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ALUMINUM VACUUM CHAMBER FOR THE SIRIUS COMMISSIONING UNDULATORS

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Abstract

Sirius is a 3 GeV fourth generation light source under commissioning by the Brazilian Synchrotron Light Laboratory (LNLS). Compact Linear Polarizing Undulators (CLPU) with a magnet vertical aperture of 8 mm have been used for the commissioning of some beamlines. Extruded aluminum vacuum chambers, having small vertical aperture of 6 mm and horizontal aperture of 40 mm, were built. This paper details the design and manufacturing processes of a complete chamber and its installation procedure at the storage ring. Challenges regarding the precision machining of the 0.5 mm wall thickness, TIG welding of aluminum, NEG coating of small apertures will also be presented.

INTRODUCTION

Four CHESS compact undulators (CCU) [1] were purchased from Kyma, whose specifications are presented in Table 1. These undulators have been used for the commissioning of the first Sirius beamlines.

Table 1: CCU22 - Technical Specification

NAME		CCU22	Unit
Period Length (λ)		22	mm
Number of periods (Np)		51	
Length (L)		120	cm
GAP (G)		8	mm
Max. Power @500mA		1.65	kW
Max. Field	Horizontal	Vertical	
	0.00	0.7	T

CNPEM designed and manufactured 1.3 meters vacuum chambers for the undulators described in the Table 1, the development process involved dealing with challenges related to the machining, welding, NEG coating and installation.

To achieve the functional requirements (requested dimension, mechanical strength, thermal dissipation, low magnetic permeability and compatibility with vacuum), the chamber was built from a 6063-T6 aluminum extruded profile, with an internal geometry developed exclusively for this application, according to the assembly presented in Fig. 1.

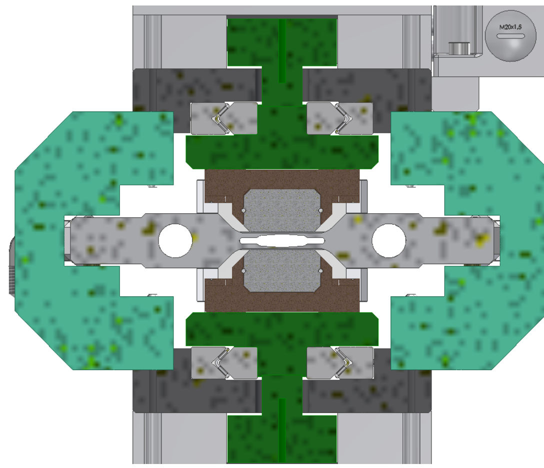

Figure 1: Cross-section of the assembly.

VACUUM CHAMBER DESIGN

Since the CCU theoretical gap is 8 mm and the vertical beam stay clear (BSC), at 0.7 m from the straight section center, is 5.6 mm for high beta sections, the chosen internal chamber aperture is 6 x 40 mm, which required a wall thickness on both sides equal to or smaller than 0.6 mm.

Several FEA analysis were carried out to evaluate the minimum wall thickness tolerable considering two different scenarios, at ambient temperature (25° C) and at NEG coating activation temperature (180° C). The design criteria considered was, for 200 °C (safety factor of 1.1), a Tensile Yield Strength of 45 MPa [2].

Considering a wall thickness of 0.4 mm, the calculated maximum von-Mises stress was 34 MPa , while with a wall thickness of 0.5 mm the calculated results was 30 MPa. However, with a thickness of 0.35 mm the result was close to the design criteria (Fig. 2), for this reason a careful dimensional validation is needed to certify that the obtained thickness after the machining process stays between 0.45 mm and 0.6 mm.

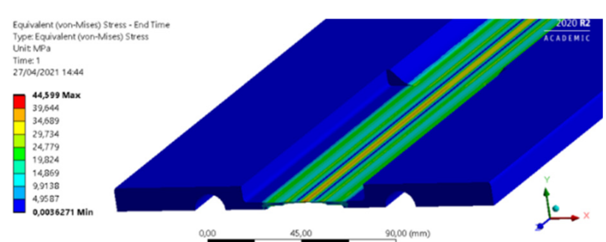

Figure 2: FEA analysis for 0.35 wall thickness at 200°C – max. von-Misses stress equal to 44 MPa.

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VACUUM CHAMBER MANUFACTURING

Vacuum Flange

Two different bimetallic Al 6061-316L stainless steel flanges were used in the planar undulator vacuum chambers. The used flanges were manufactured by two different processes: diffusion bonding – developed in-house (Fig. 3) [3] and explosion welding – supplied by Atlas Technologies. Three chambers used Atlas manufactured flanges and five chambers used CNPEM´s flanges.

Figure 3: In-house diffusion bonded bimetallic flange.

Machining Process

A support device was developed to minimize chambers' deformation during the manufacturing, especially due to the chambers' thin wall thickness. For this reason, the support device was designed to be compatible with all stages of production and was only removed when the chambers were installed in the undulators' C-shaped side shoulders (see Fig. 1). The material selected for the support device was Aluminum 5052-H112 because of its adequate properties, low cost and easy availability.

The machining was done in-house using a high precision CNC milling machine. Figure 4 shows the support device assembled right after the machining of the first side of the chamber, then with the chamber assembled in the support, the opposite side could be machined [4].

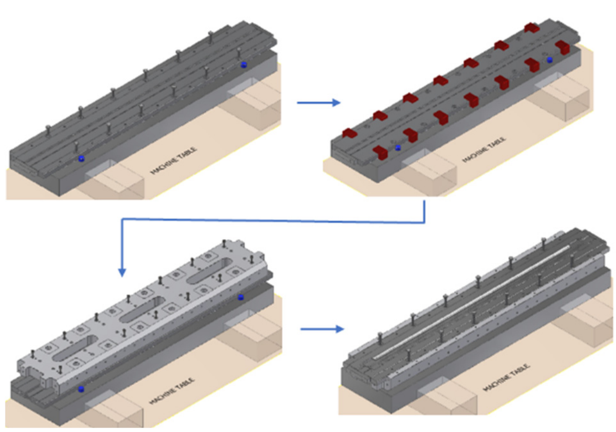

Figure 4: Machining process steps.

Dimensional Validation

After the machining process, a dimensional validation was conducted using two different methods to assure the chamber's quality and accordance with the specification.

Thin Wall Thickness Measurement The machined wall thickness was measured with Magna Mike 8600. To improve the measurement precision, a device was used to keep the perpendicularity of the probe to the chamber's surface (Fig. 5).

Figure 5: Prototype under measurement with the Magna Mike 8600.

Complete Dimensional Since the clearance between the chamber' thin wall and the undulator's poles is just 0.25 mm, a Coordinate Measure Machine (CMM) was used, to verify if the built chambers were in accordance with the specified tolerances and to assure that the assembly with the undulator could be done without mechanical interference (Fig. 6).

Figure 6: CMM measuring process.

Cleaning Process

Before the TIG welding and the NEG coating, a cleaning procedure was necessary. The procedure consisted of a 5 minutes immersion in a water solution of 3% alkaline detergent at ultrasonic bath, rinsing with demineralized water, 10 minutes immersion in a solution of 10% citric acid, rinsing with demineralized water and drying with ionized Nitrogen.

TIG Welding Process

Aluminum alloys are challenging to weld because they are more sensitive to weld contamination and prone to porosity formation.

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The welding was performed manually, using a 4043-aluminum filler metal. Several tests were done to obtain a joint with low porosity, no leak and full penetration [5].

To minimize distortions during the process, some fixtures and an inner guide were used to keep the assembly in the correct position.

Figure 7 shows a metallography analyses for one of the samples with porosity below 1%, the maximum adopted limit.

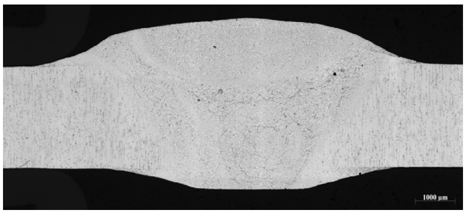

Figure 7: Welded samples metallography analyses.

NEG Coating

Since the chamber has very low conductance and installing pumps along the chamber's length would increase its complexity, to achieve UHV pressure, NEG coating is mandatory. CNPEM has designed and built a NEG coating facility after obtaining a license agreement with CERN to develop and apply NEG coating technology in the Sirius vacuum chambers [6].

NEG coating chambers of small inner dimensions is not an easy task due to difficulties in spreading the plasma along the whole cathode length and keeping the cathodes well-centered. In this way, cathode's centering ceramics were installed at the extremities of the chamber. To keep the cathode stretched, a spring was used at the bottom of the chamber.

The chambers were coated using two intertwisted Ti-Zr-V cathodes of 0.5 mm wire diameter (Fig. 8). The main coating parameters were a linear power density of 15 W/m, a magnetic field of 600 G and a Krypton pressure of 1.10^{-1} mbar.

Figure 8: The two cathodes approximate position.

INSTALLATION

The chambers were assembled in the undulator's C-shaped shoulders before the installation at the straight section of the storage ring.

Inside of a portable cleanroom, the connection between the standard chambers, transitions and the undulator's chamber were made. Once the assembly was completed, the sector was pumped down by using two pumping carts at the undulator's chamber extremities and a careful helium leak check was done to certify a leak tightness equal or better than 2.10^{-10} mbar.l/s.

Later, the bake-out for NEG activation was carried out in the sector, a special thin heater, similar to the heaters used all over the Sirius chambers [7], was used in the undulators' chambers. Figure 9 shows the bake-out process and pressure behavior of two sectors after the undulators installation. All the sectors with the undulator chambers achieved pressure equal to or better than $2\cdot10^{-10}$ mbar after the NEG activation and, after a very short period of beam conditioning, the dynamic pressures are in low 10^{-10} mbar.

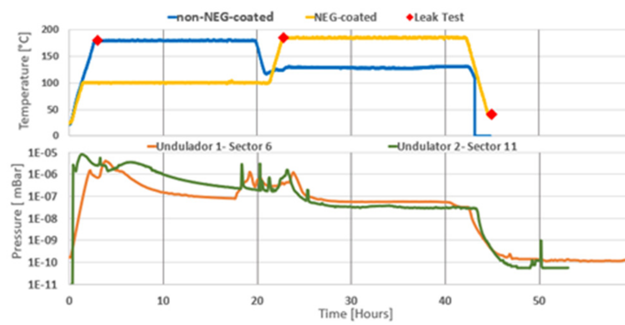

Figure 9:NEG activation and pressures behavior.

Figure 10 shows the undulator installed and ready for operation.

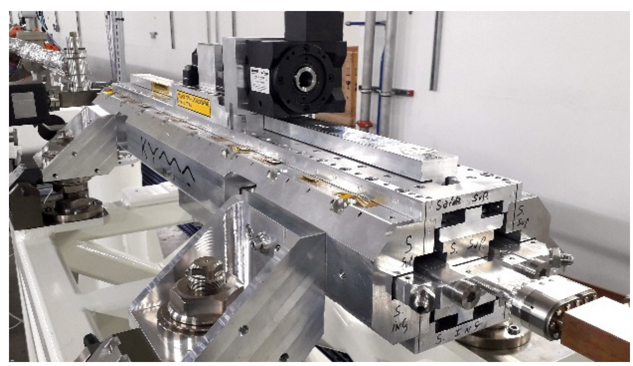

Figure 10: Undulator installed in one of the Sirius sectors.

CONCLUSION

Eight vacuum chambers for CCU undulator were in-house developed and built at CNPEM.

The developed fabrication process allowed manufacturing chambers that achieve the tight specifications of the undulator gap and the beam-stay-clear requirements.

Despite the challenges to NEG coating small gap chambers, a process was developed and showed good results.

Six chambers were installed in the storage ring and have been performing well since then.

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