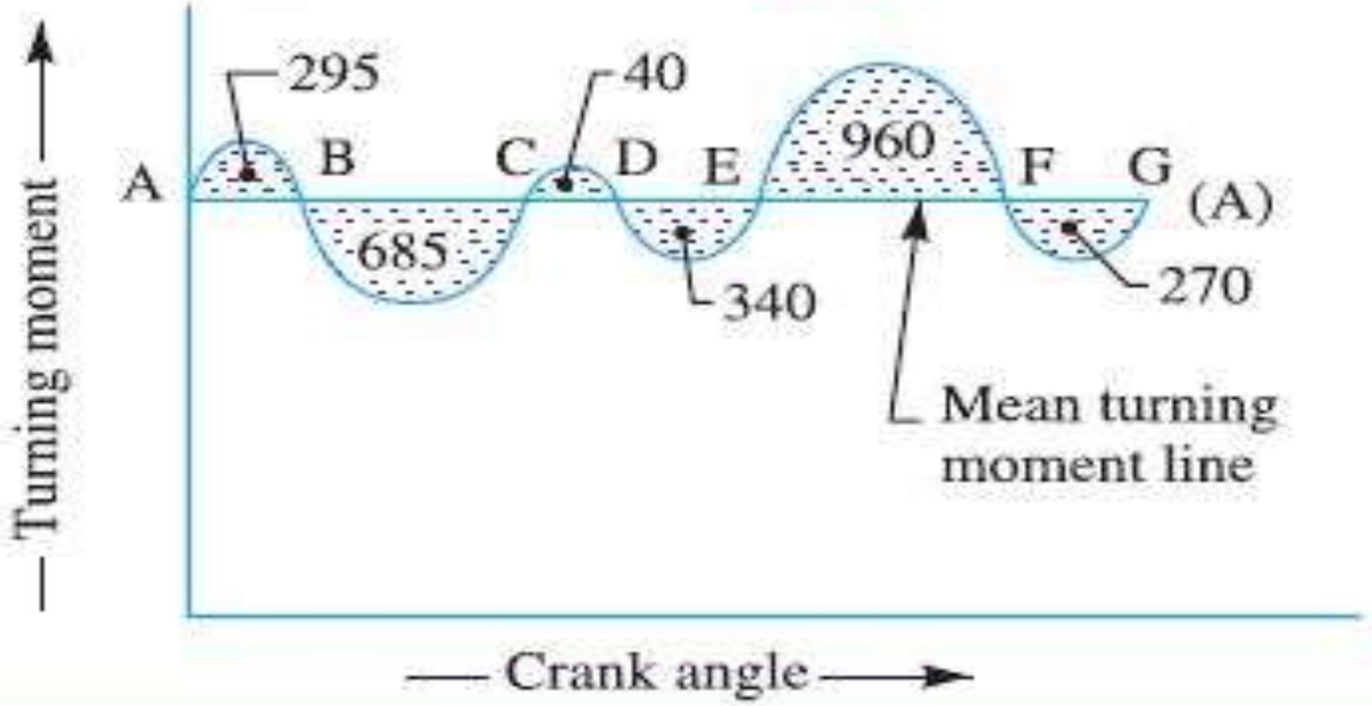


Fig. 22.6

Cross-section of the flywheel rim

Let t = Thickness of rim in metres, and

b = Width of rim in metres = $2\,t$ ...(Given)

$\therefore$ Cross-sectional area of rim,

$$A = b \times t = 2\,t \times t = 2\,t^2$$

We know that mass of the flywheel rim (m),

$$35.8 = A \times 2\pi R \times \rho = 2t^2 \times 2\pi \times 0.15 \times 7250 = 13\,668\,t^2$$

$\therefore$ $t^2 = 35.8 / 13\,668 = 0.0026$ or $t = 0.051$ m = 51 mm **Ans.**

and $b = 2\,t = 2 \times 51 = 102$ mm **Ans.**

Advantages of Flywheel

No degradation in power.

No daily cycling limitations.

No degradation in energy.

Highly accurate SOC measurement.

Non-inflammable.

Utility customer comfort with rotating machinery.

Easily recyclable.

High residual value at the end of life.

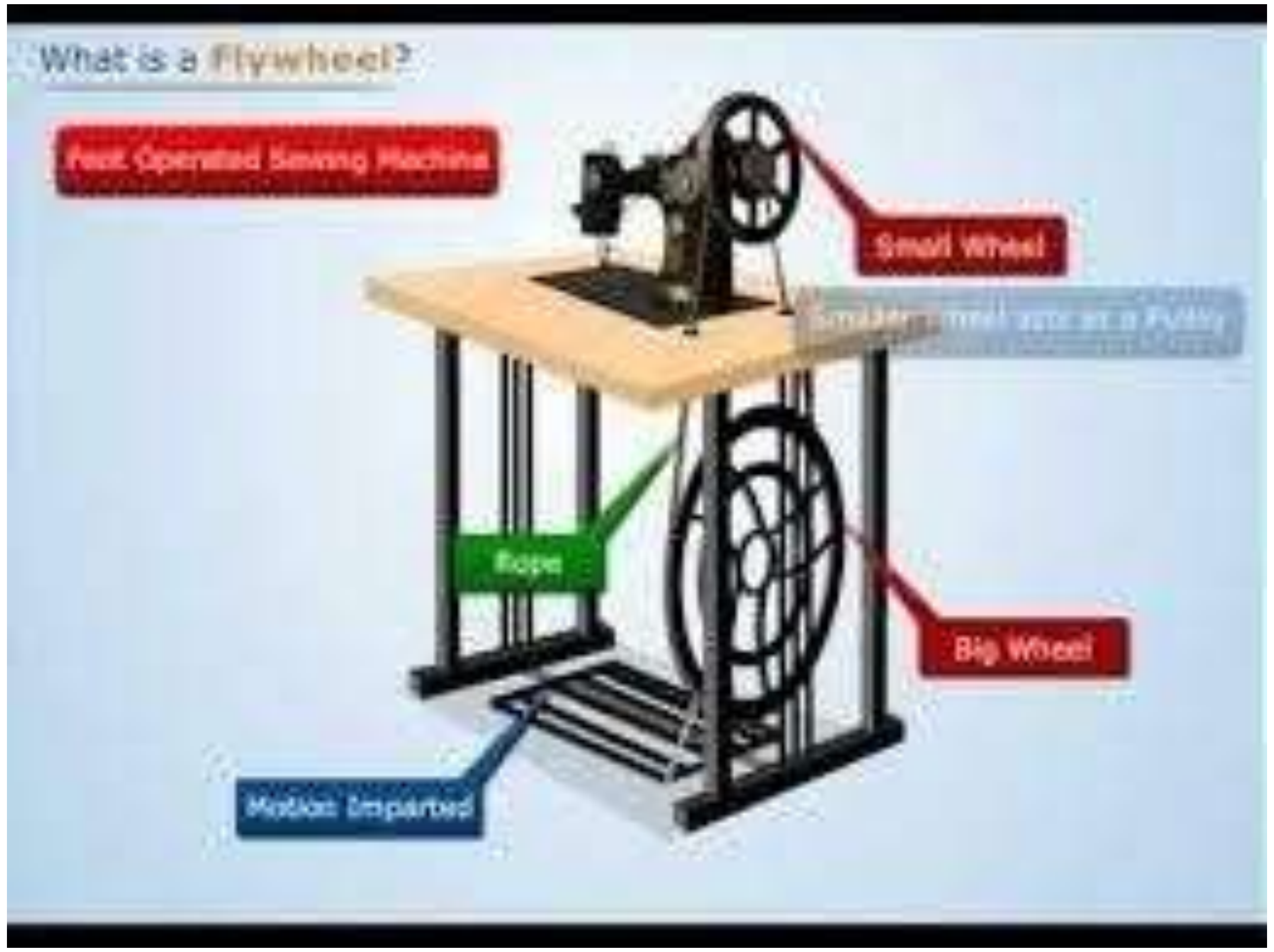
Dis advantages of fly wheel

- Unless they are couple with batteries, the run-time of a flywheel UPS is very short, typically measured in seconds.

- Flywheel design has limits, like the tensile strength of the material used for the rotor.

- They can also have a bearing failure from vibration.

APPLICATIONS OF FLYWHEEL



PROTOTYPE AND TEST

https://www.researchgate.net/publication/350097567_Application_of_flywheel_energy_accumulators_in_agricultural_robots

The use of a flywheel energy accumulator allows you to use energy recovery in agricultural machinery, without resorting to difficult-to-maintain and relatively low-life batteries.

https://www.youtube.com/watch?v=3Rn9hpghvR4

One of the remarkable ideas is AMMA(Associated Mass Mechanical Applications), which is the idea if producing electricity by gear flywheel mechanism. This fuel less power generation can offer power for Rs.2, produced by Kamma Gear Flywheel Power Generation Technology-based First Time in India, which will make a big impact in future. This technology is more advanced and affordable than renewable resources like Solar and Wind energy. Next comes M-AUTO, where the ordinary Bajaj autos are converted to electric autos. Moreover, Balaji Techno Traders also participate in the exhibition, inorder to promote super fan. There are many waste to wealth inventions in the exhibition.

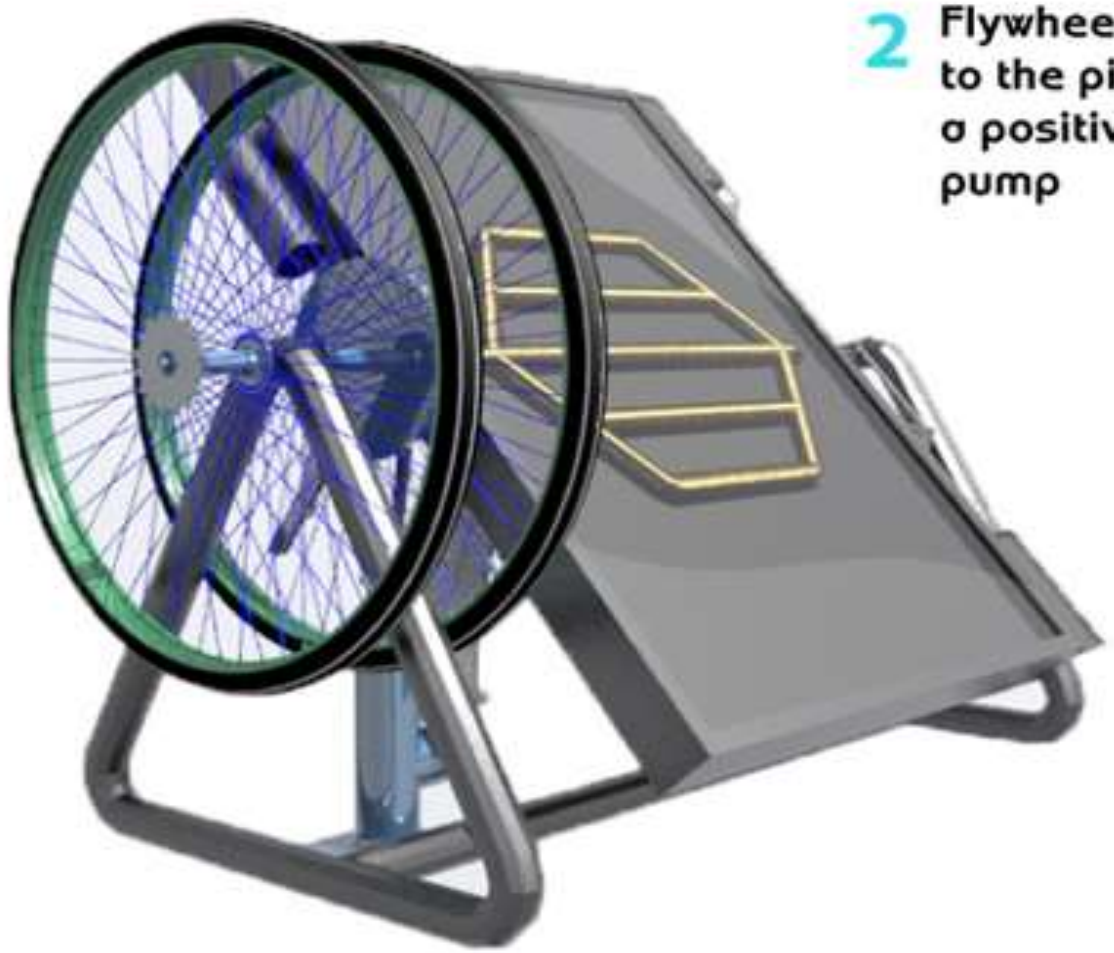
GREENPEACE

Energy [R]evolution

Integrated stirling water pumping

Concept functionality | By Mauricio Alfonso

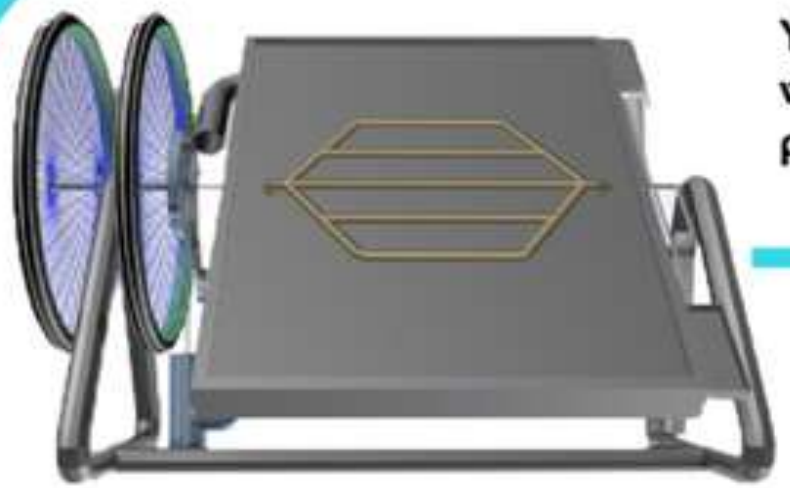
1 Box with double layered glass with wide area permits the heat of the sun to enter, moving a piston to one direction



2 Flywheel made from bicycle wheels react to the piston moving, causing it to move a positive displacement (reciprocating) pump

A passive solar tracking system is made using the same logic: if one side get's more heat, an air piston will be activated on the other side, this allows the system to stay always facing the direction of the sunlight.

3 The pumped water passes through a division of metal piping that is in contact with the air. This will cool the air down, forcing the piston to move again, and along with the flywheel momentum tha cycle begins again



You connect a hose after the water passes trough the metal piping...

MULTIPLE CHOICE QUESTIONS

The flywheel is accelerated when

(A) Driving torque > Load torque

(B) Driving torque < Load torque

(C) Driving torque = Load torque

(D) Any of the above

Which of the following is (are) true?

(A) Cast iron has poor tensile strength compared to steel

(B) Failure of cast iron flywheel is sudden and total

(C) Mach inability of cast iron flywheel is poor compared to steel flywheel

(D) All of the above

The ratio of maximum fluctuation of speed to the mean speed is called

(A) Fluctuation of speed
(B) Maximum fluctuation of speed
© Coefficient of fluctuation of speed
(D) None of the above

The difference the maximum and minimum speeds during a cycle is called

(A) Fluctuation of speed
(B) Maximum fluctuation of speed
© Coefficient of fluctuation of speed
(D) None of the above

When the torque required by the machine is more than the torque supplied by the motor, the flywheel is

(A) Accelerated

(B) Retarded

(C) Rotating with constant speed

(D) Any of the above

If the load on the engine is constant, the mean speed will be constant from the cycle, then

(A) The governor will not operate but flywheel will be acting

(B) The flywheel will be acting but governor will not operate

(C) Both flywheel and governor will be acting

(D) Both flywheel and governor will not be acting


Thank You