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Structural integrity of an X-750 jet pump beam of a BWR by means of FITNET FFS procedure

D. Ferreño [a,*], S. Cicero [a], R. Lacalle [a], I. Gorrochategui [b], F. Gutiérrez-Solana [a]

[a] Laboratorio de la División de Ciencia e Ingeniería de los Materiales (LADICIM), E.T.S. de Ingenieros de Caminos, Canales y Puertos, Universidad de Cantabria, Av. Los Castros s/n, 39005 Santander, Spain

[b] Centro Tecnológico de Componentes (CTC), E.T.S. de Ingenieros Industriales y Telecomunicaciones, CDTUC, Universidad de Cantabria, Av. Los Castros s/n, 39005 Santander, Spain

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ABSTRACT

In this paper, the *J–R* curves of the X-750 alloy, previously obtained in the rising load test environment, have been implemented in the structural integrity assessment of a jet pump beam of a boiling water reactor manufactured in this material. The analysis was performed with the FITNET FFS procedure considering the in-service loads on the beam. The critical crack lengths for the different scenarios studied have been obtained and, taking into consideration real crack length velocities, the lifespan of the beams were conservatively estimated.

1. Introduction and background

The hold down beams which form part of the jet pumps of the recirculation system of nuclear boiling water reactors (BWR) are manufactured in X-750 alloy [1]. Since the 80s, several catastrophic failures have occurred in these components. In all cases, such failures were due to the development of intergranular stress corrosion cracking processes (IGSCC). Fig. 1 shows a scheme of this model of a hold down beam. The real dimensions of the component can be appreciated in the photograph in Fig. 2.

Since 2001, highly demanding conditions must be met for the beams in order to be accepted: they are manufactured from an "open die" bar forging, machined on all surfaces and subsequently examined by penetrant liquid. In addition, the environmental contribution can be minimised by using hydrogen water chemistry (HWC) in the reactor, which reduces the amount of oxidising species in the water compared to normal water chemistry (NWC), hence reducing also the electrochemical potential (ECP), responsible for promoting both the initiation and growth of cracks.

In a previous paper [2], disposing of an in-rolled condition X-750 material, an analysis was performed of the impact of the different heat treatments contemplated by the literature on the microstructure (by means of optical microscopy and scanning electron microscopy, SEM), mechanical behaviour (Brinell and Rockwell hardness test), grain size and dimensional stability. In addition, the response to IGSCC, by means of the rising load test (RLT), was studied. A detailed description of the characteristics of the RLT was presented in [2] and in the specification [3] of the test. Briefly, this consists of a three-point bending test of notched and precracked small dimension specimens, in which the response in air (one test for each heat treatment) and in an aggressive environment, 93 °C deionised distilled water with argon sparging, (two tests for each

* Corresponding author.
E-mail address: ferrenod@unican.es (D. Ferreño).

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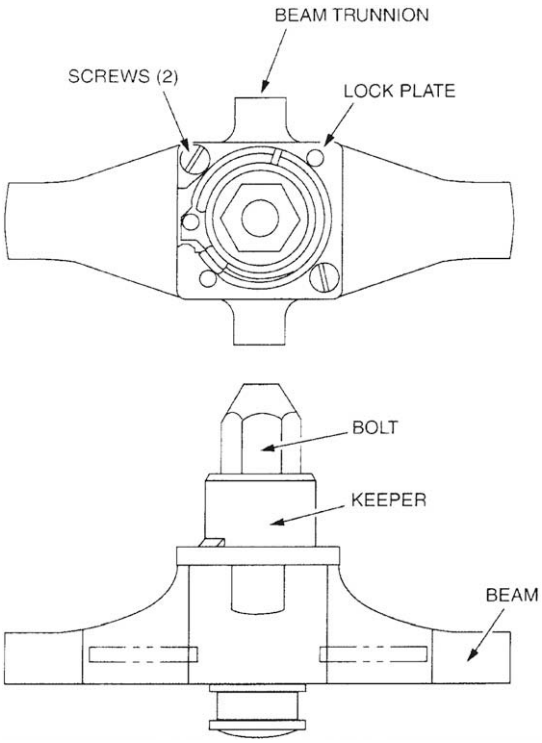

Fig. 1. Scheme of the jet pump hold down beam.

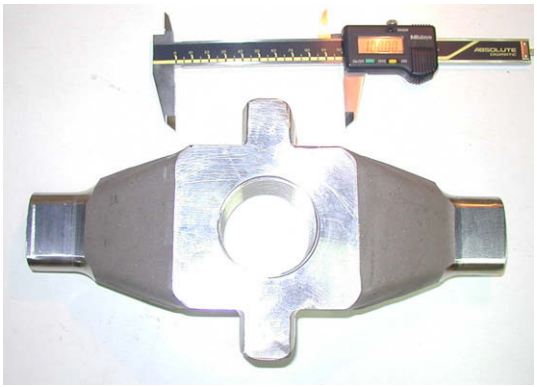

Fig. 2. Perspective of a real X-750 hold down beam.

treatment) under displacement control is compared. A displacement rate of 10^{-3} mm/s, was adopted, in agreement with the stipulations in specification [3].

The most interesting conclusion from the results obtained in [2] is that they allow AH heat treatment (equalised and aged condition), which was suspicious a priori of being responsible for the susceptibility of the material to IGSCC, to be rejected. In view of the available studies and the experience from nuclear plants, the EPRI (Electric Power Research Institute) published some recommendations about the optimum heat treatment for the X-750 alloy. The proposed treatment is the HTH (high temperature annealed and aged condition). The optimisation study performed [2] to improve the response of the X-750 alloy to IGSCC indicates that the most adequate set of parameters of the HTH heat treatment consists of a solubilisation stage of 1 h, 1093 °C, followed by an ageing stage of 24 h, 704 °C; in both stages, the cooling is performed in air.

Once the optimum HTH was determined [2], it was applied to a real X-750 jet pump beam, available for that work (see Fig. 2). Next, RLT specimens were machined from the beam and tested, thus validating the efficiency of the conclusions obtained in [2]. The available information shows that, in the past, IGSCC processes have preferentially occurred in two localised