Design and FEA of a 3D Printed Detector Window Frame

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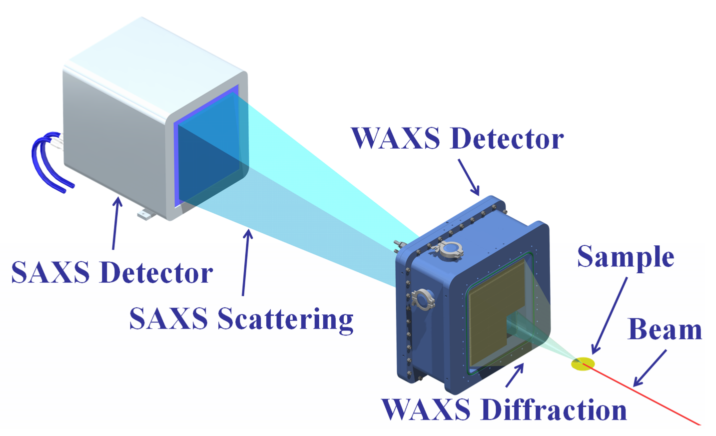
Abstract

The purpose of the project was to design and simulate a window assembly to be used in GISAX/GIWAX[a] experiments. The window lies between the sample and the WAXS[b] detector, a modified, in-vacuum detector, with modules removed to allow scattered radiation to pass through to a SAXS[c] detector positioned downstream. The window uses 75 µm thick Kapton® HN film and given the size, pressure and the short distance to the sensors, it was necessary to support it on a frame.

To avoid any information loss from shadowing of the detector, a frame was designed so that shadows will be projected into the gaps between the detector modules. The geometry was such that DMLS[d] was an effective way of producing the item. Given the slenderness of the structure and the forces it supports, the material approaches or exceeds its yield point, so a bilinear, isotropic, hardening material model was chosen; moreover, large deflections were enabled. Also, the contacts were modelled with augmented Lagrange frictional formulation. All these assumptions made the analysis strongly non-linear.

[a]Grazing Incidence Small/Wide Angle X-ray scattering
[b]Wide Angle X-ray Scattering
[c]Small Angle X-ray Scattering
[d]Digital Metal Laser Sintering

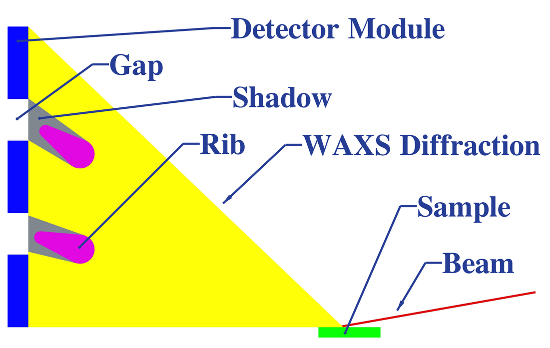
Introduction

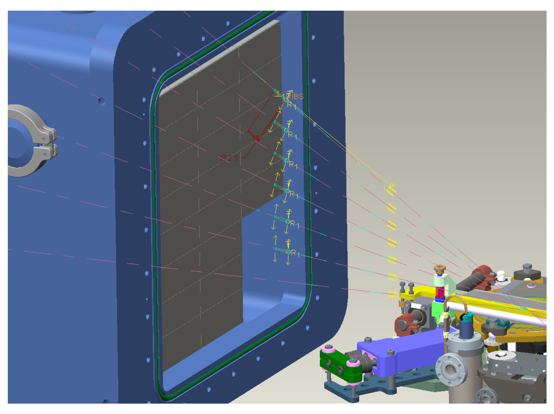


I22 is a non-crystalline diffraction beamline for physical and life sciences that records simoultaneously both SAXS and WAXS[1][2]. It is structured as follows: the beam coming from the BCO[a] hits the sample, and the diffracted light is recorded by a 2D in vacuum WAXS detector; some missing modules on the detector allow part of the radiation to pass through, so the SAXS scattering can be recorded by another detector.

[a]Beam Conditioning Optics

Window Design

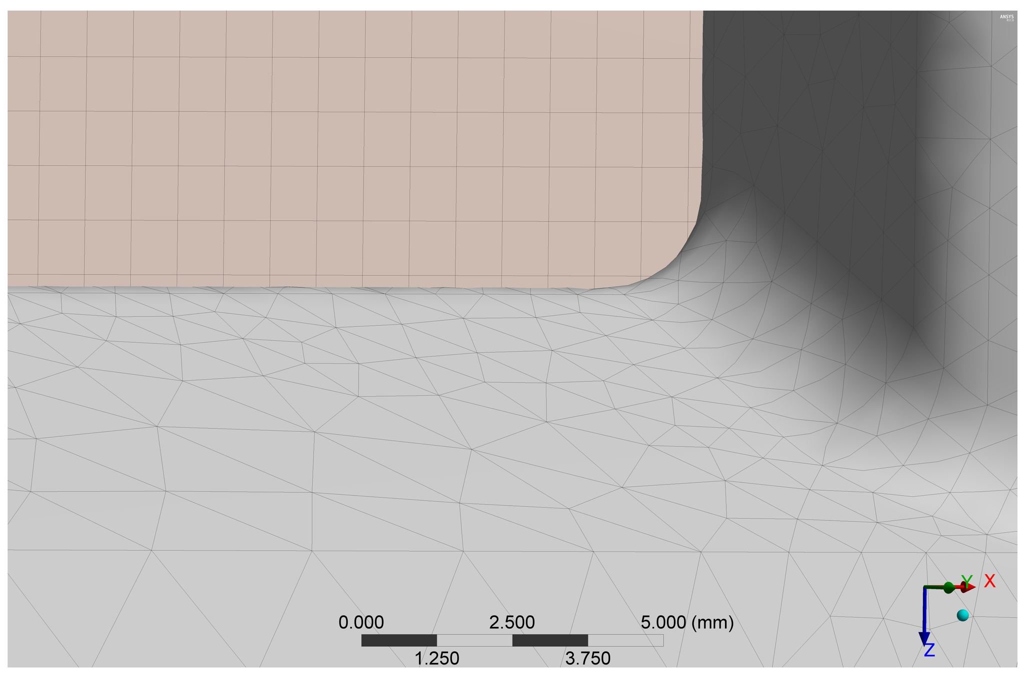




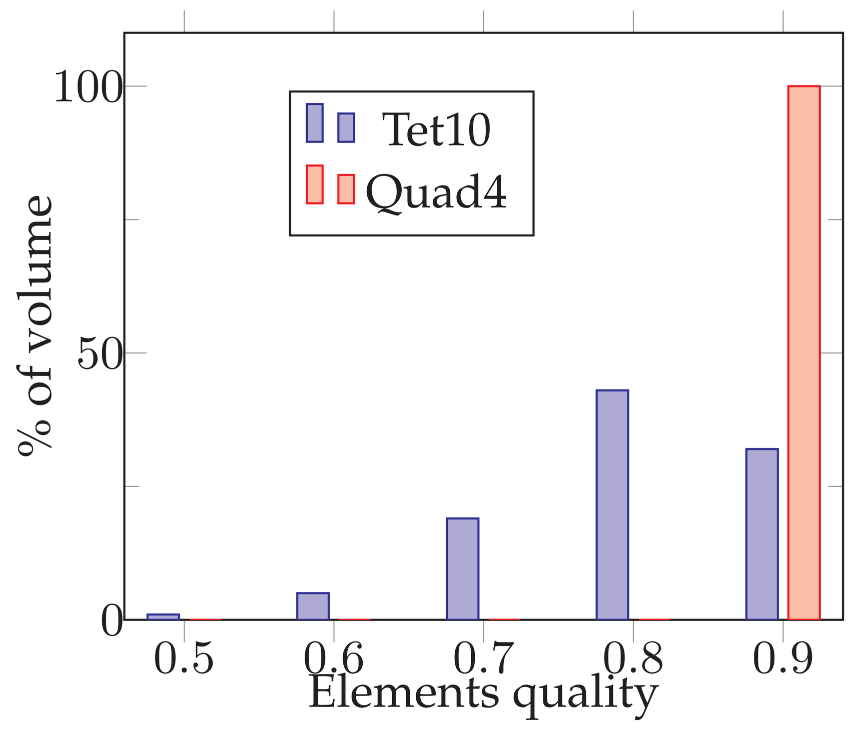
The WAXS detector is in-vacuum, so it needs a window to isolate it from the atmosphere. A 75 µm thick Kapton® HN film was used, because of its transparency to X-rays and low scattering[4]. It was necessary to support it because of the force generated by the atmospheric pressure on the film.

The detector is made up of multiple modules, with gaps between them. A 3D printed stainless steel support frame was designed; it has different ribs positioned and angled in such a way that the support's shadow would be projected into the above mentioned gaps.

FEA Setup



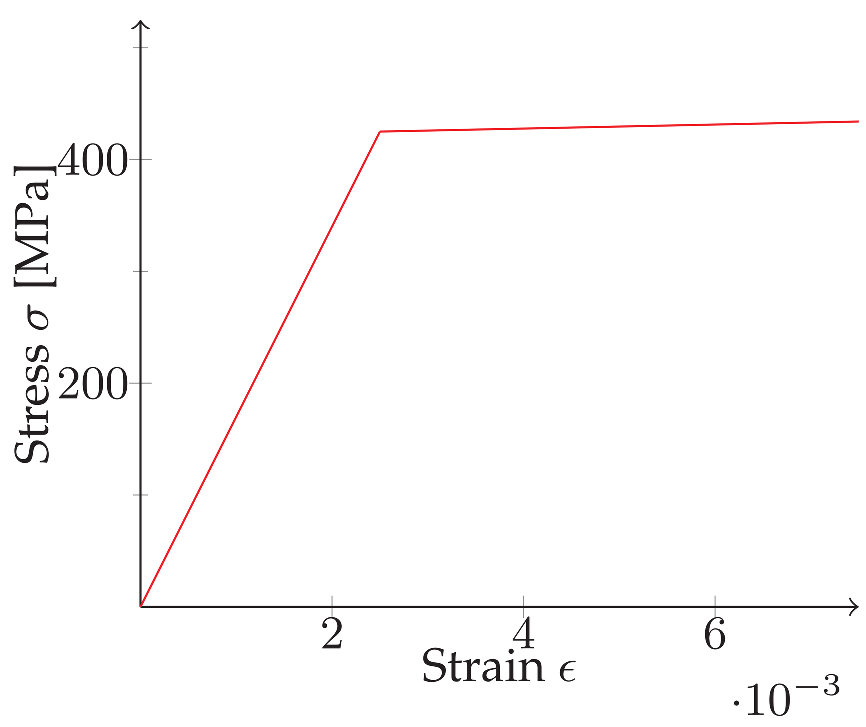
The Kapton was modelled with shell elements and the frame with solid elements.



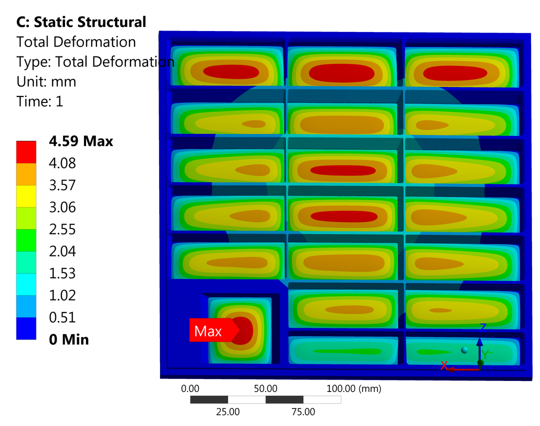
The contacts were modelled with an Augmented Lagrange frictional formulation[7].

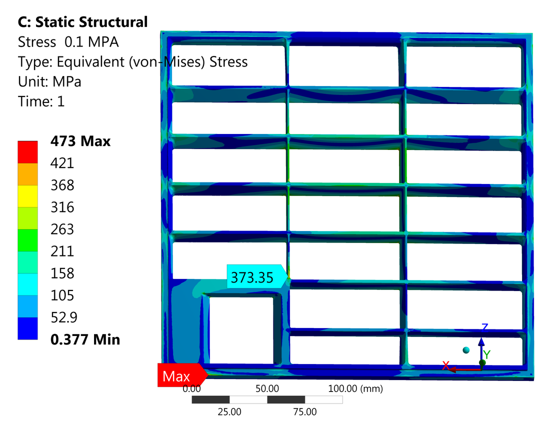
It was necessary to enable Ansys large deflections option[8].

To take into account the plastic deformation without increasing too much the complexity of the simulation, a bilinear isotropic hardening model was chosen).



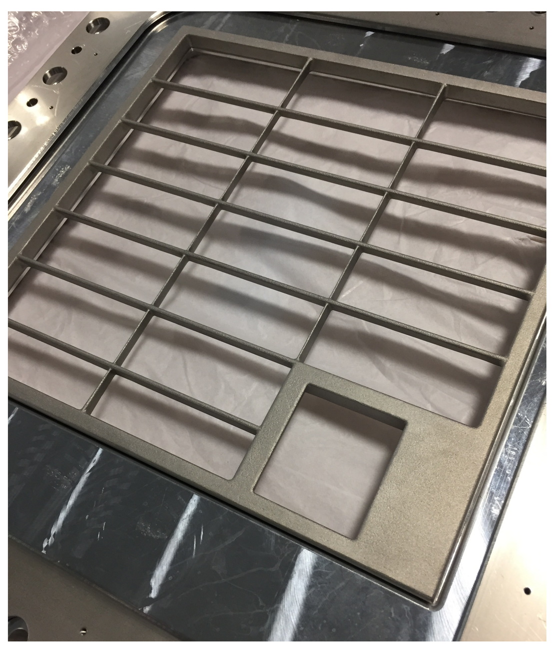
FEA Results





The results showed that the support frame would not deform sensibly; there is a point in the structure where the stress is beyond the yield point, but it is a constrained sharp corner under compressive load, so this is a numerical singularity[9]; other than that, the most stressed point is below the yield point. The displacements were not excessive for the intended use, as the structure and the Kapton window are far from the detector modules, and the structure does not deform enough to affect the shape of the shadows and make them fall outside the gaps between the modules.

Future Work



The parts were manufactured and assembled, and they went through a pressure test to check that there were no leaks or visible damage. A visual examination did not highlight any noticeable permanent deformation so the window is now operative; a test is planned to measure stress and strain, so the results can be compared to the simulated ones, to validate them.

References

[1] Diamond Light Source, http://www.diamond.ac.uk/Beamlines

[2] A. Marshall, "Upgrading a Transmission SAX/WAX Beamline to Allow High Quality GISAX/GIWAX Experiments for Soft Matter Thin Films", presented at MEDSIâĂŹ16, Barcelona, Spain, September 2016, paper THAA04.

[3] DECTRIS PILATUS3 2M-DL-L Detector System, Technical Specification and Operating Procedure, Version V1.0.

[4] M. Antimonov *et al.*, "Large-area kapton X-ray windows", in *Proc. of SPIE - The International Society for Optical Engineering.*, vol. 9588, 95880F, SPIE, Advances in X-Ray/EUV Optics and Components X, San Diego, United States, 11-12 August. DOI: 10.1117/12.2193680.

[5] 3D Alchemy, https://www.3d-alchemy.co.uk

[6] Dupont, http://www.dupont.com

[7] Ansys Blog, http://www.ansys-blog.com

[8] E. Madenci and I. Guven, "Nonlinearity", in *The Finite Element Method and Applications in Engineering Using ANSYS®*, Springer US, 2015, pp. 18–19.

[9] J. Dundurs and M. S. Lee, "Stress concentration at a sharp edge in contact problems", *Elasticity*, vol. 2, Issue 2, pp. 109-112, Jun. 1972.