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Disclosure of the wavelike component in the embrittlement kinetics of the RPV steel as an indication of the degradation resilience and irradiation induced metal structure self-organization

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Abstract

Fast neutron intensity influence on reactor materials radiation damage is a critically important question in the problem of the correct use of the accelerated irradiation tests data for substantiation of the materials workability in real irradiation conditions that is low neutron intensity. Investigations of the fast neutron intensity (flux) influence on radiation damage and experimental data scattering reveal the existence of non-monotonous sections in kinetics of the reactor pressure vessels (RPV) steel damage. Discovery of the oscillations as indicator of the self-organization processes presence give reasons for new ways searching on RPV steel radiation stability increasing and attempt of the self-restoring metal elaboration. Revealing of the wavelike process in the form of non-monotonous parts of the kinetics of radiation embrittlement testifies that periodic transformation of the structure take place. This fact actualizes the problem of more precise definition of the RPV materials radiation embrittlement mechanisms and gives reasons for search of the ways to manage the radiation stability (nanostructuring and so on to stimulate the radiation defects annihilation), development of the means for creating of more stableness self-recovering smart materials.

Keywords: RPV steel; Embrittlement; Flux; Wavelike component; Self-organization

Introduction

Influence of the neutron irradiation on Reactor Pressure Vessel (RPV) steel degradation are examined with reference to the possible reasons of the substantial experimental data scatter and furthermore – nonstandard (non-monotonous) and oscillatory embrittlement behavior. In our glance this phenomenon may be explained by presence of the wavelike component in the embrittlement kinetics [1].

We suppose that the main factor affecting steel anomalous embrittlement is fast neutron intensity (dose rate or flux), flux effect manifestation depends on state-of-the-art fluence level. At low fluencies radiation degradation has to exceed

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normative value, then approaches to normative meaning and finally became sub normative. Data on radiation damage change including through the ex-service RPVs probes taking into account chemical factor, fast neutron fluence and neutron flux were obtained and analyzed.

In our opinion controversy in the estimation on neutron flux on radiation degradation impact may be explained by presence of the wavelike component in the embrittlement kinetics [2]. Therefore flux effect manifestation depends on fluence level. At low fluencies radiation degradation has to exceed normative value, then approaches to normative meaning and finally became sub normative. As a result oscillation arises that in turn lead to enhanced data scatter [3].

Moreover as a hypothesis we suppose [4] that at some stages of irradiation damaged metal have to be partially restored by irradiation i.e. neutron bombardment serve as radiation annealing of radiation embrittlement of the steel. Nascent during irradiation structure undergo occurring once or periodically transformation in a direction both degradation and recovery of the initial properties. According to our opinion at some stage(s) of metal structure degradation neutron bombardment became recovering factor that result in increased the resilience and frontier of the steel [5].

One can assume, that factor exists which generate oscillating process in mechanism of embrittlement and become more apparent with neutron flux lowering. Conversely, at high level of the flux it is hardly noticeable because amplitude of a oscillation decrease while frequency increase. Hypothetically we assume the presence of the oscillation component in kinetics of the neutron embrittlement process that arise from radiation defects periodic beginning and annealing, which in its turn is a result of the metal structure temporal self-organization.

So, revealing of the wavelike process in the form of non-monotonous parts of the kinetics of radiation embrittlement process - sign of self-organization, that testify to periodic transformation of the structure – actualize the problem of more precise definition of the RPV materials radiation embrittlement mechanisms and give reasons for search of the ways to manage the radiation stability (nanostructuring [6] and so on to stimulate the radiation defects annihilation), development of the means for creating of more stableness self-recovering smart materials.

Possibly wavelike component in the embrittlement kinetics of the RPV steel is the manifestation of the irradiation induced metal structure self-organization.

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