MACHINE DYNAMICS

ENME 354

Lecture	**: 3**	**Year : III**
Tutorial	**: 1**	**Part : II**
Practical	**: 3/2**	

Course Objectives:

The objective of this course is to introduce students to the principles of machine dynamics, including engine forces, flywheels, gyroscopic effects, governors, and vibrations, while covering analytical and numerical methods to study system behavior and concepts of vibration measurement and condition monitoring.

1 Engine Force Analysis (2 hours)

1.1 Analytical method for velocity and acceleration of the piston and the connecting rod
1.2 Forces on the reciprocating parts of an engine
1.3 Equivalent dynamical system
1.4 Analytical method for inertia torque

2 Turning Moment Diagram and Flywheel (2 hours)

2.1 Turning moment diagram
2.2 Fluctuation of energy and coefficient of fluctuation of energy
2.3 Flywheel
2.4 Coefficient of fluctuation of speed
2.5 Energy stored in a flywheel and flywheel sizing

3 Gyroscopic Couple (4 hours)

3.1 Precessional angular motion
3.2 Gyroscopic couple
3.3 Effect of gyroscopic couple on aeroplane
3.4 Effect of gyroscopic couple on naval ship
3.5 Stability of a four wheel and two wheel vehicles
3.6 Effect of gyroscopic couple on a disc fixed rigidly at a certain angle to a rotating shaft

4 Governors (4 hours)

4.1 Function of a governor
4.2 Terms Used in governor
4.3 Types of governors: Watt, Porter, Proell, Hartnell and Pickering Governors
4.4 Sensitiveness and stability of governors

5 Vibration of Single Degree of Freedom Systems (10 hours)

5.1 Definition and effects of vibration, terms used in vibration, vibration analysis procedure
5.2 Elements of a vibrating system
5.3 Undamped vibration of single degree of freedom system
5.4 Damped vibration of single degree of freedom system
5.5 Forced harmonic response of single degree of freedom system with viscous damping
5.6 Rotating unbalance
5.7 Whirling of rotor-shaft systems
5.8 Vibration isolation and force transmissibility
5.9 Response to an external motion
5.10 Response to multi-frequency and general periodic excitations

6 Vibration of Two Degree of Freedom Systems (6 hours)

6.1 Undamped vibration of two degrees of freedom system, natural frequencies and mode shapes
6.2 Damped vibration of two degrees of freedom system
6.3 Forced harmonic vibration of two degrees of freedom system
6.4 Tuned vibration absorber

7 Vibration of Multi Degree of Freedom Systems (6 hours)

7.1 Equations of motion in matrix form
7.2 Flexibility and stiffness matrices, reciprocity theorem
7.3 Eigenvalues and eigenvectors, orthogonal properties of eigenvectors
7.4 Modal analysis

8 Vibrations of Continuous Systems (4 hours)

8.1 Differences between discrete and continuous systems
8.2 Transvers vibration of strings
8.3 Longitudinal vibration in bars
8.4 Torsional vibration in circular shafts
8.5 Transverse vibration in beams

9 Approximate Numerical Methods (3 hours)

9.1 Rayleigh method for discrete and continuous system
9.2 Dunkerley method
9.3 Matrix iteration methods

10 Vibration Measurement and Condition Monitoring (4 hours)

10.1 Vibration measurement instruments

10.2 Accelerometers and sensors
10.3 FFT basics
10.4 Spectrum analysis
10.5 Active vibration control
10.6 Condition monitoring and fault diagnosis using vibration analysis

Tutorial **(15 hours)**

1. Velocity and acceleration of the piston using the analytical method
2. Fluctuation of energy and sizing the flywheel
3. Numerical problem on gyroscopic couple, stability of vehicle and effect on aircraft and ships
4. Performance analysis of governors
5. Free and forced response of single degree of freedom system
6. Free and forced response of two degree of freedom system and design of tuned mass damper
7. Matrix formulation of equations of motion for multi-degree of freedom system, eigenvalues and modal analysis
8. Response of continuous system
9. Numerical problems using Rayleigh, Dunkerley and Matrix Iteration methods
10. Performance of vibration measuring instruments

Practical **(22.5 hours)**

1. Response of governors
2. Measurement of couple on motorized gyroscope during precession
3. Response of a spring mass system
4. Whirling of a rotating shaft and determination of critical speed
5. Measurement and analysis of machine vibration using an accelerometer

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Mark distribution*
1 and 2	4	5
3	4	5
4	4	5
5	10	12
6	6	8
7	6	10
8	4	5
9	3	5
10	4	5
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Rao, S. S. (2011). Mechanical vibrations. Pearson.
2. Kelly, S. G. (2012). Fundamentals of mechanical vibrations. McGraw-Hill Education.
3. Khurmi, R. S., Gupta, J. K. (2015). Theory of machines. S. Chand Publishing.
4. Mahanty, A. R. (2004). Machine condition monitoring: Principles and practices. Elsevier.
5. Thomson, W. T., Dahleh, M. D. (1998). Theory of vibration with applications (Latest Edition). Prentice Hall.
6. Gilat, A. (2014). MATLAB: An introduction with applications. Wiley India.