This Week's Citation Classic

NUMBER 10
MARCH 5, 1979

Cottrell A H. Theory of brittle facture in steel and similar metals.
Trans. Metallurgical Soc. AIME **212**:192-203, 1958.

Conflicts between crack theories and slip theories of fracture were resolved by a dislocation theory in which micro-cracks were formed by plastic deformation but grew under tensile stress. This enabled the transition temperature, radiation embrittlement, and other fracture effects to be explained. [The *SCI*® indicates that this paper has been cited 381 times since 1961.]

Alan Cottrell
University of Cambridge
The Master's Lodge, Jesus College
Cambridge CB5 8BL
England

June 29, 1978

"Much of the interest shown in my paper is undoubtedly due to the practical importance of brittle fracture in steel. It is a potential hazard in big engineering structures, especially in cold weather, and has destroyed many ships, bridges, boilers and chemical storage vessels, sometimes with great loss of life. The introduction of big steel pressure vessels for nuclear reactors, in the 1950s, gave the problem still greater importance.

"It was an intriguing problem scientifically. For example, a thick piece of steel could snap like glass, yet small laboratory pieces cut from it could be completely ductile and tough. The explanation of this was already known in principle through the fact that, in ordinary steel at ordinary temperatures, cracks had to be an inch or more long before they would run catastrophically. But many perplexing problems remained. For example, there was the sharp ductile-brittle transition temperature: over a few degrees the behaviour could change dramatically from ductile above this temperature to brittle, below it.

"I became interested in the problem when I joined the UK Atomic Energy Research Establishment, Harwell, in 1955. My intention there was to work on problems of radiation damage. Among these was one that concerned the safety of the big steel nuclear reactor pressure vessels: the embrittlement of steel by prolonged irradiation. It soon became clear that no scientific progress could be made with this while brittle fracture was not understood generally. There was recent evidence that cracks formed, at low temperatures in steel, as soon as the crystal grains began to yield plastically, which seemed to rule out simple theories of fracture based on an assumed pre-existence of cracks. But, why the transition temperature and the sensitivity to hydrostatic tensile stress? My idea was that dislocations on intersecting slip planes, in a crystal of iron, attracted one another and so coalesced readily to form micro-cracks at the onset of plastic yielding, which would then run if the tensile stress was high. Fortunately, it was possible to develop this theory mathematically and so to explain' quantitatively various effects of radiation, hardening, and grain size, on the transition temperature. A particularly satisfying conclusion, with good practical implications, was that reducing the grain size made the metal both harder and more ductile.

"The paper was presented as the 1958 Annual Lecture at the American Institute of Metallurgical Engineering meeting in New York. It was a very happy visit for me."