UNDULATOR CHAMBER R&D FOR SXFEL

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Abstract

The upcoming construction of Shanghai Soft X-ray Free Electron Laser Facility (SXFEL) will use 18 m small gap undulators. Each undulator is 3 meters long and will work at a minimum gap of 9 mm. This requires a vacuum chamber with an outer height of 8 mm and an elliptic inner aperture. The pressure inside of the chamber shall be less than 10-5 Pa for the beam operation. An oxygen-free copper vacuum chamber was designed and a prototype was developed. This chamber includes three parts, a copper pipe manufactured by stretching, two flanges made of clad metal and a set of supports. The main fabrication procedure and the test results for the chamber prototype are described in this paper.

INTRODUCTION

Shanghai Soft X-ray Free Electron Laser Facility (SXFEL) is with about 250 meters long, and will be completed in 2015. The six-packundulators, are important parts of this facility. Each undulator chamber has the design dimension of 3720mm length, 6.5mm×15.5mm inner aperture and 8mm height.

Table 1 Parameter of Undulator Chamber

Undulator Chamber	
Inner aperture (mm^2)	6.5×15.5
Thickness (mm)	0.75
Material	OFHC
Length (m)	3.27
Pressure (Pa)	<10-5
Inner surface roughness RA	<300nm

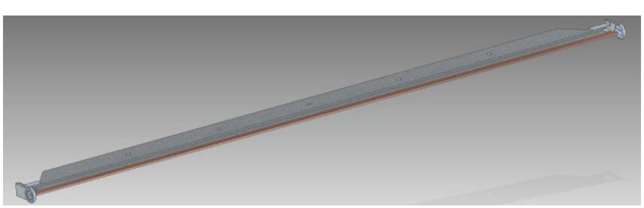

Figure 1: Schematic of Undulator chamber.

The undulator chamber consists three parts: a stretched pipe, two flanges and a set of supports. There are several technical difficulties: stretched copper pipe, in vacuum brazing and inner surface polishing.

STRETCHED COPPER PIPE

Stretched copper pipe is the key component of the undulator chamber.

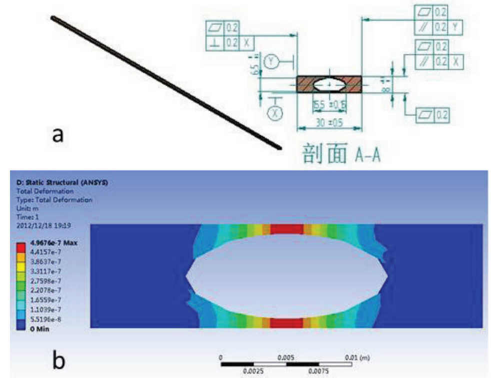

Figure 2: a. Cross section of Stretching Copper Pipe; b. Deformation of Stretching Copper Pipe.

Figure 2-a shows the copper pipe's dimensions and tolerances, and Figure 1-b shows the copper pipe's simulated deformation under vacuum condition, which seems fairly minor, noticing its 0.75mm minimum wall thickness. The total developing and manufacturing scheme and techniques are shown in Figure 3.

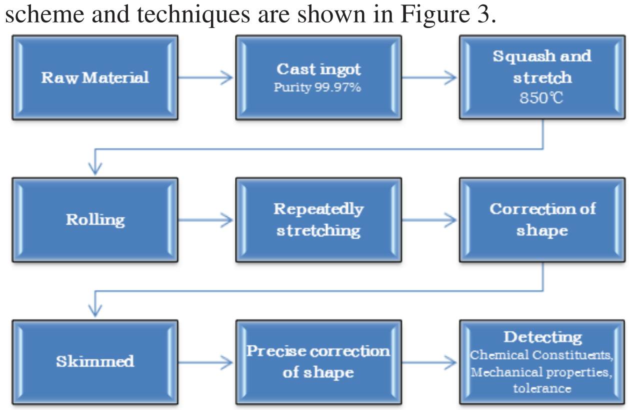

Figure 3: Development Process of Stretching Copper Pipe.

In general, the copper raw materials are firstly extruded at high temperature and then repeatedly stretched at room temperature. This method can help assuring the precision of the cross section dimension. Stepping in stretching leads to better shaping of wanted geometry. Through several molds with transitional section geometry closing to the aim shape, stretching and forming could be smooth and stable, by minimizing asymmetry and internal stress. In margin of manufacturing consumption and shaping variety, several sets of beam pipes are respectively stretched to be sufficient enough for selection. The outer cross-sectional geometry is transformed from ellipse to a rectangular of 8mm×30mm, and the inner cross-sectional geometry is from circle to a ellipse of 6.5mm×15.5mm. Figure 3 shows the procedure the copper pipes transformed.

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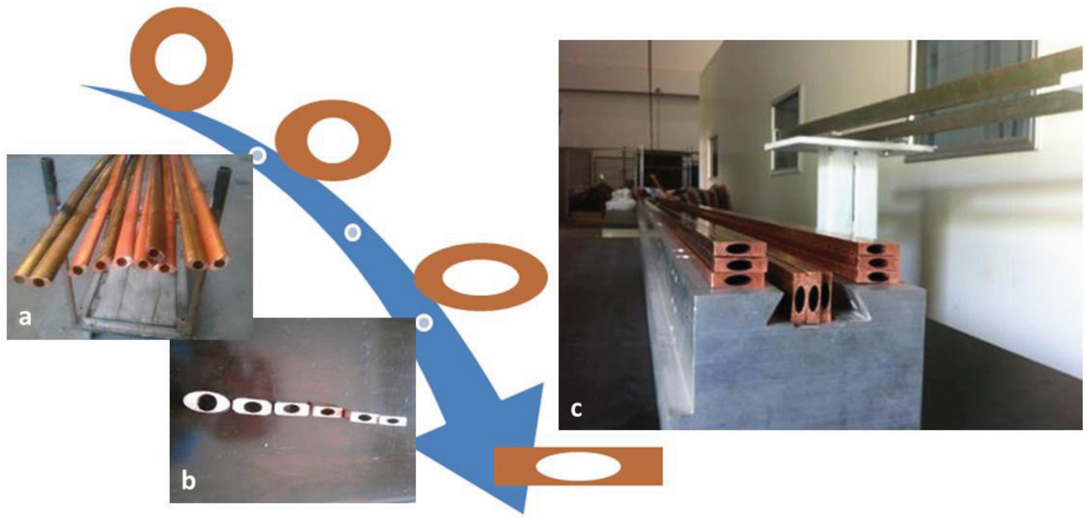

Figure 4: a. Copper pipes after extrusion; b. Cross section after each step of stretching; c Final copper pipes for undulator chamber prototypes.

INNER SURFACE POLISHING

The special operating condition-beam lining of the undulator chamber requires a glossy inner surface. The roughness of undulator chamber inner surface should be approximately 300 nm. We reach this standard with two methods. First, we polish the stretching mold to a certain degree. Second, Abrasive Flow Polishing (AFP) method is introduced to polish the inner surface of the pipes. [1]

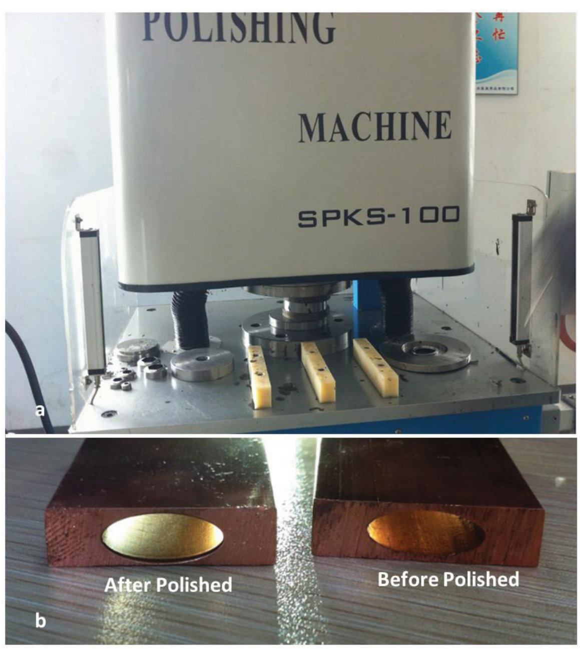

Figure 5: a. A short Pipe Polishing Progress; b. Comparing of inner surface before and after Polished.

In AFP method, the high viscosity polishing fluid travels through the pipes to achieve the inner surface polishing. With a shorter pipe polishing proved effective, the AFP method is going to be applied on the 3.2m chamber install on realistic facility, and its roughness will be inspected to verify the method's effect.

IN VACUUM BRAZING

The copper pipes are of bad strength and stiffness. Support plates with good strength are needed to be welded on one shorter edge of the rectangular to control displacement and deformation. At the same time, with high precision CNC (Computer Numerical Control) machining, the support plates can regulate the lining of the copper pipes. In the future, installation and alignment of the undulator chamber will also be achieved through support plates. The support plates' material is stainless steel, because of its good rigidity and close linear expansion coefficient to copper.

Considering the welding resulted deformation and some other factors, we are going to use vacuum welding in the hydrogen furnace to weld the side support plates and the two flanges onto the chamber. Vacuum brazing will effectively control nonuniform of thermal deformation and get neat weld joints. The chamber's 3 meter length is a problem for causing probable excessive bending or distortion while heating in furnace. To solve this problem, we will produce a set of tooling to stabilize during welding. There will be Nickel plating on the surface of stainless steel to make easier welding onto copper chamber.

VACUUM TEST

After manufacturing, the undulator chamber will be baked out at SSRF. For no vacuum gauge or probe could be installed inside beam liner, in-tube vacuum degree and residue gas pressure distribution will be deducted by the vacuum degree measured by vacuum gauge at the outlet.

CURRENT PROGRESS

The undulator chamber prototype's copper pipes have completed its stretching. Now the AFP experiment is in progress and experimental welding will begin soon. The undulator chamber prototype is expected to be completed in July.

ACKNOWLEDGEMENTS

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REFERENCES

[1] G. Lanfranco et al., Development Of Ultra-High Quality Surface Finish Undulator Vacuum Chambers for the FERMI@ELETTRA Project, Proceedings of IPAC'10, Kyoto, Japan.

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