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Evolution of stresses induced by hydrogen transport through a plate

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Evolution of a complex stress field induced by hydrogen diffusion through a thin membrane has been studied. The concentration-caused strain as a function of time and coordinate was determined at the linear approximation. Expansion of these functions in series allows to evaluate contributions to the total stress field due to the concentration inhomogeneity and instability. For hydrogen diffusion in palladium, computer-aided calculations have shown that at the initial unsteady state process stages, the greatest contribution is due to stresses caused by the speed gradient and to those depending on the deformation speed. At the steady stage, their influence becomes essentially zeroed but Hook stresses attain maximum values.

В работе исследована эволюция сложного поля напряжений, сопровождающих поток водорода сквозь тонкую мембрану. В рамках линейного приближения определена функция концентрационной деформации в зависимости от координаты и времени. Разложение этой функции в ряд позволяет оценить вклады, обусловленные неоднородностью и нестационарностью концентрации в общее поле напряжений. Проведенные компьютерные вычисления для случая диффузии водорода в палладии показали, что на начальных стадиях, когда степень неравновесности процесса велика, наибольший вклад дают напряжения, обусловленные градиентом скоростей, и напряжения, зависящие от скорости деформации. На установившейся стадии их влияние практически исчезает, а величина гуковских напряжений достигает максимальных значений.

The development of novel solid fuel cells where electricity is produced by combustion of hydrogen, methane and other gases has stimulated the interest in the problem of gas transport in solids and has brought new problems about. Investigation of reliability and durability of such fuel cells is among important aspects of the problem concerning the materials science. The mechanical behavior of solids during gas transport therethrough is still not enough explored. The concentration-caused expansion of solids at gas saturation may change their strain and stress state and result in structural changes, thus causing the degradation of the fuel element functional parts. Also, there are membrane fuel cells. Stacks of such cells are now in wide use. Specific features of gas transport through thin membrane are not explained sufficiently to date. In general, the gas transport through a material (in particular, hydrogen transport) is a complex process, that renders many-sided influence upon the material by changing mechanical and other properties [1, 2].

In this work, an attempt is done to study the complex stress state arising when a gas passes through an isotropic material. The main factors defining the stress state are considered as well as the state effect on the material structure. The problem is considered within the elastic region taking as an example the evolution of strain field accompanying hydrogen transport in metals.

The problem of one-dimensional hydrogen transport through a thin membrane is considered. Let an infinite plate of the thickness h be subjected to hydrogen flow under pressure in the direction X_3 perpendicular to the plate plane X_1X_2. The equi-