



# GUJARAT TECHNOLOGICAL UNIVERSITY

**Program Name: Diploma Engineering**

**Level: Diploma**

**Branch: Metallurgy Engineering**

**Subject Code: DI04021081**

**Subject Name: Failure Analysis**

<b>W. e. f. Academic Year:</b>	2025-26
<b>Semester:</b>	4 <sup>th</sup>
<b>Category of the Course:</b>	Professional Elective - II

<b>Prerequisite:</b>	The Failure Analysis course introduces students to the principles, causes, and investigation methods of material and component failures in engineering applications. It focuses on understanding how and why metallic materials fail during service and how such failures can be analyzed, interpreted, and prevented through sound metallurgical knowledge and engineering practices.
<b>Rationale:</b>	Failures of metallic components are common in industries such as automotive, railways, power plants, construction, and manufacturing. These failures often lead to production losses, safety hazards, and high maintenance costs. To minimize such incidents, engineers must understand the causes, mechanisms, and prevention of material failures. This subject enables diploma students in Metallurgy to apply their knowledge of physical and mechanical metallurgy to analyze and interpret the causes of failures in real-world components. It bridges the gap between theoretical materials science and practical industrial problem-solving.

## Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Explain the importance of failure analysis and outline the general procedures used in investigating material failures.	U
02	Differentiate between ductile and brittle fractures, describe their characteristics, and explain the concept of ductile-to-brittle transition.	A
03	Interpret the features of fatigue and corrosion-related failures and identify their causes and <b>suggest</b> preventive measures.	A
04	Describe high-temperature failure mechanisms such as creep and explain common failure modes in boilers and power plant tubes.	U

*\*Revised Bloom's Taxonomy (RBT)*



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### 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(M)	PA(I)	ESE(V)	
2	0	4	4	70	30	20	30	150

### Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	<b>Introduction to Failure Analysis</b> 1.1 Importance and need of failure analysis in industries. 1.2 Fundamental causes of material failures (design, material selection, processing, service conditions). 1.3 General steps and practices in failure investigation.	8	26
2.	<b>Types of Failure: Ductile and Brittle Fracture</b> 2.1 Various types of fractures. 2.2 Ductile fracture: theory, mechanism, and characteristics (cup-and-cone, micro void coalescence). 2.3 Brittle fracture: theory, mechanism, and characteristics (cleavage, intergranular, transgranular). 2.4 Ductile-to-brittle transition behavior and factors affecting it.	8	28
3.	<b>Fatigue and Corrosion Failures</b> 3.1 Fatigue failure: stages, S–N curve, and characterization of fatigue fracture surfaces. 3.2 Types of fatigue: corrosion fatigue, contact fatigue, thermal fatigue. 3.3 Corrosion and corrosion-related failures – hydrogen embrittlement, Stress Corrosion Cracking (SCC), and their prevention.	8	28
4.	<b>High Temperature Failures</b> 4.1 Characterization of high-temperature failures. 4.2 Creep mechanism and creep fracture. 4.3 Failures of boilers and pressure vessels. 4.4 Tube failures in thermal power plants – types, causes, and preventive measures.	6	18
<b>Total</b>		<b>30</b>	<b>100</b>



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## Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	U Level	A Level	N Level	E Level	C Level
30	40	30			

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) Books:

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Understanding How Components Fail	Donald J. Wolpi	ASM International, Materials Park, Ohio, USA Titanium: A Technical Guide, 2nd Edition
2	Analysis of Metallurgical Failures	V.J. Colangelo & F.A. Heiser	John Wiley & Sons, New York, 1974, 047116450X
3	ASM Handbook Volume 11: Failure Analysis and Prevention	William T. Becker, Roch J. Shipley,	American Society for Metals, Metals Park, Ohio. 2021, 978-1-62708-293-8
4	Metals Hand Book – Eight Edition – Fractography,	F. H. Norton	American Society for Metals, Metals Park, Ohio
5	Engineering Materials – Selection and Value Analysis	H. J. Sharp	Elsevier Publishing Company Inc., New York.1966
6	Failure Analysis of Engineering Materials	Charles R. Brooks & Ashok Choudhury	McGraw-Hill, 2002

### (b) Open source software and website:

- <https://archive.nptel.ac.in/> (Fracture, Fatigue and Failure of Materials - YouTube, Failure analysis and Prevention - IITR - YouTube)
- [https://onlinecourses.nptel.ac.in/noc21\\_me14](https://onlinecourses.nptel.ac.in/noc21_me14)
- <https://www.ansys.com/en-in/simulation-topics/what-is-failure-analysis>



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- <https://www.asminternational.org> (Bearing failure analysis identifies lubrication issues at South African sugar refinery - ASM International)

## Suggested Course Practical List

Sr. No.	Practical List	Unit No.	Approx. Hrs. Required
1	Visual inspection of failed components (shaft, bolt, gear) and Identify failure features	I	4
2	Preparation of a failure investigation flowchart with systematic step	I	4
3	Dye Penetrant Test (DPT) for surface crack detection	I	4
4	Study of ductile fracture sample under microscope	II	2
5	Study of brittle fracture sample under hand lens / microscope	II	2
6	Charpy/Izod impact test to observe ductile-to-brittle transition	II	2
7	Observation of fatigue fracture surface (beach marks / striations)	III	4
8	Demonstrate corrosion mechanism and types.	III	4
9	Stress corrosion cracking case study (images / videos)	III	4
10	Creep test demonstration / observation on lead/tin specimen	IV	2
11	Study of boiler tube / high-temperature failure samples	IV	4
12	Thermal fatigue or thermal shock case study / demonstration	IV	2
13	Comparative study of failed ductile, brittle, fatigue, and creep samples	I-IV	4
14	Mini-project: Analyze an industrial failure and prepare a report	I-IV	8
15	Group presentation on failure prevention measures (material selection, heat treatment, design)	I-IV	10



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## List of Laboratory/Learning Resources Required:

Sr. No.	Instrument
1.	Optical Microscopes, Scanning Electron Microscopes (SEM), and Transmission Electron Microscopes (TEM)
2.	Ultrasonic Testing , Magnetic Particle Inspection, and Dye Penetrant Testing equipments
3.	Tensile testing machines, Hardness testers, and Impact testing machine
4.	Sample cutting and polishing setup, Chemical analysis tools
5.	Failure analysis samples for case studies (Boiler tubes, Turbine blades, Axle-Wheel shaft etc.)

## Suggested Project List:

1. Prepare models of Fracture mode
2. Case Study on Ductile-to-Brittle Transition in Steel Component
3. Prepare charts of steps involved in failure investigation
4. Failure Analysis Report on a Rejected Industrial Component

## Suggested Activities for Students:

1. Debate on historical failures (e.g., bridges, aircraft, pipelines)
2. Visit industries or use online virtual labs to study boiler tube failures, pipeline corrosion, or automotive component failures.
3. NDT Demonstrations
4. Case Study on ductile vs. brittle vs. fatigue vs. creep failures

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