



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME02000471

Subject Name: Dynamic Design of Mechanical Systems

w. e. f. Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Must be having knowledge of Dynamics of Machinery.
Rationale:	To cover theoretical foundations, advanced applications, and practical aspects, ensuring students gain in-depth expertise in learning methodologies which would enable them to predict dynamic behaviour – vibration responses of mechanical systems and associated governing parameters affecting the dynamic performance of actual systems.

Course Outcome:

After Completion of the Course, the students will able to:

No	Course Outcomes	RBT level
1	To make aware the students about how to prepare mathematical models for capturing the dynamic behaviour of structures representing the real mechanical systems.	
2	To provide an advanced understanding of the dynamic behaviour of mechanical systems.	
3	To equip students with tools and techniques for modelling, simulation, and optimization of dynamic systems.	
4	To enable the design and analysis of mechanical systems for dynamic performance under varying operating conditions.	

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
L	T	PR	C	Theory		Tutorial / Practical		
				ESE (E)	PA / CA (M)	PA/CA (I)	ESE (V)	
3	0	2	4	70	30	30	20	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
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1.	Fundamentals of Dynamics and System Design Review of dynamics and mechanics: Newtonian mechanics, D'Alembert's principle. Overview of system design principles: dynamic considerations in design, case studies on dynamic design challenges.	06	14
2.	Vibrational Analysis in Design: Single Degree of Freedom Review on Longitudinal and Torsional Single-Degree-of-Freedom (SDOF) systems: Free undamped and damped systems, and forced undamped and damped vibrations. Motion and Force transmissibilities and their practical application aspects. Effect of damping on transmissibility curves using programming tools. Vibrational Analysis in Design: Multi-Degree-of-Freedom (MDOF) systems Frequency Response Functions (FRFs). Eigenvalue problems, mode shapes, and modal analysis. Modal parameter extraction techniques for single degree and multi-degree of freedom systems. Proportional damping, Viscous damping.	10	22
3.	Mathematical Modelling of Mechanical Systems Modelling techniques: Lumped parameter and distributed parameter systems, Linear and nonlinear systems. Real mechanical systems and their physical models. Governing equations of motion: Derivation of equations of motion using Newton-Euler and Lagrange methods. Equations of motion using Matrix method for MDOF systems.	10	22
4.	Continuous systems: Vibrations in Strings, Rods, Bars, beams and plates. Vibration isolation and control strategies, Viscoelastic damping layer treatment.	10	22
5.	Advanced Computational Techniques Finite Element Analysis (FEA) in dynamic system designs: Modal analysis, harmonic analysis, and transient analysis using advanced FEA software and programming tools. Dynamic Design Considerations Mass alteration and material selection for improving dynamic performance: Lightweight materials, composites, and high-strength alloys.	09	20
Total		45	100

Suggested Specification Table with Marks (Theory):



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Distribution of Theory Marks

R Level	U Level	A Level	N Level	E Level	C Level
10	20	20	20	20	10

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Text Books:

1. "Theory of Machines and Mechanisms" by John J. Uicker Jr., Gordon R. Pennock, Joseph E. Shigley, Publisher: Oxford University Press.
2. "Mechanical Vibrations" by S. S. Rao, Publisher: Pearson Education.
3. "Engineering Mechanics: Dynamics" by J. L. Meriam and L. G. Kraige, Publisher: Wiley
4. "Dynamics of Machinery" by J. S. Rao and R. V. Duggipati, Publisher: New Age International.
5. "Principles of Vibration" by Benson H. Tongue, Publisher: Oxford University Press

Reference Books:

1. "Principles of Dynamics" by Donald T. Greenwood, Publisher: Pearson Education.
2. "Advanced Dynamics" by Donald T. Greenwood, Publisher: Cambridge University Press.
3. "Vibrations and Waves in Continuous Mechanical Systems" by Peter Hagedorn and Anirvan DasGupta, Publisher: Wiley
4. "Finite Element Procedures in Engineering Analysis" by Klaus-Jürgen Bathe, Publisher: Prentice Hall
5. "Applied Nonlinear Dynamics: Analytical, Computational, and Experimental Methods" by Ali H. Nayfeh and Bala Balachandran, Publisher: Wiley
6. "Structural Dynamics: Theory and Applications" by Mario Paz and William Leigh, Publisher: Springer
7. "Multi-body Dynamics: Monitoring and Simulation Techniques" by Friedrich Pfeiffer and Claus Glocker, Publisher: Springer
8. "Rotordynamics of Turbomachinery" by John M. Vance, Publisher: Wiley



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Suggested Course Practical List:

(A) List of Experiments:

1. Study the natural frequencies and perform experiments for free undamped and damped Vibration Analysis of a Single-Degree-of-Freedom (SDOF) System.
2. Study the natural frequencies and perform experiments for free undamped and damped Vibration Analysis of a Two-Degree-of-Freedom (TDOF) System.
3. Investigate the response of an SDOF system under harmonic excitation.
4. Theoretical calculations and simulations to determine mode shapes and natural frequencies of a two-mass system.
5. Use FEA software to perform modal and harmonic analysis on mechanical components.
6. Analyze the performance of vibration isolators under varying excitation frequencies.
7. Calculations to determine natural frequencies of Chladni (Circular, triangular and rectangular) plates and observing mode shape patterns.
8. Study the dynamic response of Beams and Plates under harmonic excitation using modal exciters.
9. Measure time and frequency domain responses for different mechanical systems of practical significance.
10. Measure vibration levels and natural frequencies using sensors and data acquisition systems for various mechanical systems.

(B) Simulations:

1. Finite element modeling of structures using software like ANSYS, Abaqus, or HyperWorks.
2. Modal analysis - dynamic simulations for extracting damping, natural frequencies and mode shapes.
3. Seminar project modelling and simulation.

List of Laboratory/Learning Resources Required:

Software/Programming language:

ANSYS Workbench/MSC NASTRAN/Abaqus/SolidWorks Software
MATLAB or Python

Suggested Activities for Students:

Project Work:



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A subject seminar project as term work may be given to the students for analyzing real life problems for better understanding of the dynamic behavior of systems. The students may be advised, as per their interest, to get into the mathematical modelling aspects of the following real-life based scenario to highlight the versatility of mathematical modeling across various mechanical systems. For this task, they may refer journal articles & research work from renowned publishers such as: Journal of Sound and Vibration, Journal of Acoustical Society of America, Applied Acoustics, Mechanical Systems and Signal Processing, ASME Journal of Mechanical Design and many more.

A few example of mechanical systems are given hereunder, just to have an idea about the research work which may be carried out. This would also help the students to decide about their dissertation work as well.

1. Modelling of Automobile Suspension Systems: Model spring-damper systems for suspensions, analyze vibrations and optimize damping coefficients for ride comfort and road handling.
2. Engine Dynamics Modelling: Develop models for crankshaft motion, piston dynamics, and valve timing, Simulate engine noise, vibration, and harshness (NVH).
3. Vehicle Dynamics: Longitudinal and lateral dynamics for braking, acceleration, and cornering, Study stability and rollover prevention using dynamic models.
4. Robotic Arms: Model kinematics and dynamics of multi-joint robotic manipulators, Simulate trajectory planning and optimize motion for pick-and-place tasks.
5. Mobile Robots: Develop dynamic models for wheeled and legged robots for navigation and obstacle avoidance.
6. Industrial Machinery, Rotating Machinery: Model dynamic behavior of rotors to predict critical speeds and vibration modes, analyze gyroscopic effects in turbines and compressors.
7. Conveyor Systems: Develop models for belt tension and motor power requirements under varying dynamic loads for different boundary and operating conditions.
8. Cutting Tools: Simulate tool chatter during machining and optimize cutting conditions.
9. Structural Dynamics: Model structures under seismic or wind loads to predict oscillations and stresses, analyze damping requirements and optimize material usage, simulate wave and wind-induced vibrations and optimize stability.
10. Wind Turbines: Model blade dynamics under variable wind conditions, study the impact of rotor imbalance and aerodynamic loading.
11. Dynamic Modeling of CNC Machines: Simulate spindle dynamics and tool vibration for precision machining.

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