PRESS FORMING TESTS OF SUPERCONDUCTING SPOKE CAVITY FOR LASER COMPTON SCATTERED PHOTON SOURCES

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Abstract

We are developing the superconducting spoke cavity for laser Compton scattered (LCS) photon sources. We adopt the superconducting spoke cavity for electron beam drivers to realize a wide use of LCS X-ray and γ-ray sources in academic and industrial applications. The spoke cavity can make the accelerator more compact than an elliptical cavity because the cavity size is small at the same frequency and the packing factor is good by installing couplers on outer conductor. Though our proposal design for the photon source consists of the 325 MHz spoke cavities in 4K operation, we are fabricating the half scale model of 650 MHz spoke cavity in order to accumulate our cavity production experience by effective utilization of our limited resources. Since the spoke has more complicated structure than an elliptical cavity, we performed press forming tests for the half spoke. Though there occurred wrinkles around the spoke side corner at the 1st press forming test, we obtained good results at the 2nd forming press test after modifying the molds. The pressed shapes were estimated with 3-dimensional measurements.

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. The LCS photon sources are required to be compact for academic and industrial use. Since the spoke cavities have many advantages such as smaller cavity size than elliptical cavity of the same frequency and shortening the distance between cavities, we are developing the superconducting spoke cavity for LCS photon sources [2].

Since the spoke cavities are mainly developed for low beta beam acceleration, we have designed the cavity shape by optimizing with genetic algorithm for electron acceleration [3]. The designed shape is shown in Figure 1. According to the cavity design we fabricated the die set for the half-spoke press forming 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. The frequency of the first fabrication model of the spoke cavity was changed to 650 MHz in order to use the KEK machine shop effectively and accumulate our cavity production experience within limited resources.

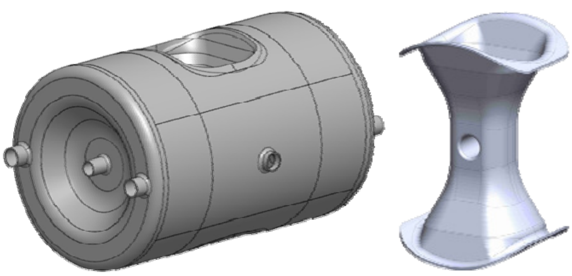

Figure 1: Schematic view of spoke tank (left) and spoke shape (right).

PRESS FORMING TEST

1st Press Forming Test

The 1st press forming test was carried out to confirm the die set performance. The copper and aluminium 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 from bottom dead center. Figure 3 shows the transition of cross sections of press formed shapes around the position where the wrinkles occurred. This indicates that the plate is bended largely at the slide position of 41 mm up from the bottom dead center and this bended area was deformed to wrinkles after the process of press forming.

The rubbed trace could be observed at the side of the press formed plates. The trace was considered to be caused by being caught at the die corner. Therefore the plate was bended more than expected and further deformation leading to wrinkles occurred with the slide moving further downward.

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

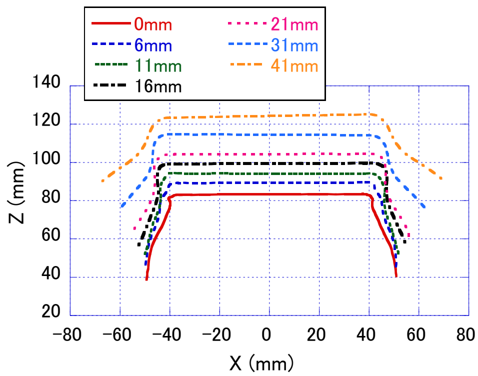

Figure 3: Cross sections of press formed shapes by changing the slide position from the bottom dead center.

Mold Modification

As a countermeasure for wrinkles we increased the sheet thickness. Figure 4 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 as shown in Figure 5. The thicker plate is expected to avoid forming wrinkles at the corner.

The center part of die center of the first die set was flat as shown in Figure 6 (top). Though the center shape was supposed to be formed according to the inner punch shape, the space between the inner punch and the die center was one of reasons of the wrinkles. We changed the die center shape to determine the corner shape with inner punch and die center as shown in Figure 6 (bottom right).


Figure 4: Deformation with the plates of 2.5 mm (top) and 1.5 mm thick (bottom).

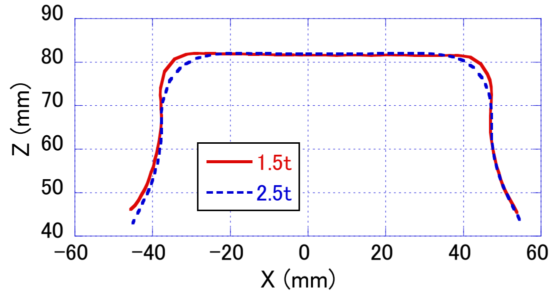

Figure 5: Cross sections of press formed shapes of aluminium plates of 1.5mm and 2.5mm thick.

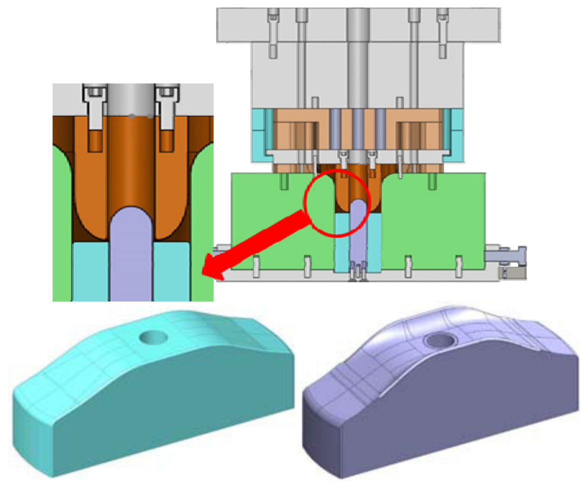
Figure 6: Schematic view of the first die set (top), the die center (bottom left) and modified die center (bottom right).

2nd Press Forming Test

After modification of the die set the second press test was performed with the sheets of aluminium, copper, and niobium of 2.5 mm thick. There occurred neither wrinkle nor break for niobium sheets. The burring was also performed for all the sheets. The press formed shape after burring is shown in Figure 7.


Figure 7: Press formed shape after burring with niobium sheet of 2.5 mm thick.

3D MEASUREMENT

The 3-dimensional shape measurements were performed to investigate the shape of pressed half-spoke in detail with the precise 3D measurement device of ZEISS UPMC850 at KEK as shown in Figure 8 (left), and the simple 3D measurement device made with the laser displacement sensor and optical stages as shown in Figure 8 (right).

Figure 9 shows the measured results for each measurement. Though the transverse cross sections are almost same, the longitudinal cross sections were a little different. Since the simple 3D measurement cannot measure the whole body all together because of the limitation of the optical stage range, the measurement area was divided into several parts and the measurement data were combined. The method used for this combination includes a little error and seems to cause these differences.

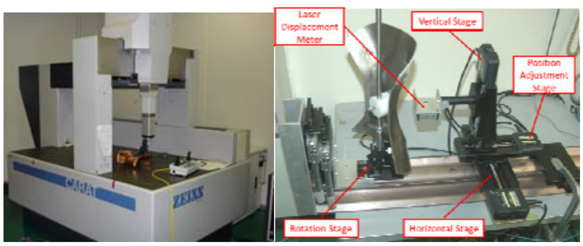

Figure 8: Precise 3D measurement device of ZEISS UPMC850 at KEK (left) and simple 3D measurement device made with the laser displacement sensor and optical stages (right).

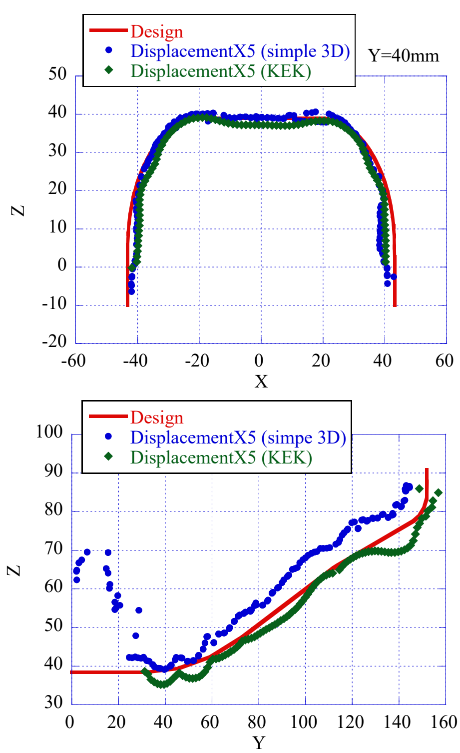

Figure 9: Transverse and longitudinal cross sections measured with the precise and simple 3D measurement devices.

TRIMING

The next step for press forming of half spoke is trimming. Trim jigs were designed and fabricated with chemical wood as shown in Figure 10. Trim test was done for copper model. We are now adjusting trim condition for niobium half spoke.

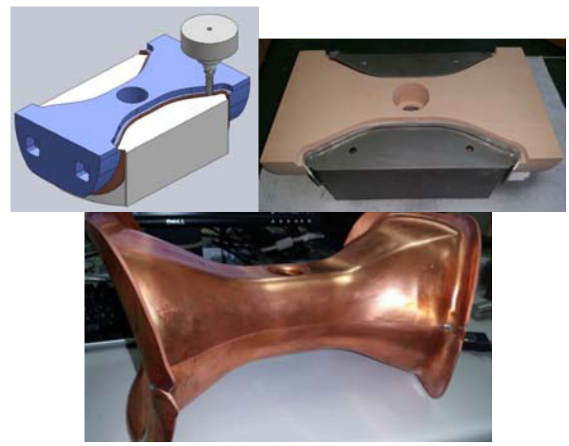

Figure 10: Designed (top left) and fabricated (top right) trim jig. Temporally assembled copper spoke (bottom).

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. At the 1st press forming test the wrinkles were formed around the corner of half-spoke and these wrinkles seem to be related to the plate thickness and the corner shape of die which prevents the plate from being dragged smoothly. After modification of the die set the 2nd press forming test with thicker plate was carried out and resulted in successful press formed shape.

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