

The Resilience of Grade 91 Steel: How Pre-straining Alters Structural Integrity

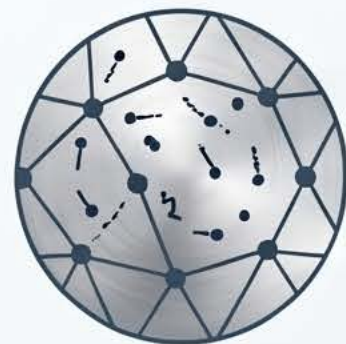
Power plant components like Grade 91 steel accumulate localized plastic damage (pre-strain) over years of service. This study uses Small Punch Testing (SPT) and 3D modelling to reveal how this "hidden" plasticity significantly weakens material durability and changes its fracture behaviour.

Impact on Mechanical Strength



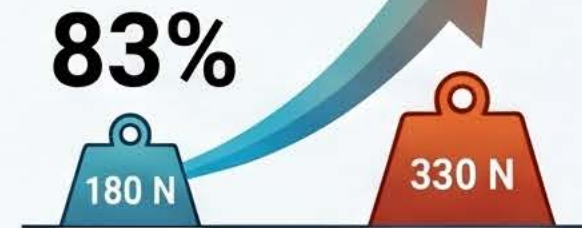
Pre-strain Level	Yield Load (CEN Method)	Maximum SPT Load
0% (As-received)	180 N	2100 N
12% Pre-strained	330 N	1780 N

Strengthening vs. Weakening

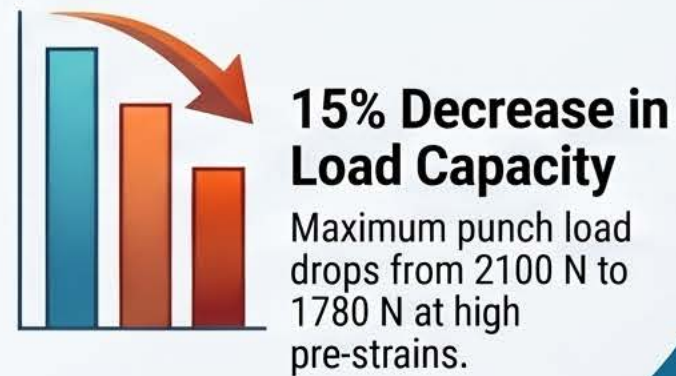


Dislocation density reduces work-hardening.

Initial strengthening is eventually outweighed by early necking and reduced ductility.

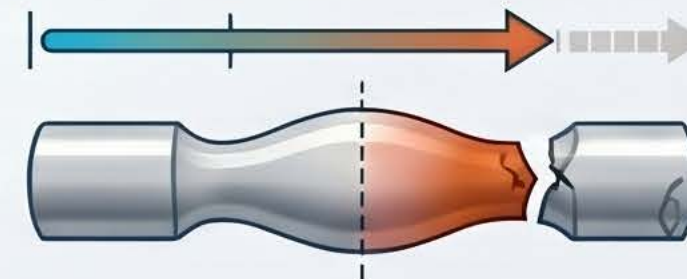


Increase in Yield Load
Yield load rises from 180 N to 330 N as pre-straining reaches 12%.



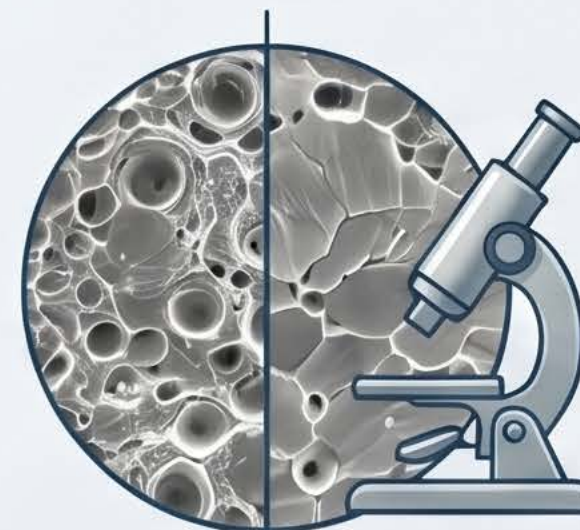
As-Received
Pre-Strained

Deformation & Fracture Behaviour



Early Fracture Initiation: 5% Reduction in Fracture Displacement

Displacement at fracture drops from 2.25 mm to 2.13 mm with pre-straining.



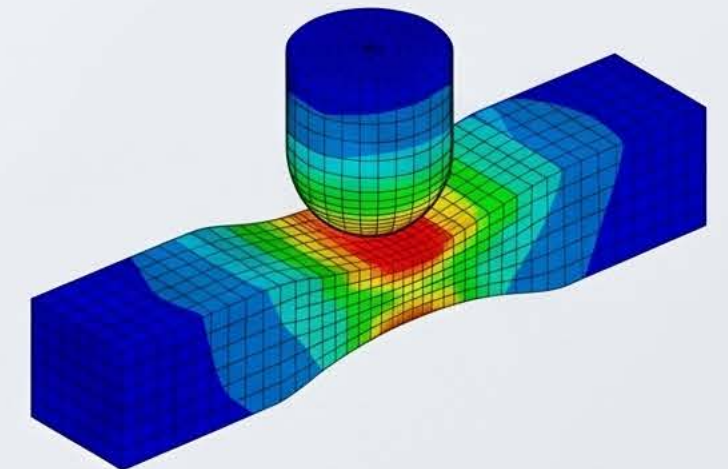
As-received (Ductile)

High Pre-strain (Brittle-like)

Ductility Loss: Transition to Brittle-like Facets

High pre-strain promotes a shift from ductile dimples to brittle microscopic characteristics.

Precision Modelling Success



3D simulations validated results.

Finite element modelling accurately predicted stress distribution and the onset of fracture.