FABRICATION OF SUPERCONDUCTING SPOKE CAVITY FOR COMPACT PHOTON SOURCE

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Abstract

We are developing electron beam drivers used for laser Compton scattered (LCS) photon sources. For realizing a wide use of LCS X-ray and γ-ray sources in academic and industrial applications, we adopt the superconducting spoke cavity to electron beam drivers. The spoke cavity has advantages such as relative compactness in comparison with an elliptical cavity of the same frequency, robustness with respect to manufacturing inaccuracy due to its strong cell-to-cell coupling, the better packing in a linac to install couplers on outer conductor. On the other hand the spoke cavity has disadvantage of more complicated structure than an elliptical cavity. Though our proposal design for the photon source consists of the 325 MHz spoke cavities in 4K operation, we have begun to fabricate the half scale model of 650 MHz spoke cavity in order to accumulate our cavity production experience by effective utilization of our limited resources. We fabricated the die set, performed press forming test and measured the formed shape. In this paper, we present our fabrication status.

INTRODUCTION

We are developing laser Compton scattering (LCS) X-ray and gamma-ray sources combined with an energy-recovery linac (ERL) and a laser. The LCS X/γ-ray source is expected for application of non-destructive assay system of nuclear materials with nuclear resonance fluorescence [1], analysis of nano-structure, drug development, medical diagnostics, and so on. We are developing the superconducting spoke cavity for LCS photon sources [2]. Spoke cavities have many advantages such as shortening the distance between cavities, small frequency detune due to micro-phonics and easy adjustment of field distribution for strong cell coupling. We have optimized the cavity shape with genetic algorithm [3], fabricated the die set for the half-spoke on the basis of die design simulation and started press forming test.

The spoke cavity for the compact X-ray source was originally designed at 325 MHz, which can be operated at 4 K. We have, however, recently changed our R&D plan to fabricate a 650 MHz cavity prior to 325 MHz one. This is because a 650 MHz cavity can be fabricated almost "in-house" at the KEK machine shop and suitable for accumulating our cavity production experience within limited resources. Once we learn the design and production process of spoke cavities at 650 MHz, we can easily apply our expertise to production of spoke cavities with difference frequencies.

FABRICATION OF DIE SET

Press forming process consists of three steps such as moving the inner punch, moving the center die and the inner punch together, and moving the outer punch. To realize these steps in a sequence of one slide action the press machine requires a die cushion to control the die center motion and the die set requires a spring functioning component such as a gas spring to control the inner punch motion by the load.

We planned at the beginning to use the press machine of AMADA SDE1522 in KEK, which specifications are shown in Table 1. The die height of the press machine was not enough to mount the die set of half size of original 325MHz-design die set, we have redesigned the die set by changing the type and number of the gas springs and reducing the thickness of the die set as thin as possible. Though the press machine changed to AIDA NC1-15 due to operator's schedule, this machine has similar specifications to AMADA SDE1522.

The components of the die set which contact with the sheet metals are made of extra super duralumin of A7075 or ANP79. The other components of the die set which support the whole structure are made of SS400. The assembled die set mounted to the press machine is shown in Figure 1.

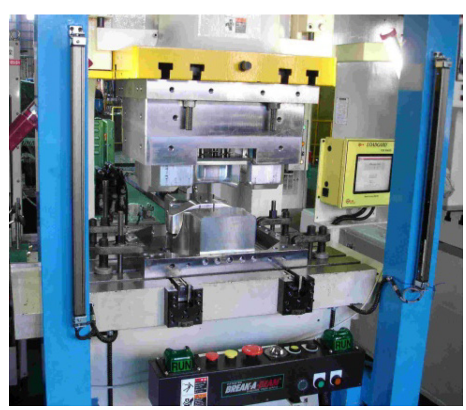

Figure 1: Assembled die set was mounted to press machine.

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Table 1: Specifications of Press Machines

Press machine	AMADA SDE1522	AIDA NC1-15
Capacity of nominal force	1500 kN	1500 kN
Slide stroke	225 mm	200 mm
Die height	430 mm	400 mm
Capacity of die cushion	80 kN	100 kN
Die cushion stroke	80 mm	80 mm

PRESS FORMING TEST OF HALF-SPOKE

Press forming test was carried out to confirm the die set performance. The copper and aluminum plates of 1.0 mm, 1.5 mm and 2.5 mm thick were prepared. The result of the press forming test with annealed Cu plate of 1.5 mm thick is shown in Figure 2 (left). There occurred wrinkles around the spoke side corner. These wrinkles also occurred with 1.0 mm thick plate and with annealed Al plate of 1.5 mm thick as shown in Figure 2 (right). In order to investigate the cause of the wrinkles unannealed Al plates of 1.5mm thick were pressed changing the slide position of the press machine to 16 mm, 11 mm, 6 mm and 0 mm from bottom dead center. Figure 3 shows the side views of the press formed plates. The cracks were caused owing to the unannealed plates.

Though the plate should be dragged along the die smoothly with the slide moving downward, the plate was a little caught at the die corner between upper and inside surfaces in the test. Therefore the plate was bended more than expected and further deformation leading to wrinkles occurred with the slide moving further downward. The rubbed trace caused by being caught at the die corner can be observed at the side of the press formed plates of Figure 3.

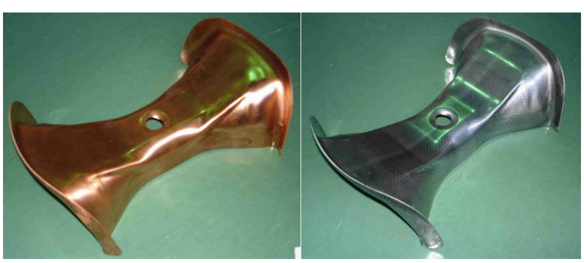

Figure 2: Press forming of half-spoke with 1.5 mm thick plates of copper (left) and aluminum (right).

3D MESUREMENTS OF HALF-SPOKE

The 3-dimensional shape measurements were performed to investigate the shape of pressed half-spoke in detail. A simple 3D measurement system was set up with a laser displacement sensor, three linear stages and a rotary stage as shown in Figure 4. The surface position was scanned by moving the laser displacement sensor. Since the measuring range of the laser displacement sensor was 50 mm ±10 mm, the distance from the sensor to the surface was kept constant near the center of the measuring range by moving the position adjustment stage.

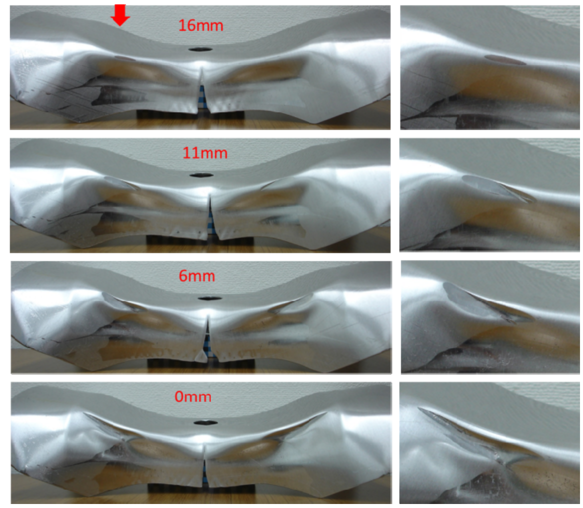

Figure 3: Press forming of unannealed aluminum plate by changing the slide position of 16 mm, 11 mm, 6 mm and 0 mm from bottom dead center. Red arrow shows the position of cross section of Figure 6.

The sensor was also moved for the laser to be incident perpendicularly on the surface by moving the rotary and horizontal stages.

The result of measuring the half-spoke shape pressed only with the inner punch is shown in Figure 5. This figure shows the contour of the difference of the pressed shape from the design shape. The base part of the half-spoke has large differences since the base of the half-spoke was not pressed. The center front of the half-spoke was formed as designed and the center side was wider than the design due to spring back. The corner of the half-spoke has large difference due to wrinkles. Figure 6 shows the transition of cross sections of press formed shapes around the position of large difference as shown by the arrow in Figure 3. This indicates that the plate is bended largely at the position of 41 mm up from the bottom dead center and this bended area was deformed to wrinkles after the process of press forming.

Figure 7 shows the difference of deformation compared with the plates of 1.5 mm and 2.5 mm thick. In this press forming the slide was moved down to the position where the minimum gap between the die and the inner punch became 2.5 mm. The plate of 2.5 mm thick has less deformation around the corner than that of 1.5 mm thick. The thicker plate is expected to avoid forming wrinkles at the corner.

CONCLUSION

The die set for the half-spoke was fabricated and press forming test was carried out with copper and aluminum plates to check performance of the die set. The wrinkles were formed around the corner of half-spoke and these wrinkles seem to be related to the corner shape of die which prevents the plate from being dragged smoothly. We are planning to modify the die set and to use thicker plate for the next press forming test.

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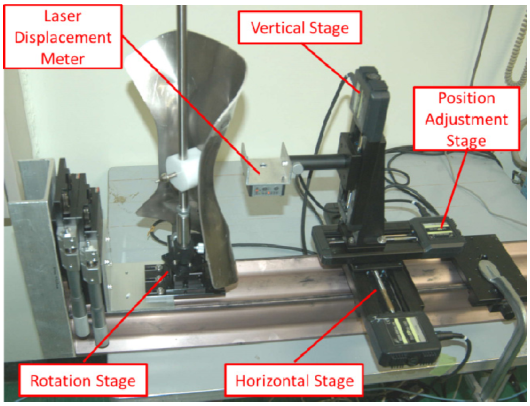

Figure 4: Setup for 3D shape measurement system using laser displacement meter and linear/rotary stages.

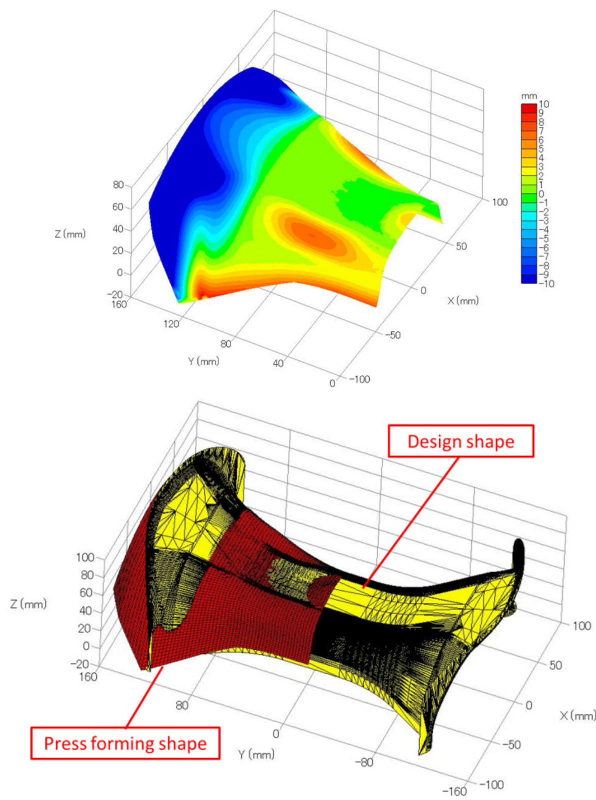

Figure 5: Contour plot of difference of press formed shape from design shape (top). Press formed shape and design shape are shown together (bottom).

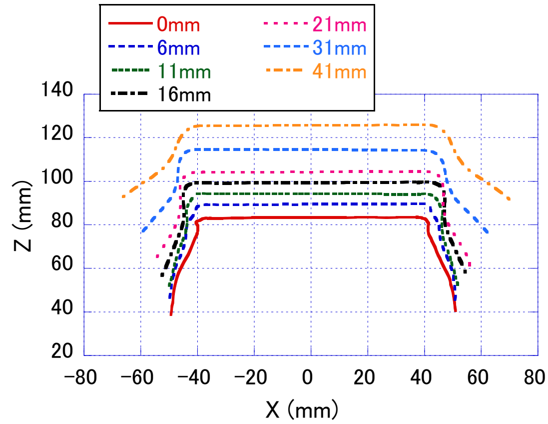

Figure 6: Cross sections of press formed shapes by changing the inner punch position from the bottom dead center.

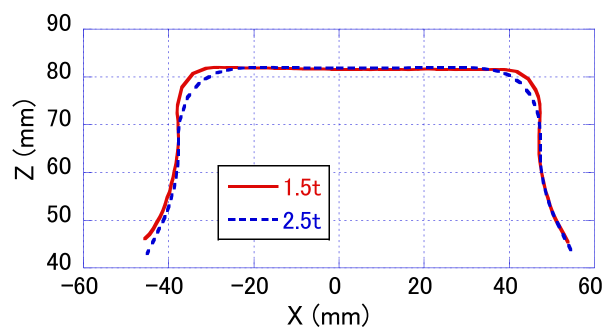

Figure 7: Cross sections of press formed shapes of aluminum plates of 1.5mm and 2.5mm thick.

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REFERENCES

[1] R. Hajima *et al.*, "Proposal of nondestructive radionuclide assay using a high-flux gamma-ray source and nuclear resonance fluorescence", *J. Nucl. Sci. and Tech*, vol. 45, pp. 441–451, 2008.

[2] R. Hajima *et al.*, "Linac-Based Laser Compton Scattering X-Ray and Gamma-Ray Sources", in *Proc. LINAC2012*, pp. 734-737.

[3] M. Sawamura *et al.*, "Development of Superconducting Spoke Cavity for Laser Compton Scattered Photon Sources", *Proc. IPAC2014*, pp. 1946-1948.