OPTIMIZATION FOR THE APS-U MAGNET SUPPORT STRUCTURE*

MEDSI 2016
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

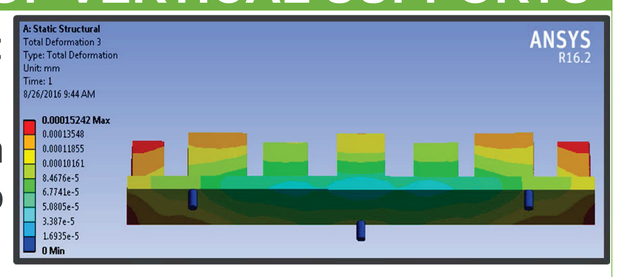
Zunping Liu †, Jeremy Nudell, Curt Preissner, Jeff Collins, and Herman Cease
Mechanical Engineering and Design Group, APS Engineering Support Division, Advanced Photon Source, Argonne National Laboratory, USA

ABSTRACT

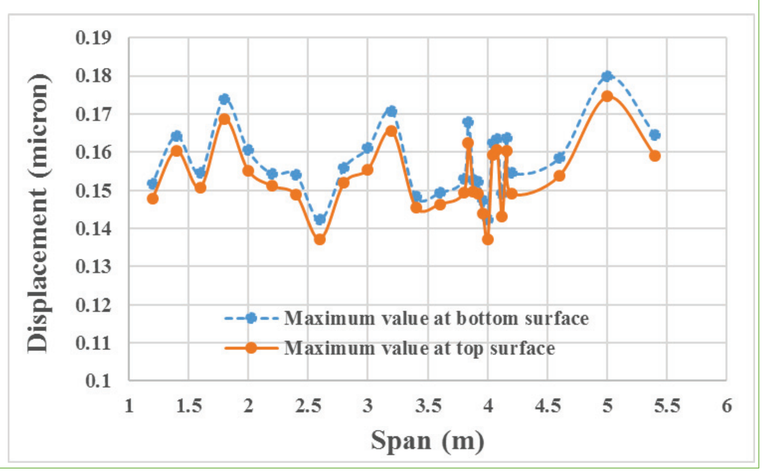
- The Advanced Photon Source Upgrade (APS-U) is to replace the existing storage ring with a multi-bend achromat (MBA) accelerator lattice.
- A three-point semi-kinematic vertical mount for the magnet modules is considered as the best approach for the APS-U removal and installation. The current planning calls for a 12-month shutdown and testing period, prior to resumption of operations. The assembly and installation alignment tolerance of 100 microns RMS for girder-to-girder alignment is specified [1].
- The APS-U specifies 9 nm RMS as magnet-to-magnet vibration tolerance and 30 microns RMS as magnet-to-magnet static tolerance within a girder [1]. These require structure optimization. Parametric studies are performed during optimization.
- This poster details the structure optimization, including three-point positioning, material selection, and topology optimization.

SPACING OPTIMIZATION OF VERTICAL SUPPORTS

- Initial geometry of FODO girder: 5.568 (L) x 1.1 (W) X 0.16 (T) m^3.
- Three supports: ϕ0.1 m and 0.2 m (L). one at central of one side, two symmetrically at the other side.



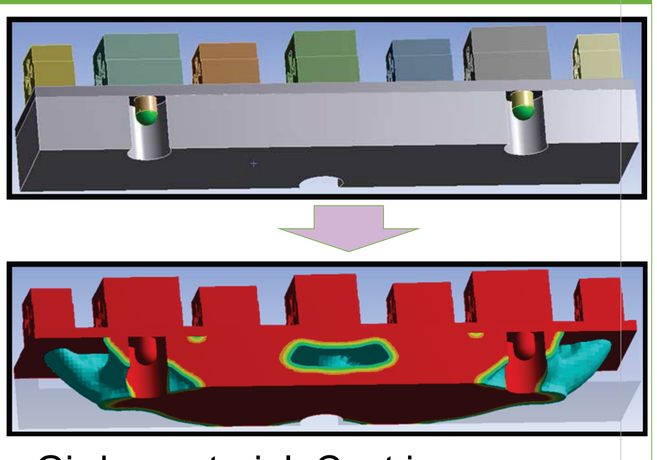
- The span along the short side ➔ Maximized and preferred from the point view of stability and the rolling mode of vibration.
- The span along long side ➔ Optimized. Maximum value of displacement vs. span ➔ 2.6 or 4 m span



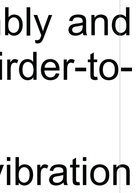
1ST TOPOLOGY OPTIMIZATION

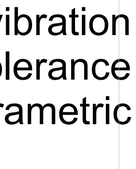
Software: Genesis® Topology for Ansys Mechanical (GTAM) [4-6]

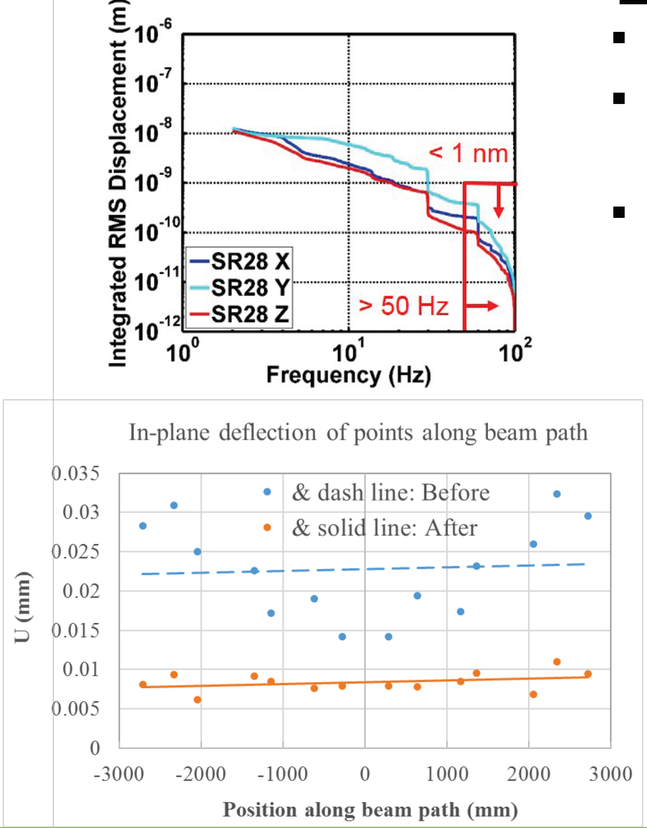
- Constraint – 1: Minimize strain energy
  ➔Minimize in-plane deflection at points along beam path
- Constraint – 2: Maximize frequency response

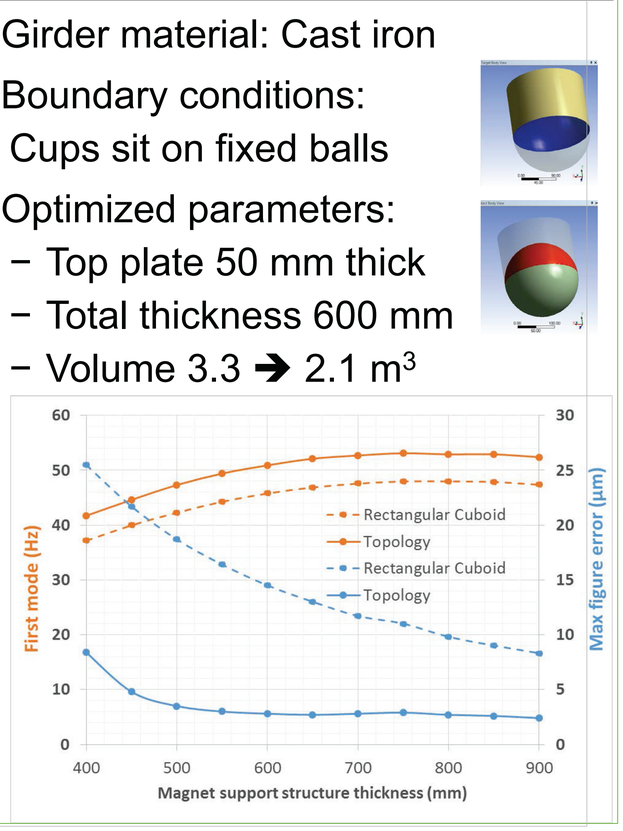


- Girder material: Cast iron
- Boundary conditions: Cups sit on fixed balls
- Optimized parameters:
  - Top plate 50 mm thick
  - Total thickness 600 mm
  - Volume 3.3 ➔ 2.1 m^3



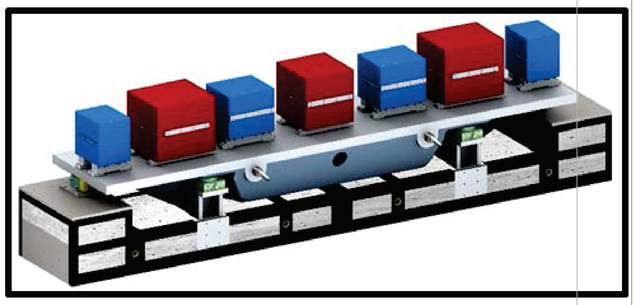






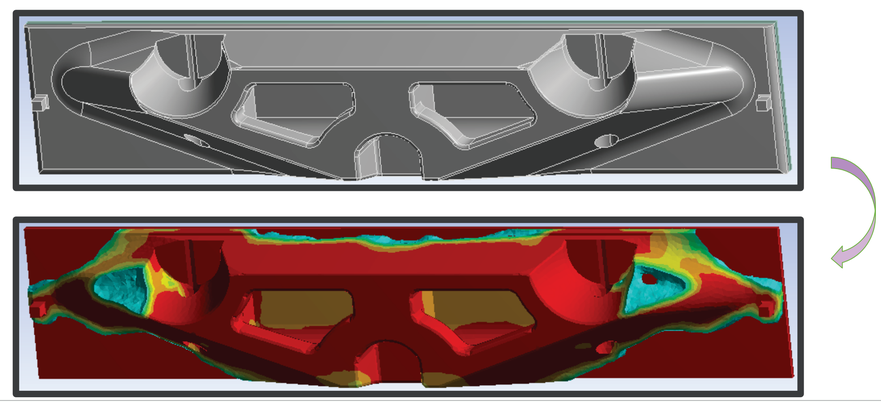
PROTOTYPE OF PRELIMINARY DESIGN

- Preliminary design is based on the optimized geometry in conceptual design phase.
  - 0.6 m thick & 3 m span
- Ductile cast iron, A536, GR 60/40/18
  - Design flexibility, low cost, vibration damping properties
- Airloc 414-KSKC wedge jacks as vertical supports [2]
- Maximum figure of error 14 microns along beam path [2]
- 1st mode frequency of assembly: 39 Hz [2]



2ND TOPOLOGY OPTIMIZATION

- The girder geometry is fed back into the model for further optimization. This simple step shows that the volume further decreases from 1.83 to 1.57 m^3



CONCLUSIONS

- Structure optimization plays an important role in the conceptual design phase. It leads to the right direction for preliminary design in terms of mass reduction and sound performance.
- Spacing optimization of vertical supports are performed. It leads to a guidance for next step.
- Topology optimization is performed. The material utilization is maximized.
- Parametric studies are performed for FODO girder design and optimization. The design specifications are met.

NEXT STEPS

- The preliminary prototype is under test.
- In case that the current prototype does not meet the specifications during test, the 2nd topology optimization results would be realized in design.
- Further iteration of optimization includes topology optimization to give optimized thickness and geometry, and material selection to further increase the girder mode frequency.

REFERENCES

[1] G. Decker, “Design Study of an MBA Lattice for the Advanced Photon Source,” Synchrotron Radiation News, 27:6, 13-17, 2014, DOI: 10.1080/08940886.2014.970932.
[2] J. Nudell et al., “Preliminary Design and Analysis of the FODO Module Support System for the APS-U Accelerator,” in Proceedings of MEDSI 2016, 11~16 SEPT, 2016, Barcelona, Spain.
[3] C. Preissner et al., “Nostradamus and the Synchrotron Engineer: Key Aspects of Predicting Accelerator Structural Response,” in Proceedings of MEDSI 2016, 11~16 SEPT, 2016, Barcelona, Spain.
[4] M.P. Bendsoe and N. Kikuchi, “Generating Optimal Topologies in Structural Design Using a Homogenization Method,” Comp. Meth. Appl. Mech. Eng., Vol.71, 1988, pp.197-224.
[5] J.P. Leiva and et al., “Modern Structural Optimization Concepts Applied to Topology Optimization,” Proceedings of the 40th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Material Conference. St. Louis, MO, April 12-15, 1999, pp.1589-1596.
[6] http://www.vrand.com/GTAM.html

* Work supported by the U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357
† zpliu@anl.gov

Argonne NATIONAL LABORATORY