The final design and manufacturing process for the ESS Monolith Vessel

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Introduction
ESS project

ESS is an ongoing project to build a 5 MW spallation source in Lund (Sweden) with a total budget $\sim 1800\text{Me}$. There is 17 Eu countries that take part in the project. Spain contributes with 3% of the total construction cost.
ESS-BILBAO Consortium

Role and functions

- ESS-Bilbao is public consortium between Spanish Central Government and regional government of Vase Country region.
- ESS-BILBAO has been nominated as Spanish representing entity for ESS operational phase.
- Staff of 50 scientists & engineers.
- The collaboration between ESS-Bilbao and IFN started on 2009. ESS-bilbao Target division is working at IFN facilities in Madrid.
- On December 2014, ESS-Bilbao was chosen as ESS partner for Monolith Vessel.
- KO meeting held on December 2015.
- On February 2017, Critical design review for the Lower and medium vessel.
- Contract for LMV manufacturing awarded on September 2018 to AVS+CADINOX.
- Manufacturing is on going.
Introduction

ESS Monolith Vessel on ESS target station

Monolith Vessel
- Helium compatible
- Vacuum compatible
- 40 year life time
- Safety related equipment
- RCC-MRx, N3Rx
- φ 6 x 12 m
- 75000 kg mass
Introduction

ESS Monolithic Vessel on ESS target station

- Moderator Cup
- Connection Ring
- Vessel Head
- Medium Vessel
- Lower Vessel

Neutron Beam Ports

- Proton Beam
- NNBAR portblock
Critical design review
Critical design review

Design analysis

The design proposed on CDR (July 2017) was optimized according to several load cases (vacuum, 2 bar overpressure, seismic events ...). The CDR was approved on late 2017 but due to administrative reasons the Call for tender was not published until Summer 2018.

Bluckling elastoplastic analysis for a 20 mm predeformed geometry
Critical design review

Design analysis

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Seismic events analysis.
Critical design review

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Seismic events analysis.

![Seismic events analysis diagram]
Critical design review

Manufacturing plan

The propose manufacturing plan considers to build the vessel is a single piece, cutted after the pressure test and ship to Lund in tow sections. This proposal includes significant on site work for bevel preparation and final welding.

Assembling scheme

[Diagram showing assembly scheme with labels for Bottom plate, Central pilar, Support ring, Neutron port extension, Neutron port, Base plate, and Concrete, with dimensions and annotations for phi 5500 ± 8 and coordinates 20, 25, 1, and other details.]
Redesign work
Redesign work

Contract awarded to AVS+CADINOX

On September 2018, the manufacturing contract was awarded to AVS+CADINOX. The new manufacturing team adapted the design to his technical capacities in order to minimize on site work. Its facilities has a limitation in the maximum height of the vertical lathe and thus the vessel was split in two sections flange connected.

CADINOX vertical lathe. Maximum height $\sim 3$ m

Bolted connection + sealing weld on site
Redesign work

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CADINOX vertical lathe. Maximum height $\sim 3$ m
AVS+CADINOX change requested

The thickness of the flanges and lateral walls were increased to withstand the loads produced in the machining process. The connection between both sections relies on bolted flange seal welded on site.

Vessel split in two sections flanged

Surfaces to be machined after welding process
Redesign work

**AVS+CADINOX changes requested**

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Vessel split in two sections flanged
Redesign work

Welding book

The monolith have to be compatible with nuclear design rules ($RCC - MR_x N3R_x$) and vacuum. This limits the welding technologies for TIG (141) which is not feasible for large components. The solution is to combine TIG (141) welding for root passes facing the vacuum and submerge arc for the bulk (121).

WPQR and welding book

<table>
<thead>
<tr>
<th>ESS WPS n°</th>
<th>Tipo de soldadura</th>
<th>Material base</th>
<th>Proceso soldadura</th>
<th>Automatización</th>
<th>Espesores (mm)</th>
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<tbody>
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<td></td>
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<td>BW-chapa</td>
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<td>141 (TIG)</td>
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<td>FW</td>
<td>X2CrNiMo17-12-2 (316L)</td>
<td>141 (TIG)</td>
<td>Manual</td>
<td>T1=6 / T2=25</td>
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<td>BW-chapa</td>
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<td>141 (TIG)</td>
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<td>2,9 (D26,7)</td>
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<td>25 (D450)</td>
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<td>121(SAW)</td>
<td>Semi-automático</td>
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Redesign work

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Manufacturing process
Manufacturing process

Raw material provided by Outokumpu

The raw material is composed by ~ 45 tonnes of plates with thicknesses from 25 to 90 mm and more than 4 tonnes of filled material for TIG and Submerged arc welding processes. The production takes more 20 weeks an the material was delivery in July 2019.

Raw material and filled material (~ 4 tones) delivery

Plates delivery

Dimensional control
Manufacturing process

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Raw material and filled material (~ 4 tones) delivery

Welding consumables

Quality labels (TIG wire)
Manufacturing process

Flanges welding

The flanges are manufactured on six sections that will be TIG welded and machined to compensate the deformations. The welding process and the NDI inspections are completed.

Flange welding completed (70 mm manual TIG (141))

WPS

<table>
<thead>
<tr>
<th>Welding process</th>
<th>Welding position</th>
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</table>

Joint design: [Diagram]

Welding sequence:

- [Diagram]
- [Diagram]

Flanges assembly

Manufal TIG (141) welding
Manufacturing process

**Bottom plate**

The bottom plate is assembled on three sections welded (60 mm thickness). On top of this structure the central supports are welded (filled non continuous welding).

**Bottom plate (100 mm submerged arc (121) + TIG (141))**
Manufacturing process

Bottom plate (100 mm submerged arc (121) + TIG (141))

<table>
<thead>
<tr>
<th>WMAP</th>
<th>WPS</th>
<th>Welding detail according Boiler drawing N053.010.001_SHEET 1-4</th>
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</table>

WS1-WS4 Summerged arc (121)
WS5 TIG semiautomatic (141)

Bottom plate welding completed
Manufacturing process

Bottom plate (100 mm submerged arc (121) + TIG (141))

Support blocks

Spot TIG welding (141)
Manufacturing process

Medium vessel wall

<table>
<thead>
<tr>
<th>WMAP</th>
<th>WPS</th>
<th>Welding detail according Boiler drawing N053.010.002_SHEET 1-2</th>
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</table>

Joint design

Welding sequence

Plates after bending

Bending process
Conclusions
Conclusions

Main remarks

- The design has been adapted to supplier technical capacities.
- Raw material reception was completed in June 2019
- Welding qualification processes were completed on August 2019.
- Manufacturing is ongoing and the component will be delivered in Q1 2020.