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Internal corrosion of EK164 and CHS68 fuel pin cladding steels of uranium dioxide fast power reactor

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Abstract

Austenitic chromium-nickel steel EK-164 is the promising material for manufacturing claddings of fuel pins of fast nuclear reactors. Physical and chemical compatibility with typical nuclear fuel compositions on the basis of uranium dioxide pellets is an important aspect of ensuring fuel cladding operability. Post-irradiation examination of irradiated combined fuel assembly with maximum burnup 9.1% FIMA and damaging dose of 77.3 dpa equipped with fuel pins with claddings made of CHS-68 and EK-164 steels in cold-worked state was performed. Gamma-scanning, electric potential resistometry and optical metallography methods were applied in the examination. According to the gamma-scanning and resistometry data high-temperature sections of fuel pins are the potential centers of development of fuel pin cladding corrosion. Comparative analysis of internal corrosion of fuel pin claddings made of EK-164 and CHS-68 steels along the reactor core height was performed. In the section with maximum power density at operational temperatures below 540 °C depth of corrosion of CHS-68 steel from the side of fuel did not exceed 15 µm. On similar sections of fuel pin cladding made of EK-164 steel depth of internal corrosion amounted to 10 µm. Maximum of corrosion damage for both steel types was registered at temperatures in the range from 600 °C to 650 °C. In this case depth of corrosion damages in the form of intercrystalline and general corrosion did not exceed 20 µm. No significant differences in the corrosion mechanism between the steels were found. Local exacerbation of corrosion at the junctions between fuel pellets and in places of concentration of cesium fission fragments was detected. And contrariwise in place of narrowing residual gap between fuel and cladding, where cesium is not present, corrosion of EK-164 steel is minimal. Maximum thinning of cladding of the investigated fuel pins with maximum burnup of 9% FIMA amounted to not more than 5% of the original thickness.

Keywords: Fuel pin; Cladding; Resistogramm; Gamma-scanning; Metallography; Corrosion.

Introduction

Studies of cladding materials of BN-600 reactor combined fuel assembly pins with maximum burnup of 9.1% FIMA and maximum exposure equal to 77.3 dpa [1] demonstrated advantages of the improved steel of austenitic class 07C–16Cr–19Ni–2Mo–2Mn–Nb–Ti–Bcw (hereinafter referred to on the text as CHS-68cw steel) [2] as compared with standard cladding material 06C–16Cr–15Ni–2Mo–2Mn–Ti–V–Bcw (hereinafter referred to on the text as CHS-68cd steel) as pertains to swelling parameters and physical and mechanical properties.

Another important aspect of ensuring the required performance of fuel pins of power reactors is the physical and chemical compatibility of fuel pin cladding with uranium dioxide based fuel rod of pellet type [3].

Results of comparative studies of internal corrosion of fuel pin claddings made of EK-164cw and CHS-68cw steels are reviewed in the present paper. Irradiation conditions are summarized in Table 1.

Results of studies

Control of outside surface of irradiated fuel pins by electric potential method is one of the main non-destructive methods for evaluation of the effects of radiation induced swelling,

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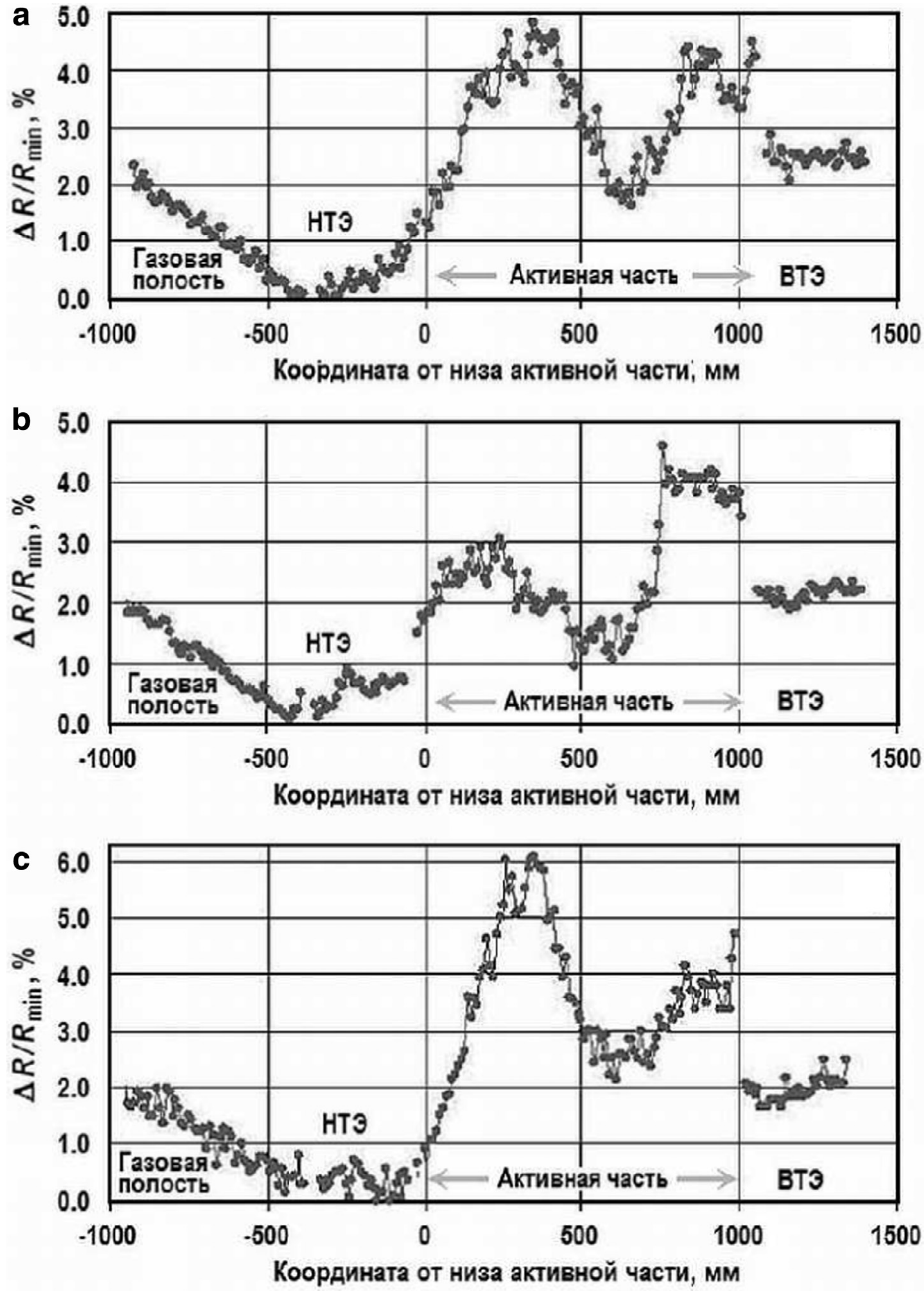

Координата от низа активной части, мм	Coordinate from fuel pin active part bottom, mm
Газовая полость	Gas void
НТЭ	Lower blanket
ВТЭ	Upper blanket
Активная часть	Active part

Fig. 1. Resistogramms of fuel pins: (a) cladding made of EK-164cw steel (maximum swelling 4.9%); (b) cladding made of EK-164cw steel (maximum swelling 3.2%); and (c) cladding made of CHS-68cw steel (maximum swelling 7.4%).

phase transitions, local defects and corrosion of cladding materials [4]. Resistogramms for a number of investigated fuel pins in the combined fuel assembly are presented in Fig. 1. Analysis of central sections of the resistogramms (coordinates from 0 to 700 mm) evidences that relative growth of electrical resistivity of cladding is directly proportional to the degree of radiation induced swelling of structural materials. The second peak in the resistogramms (coordinates from 700 to 1030 mm) limited within the high-temperature part of fuel pins by the upper blanket section is the result of thinning of cladding caused by internal corrosion. Practically equal value of increment of electric resistivity not depending on the material and the degree of swelling is the specific feature of the upper part of fuel pins selected for comparison.