MECHANICAL STRAIGHTENING OF THE 3-m ACCELERATING STRUCTURES AT THE ADVANCED PHOTON SOURCE

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Abstract

A project is underway at the Advanced Photon Source to mechanically straighten the thirteen 3-meter accelerating structures in the Linear Accelerator (Linac) in order to minimize the transverse wake-field, and improve charge transport efficiency and beam quality. Flexure supports allow positioning of the structures in the X and Y directions. Mechanical design of the flexure support system, straightening techniques, mechanical measurement methods, and mechanical and RF results will be discussed.

INTRODUCTION

The Linac of the Advanced Photon Source at Argonne National Laboratory is composed of thirteen S-Band accelerating structures operating at 2856MHz. The thirteen accelerating structures are in the process of being mechanically straightened off-line to reduce transverse wake-field and improve beam performance with thermionic and photocathode guns. Using a modified SLAC design [1], flexure (flex) supports are used on a strong-back to mechanically straighten the structures with a goal of within ± 200 µm in the X (horizontal), and Y (vertical) directions. Prior to straightening, the deformation of the operational structures was greater than 1 mm in X, and greater than 6 mm in Y. It is believed that rigid water connections to the structures contributed to the gross deformation in the Y direction. The location of quadrapole (quad) magnets vary for each structure which requires that the flex supports are locatable on the strong-back to accommodate different configurations. The magnets can also hinder achieving the ± 200 µm tolerance throughout the entire 3-m length due to restricted access for straightening hardware. An operational structure prior to straightening and without the new support system is shown in Fig. 1.

FLEXURE SUPPORT DESIGN

The flex supports are a modified SLAC design with locatable pedestals, halos, and cell saddles, which can be mounted at a desired location on the strong-back, depending on the deformation profile of the structure and the position of quad magnets at the chosen installation location. The SLAC flex support consists primarily of a 5-piece riveted assembly while the ANL version is a 2-piece electrical discharge machined (EDM) assembly, as shown in Fig. 2. In both designs, thin wall side plates allow movement in the Z direction while a phosphor bronze center plate strives to maintain the Y elevation, and minimize X tilt and Z twist. Setscrews are provided on the flex support and halo to move the structure in the desired X, Y and XY directions.

Figure 1: Original Linac structure located in the APS with quad magnets and rigid water lines.

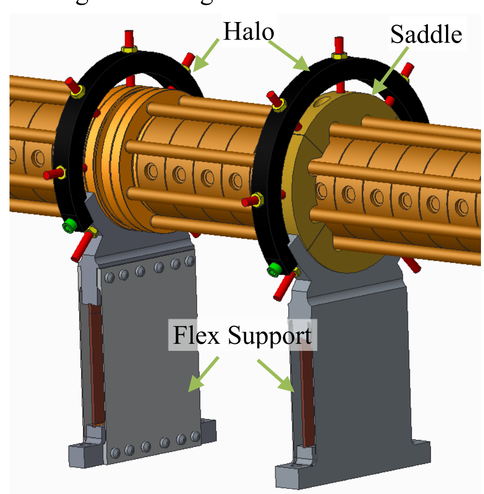

Figure 2: Section of Linac structure with supports: left - SLAC riveted assembly, right - ANL EDM assembly.

STRAIGHTENING TECHNIQUES AND MECHANICAL MEASUREMENT METHOD

X and Y base-line profiles are established using a portable articulating arm coordinate measuring machine (CMM) [2]. Eight points are taken around the circumference of the cells and 2D and 3D axes are created using the CMM measurement software. A base-line 2D XY profile for structure 008 is shown in Fig. 3. A typical 3D profile for a structure is shown in Fig. 4. With the base-line profiles established, the support pedestals are mounted to a strong-back. Support pedestal positions are determined using the deformation profiles and the position of the quad magnets at the installation location. Fig. 5 shows a structure ready to be measured and straightened with supports in place, mounted on a strong-back, with the portable CMM in close proximity. With supports connected, the straightening process begins by adjusting the support and halo setscrews on a single support as needed. The adjustment is made mainly in the Y direction to achieve ~ ½ the overall distance needed to meet tolerance. The same method is used on the next support in line until all supports have completed the 1st iteration. Surveys using optical instruments are used to measure the Y elevations as each of the supports is adjusted. Once an iteration is completed, the portable CMM is used on a number of cells to obtain that iteration's deformation profile. This process is repeated until a support section has reached the ± 200 µm tolerance. The setscrews on that support are then locked down with jam nuts and the process moves to the remaining supports. An XY profile for structure 008 after the 1st iteration is shown in Fig. 6. When it is believed that the entire structure is within tolerance, a full set of measurements on all the cells is made using the portable CMM. In general, between 5 and 10 iterations are necessary to achieve tolerance.

Using a "best-fit" line derived from the final XY profiles, the structure is installed in the Linac tunnel where it is optically aligned to the beamline and the straightness is verified using the portable CMM, to ensure that no additional deformation occurred during transport between buildings.

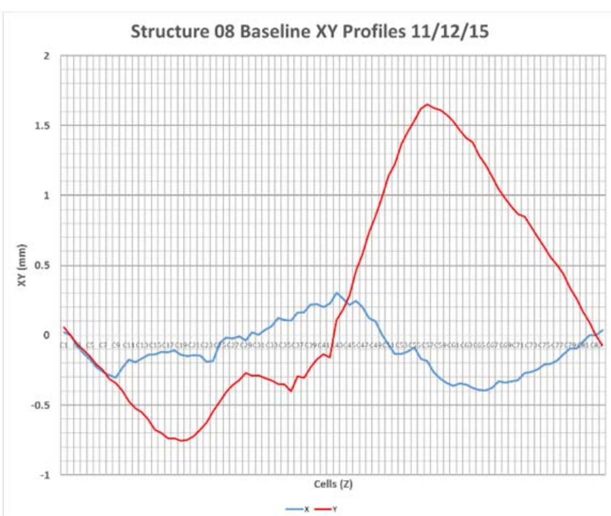

Figure 3: 2D baseline XY straightness profiles of structure 008.

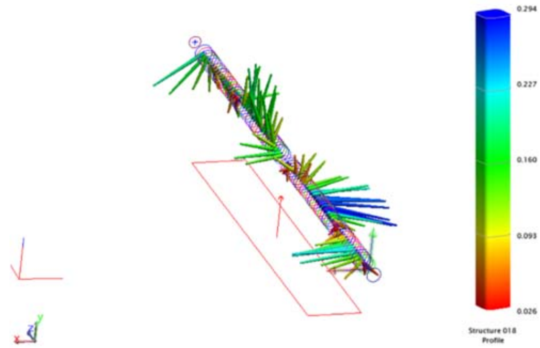

Figure 4: Atypical 3D baseline straightness profile of a structure.

Figure 5: Linac structure on strong-back with supports and portable CMM.

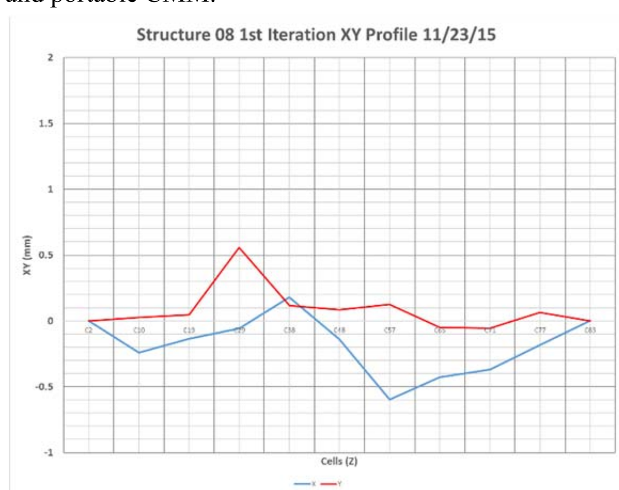

Figure 6: Structure 008 2D XY profiles after 1st iteration.

MECHANICAL AND RF RESULTS

Four structures have been mechanically straightened using the technique outlined above. A comparison of mechanical deformation and RF return loss before and after straightening are summarized in chronological order in tables 1 and 2. Structure 015 was straightened to within tolerance but was not installed due to degraded return loss of -12 dB due to the straightening process. Although a network analyzer was connected to the structure to monitor S_{11} during the saddle placement and straightening, bead-pull and tuning infrastructure were not yet implemented.

Structure 008 was the 2nd structure to be straightened. It met the ± 200 µm tolerance and was installed at location L2:AS1 in January 2016. This structure was also straightened before the bead-pull and tuning setup was in place, therefore the match, while acceptable, was not optimum with an S_{11} of -23.8 dB. The tuning of each cell was unknown.

It has since been determined that both overtightening the saddle pieces and the straightening process itself caused a degradation of RF performance. Some cells in contact with the saddles exceeded the 120° ± 1° cell specification by more than the tuning adjustment capability of the cell. It was determined that the saddles slightly deformed the cells and in the process detuned the cell. A procedure is now in place to carefully place the saddles using 0.015" shims between the 0.020" EDM cuts of the 4-piece saddles. The saddles with 0.015" shims were tested using a bead-pull set-up and found not to cause an appreciable difference in the RF characteristics of the cells. A new wider saddle design is being considered to distribute the load over more than one cell iris. A cell saddle being placed with .015" shims is shown in Fig. 7, and a conceptual model of the wider saddle is shown in Fig. 8.

For the remaining structures in table 2, bead-pulls have been performed before and after straightening, and retuning of the structure has been found to be necessary to achieve optimum RF performance after the ± 200 µm tolerance was achieved [3]. Structure 016 was straightened within specifications and retuned to -32.0 dB. It was installed at location L2:AS2 in May of 2016, but was damaged due to arcing that is not believed to be related to the straightening process or retuning. Structure 018 was the 4th structure to be straightened. Due to its sinusoidal 2D X profile and the location of two quad magnets, it only achieved ± 260 µm straightness. It was vacuum baked after straightening which pushed it to ± 360 µm straightness. It was retuned to an S_{11} of -27.8 dB and installed in September 2016 at the L2:AS2 location replacing the damaged structure 016.

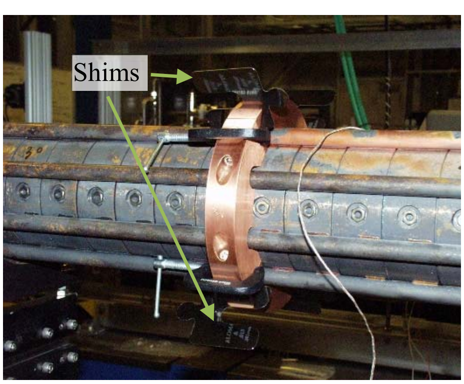

Figure 7: Cell saddle being placed on a structure using .015" shims.

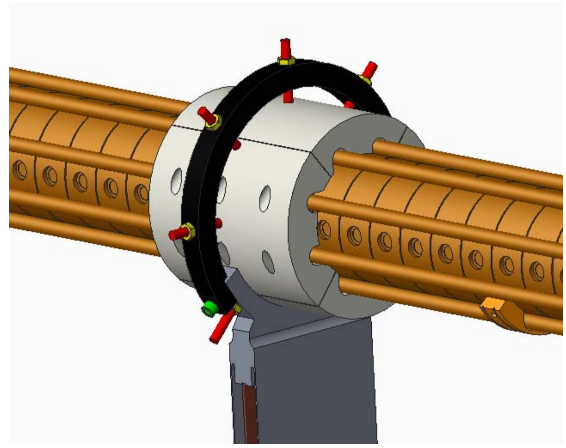

Figure 8: Conceptual model of a wider four-cell saddle.

Table 1: Mechanical Summary of Structures

SN	Straightness Before	Straightness After
015	± .98 mm	± .14 mm
008	± 1.2 mm	± .17 mm
016	± 2.7 mm	± .18 mm
018	± 1.9 mm	± .36 mm*

*0.26 mm after straightening, 0.36 mm after vacuum bake

Table 2: RF Summary of Structures

SN	S_{11} Before Straightening	S_{11} After Straightening	S_{11} After Retuning
015	-30.0 dB	-12.0 dB	N/A
008	-27.7 dB	-23.8 dB	N/A
016	-27.3 dB	-15.2 dB	-32.0 dB
018	-25.2 dB	-14.8 dB	-27.8 dB

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