Investigation of the fuel Investigation of the fuel rod friction force on the spacer grid of the APR1400 Nuclear fuel Assembly

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Introduction

- The spacer grid supports the fuel rod, maintain spacing between fuel rods, provide for coolant mixing, and resist the external loads.
- The spacer grids provide lateral restraint to the fuel rod, therefore, maintaining the fuel rod array by providing frictional restraint in the axial direction. With the operation of the reactor and neutron irradiation in the reactor, stress relaxation of the spacer grid spring is induced and spring force reduces.
- FR and SG create non-linear friction force between the fuel rod tube and spring against the fuel assembly external lateral force. The rod grid interaction leads to fuel assembly lateral stiffness.

Methods

The spacer grid single cell design

- A unit spacer grid consists of four spacer grids. The full grid and unit spacer grid cell with a fuel rod clad is shown in Figure 1.

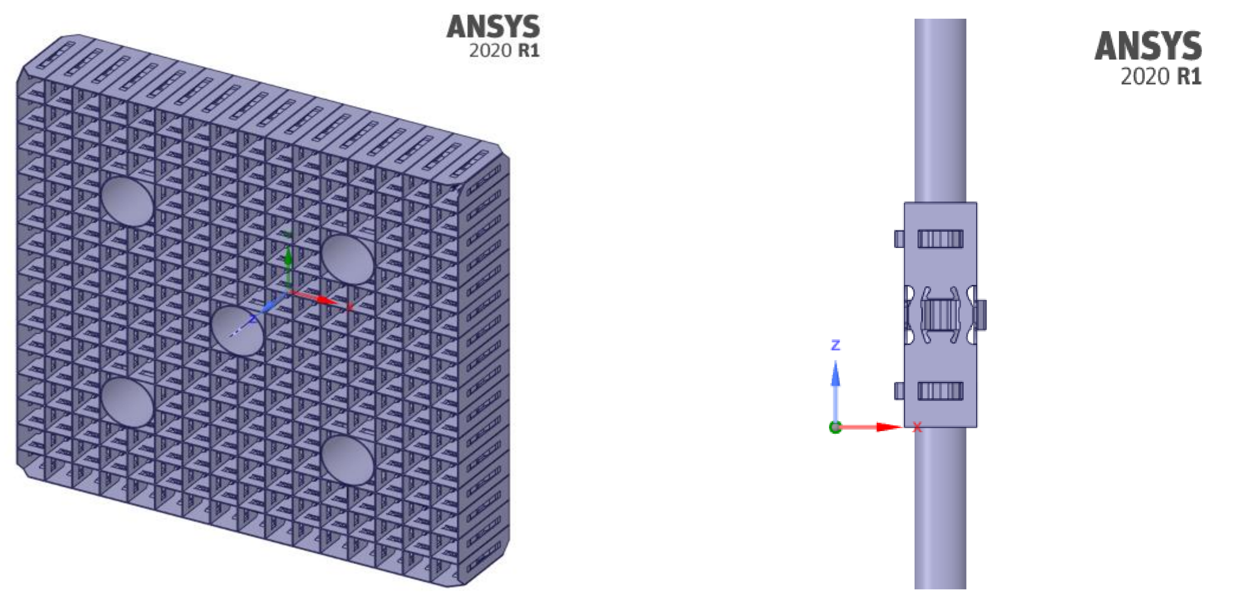


Fig 1: Full grid and unit Spacer grid cell

- The structural performance of the four spacer grids is important for the support of the fuel rod. The fuel rods supporting parts in the spacer grids are the springs and dimples. When inserted into the spacer grid, most deformation takes place in the spring, because the dimple is stiffer.
- The fuel rod-grid interaction exhibits nonlinear behavior making it hard to calculate flexural rigidity numerically.

Mesh

- For the analysis sufficient numbers of nodes and elements were generated in the three-dimensional model and are expected to give reliable results.
  - Mapped mesh presented in Figure 2 and applied in the 3D model using the linear element order and default element size

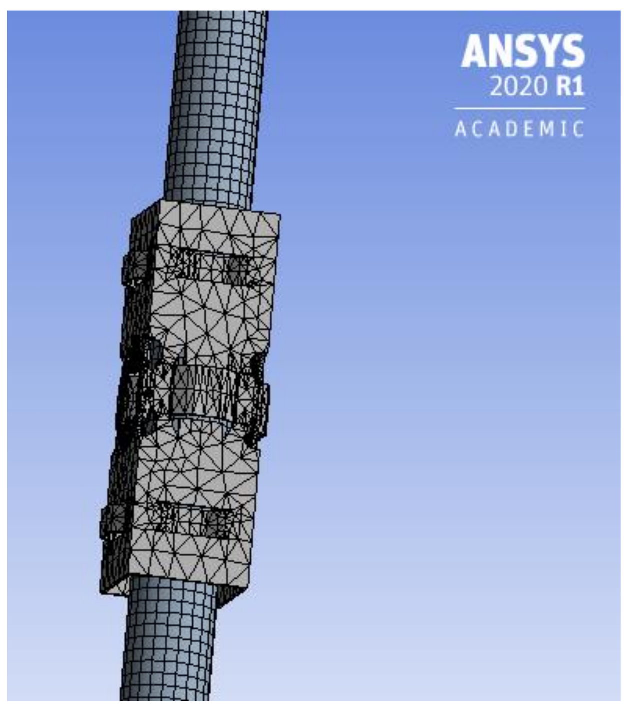
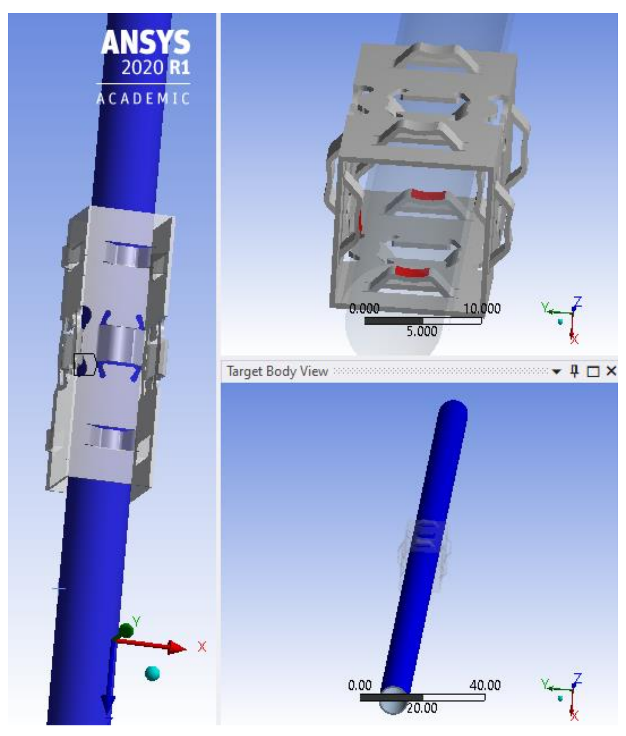


Fig 2: Mesh

Boundary conditions and load application

- The contact connection between the fuel rod clad and the grid spring inner surface was set as frictional contact



- Fixed support was applied on the grid cell and the force applied on the fuel rod clad to counter the grid spring force. A force of 100 N was applied in the lateral direction.

Results

- Applying the fixed support and the force boundary conditions, as well as the frictional contact, the analysis was run to get the deformation and equivalent stress in the fuel rod in each of the directions

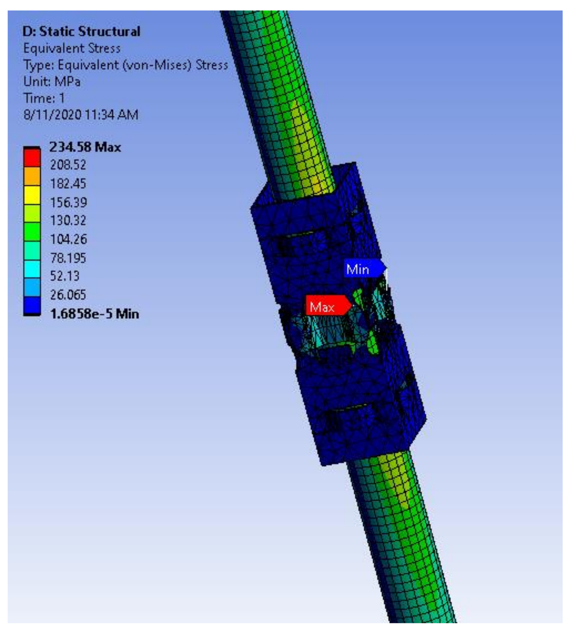
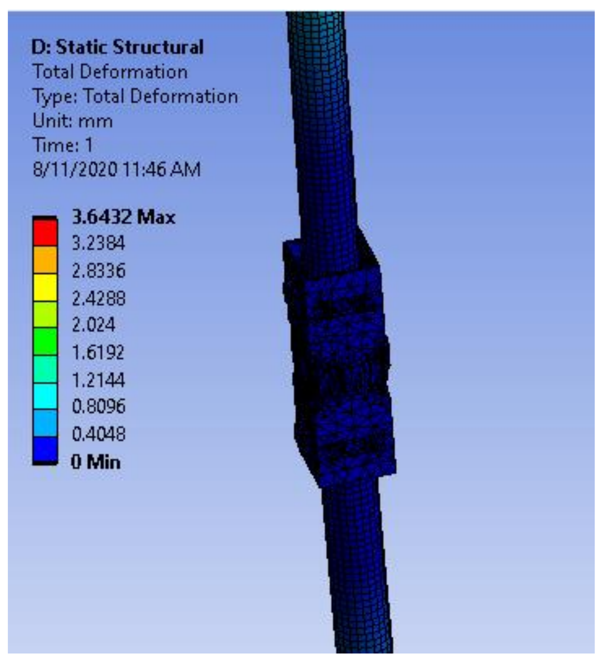


Fig 4: Equivalent stress

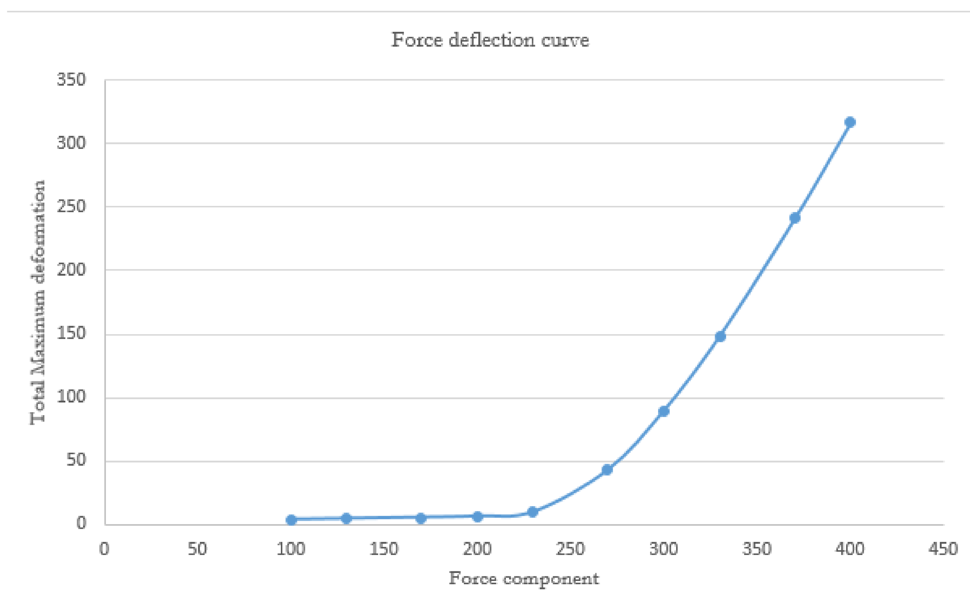


- The maximum equivalent Von Mises stress was 234.58 MPa and occurred at the spring contact with the fuel rod clad. The maximum deformation was 3.6432 mm which is slightly over the test value of 2 mm.

Table 1: Force component against deflection

Force component (N)	Total maximum deformation (mm)
100	3.6432
130	4.2635
170	5.2041
200	6.1881
230	9.489
270	42.714
300	89.603
330	148.72
370	241.02
400	316.89

- Table shows the resultant force component and the resulting maximum deflection. A curve showing this relationship is illustrated in Figure 7. It shows a nonlinear relationship similar to test results.



Conclusion

- The analysis was carried out on an individual grid cell to show the behavior of the entire fuel assembly. The lateral vibration and stiffness were compared to the test results.
- The fuel rod-grid interactions show nonlinear behavior due to the slippage that occurs between the rod clad and the grid spring.
- The grid dimples are stiffer and there's minimal deformation at the dimple locations.

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