DEPARTMENT OF MECHANICAL ENGINEERING

ME6505 – DYNAMICS OF MACHINES

UNIT -1 FORCE ANALYSIS
PART - A

1. What are the conditions for a body to be in static and dynamic equilibrium?

Necessary and sufficient conditions for static and dynamic equilibrium are

1. Vector sum of all forces acting on a body is zero.
2. The vector sum of the moments of all forces acting about any arbitrary point or axis is zero. First condition is the sufficient condition for static equilibrium together with second condition is necessary for dynamic equilibrium.

2. Define static force analysis.

If components of a machine accelerate, inertia is produced due to their masses. However, the magnitudes of these forces are small compared to the externally applied loads. Hence inertia effects due to masses are neglected. Such an analysis is known as static force analysis.

3. Define force and applied force.

Force is a push or pull, which acts on a body changes or tends to change, the state of rest or of uniform motion of the body. A force is completely characterized by its point of application, its magnitude and direction.

The external force acting on a system of body from outside the system are called applied force. The applied forces are classified as active and reactive force.

4. When will the two-force member is in equilibrium?

The member under the action of two force will be in equilibrium if,

1. The two forces are of same magnitude,
2. The forces act along the same line, and
3. The forces are in opposite direction

5.Differentiate between static force analysis and dynamic force analysis.

If components of a machine accelerate, inertia forces are produced due to their masses. If the magnitudes of these forces are small compared to the externally applied loads, they can be neglected while analysing the mechanism. Such an analysis is known as static force analysis.

6. State D'Alembert's principle.

D'Alembert's principle states that the inertia forces and torques, and the external forces and torques acting on a body together result in statically equilibrium. In other words, the vector sum of all external forces acting upon a system of rigid bodies is zero. The vector sum of all external moments and inertia torques acting upon a system of rigid bodies is also separately zero.

7. How you will reduce a dynamic analysis problem into an equivalent problem of static equilibrium?

By applying D'Alembert's principle to a dynamic analysis problem, we can reduce it into an equivalent problem of static equilibrium.

8. State the principle of super position.

The principle of super position states that for linear systems the individual responses to several disturbances or driving functions can be superposed on each other to obtain the total response of the system.

9. Give one example each for linear and non-linear system.

Linear system: Example: Spring system.

Non-linear system: Example: Systems with static or coulomb friction, backlash. Principle of super position has a limitation that it cannot be applied for *non-linear systems*. When the connecting rod is large the piston executes *simple harmonic* motion.

10. Define Piston effort.

Piston effort is defined as the net or effective force applied on the piston, along the line of stroke. It is also known as effective driving force (or) net load on the gudgeon pin.

11. What do you mean by crank effort or turning moment on the crank shaft?

It is the product of the crank-pin effort (FT) and crank pin radius (r).

12. Define compound pendulum or torsional pendulum.

A rigid body suspended vertically at a point and oscillating with very small amplitude under the action of gravitational force is known as compound pendulum or torsional pendulum.

13. What are the requirements of an equivalent dynamical system?

The mass of the rigid body must be equal to the sum of masses of two concentrated masses. i.e. m1 + m2 = m

The centre of gravity of the two masses must coincide with the centre of gravity of the rigid body. i.e. m1l1 = m2l2

14 . What is meant by turning moment diagram or crank effort diagram?

It is the graphical representation of the turning moment or crank effort for various position of the crank. In turning moment diagram, the turning moment is taken as the ordinate (Y-axis) and crank angle as abscissa (X-axis)

15. Define Inertia force.

The inertia force is an imaginary force, which when acts upon a rigid body, brings it in an equilibrium position.

Inertia force = - Accelerating force = - ma

16. Differentiate the function of flywheel and governor.

1. The function of flywheel is to reduce the fluctuations of speed during a cycle above and below the mean value for constant load from prime mover. The function of governor is to control the mean speed over a period for output load variations.
2. Flywheel works continuously from cycle to cycle. Governor works intermittently, i.e. only when there is change in the load.
3. Flywheel has no influence on mean speed of the prime mover. Governor has no influence over cyclic speed fluctuations.

17. Define Inertia Torque.

The inertia torque is an imaginary torque, which when applied upon the rigid body, brings it in equilibrium position. It is equal to the accelerating couple in magnitude by opposite in direction.

18. What do you understand by the fluctuations of energy and maximum fluctuation of energy?

The variations of energy above and below the mean resisting torque line are called fluctuations of energy. The difference between the maximum and the minimum energies is known as maximum fluctuation of energy.

19. Define coefficient of fluctuation of energy.

It is the rat6io of maximum fluctuation of energy to the work done per cycle.

20. Define coefficient of fluctuation of speed.

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

21. List out the few machines in which flywheel are used.

1. Punching machines, 2. Shearing machines, 3.Riveting machines, and 4.Crushing machines.

UNIT 2 - BALANCING

1. Write the importance of Balancing?

If the moving part of a machine are not balanced completely then the inertia forces are set up which may cause excessive noise, vibration, wear and tear of the system. So, balancing of machine is necessary.

2. Why balancing of dynamic forces are necessary?

If dynamic forces are not balanced, they will cause worse effects such as wear and tear on bearings and excessive vibrations on machines. It is very common in cam shafts, steam turbine rotors, engine crank shafts, and centrifugal pumps, etc.,

3. Write the different types of balancing?

1. Balancing of rotating masses
1. Static balancing
2. Dynamic balancing
2. Balancing of reciprocating masses.

4. Write the condition for complete balancing?

1. The resultant centrifugal force must be zero and
2. The resultant couple must be zero.

5. State the reasons for choosing multicylinder engines.

Unlike single cylinder engines , multicylinder engines can be completely balanced.

6. Whether grinding wheels are balanced or not? If so why?

Yes, the grinding wheels are properly balanced by inserting some low-density materials. If not the required surface finish won't be attained and the vibration will cause much noise.

7. Why complete balancing is not possible in reciprocating engine?

Balancing of reciprocating masses is done by introducing the balancing mass opposite to the crank. The vertical component of the dynamic force of this balancing mass gives rise to "Hammer blow". In order to reduce the Hammer blow, a part of the reciprocating mass is balanced. Hence complete balancing is not possible in reciprocating engines.

8. Differentiate between the unbalanced force due to a reciprocating mass and that due to revolving masses.

1. Complete balancing of revolving mass can be possible. But fraction of reciprocating mass only balanced.
2. The unbalanced force due to reciprocating mass varies in magnitude but constant in direction. But in the case of revolving masses, the unbalanced force is constant in magnitude but varies in direction.

9. What are the various cases of balancing of revolving masses?

1. Balancing of single rotating mass by a single mass rotating in the same plane.
2. Balancing of single rotating mass by two masses rotating in different planes.
3. Balancing of several rotating masses in a single plane.
4. Balancing of several rotating masses in different planes.

10. What are the effects of an unbalanced primary force along the line of stroke of two-cylinder locomotive?

1. Variation in tractive force along the line of stroke, and
2. Swaying couple.

11. Define tractive force.

The resultant unbalanced force due to the two cylinders along the line of stroke is known as tractive force.

12. What is swaying couple?

The unbalanced force acting at a distance between the line of stroke of two cylinders, constitute a couple in the horizontal direction. This couple is known as swaying couple.

13. What is the effect of hammer blow and what is the cause of it?

The effect of hammer blow is to cause the variation in pressure between the wheel and the rail, such that vehicle vibrates vigorously. Hammer blow is caused due to the effect of unbalanced primary force acting perpendicular to the line of stroke.

14. What are in-line engines?

Multi-cylinder engines with the cylinder centre lines in the same plane and on the same side of the centre line of the crank shaft are known as in-line engine.

15. What are the conditions to be satisfied for complete balance of in-line engine?

1. The algebraic sum of the primary and secondary forces must be zero, and
2. The algebraic sum of the couples due to primary and secondary forces must be zero.

16. What is hammer blow?

The effect of an unbalanced primary force perpendicular to the line of stroke is to produce variation in pressure on the rails, which results in hammering action on the rails. The maximum

magnitude of the unbalanced force along the perpendicular to the line of stroke is known as a hammer blow.

17. **Can a single cylinder be perfectly balanced?**
    No, a single cylinder cannot be perfectly balanced. Because the unbalanced forces remain constant in direction, but vary in magnitude.
18. **Why radial engines are preferred?**
    Here, the connecting rods are connected to a common crank and hence the plane of rotation of the various cranks os same, therefore no unbalanced primary couples or secondary couples. Hence radial engines are preferred.
19. **Why rotating masses are dynamically balanced?**
    If they are not dynamically balanced then unbalanced forces will cause wear and tear in bearings, and vibrations in machines. It is very common in cam shafts, steam turbine rotors, engine crank shafts.

20. **Write short note on effect of firing order in multicylinder engines.**
    There are many possibilities of firing order can take place in multicylinder engines. To overcome vibrations, fuel distribution, exhaust distribution different firing orders are chosen.
21. **Mention two methods to avoid derailment of locomotive.**

22. **Why cranks of a locomotive are generally at right angles to one another?**
    Inorder to facilitate the starting of any locomotive in any position (to have uniform turning moment), cranks are placed at right angles.
23. **Mention two methods to avoid derailment of locomotive.**
    By coupling the wheels together, increases the wheels resistance against slipping on the rails. This resulting in more tractive force.
    By running the engine below the permissible value of angular speed of wheel to avoid lifting of wheel from the track.

UNIT 3 FREE VIBRATIONS

1. **What is vibration isolation?**
   The ratio of the force transmitted (FT) to the force applied (F) is known as the isolation factor or transmissibility ratio of the spring support

2. **What are the causes of vibration?**
   The causes of vibration are unbalanced forces, elastic nature of the system, self-excitations, winds and earthquakes.

3. **Define Period and cycle of vibration.**
   Period is the time interval after which the motion is repeated itself. Cycle is defined as the motion completed during one-time period.

4. **Define frequency of vibration.**
   It is the number of cycles described in one second. Its unit is Hz.

5. **How will you classify vibration?**
   1. Free vibrations

a) Longitudinal vibration,
b) Transverse vibration, and

c) Torsional vibration.
2. Forced vibrations, and
3. Damped vibration.

6. What is meant by free vibration and forced vibrations?

When no external force acts on the body, after giving it an initial displacement, then the body is said to be under free or natural vibration. When the body vibrates under the influence of external force, then the body is said to be under forced vibrations.

7. What do you meant by damping and damped vibration?

The resistance against the vibration is called damping. When there is a reduction in amplitude over every cycle of vibration, then the motion is said to be damped vibration.

8. Define resonance.

When the frequency of external force is equal to the natural frequency of a vibrating body, the amplitude of vibration becomes excessively large. This phenomenon is known as resonance.

9. What do you mean by a degree of freedom or movability?

The number of independent coordinates required to completely define the motion of a system is known as degree of freedom of the system.

10. What is equivalent spring stiffness?

Equivalent spring stiffness is the measure of overall spring stiffness of any system having more than one spring connected in series or parallel.

13. List out the various methods of finding the natural frequency of free longitudinal vibrations.

1. Energy method, 2. Equilibrium method and 3. Rayleigh's method.

14. Distinguish between critical damping and large damping.

If system is critically damped, the mass moves back very quickly to its equilibrium position within no time. Whereas in large damping, the mass moves slowly to the equilibrium position.

15. When do you say a vibrating system is under damped?

The equation of motion of a free damped vibration is given by $d^2x + c\,dx + s = 0$

If $(s/m) > (c/2m)^2$, then radical becomes negative. The two roots k_1 and k_2 are known as complex conjugate. Then the vibrating system is known as under damping.

16. Define critical or whirling or whipping speed of a shaft.

The speed at which resonance occurs is called critical speed of the shaft. In other words, the speed at which the shaft runs so that the additional deflection of the shaft from the axis of rotation becomes infinite is known as critical speed.

17. What are the factors that affect the critical speed of a shaft?

The critical speed essentially depends on

a) the eccentricity of the C.G. of the rotating masses from the axis of rotation of the shaft,
b) diameter of the disc,
c) span of the shaft, and
d) type of supports connections at its ends.

18. What are the causes of critical speed?

1. Eccentric mountings,
2. Bending due to self-weight, and
3. Non-uniform distribution of rotor material.

19. Define damping ratio.

It is defined as the ratio of actual damping coefficient to the critical damping coefficient.

20. Define logarithmic decrement.

Logarithmic decrement is defined as the natural logarithm of the amplitude reduction factor. The amplitude reduction factor is the ratio of any two successive amplitudes on the same side of the mean position.

21. What is viscous damping?

Vibrating systems, the effect of friction is referred to as damping. The damping provided by fluid resistance is known as viscous damping.

22. What is damping?

The resistance against the vibration is called damping. When there is a reduction in amplitude over every cycle of vibration, then the motion is called damped vibration.

24. What are the types of damping?

Couloumb damping, viscous damping, solid damping, slip damping.

25. Give the limit beyond which damping is detrimental.

When damping factor $\zeta>1$, aperiodic motion is resulted. That is aperiodic motion means the system cannot vibrate due to over damping. Once the system is disturbed will take infinite time to come back to equilibrium position.

UNIT 4 FORCED VIBRATIONS

1. What is meant by dynamic magnifier or magnification factor?

It is the ratio of maximum displacement of the forced vibration to the deflection due to the static force.

2. What is meant by transmissibility?

When a machine is supported by a spring, the spring transmits the force applied on the machine to the fixed support or foundation. This is called as transmissibility.

3. Define transmissibility ratio or isolation factor.

The ratio of force transmitted to the force applied is known as transmissibility ratio.

4. Briefly explain elastic suspension.

When machine components are suspended from elastic members, the vibrational force produced by the machine components will not be transmitted to the foundation. This is called as elastic suspension.

5. Specify any two-industrial application where the transmissibility effects of vibration are important.

1. All machine tools, and

2. All turbo machines.

6. Specify the importance of vibration isolation?

When an unbalanced machine is installed on the foundation, it produces vibration in the foundation. So, in order to prevent these vibrations or to minimize the transmission of forces to the foundation, vibration isolation is important.

7. What are the methods of isolating the vibration?

1. High speed engines/machines mounted on foundation and supports cause vibrations of excessive amplitude because of the unbalanced forces. It can be minimized providing spring-damper, etc.
2. The materials used for vibration isolation are rubber, felt cork, etc. These are placed between the foundation and vibrating body.

8. Define torsional vibration.

When the particles of a shaft or disc move in a circle about the axis of the shaft, then the vibrations are known as torsional vibrations.

9. Differentiate between transverse and torsional vibration.

1. In transverse vibrations, the particles of the shaft move approximately perpendicular to the axis of the shaft. But in torsional vibrations, the particles of the shaft move in a circle about the axis of the shaft.
2. Due to transverse vibrations, tensile and compressive stresses are induced. Due to torsional vibrations, torsional shear stresses are induced in the shaft.

10. Define node in torsional vibration.

Node is the point or the section of the shaft at which amplitude of the torsional vibration is zero. At nodes, the shaft remains unaffected by the vibration.

11. Define torsional equivalent shaft.

A shaft having variable diameter for different lengths can be theoretically replaced by an equivalent shaft of uniform diameter such that they have the same total angle of twist when equal opposing torques are applied at their ends. Such a theoretically replaced shaft is known as torsionally equivalent shaft.

12. What are the conditions to be satisfied for an equivalent system to that of geared system in torsional vibrations?

1. The kinetic energy of the equivalent system must be equal to the kinetic energy of the original system.
2. The strain energy of the equivalent system must be equal to the strain energy of the original system.

UNIT 5 GOVERNORS & GYROSCOPES

1. Explain the function of Governor?

The function of a governor is to maintain the speed of an engine within specified limits whenever there is a variation of load. Governors control the throttle valve and hence the fuel supplies to cater the load variation in engines.

2. What is the principle of inertia governors?

In inertia governors, the balls are so arranged that the inertia forces caused by an angular acceleration or retardation of the shaft tend to alter their positions.

3. What is equilibrium speed?
The speed at which the governor balls arms, sleeve, etc., are in complete equilibrium and there is no upward or downward movement of the sleeve on the spindle is known as equilibrium speed.

4. Explain controlling force?
An equal and opposite force to the centrifugal force acting radially inwards (i.e. centripetal force) is termed as controlling force of a governor.

5. Explain the governor effort?
The mean force acting on the sleeve for a given percentage change of speed for lift of the sleeve is known as the governor effort.

6. Define power of a governor?
The power of a governor is the work done at the sleeve for a given percentage change of speed. It is the product of the mean value of the effort and the distance through which the sleeve moves.

7. Explain sensitiveness of governors?
The sensitiveness is defined as the ratio of the mean speed to the difference between the maximum and minimum speeds.

8. What is meant by hunting?
The phenomenon of continuous fluctuation of the engine speed above and below the mean speed is termed as hunting. This occurs in over sensitive governors.

9. Explain the term stability of the governor?
A governor is said to be stable if there is only one radius of rotation for all equilibrium speeds of the balls within the working range. If the equilibrium speed increases the radius of governor ball must also increase.

10. Explain isochronism.
A governor with zero range of speed is known as an isochronous governor.

11. Give the application of gyroscopic principle.
It is used a) in instrument or toy known as gyroscope, In ships in order to minimize the rolling and pitching effects of waves, and In aeroplanes, monorail cars, gyrocompasses, etc.

12. Define steering, pitching and rolling.
Steering is the turning of a complete ship in a curve towards left or right, while it moves forward. Pitching is the movement of a complete ship up and down in a vertical plane about transverse axis. Rolling is the movement of a ship in a linear fashion.

13. Explain gyroscopic couple?
If a body having moment of inertia I and rotating about its own axis at ω rad/sec is also caused to turn at ωp rad/sec about an axis perpendicular to axis of spin, then it experiences a gyroscopic couple of magnitude ($\omega\ \omega_p$) in an axis which is perpendicular to both the axis of spin and axis of precision.

14. Define Bow and Stern.

The fore end of the ship is called *bow* and the rear end is known as *stern or aft*.

15. Define the term system.
A system is an assembly of components and linkages designed to fulfil some particular function.

16. Define transfer function.
A transfer function is the ratio of output from the block and input to the block.

17.What is meant by lag in response?
In any control system, there is a delay in response due to some inherent cause and it becomes difficult to measure the input and output simultaneously. This delay in response is termed as lag in response.