of ramie, found to be 84–85 A. by deposition of metals[3], and the greater width of the spaces of these fibres can be accounted for by assuming them to be more loosely built than ramie.

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Crack Initiation in Hydrogenated Steel

THE interaction between hydrogen and steel results in various embrittlement phenomena. For example, it has long been known that flakes, or internal hair-line cracks in alloy steel forgings, are related to the presence of hydrogen retained from the steel-making process. On the other hand, embrittlement of electroplated high-strength steel parts is caused by hydrogen introduced during pickling or electroplating processes. A particularly disturbing form of hydrogen embrittlement is static fatigue, or brittle delayed fracture at relatively low applied stresses[1].

The basic mechanism of these hydrogen-induced phenomena is crack initiation and controlled crack propagation. The time-dependent growth of flakes in heavy steel forgings has been amply demonstrated[2]. Also, static-fatigue failure has been shown to result from the initiation and slow growth of a crack[3].

The crack initiation process is of particular interest, since recent research in this laboratory indicates the existence of a true incubation period for crack initiation. This behaviour is indicated by electric resistance measurements on hydrogen-charged specimens under static load. Notched specimens of 4340 steel (0·40 per cent carbon, 1·7 per cent nickel, 0·85 per cent chromium, 0·25 per cent molybdenum) were charged with hydrogen, plated with cadmium and baked to produce a uniform distribution of hydrogen. Upon loading, an immediate increase in specimen resistance was observed, resulting from a decrease in notch area caused by deformation. The resistance then remained constant for some time, and this is taken as the incubation period. A subsequent increase in resistance resulted from the decrease in notch area caused by crack initiation and propagation.

On this basis, incubation periods varying in length from a few seconds to as long as 18 hr. have been observed. The length of the incubation period depends primarily upon average hydrogen concentration, and is essentially independent of the applied stress.

The existence of the incubation period is compatible with either of the two major theories which purport to explain hydrogen embrittlement. Zappfe[4] suggested that molecular hydrogen might be precipitated in internal 'voids' and build up pressure sufficient to cause premature fracture. On the other hand, Petch and Stables[5] apply the Griffith–Orowan theory of delayed fracture of glass to the case of hydrogen embrittlement. They propose that hydrogen atoms may be adsorbed on the surfaces of internal micro-cracks, thereby lowering the critical stress necessary for extension of the crack.

A critical feature of both theories is that hydrogen does not cause embrittlement unless localized in a small region. The rate of delivery of hydrogen to the potentially embrittled region is controlled by the diffusion-rate of hydrogen in steel. If the average hydrogen concentration is low, then a substantial time interval may be necessary to build up the hydrogen concentration at the point of crack initiation. Thus, the length of the incubation period would be controlled by the average concentration of hydrogen, as was observed.

Consideration of the incubation period is vital to any critical discussion of hydrogen embrittlement. For example, one of the unique characteristics of hydrogen embrittlement is that the fracture ductility decreases with decreasing strain-rate. Of course, this fracture ductility is dependent upon both initiation and propagation of a crack; nevertheless, it is evident that, for a given incubation period, a low strain-rate test will be more likely to detect embrittlement than a high strain-rate test. If the strain-rate is so high that the specimen fractures in less time than the incubation period, then hydrogen embrittlement will not be detected.

This behaviour must be reflected in the design of a suitable test for detection of hydrogen embrittlement. Apparently, a mechanical test will be inadequate if the test duration is less than the incubation period. Since we have observed incubation periods of substantial duration, short time tests such as normal tensile and bend tests may not be discriminating. Thus, under these conditions, the steel may exhibit normal ductility but will still be subject to brittle delayed fracture.

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Preferred Precipitation on Dislocation Lines in an Aluminium Alloy

ELECTRON micrographs of aged specimens of aluminium – 4 per cent copper reveal the structures associated with the presence of $GP1$, $GP2$, θ' and θ, precipitates after various heat treatments[1]. The sequence of formation (with some overlapping) at low temperatures is $GP1$, $GP2$ and θ', whereas at high temperatures it is θ' and then θ, the equilibrium phase. At some ageing temperatures precipitation within the lattice is believed to occur preferentially on edge dislocations, and Wilsdorf and Kuhlman-Wilsdorf[2] and Thomas and Nutting[3] have recently demonstrated this in electron micrographs.

We have attempted to trace dislocation lines in an unworked crystal of aluminium – 4 per cent copper by electron microscopical studies of preferred precipitation. High-temperature ageing was used,