formation of brittle layers during hot isostatic pressing of bimetal joints of ITer components

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The vacuum-tight bimetal CuCrZr/316L(N) joint is one of the critical structural elements of plasma-facing components (PFC) of the International Thermonuclear Experimental Reactor (ITER). At the NIIEFA, the method of diffusion welding under hot isostatic pressing (HIP) was selected for manufacturing of the bimetal joint.

The parameters specified by the ITER IO have been attained during the experimental works performed at NIIEFA in order to develop the technology for manufacturing of the bimetal joint [1]. But, the reject rate caused by defects in the bimetal joint was as high as 50% in some experiments, which is unacceptable. These defects represent a discontinuity in the form of cracks.

The analysis of the problem has revealed the characteristic feature of the diffusion joint of the materials under study, namely, formation of a zirconium-enriched layer in bronze near the joint boundary. The authors have found only one citation of this problem in the literature [2]. This layer being the zone of crack propagation in defective items.

It was supposed that zirconium forms separate phases in the volume of the bronze surface layer, which undergoes plastic deformation (during mutual compression, when in contact with stronger steel) followed by recrystallization as the temperature rises. Then, zirconium enters into a chemical combination with elements diffusing from steel.

A run of tensile tests was carried out at an increased temperature of samples containing the bimetal joint. It has been revealed that the probability of fracture over the bimetal joint increases with the test temperature.

One of the possible ways for optimization of the chemical composition in the joint zone, that is, application of an intermediate nickel layer, was found in [3]. The experimental work was undertaken on diffusion welding using two types of the intermediate nickel layer, namely, an electroplated coating and a foil.

From the results obtained it may be concluded that, with the intermediate nickel layer introduced between the mating bronze-steel surfaces by any of the analyzed methods, the zones with an increased concentration of zirconium are not ruled out, but their intensity and the character of their arrangement are changed. With a nickel foil used, separate inclusions of zirconium phases are observed, which do not form a continuous layer.

References

1. A.A. Gervash, D.A.Glazunov, D.V. Lyanzberg, I.V. Mazul, A.Y. Ogursky, P.Y. Piskarev, V.V.Ruzanov, Refinement of the technology of hot isostatic pressing of vacuum-tight bimetallic joint of ITER in-vessel components // Innovative designs and technologies of nuclear power: Collection of papers of the V International Scientific and Technical Conference. Мoscow: Published by JSC “NIKIET”, 2018, p. 2428–2434.
2. S.H. Goods, J.D. Puskar. Solid state bonding of CuCrZr to 316L stainless steel for ITER applications // Fusion Engineering and Design, 86 (2011), p. 1634–1638.
3. N.F. Kazakov, Diffusion welding of materials, Second revised edition. Мoscow: “Mashinostroenie”, 1976, 312 p. (in Russian).