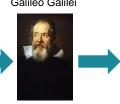
FROM METALS TO NANOMATERIALS: A COMPREHENSIVE APPROACH TO FRACTURE TOUGHNESS

ASSESSMENT



~1500s Early observations on the scalability of fracture in materials



Formulation of scaling laws for bars under tension and bending: recognition of the "size for fracture problems effect"



Establishment of systematic experimental tests in steel



Development of the fundamental theory for brittle fracture, explaining crack propagation based on energy balance



1957 Formalization of the Stress Intensity Factor (SIF) concept to quantify stress fields around cracks



First publication of ASTM E399, standardizing the measurement of linearelastic plane-strain fracture toughness (K_{Ic}) for metallic materials



Mid-1970 Development of nanoindentation technique to measure mechanical properties of very small material volumes

Official discovery of multi-walled carbon nanotubes

S. Iijima, A. Koshio,

M. Yudasaka

1996 First publication of ASTM E1820, standardizing elasticplastic fracture toughness (J_{Ic}, CTOD) for ductile materials

Early 2000s onwards Significant advancements of multi-scale modeling for fracture analysis

Metals

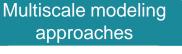


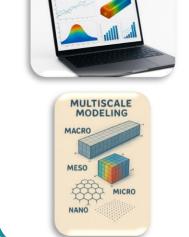
Nanomaterials

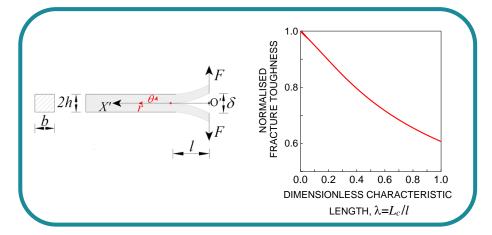




Nanoindentation, AFM, TEM







Future frontiers in fracture toughness assessment and material design:

- · Role of Artificial Intelligence and Machine Learning in fracture behavior prediction
- · Development of novel materials with enhanced toughness
- · Impact on engineering education and diverse industrial applications





