



## Simulation of Spacer Grid Static Compression Test Using Finite Element Models

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### 1. Introduction

The arrangement of fuel rods containing uranium, configured as fuel assemblies, was described by Gouvêa et al. (2000) [1] as a distributed and reticular bundle design. The spacer grids are highlighted as an important structural element that must withstand static and dynamic loads during transportation and operation within nuclear reactors. Consequently, as part of the validation of the fuel assembly design, it is essential to evaluate the mechanical behavior of the spacer grid to mitigate potential fuel assembly failure.

Spacer grid tests are necessary to verify its resistance limits, as well as to check the loads of the bench fixing devices of the fuel assembly which hold the spacer grid for the insertion of the fuel rods during the manufacturing process. In this context, the static compression test simulates this specific condition for the spacer grid, obtaining the limits for compressive loading. This test is carried out using a universal tensile machine, which applies a compressive load to the spacer grid. A computer system is used for data acquisition, recording the forces and displacements at specified increments, and capturing the maximum compression force achieved [2]. Figure 1 illustrates the test device setup and a typical fuel assembly bench.

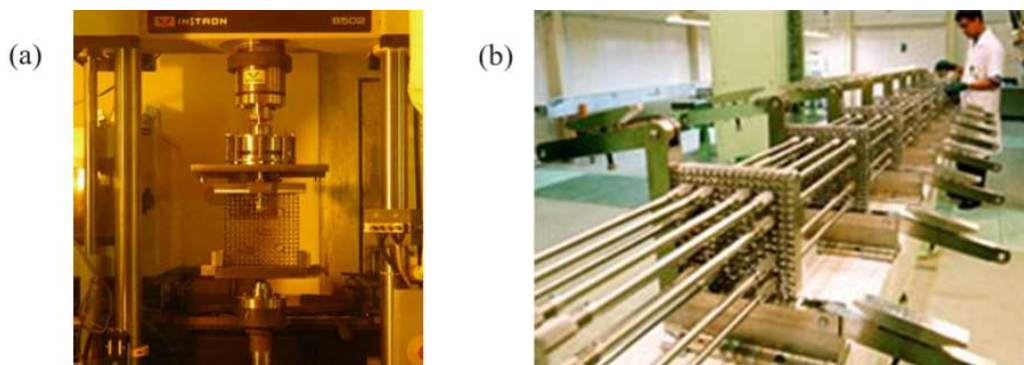


Figure 1: (a) Static compression test [4] (b) A fuel assembly bench [3].

## 2. Methodology

The studied spacer grid is a component of a typical 17x17 fuel assembly Pressurized Water Reactor (PWR) manufactured using nickel-chromium-based alloy strips welded by brazing technique, and submitted to an ageing process in a vacuum furnace. The three-dimensional (3D) model was designed to evaluate the spacer grid behavior of a 3x3 segment under static compression test conditions, as illustrated in Fig. 2. Block A represents the upper part of the test machine which receives the displacement load, and it can move vertically. Block B represents the bottom part whose movements are limited. All contacts between spacer grid and the blocks are frictional (static friction coefficient equal to 0.25 [2]), and the reaction force is obtained from computational simulation.

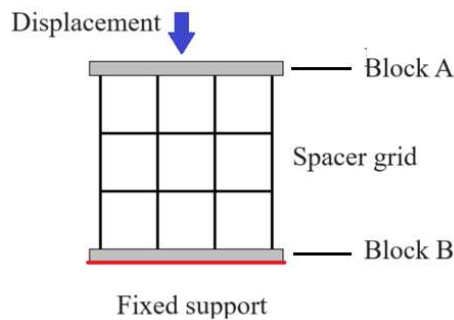


Figure 2: Boundary conditions of the adopted 3D model.

Two 3D models representing 3x3 spacer grid were prepared using the software Ansys 2023, as showed in Fig. 3: a full 3D model and a shell 3D model, features as dimples, springs or vanes were not considered. The real spacer grid has its strips welded by brazing technique, so for better approach, a filler material was added along the strips width of the models and these contacts were considered as bonded. The filler material is BNi-7 of AWS (*American Welding Society*) classification, and it was inserted into the program engineering data.

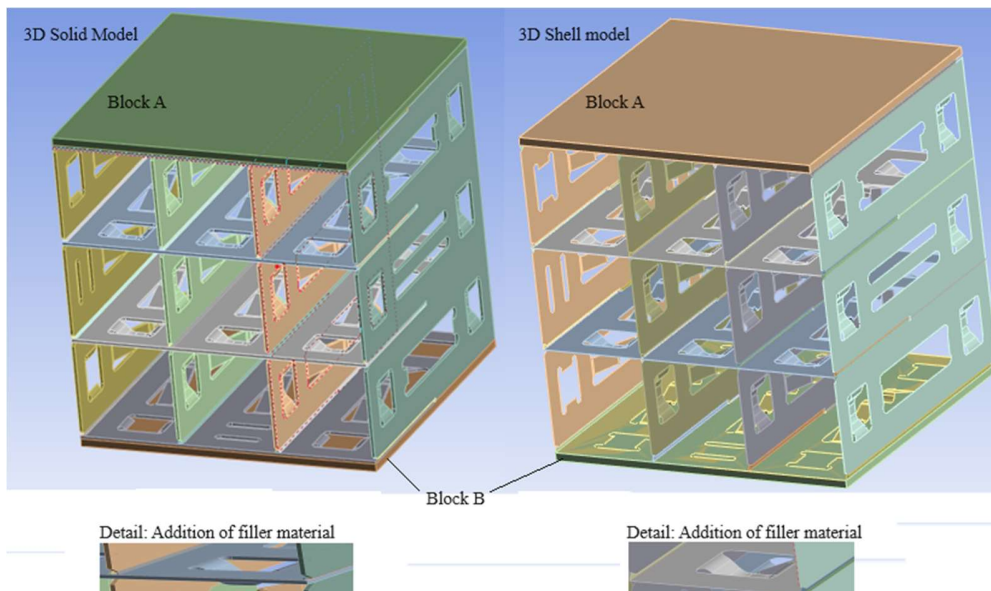


Figure 3: 3D models developed in the software Ansys.

A displacement was vertically imposed on the upper part of Block A in order to compress the spacer grid between the two blocks. Block B is supported on a fixed plate and the reaction force of the assembly was 2

obtained at each step of displacement varying from 0 up to 0.04 mm. Simulations at room temperature using the same model were carried out for different mesh sizes: 1 mm, 2 mm, and 2.5 mm.

### 3. Results and Discussion

The 3D model solution reaction force for each mesh was plotted to observe the convergence as shown in Fig. 4. The 3D shell model converges more quickly than the solid one due to the lower element quality of 3D solid mesh compared to 3D shell mesh [5].

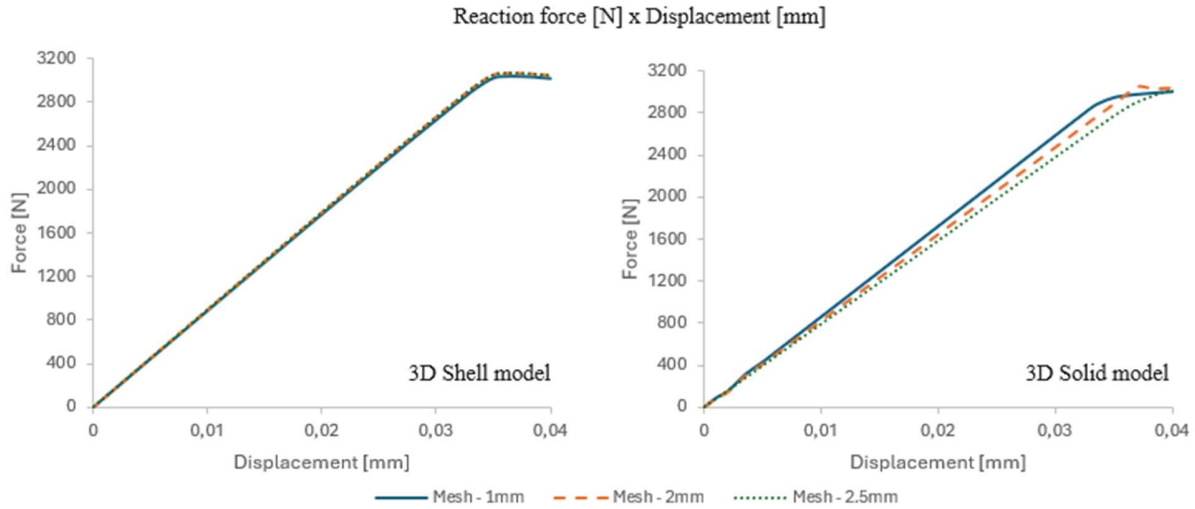


Figure 4: Reaction force for each mesh size.

Table I presents the computer resources and elapsed time revealing optimization of time and computational memory usage when opting for the shell model.

Table I: Computer resources for each type of 3D model and mesh size.

Mesh size (mm)	3D Solid mesh			3D Shell mesh		
	1.0	2.0	2.5	1.0	2.0	2.5
Number of nodes	283620	166083	153182	46900	28058	26030
Number of elements	313159	165072	145729	52637	32799	30849
Memory usage (GB)	8.86	5.67	5.13	1.99	1.42	1.31
CPU elapsed time	25min 41s	20min 13s	17min 1s	5min 42s	4min 2s	3min 42s

Comparing the 3D models for mesh size of 1 mm presented in Fig 5: both models begin to enter the plastic region with a displacement of 0.035mm, which corresponds to a reaction force of 2944N for solid and 3022N for shell model. The simulations present the same deformation aspect.

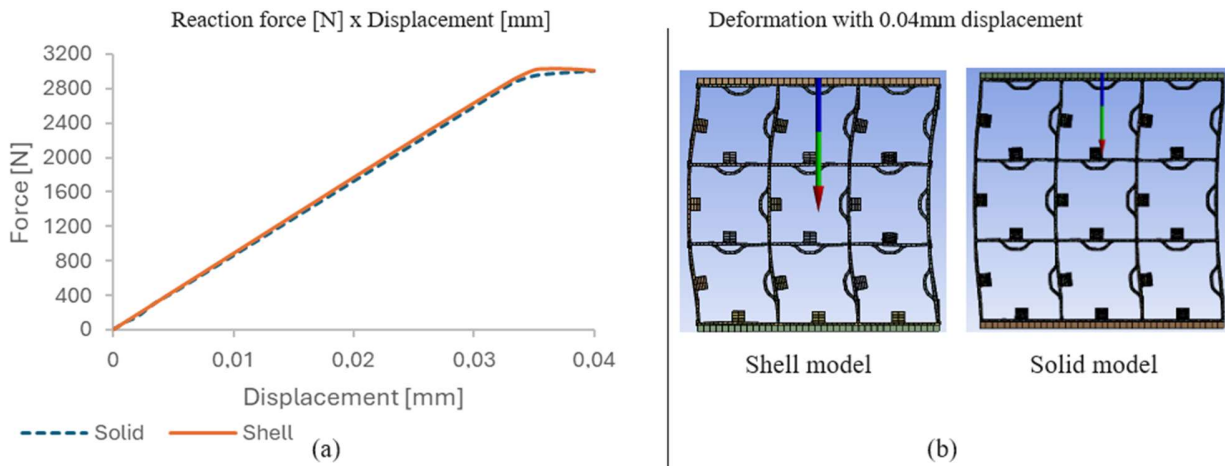


Figure 5: Reaction force for each mesh size (a) and deformation aspect (b) - 3.5 times scale.

#### 4. Conclusions

The 3D models developed presented the same graphic appearance (force x displacement) where it was possible to clearly identify the plastic region. The meshes obtained in the solid model have poor quality elements, that makes more difficult the mesh convergence in complex geometries. Other important point is that the calculated forces were closed for both studied 3D models. The use of the shell model was more efficient in consuming computational resources, proving, overall, to be the best model in the study.

A comparison between results of an experimental static compression test for segments of the spacer grid and the shell model simulation could be carried out as future work in order to validate the results obtained by computational simulation as part of a validation process of new designs of PWR fuel assemblies.

#### Acknowledgements

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#### References

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