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Stress analysis of screws in the fuel channel fastener assembly

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Explicit integration method
Dynamic impact

A B S T R A C T

The function of fuel channel fastener assembly is to keep enough clearance between fuel channels, allowing the insertion of control rod and fixing the channel on the fuel bundle. The assembly device is not safety related component, however, in case of the screw breaking, it may cause loose parts, which might adversely affect the normal operation of inserting and pulling fuel assemblies, and/or the movement of the control rods. In this paper, the possible loading conditions applied to the fuel channel fastener assembly are considered to analyze the stress state in screw.

In order to assess the improper positioning of fuel channel, explicit finite element procedures is employed to simulate the complex contact/impact behaviors occurring between the fastener assembly and the neighboring fuel channel or the fuel rack, in which the effects of dynamic impact on the screw and initial contact speed are the main concern.

The analysis results reveal that the reduced neck close to the screw head has the highest stress. If the external loads drive the stress up to the yielding limit, crack initiation will occur on the screw neck and thereby, under the tensile loadings and reactor core environment, initiating intergranular stress corrosion cracking (IGSCC) on the screw.

1. Introduction

Fig. 1 shows the configuration of the fuel channel fastener assembly, which consists of fastener, spring, spring washer and screw components. The screw is screwed into the fuel bundle device, to fix the whole fastener assembly at the corners of the fuel channel. The function of the fastener assembly is to keep the clearance between fuel channels for the insertion of the control rod [1]. Although the fastener assembly is a non-safety related component, whose failure or damage, such as the break of the screw, may affect the function of other safety related components. Considering the possible static and dynamic loading conditions, this paper analyzes the stress distribution on the screw of the fuel channel fastener to assess the cracking susceptibility of the screw.

Two different fastener assembly types are studied in this paper. One is designed by Siemens Power Company [2], noted as Old Type, and the other is designed by AREVA Company [3], noted as New Type. The ABAQUS finite element program is used to evaluate the effects of different loads, such as the design screw preload, and the dynamic impact of the fastener assembly with the neighboring fuel channel or fuel rack on crack initiation.

The dynamic analysis adopts the explicit integration method [4] to calculate the effects of impact loading, where different fuel channel descending speeds are assumed. The analyzed results show that the screw necking area experiences a higher stress concentration phenomenon.

2. Numerical models and related settings

Fig. 2 shows the old type and new type fastener designs, whereas Fig. 3 presents the assembly model. These two designs have similar configuration but different geometry and sizes. Fig. 4 shows the finite element meshes of the fuel channel fastener model. The C3D8 [5] element type is used for static problems, while the C3D8R [5] element type with hourglass control setting is adopted for dynamic analysis. A sensitivity study which uses C3D8 elements type is also done, and the calculated results are compared with the results using C3D8R element type. Table 1 gives the mechanical property of X-750 nickel alloy [6,7], which was used to model the elasto-plastic material property of the whole fastener assembly components in both static and dynamic analyses.

The fuel bundle and fuel channel are not physically modeled, instead, a single reference point is used to represent them. The restraining effect of the fuel bundle/fuel channel on the fastener assembly is simulated by assuming that the reference point is coupled with the screw thread during the evaluation process. In

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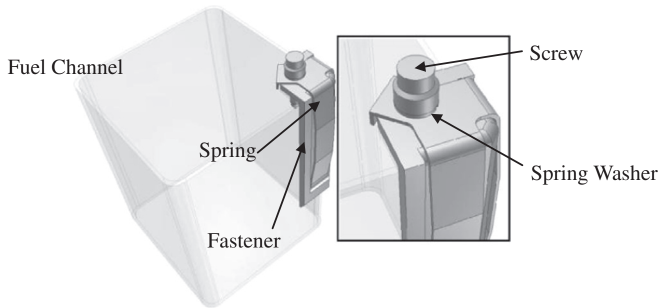

Fig. 1. Detail configuration of the fastener assembly.

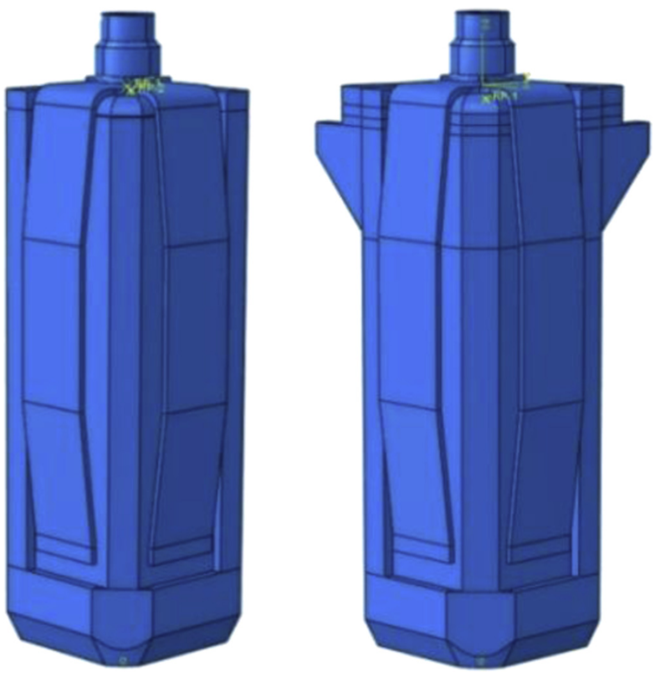

Fig. 2. Old (left) and new (right) type fastener models.

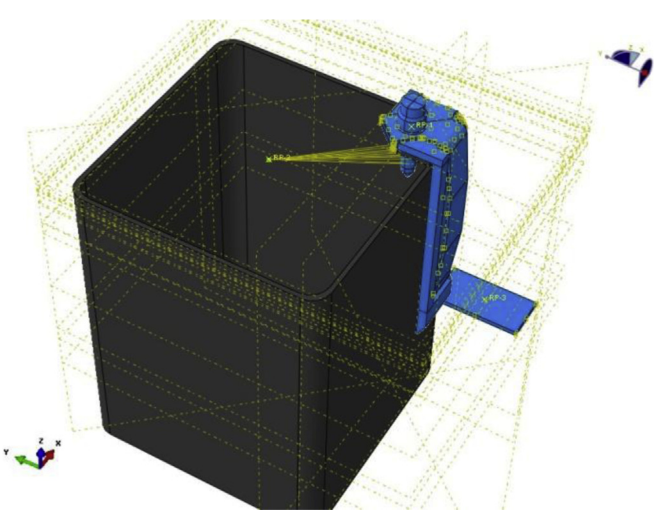

Fig. 3. Fuel assembly model for evaluation.

Fig. 4. Finite element model of the fuel channel fastener assembly.

Table 1
Material properties for the fastener assembly model.

Elastic (reference temperature: 80 °F)	
Young's modulus	31×10^3 ksi
Poissions' ratio	0.29
Density	0.299 lb/in^3
Plastic	
Minimum ultimate tensile strength	160 ksi
Minimum yield strength (0.2% offset)	100 ksi
Minimum ultimate elongation	20%

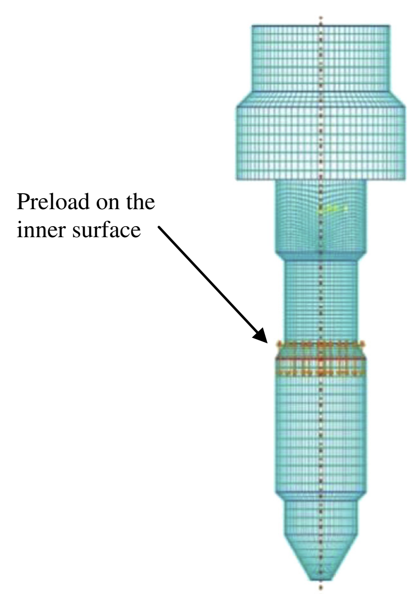

Fig. 5. Preload applied on the screw.