Accident Analysis of High Density Storage Rack for Fresh Fuel Assemblies

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1. Introduction

Recently KONES and KNF have developed the so-called suspension-type High Density Storage Rack (HDSR) for fresh fuel assemblies. The USNRC OT position paper [1] specifies that the design of the rack must ensure the functional integrity of the fuel racks under all credible fuel assembly drop events. In this context the functional integrity means the criticality safety. That is to say, the drop events must not bring any danger to the criticality safety of HDSR. This paper shows the results of the analysis carried out to demonstrate the regulatory compliance of the proposed racks under postulated accidental drop events.

2. Rack Structure and Mechanical Accidents

In this section some structural features of the module are described and the assumed three different types of accidents are introduced.

2.1 ㄴ tructure of HDSR

HDSR consists of three parts, lid-, body- and pedestal part. Fig. 1 shows schematically the module with 4x17 racks. During normal operations the fuel assemblies are hanging from the lid through the round bar and the suspension device. The basket cell, which is made of borated stainless steel (BSS, ASTM A887 Type B6) with minimum boron content of 1.5 wt% boron, functions not only as structure but also as neutron absorber. For the support bolt special stainless steel, precipitation hardened ASTM A564 Type 630, is applied. Other components use normal stainless steel, ASTM A240 Type 304.

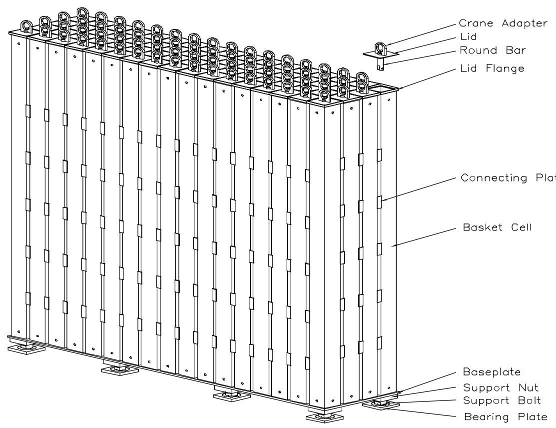

Fig. 1 The structure of the racks

2.2Assumed accidents

In this paper three different categories of mechanical accident are investigated. In the so-called "shallow drop" event, a fuel assembly and its handling tool, whose overall weight amounts to 750 kg, are assumed to drop vertically and hit the top of the rack. The deformation produced by the impact is expected to be confined to the region of collision. The "deep drop" events postulate that the fuel assembly falls through an empty storage cell impacting the rack baseplate. The deep drop events are classified into two scenarios, namely, drop in an interior cell away from the support pedestal (deep drop-1 case), and drop through the cell located above a support leg (deep drop-2 case). Fig. 2 shows the drop position in the racks for each case.

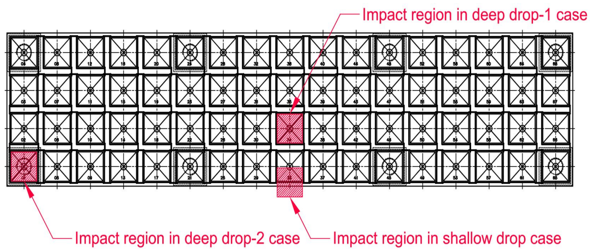

Fig. 2 Three different types of drop events

3. Evaluations and Results

Finite element simulations are performed using the program package ABAQUS/Explicit for the above described three different drop cases. The falling fuel assembly is assumed as a rigid body to achieve the conservative results.

3.1 Shallow drop case

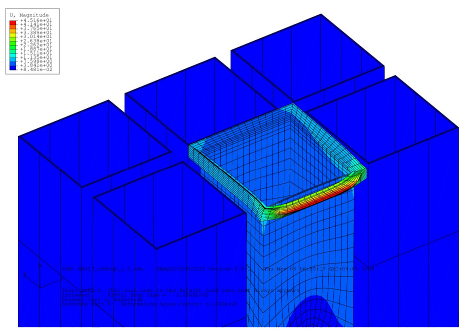

Fig. 3 Deformation of the Lid-flange

At first the impact effects of the drops from different heights are investigated. As a result only in case of drops under the height of 1.2 m from the ground level (815mm from the top of the cell) the depth of damage remains limited to the portion of the cell above the top of the "active fuel region" (805mm downwards from the top of the cell). Therefore the operation with fuel assemblies must be limited under this height to eliminate the danger to the criticality safety of HDSR.

The lid-flange on top of the basket cell functions as a primary impact absorber too. The lid-flange is welded onto the basket cell only in its bottom part. During drop impact this welding part plays a role as a hinge. Therefore the lid-flange rotates and deforms outwards from its original position as shown in Fig. 3 and can absorb the impact energy primarily. Fig. 4 shows the Tresca stress at t = 0.0117 sec. As expected the maximum stress appears in lid-flange and it suffers very severe plastic deformation. But the overall region of the plastic deformations is confined only to the top part of the cell.

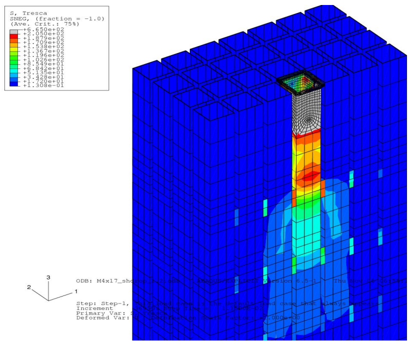

Fig. 4 Tresca stress in case of shallow drop

3.2 Deep drop-1 case

In this case the maximum Tresca stress 313MPa (see Table 1) in baseplate already exceeds the yield stress, so the plastic deformations appear. But its magnitude amounts only to 9.2mm vertically. It brings no danger to the criticality safety of HDSR.

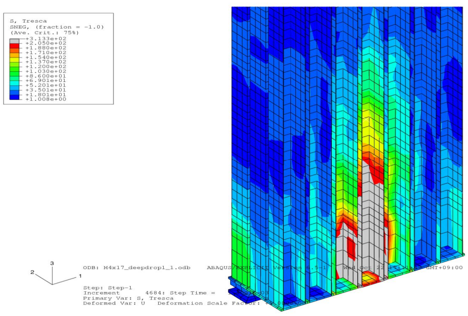

Fig. 5 Tresca stress in case of deep drop-1 case

3.3 Deep drop-2 case

In deep drop-2 case the impact causes the maximum Tresca stress 1076MPa (see Table 1) and the minimum principal stress -1097MPa in support bolt, so a very severe compression is expected to appear. But its deformation amounts only to 6.3 mm vertically. Fig. 6 shows also the stress in the concrete floor under the bearing plate. The vertical maximum stress increases up to 53MPa, much higher than the allowable compression stress 19MPa of the concrete. Therefore some cracks could develop locally under the baseplate.

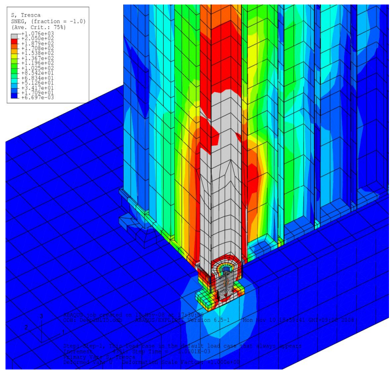

Fig. 6 Tresca stress in case of deep drop-2 case

Table 1: The results of three different accident cases

Components	Yield stress [MPa]	True ultimate stress [MPa]	Maximum Tresca stress [MPa]		
			Shallow drop	Deep drop scenario-1	Deep drop scenario-2
Lid-flange	170	679	665	-	-
Cell	205	618	358	260	245
Connecting plate	170	679	197	227	215
Baseplate	170	679	43	313	294
Support nut	170	679	27	165	279
Support bolt	795	1,100	37	288	1076
Bearing plate	170	679	25	133	229

4. Conclusions

In this paper a new designed HDSR is introduced. The effects of three different drop accident cases, one shallow drop and two deep drops, are investigated. Though all three drop events show severe plastic deformations, any danger to the criticality safety of HDSR is not expected on all three drop events considered. In conclusion the regulatory compliance of the proposed racks under postulated accidental drop events is proved.

REFERENCES

[1] OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications, dated April 14, 1978