DESIGN OF MACHINE ELEMENTS

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NRCM ENGINEERING

ENGINEERING MATERIALS & DESIGN

Course Introduction
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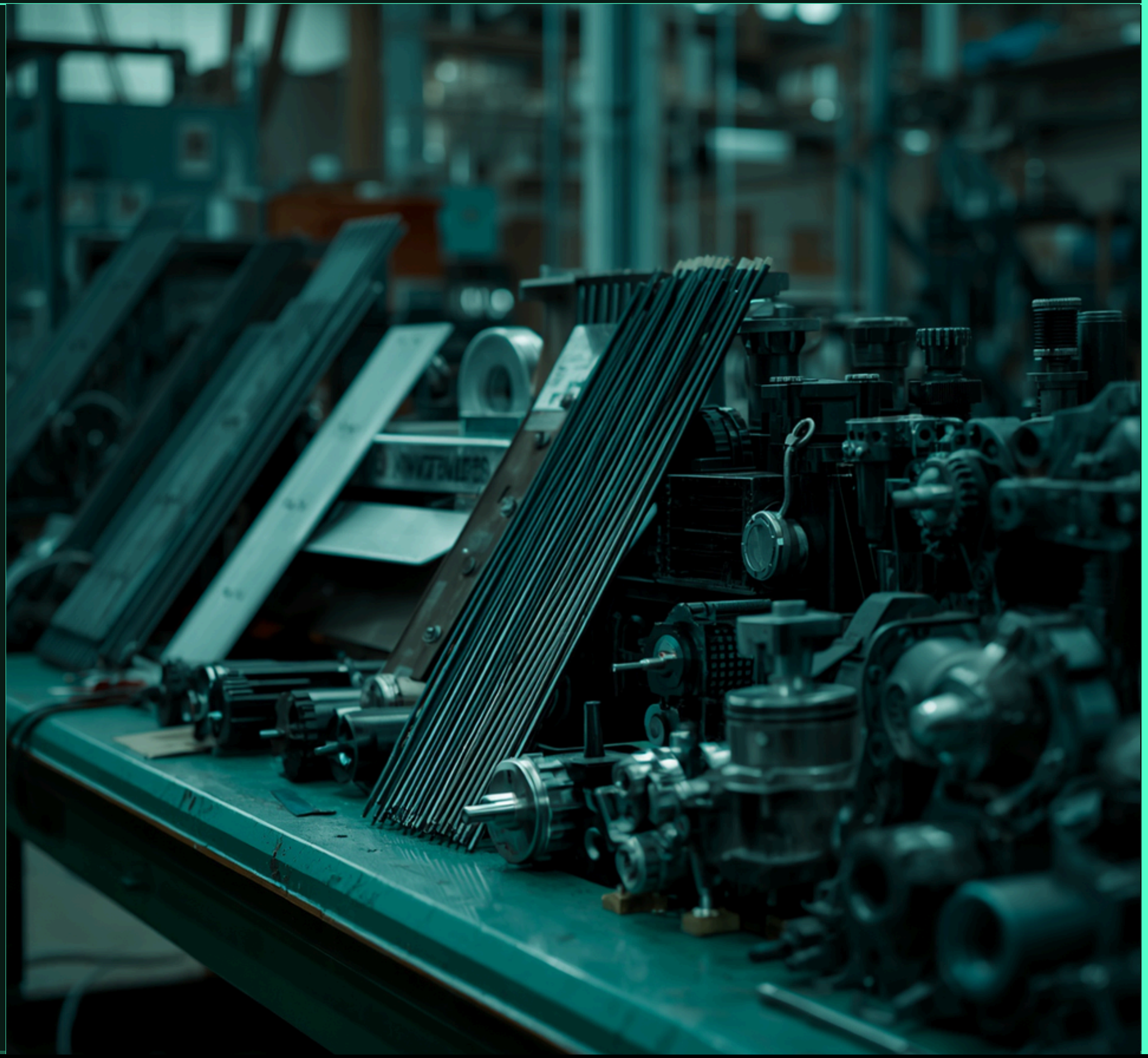
This course covers general considerations in the design of engineering materials — including material properties, selection criteria, and manufacturing considerations in design. Topics include tolerances, fits, BIS codes of steels, static strength, stress theories, and stiffness concepts in tension, bending, and torsion.



ENGINEERING MATERIAL PROPERTIES

Mechanical, Thermal & Chemical Properties

Material properties are critical in engineering design decisions. Mechanical properties include strength, hardness, ductility, toughness, and elasticity — determining how a material responds to applied forces. Thermal properties such as conductivity, expansion, and heat resistance influence performance under temperature variations. Chemical properties including corrosion resistance and oxidation behavior ensure material durability in service environments. Selecting the right material based on these properties ensures structural integrity, safety, and cost-effectiveness in engineering design.

MATERIAL SELECTION IN ENGINEERING DESIGN

Key Factors Influencing Material Choice

The selection of engineering materials is governed by multiple critical factors: Strength & Durability – ability to withstand applied loads and environmental conditions. Cost & Availability – economic feasibility and supply chain reliability. Manufacturability – ease of machining, forming, welding, and processing. Application Requirements – thermal, electrical, and chemical compatibility. BIS codes and standards guide appropriate material specification for safe and optimized design outcomes.

MANUFACTURING CONSIDERATIONS IN DESIGN

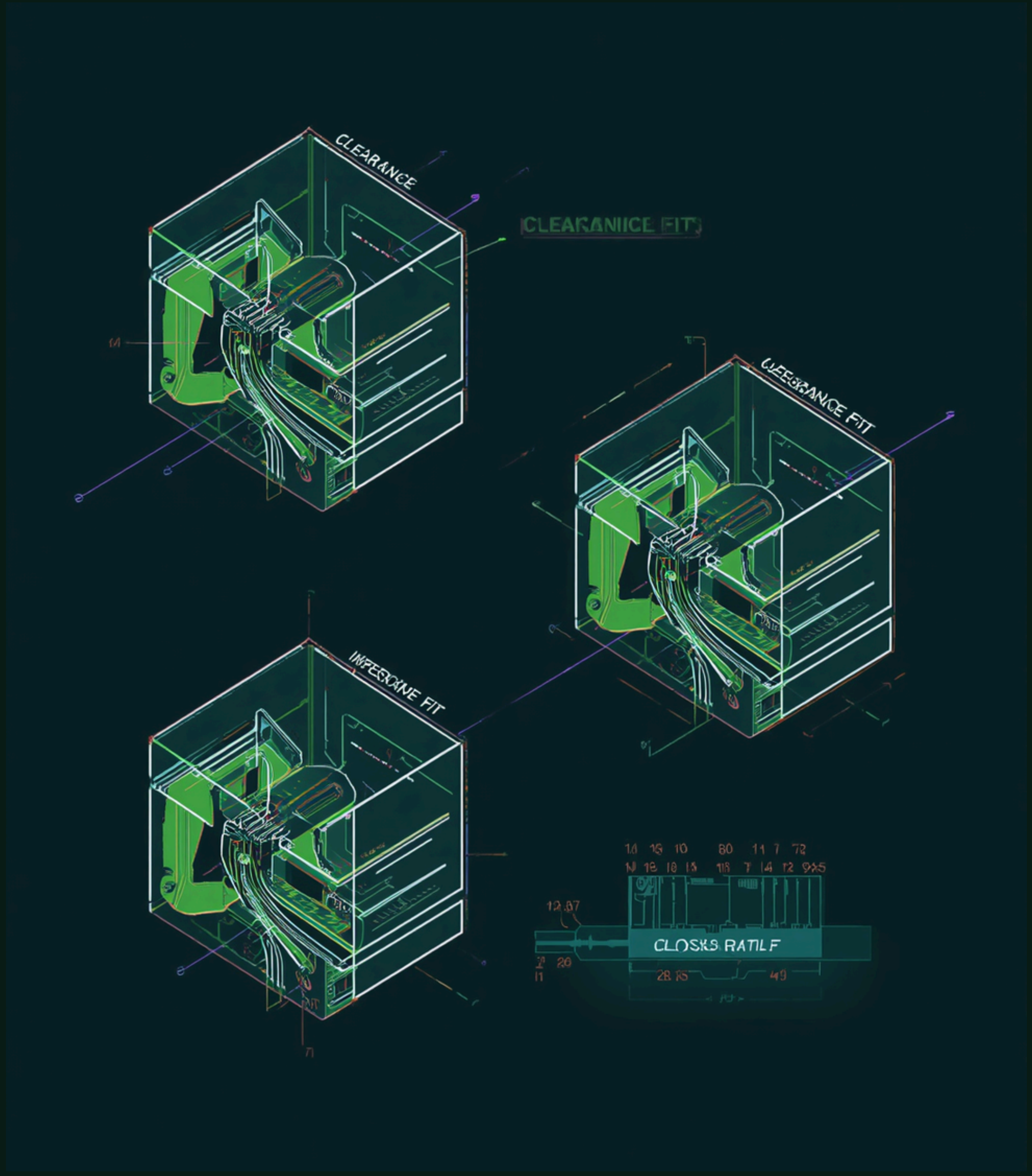
Process-Driven Design Decisions

Manufacturing processes fundamentally shape engineering design choices. Casting allows complex geometries but requires draft angles and uniform wall thickness. Forging produces high-strength components with superior grain structure. Machining offers precision but increases cost with complexity. Forming processes like stamping and rolling suit high-volume production. Each process imposes unique constraints on tolerances, surface finish, and material selection — all governed by BIS codes and standards.

TOLERANCES AND FITS

Types of Fits & BIS Standards

Types of Fits: Clearance Fit – gap between mating parts; Interference Fit – shaft larger than hole, requiring force assembly; Transition Fit – may result in either clearance or interference. BIS Codes define tolerance grades (IT01–IT16) and fundamental deviations for shafts and holes, ensuring dimensional accuracy, interchangeability, and reliable performance in mechanical assemblies.



BIS CODES OF STEELS

Classification & Designation Systems

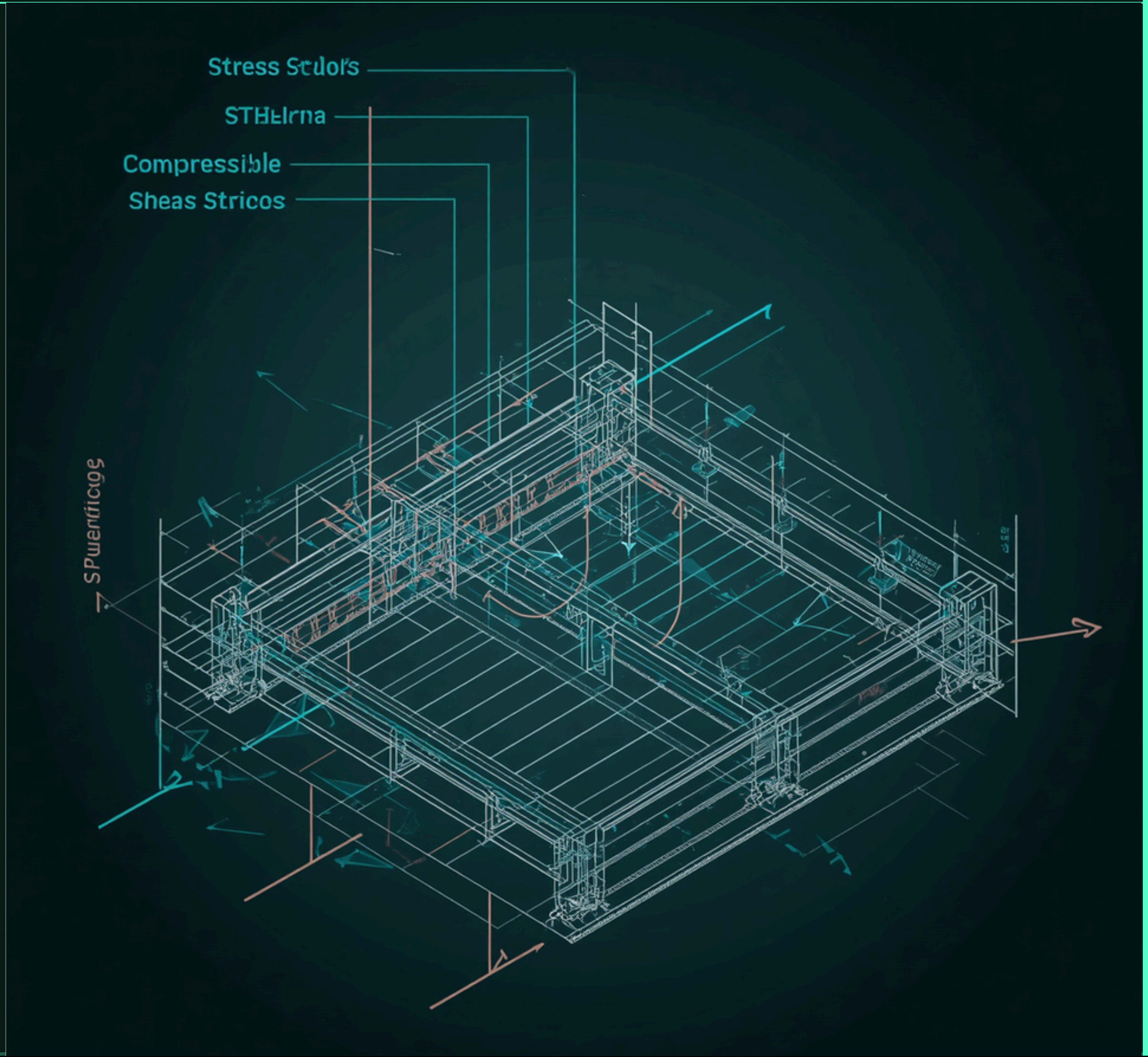
BIS (Bureau of Indian Standards) provides standardized codes for engineering steels. IS 1570 covers wrought steels, while IS 2062 specifies structural steels. Steel designation includes chemical composition, tensile strength, and heat treatment codes. Example: 40Cr4 denotes 0.40% carbon with 1% chromium alloy steel. BIS codes ensure material traceability, quality assurance, and interchangeability in mechanical design applications across industries.

DESIGN FOR STATIC STRENGTH

Simple Stress Analysis

Static strength design involves analyzing three fundamental stress types:
- Tensile Stress (σ = F/A): Force pulling a material apart, causing elongation along the load axis.
- Compressive Stress: Opposing force that squeezes or shortens a member along its axis.
- Shear Stress (τ = V/A): Force acting parallel to a cross-section, causing sliding or angular deformation.

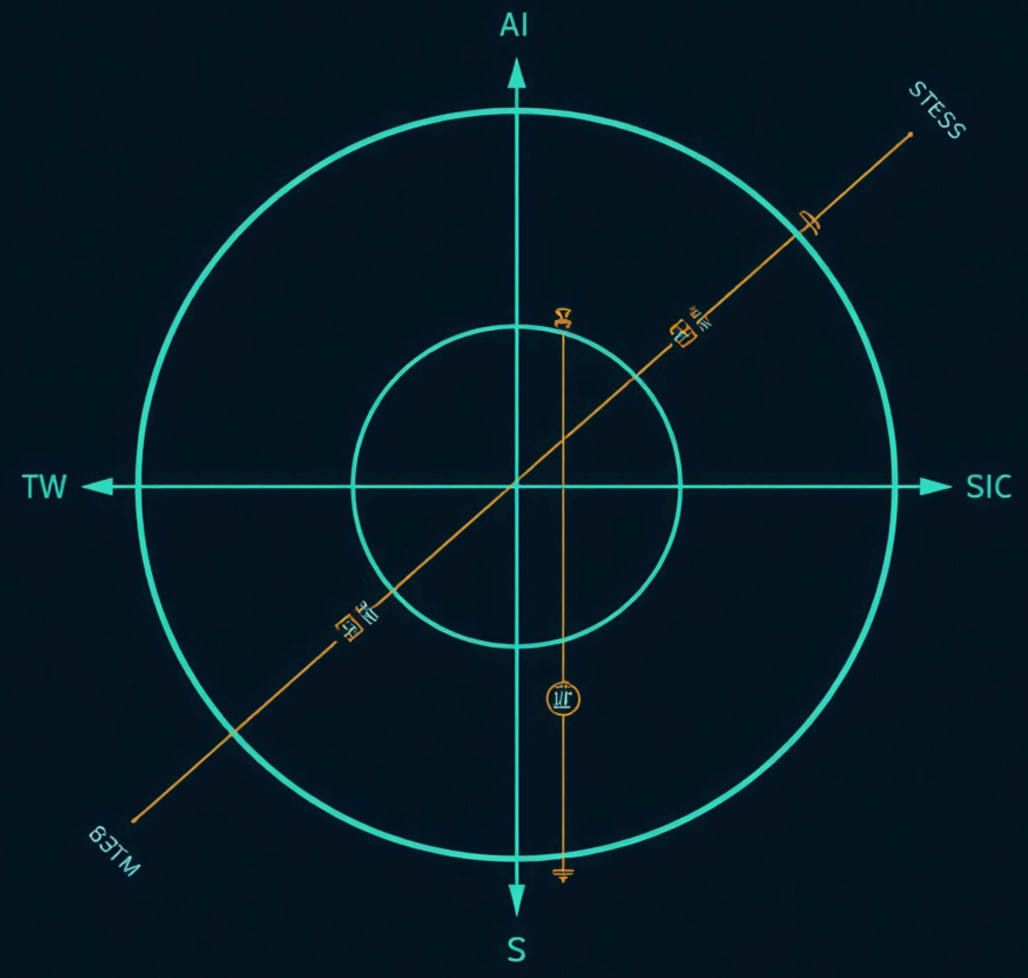
Proper identification and calculation of these stresses is the foundation of safe mechanical design.



COMBINED STRESSES

Principal Stresses & Stress Transformation

When a structural member is subjected to multiple loads simultaneously, combined stresses arise. Principal stresses represent the maximum and minimum normal stresses acting on a plane where shear stress is zero. Mohr's Circle is a graphical method to determine principal stresses, maximum shear stress, and stress transformation at any orientation. For a general 2D stress state with normal stresses σ_x, σ_y and shear stress τ_{xy}, principal stresses are: $\sigma_{1,2} = (\sigma_x+\sigma_y)/2 \pm \sqrt{[((\sigma_x-\sigma_y)/2)^2 + \tau_{xy}^2]}$. The angle of the principal plane: $\tan(2\theta_p) = 2\tau_{xy}/(\sigma_x-\sigma_y)$. Maximum shear stress: $\tau_{max} = \sqrt{[((\sigma_x-\sigma_y)/2)^2 + \tau_{xy}^2]}$.

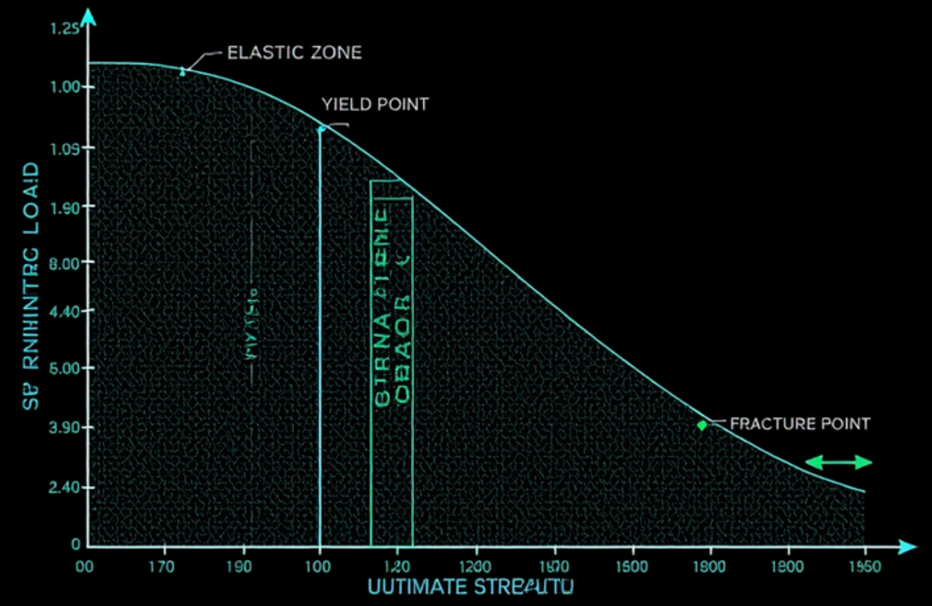


TORSIONAL & BENDING STRESSES

Shaft Design & Beam Analysis

Torsional stress: $\tau = Tr/J$, where T is torque, r is radius, and J is polar moment of inertia. Bending stress: $\sigma = My/I$, where M is bending moment and I is area moment of inertia. Combined bending-torsion loading uses equivalent moment: $Me = \sqrt{(M^2 + T^2)}$. Critical in shaft design, gear systems, and structural beams under complex loading conditions.

IMPACT STRESSES & STRESS-STRAIN RELATIONS



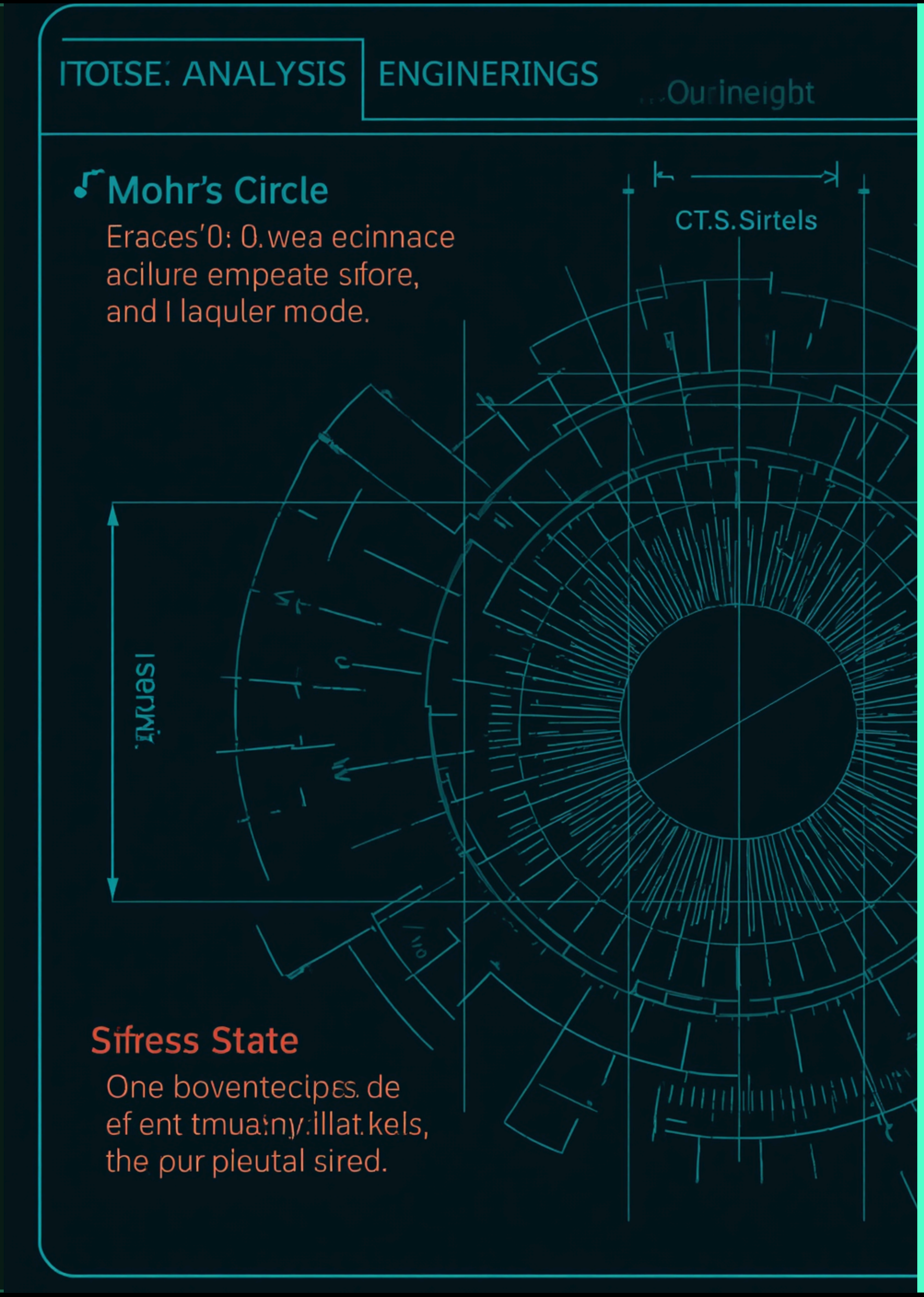
Dynamic Loading & Material Behavior

Impact stresses arise from sudden dynamic loads, analyzed using energy methods. The stress-strain curve defines elastic, yield, and plastic zones. Key parameters include modulus of elasticity, yield strength, ultimate strength, and toughness. Resilience measures energy absorption before yielding, while toughness indicates total energy absorption capacity up to fracture.

THEORIES OF FAILURE

Predicting Material Failure Under Complex Loading

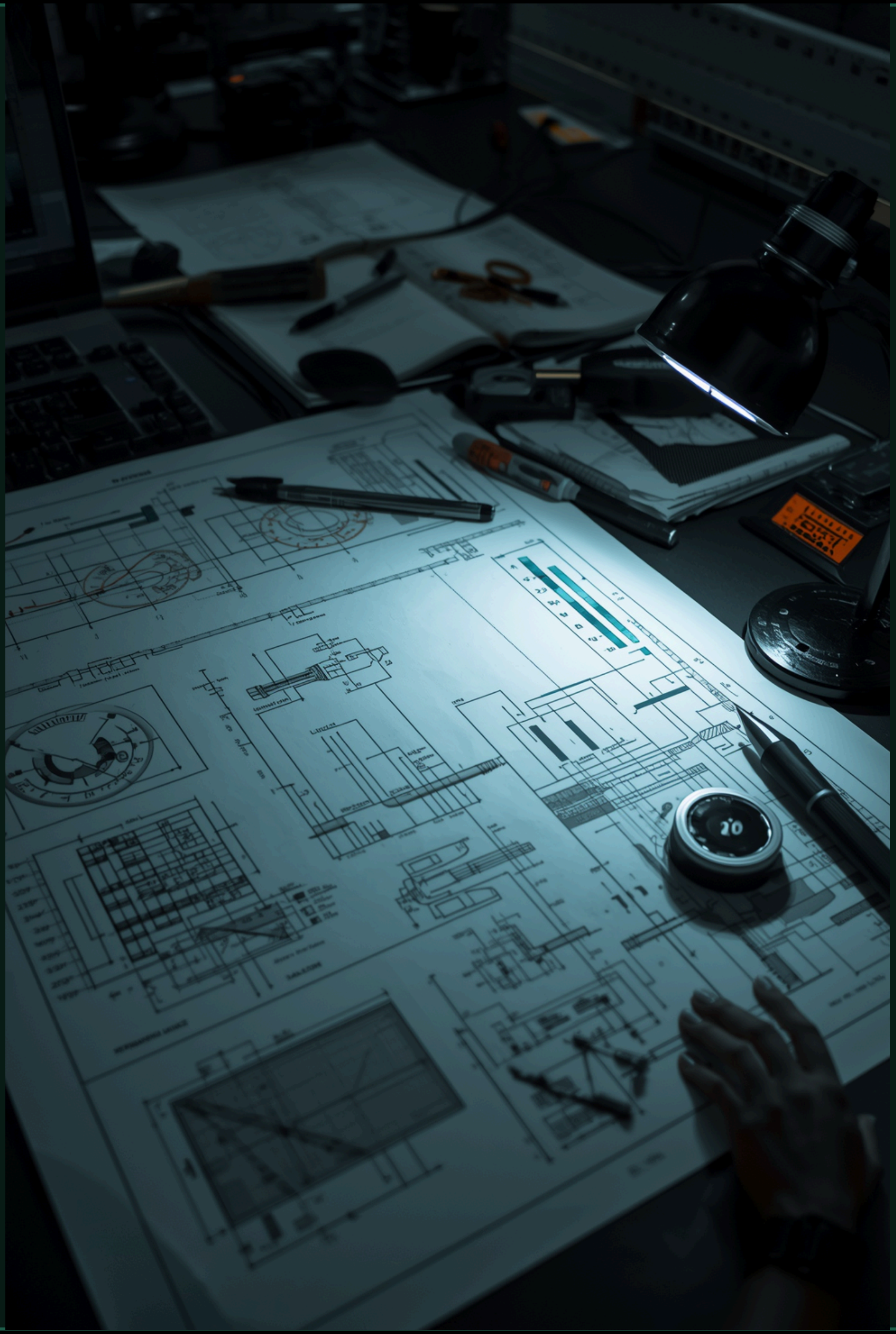
1. Maximum Normal Stress Theory (Rankine): Failure occurs when max principal stress reaches yield strength.
2. Maximum Shear Stress Theory (Tresca): Failure when max shear stress equals half the yield strength.
3. Distortion Energy Theory (Von Mises): Failure when distortion energy equals that at uniaxial yield.
4. Maximum Normal Strain Theory (Saint-Venant): Failure when max principal strain reaches yield strain.
5. Mohr's Theory: Uses Mohr's circles to define failure envelope for brittle materials under combined stresses.



FACTOR OF SAFETY & DESIGN PRINCIPLES

Design for Strength and Rigidity

Factor of Safety (FOS): Ratio of material strength to allowable stress, ensuring reliable performance under uncertainty. Design for Strength: Components must withstand static, dynamic, and impact loads without failure. Design for Rigidity: Controlling deflection and deformation within acceptable limits. Preferred Numbers: Standardized series (R5, R10, R20, R40) for rationalizing dimensions and sizes per BIS standards, enabling interchangeability and efficient manufacturing across engineering applications.



THE CONCEPT OF STIFFNESS

Tension, Bending, Torsion & Combined Loading

Stiffness defines a structure's resistance to deformation under load. In tension: $k = AE/L$. In bending: $k = 48EI/L^3$ (simply supported). In torsion: $k = GJ/L$. Combined loading requires superposition of individual stiffness contributions. Stiffness governs both strength and rigidity in engineering design.

THANK YOU!

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CONTACT FOR QUERIES