Birla Institute of Technology & Science, Pilani
Hyderabad Campus

SECOND SEMESTER 2024-2025

Course Handout Part II

Date: 02-01-2025

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No. : **ME F434**
Course Title : ***Digital Twins in Mechanical Engineering***
Instructor-in-Charge : Dr. Sabareesh G R

Scope and Objective of the Course:

This course is designed to acquaint the students with topics in vibrations and control. The emphasis is on application to common engineering situations. The course will cover topics on digital twins for condition monitoring and prognostics - Digital Twins for prognostics, fault diagnosis in rotating machines, electrical machinery faults, thermography, computer vision technique for wear debris analysis, acoustic analysis, mathematical modelling and physics-based approach, communication protocols between physical and virtual systems, data driven or AI/ML- based approach for digital twins, and hybrid approach. Digital twins in Manufacturing- operations improvement, tool condition monitoring, 3-D printing. Digital Twins in Aerospace systems and automobiles.

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Textbooks:

T1. A R Mohanty, Machinery Condition Monitoring, Principles and practices, Taylor and Francis.

Reference Books:

[R1] J.S.Rao, Vibration Condition Monitoring of Machines, CRC Press
[R2]S K Pal, D Mishra, Arpan Pal, Samik Datta, Debashish Chakravarty, Srikanta Pal, Digital Twin-Fundamental concepts to application in Advanced Manufacturing- Springer
[R3] H. P. Bloch and F. P. Geitner, Practical Machinery Management for Process Plants, Vol. 1, 2 3 & 4., Gulf Publishing Company, 1983
[R4] A. V. Oppenheim and R.W. Shafer, Digital Signal Processing, Prentice-Hall, Inc., 1975

Course Plan:

Lecture No.	Learning objectives	Topics to be covered	Text Book
1-3	Introduction to Digital Twins	Introduction to digital twins	Class Notes
4 -6	Mechanical Faults in Machinery	Types and causes of mechanical machinery faults	T1, R1
7-8	Electrical machinery faults	Types and causes of electrical machinery faults- Short circuits, Over loads, Ground Faults, Phase Imbalance, Insulation Failure	T1, R1

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9-11	Introduction to Fault diagnosis in rotating machines	Predictive and Preventive Maintenance, Condition based Maintenance	T1
12-14	Vibration and acoustic analysis	Time domain analysis, Frequency Domain Analysis, Time-Frequency, Acoustic Emission Testing, Noise Measurement and Sound Spectrum Analysis	T1, R3
15-17	Thermography, computer vision technique for wear debris analysis	Introduction to thermography, working, applications, faults detected using thermography, Debris analysis, Steps in wear debris analysis using computer vision	T1
18-20	Mathematical modelling and physics-based approach for digital twins	Main approaches, Integrating mathematical model with real data, Challenges	Class Notes
21-23	Communication protocols between physical and virtual systems	Introduction to MQTT, CoAP, DDS, OPC-UA, AMQP, Edge computing protocols	Class Notes
24-27	Data driven or AI/ML- based approach for digital twins	Data Types and Data Flow in a Data-Driven Digital Twin, Challenges	Class Notes
28-30	Hybrid Approach in digital twins	Physical assets and data integration, Virtual models, AI and analytics, Decision making layer	Class Notes
31-34	Digital twins in Manufacturing-operations improvement, tool condition monitoring	Predictive Maintenance & Equipment Health Monitoring Production Line Optimization Quality Control & Process Optimization Supply Chain & Inventory Management, Case Studies	R2, Class Notes
35-37	Digital twins in 3-D printing	Design Optimization and Prototyping, Real-time Monitoring and Quality Control, Predictive Maintenance, End-of-Life (EOL) Tracking and Recycling, Case Studies	Class Notes
38-42	Digital Twins in Aerospace systems and automobiles	Aircraft fleet management, Engine health monitoring, design and testing, Vehicle design and Simulation, Supply Chain optimization, Predictive Maintenance, Case Studies	Class Notes

Evaluation Scheme:

Component	**Duration**	**Weightage**	**Date & Time**	**Nature of component**
Mid-Semester Test	90 min	25%		CB
Laboratory / Project		30%		OB
Term Paper & Case Studies		10%		OB
Comprehensive Examination	180 mins	35%		CB

Chamber Consultation Hour: To be announced in the class.

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Notices: All the notices regarding the course will be displayed on the CMS.

Make-up Policy: Only for genuine cases with prior permission

INSTRUCTOR-IN-CHARGE