DIFFUSION WITH TRAPPING AND FAST DIFFUSION PATHS

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1.   INTRODUCTION

This paper presents some new analytical results and formulations for two diffusion problems relevant to aircraft structural materials.   The first arises in connection with hydrogen embrittlement of high-strength steels and the second involves the transient re-distribution of lithium during a novel heat-treatment for aluminium-lithium alloys.

Hydrogen typically enters steel in service either as a by-product of cadmium plating (which is done for corrosion protection), or during the application of paint strippers, or during stress-corrosion cracking in aqueous environments [1-3].   The problem of characterizing the detrimental effect of hydrogen can be conceptually divided into two stages : (i) quantify the transport aspect, by solving the relevant diffusion equation subject to appropriate initial and boundary conditions; (ii) quantify the damage kinetics, assuming a given local hydrogen content.   It is known that hydrogen diffusion in steels is non-Fickian, and this has been attributed to the trapping of hydrogen at various sites such as lattice dislocations, grain boundaries or the interfaces with precipitates within the grains. A phenomenological theory of diffusion with trapping, due to McNabb and Foster [4], requires three parameters to characterize trapping.   These parameters can be estimated experimentally from permeation tests.   The McNabb-Foster equations are non-linear and therefore generally intractable analytically, but an exact analytical expression has been derived in [4] for the time-lag in a permeation test, when the boundary condition at the input face is one of fixed concentration, which is appropriate for gas-phase charging.   An extension of this result is presented in §2 for the more complicated boundary condition describing electrolytic charging under potentiostatic control.   This form of charging simulates more closely than gas-phase charging the hydrogen-entry conditions during plating or stress corrosion.