Fusion Engineering and Design xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Status of casing manufacturing for JT-60SA toroidal field coils

Paolo Rossi [a,*], Antonio Cucchiaro [a], Gian Mario Polli [a], Mariantonietta Gabriele [b], Massimiliano Tacconelli [b], Valerio Tomarchio [c], Sam Davis [c]

[a] ENEA, Department of Fusion and Technology for Nuclear Safety and Security, Via Enrico Fermi 45, 00044 Frascati, Rome, Italy
[b] Walter Tosto, Via Erasmo Piaggio, 66100 Chieti, Italy
[c] Fusion for Energy, JT-60SA European Home Team, Boltzmannstrasse 2, D-85748 Garching, Germany

HIGHLIGHTS

- A contract between ENEA and Walter Tosto started on July 2012 for the construction of 18 TF coil casings for JT-60SA.
- Detail design, qualification of welding process and manufacturing of mock-ups representative of the casing have been completed.
- Casing manufacturing activities started in 2014 and fourteen casings have been satisfactorily completed within September 2016.
- The completion of the procurement of eighteen casings and two spare ones for a total of twenty casings is foreseen in 2017.

ARTICLE INFO

Article history:
Received 3 October 2016
Received in revised form 20 February 2017
Accepted 7 March 2017
Available online xxx

Keywords:
JT-60SA
Superconducting toroidal magnet
Toroidal field coil
Tokamak

ABSTRACT

In the framework of the Broader Approach program, ENEA is in charge of supplying 20 Toroidal Field (TF) coil casings for the superconducting tokamak JT-60SA being assembled in Naka site, Japan.

ENEA commissioned the company Walter Tosto (Chieti, Italy) to fabricate two sets of 10 casings each to be delivered to ASG Superconductors (Genoa, Italy) and General Electric (Belfort, France), in charge of the following integration of the winding packs into the casings.

The composition of the casing components and the detail design of the interfaces have been finalized under the coordination of Fusion for Energy (F4E) and the agreement of the other parties. Two different sets of mock-ups representative of the components have been realized to validate fabrication methods and special welding processes. The manufacturing activities have been divided in different production steps: composition of the components by cutting, forming and welding and then machining to the final shape.

The first seven casings have been completed during 2015 and are being used for the completion of the TF coils. On the base of manufacturing experience of the first casing components and the completion of the first coils, the production process has been improved and the schedule optimized. This paper reports the status of casing manufacturing.

1. Introduction

In the framework of the Broader Approach program, ENEA commissioned in 2012 the company Walter Tosto (WT) (Chieti, Italy) to fabricate 18 Toroidal Field (TF) coil casings for the superconducting tokamak JT-60SA being assembled in Naka site, Japan [1].

The design of the casing components was finalized under the coordination of Fusion for Energy (F4E) and the definition of the interfaces was agreed with ASG Superconductors (ASG) (Genoa, Italy) and General Electric (GE) (Belfort, France), in charge of the integration of the winding packs into the casings [2,3].

The manufacturing activities were divided in different production steps: composition of the components by cutting, forming, welding and then machining of the components to the final shape. Mock-ups representative of the components were realized to validate fabrication methods and special welding processes. The casing production started in 2014 and the first casings were delivered during 2015. On the basis of the first casing manufacturing experience and after the completion of the first coils, production process was improved and is effectively progressing.

* Corresponding author.
E-mail address: paolo.rossi@enea.it (P. Rossi).

http://dx.doi.org/10.1016/j.fusengdes.2017.03.032
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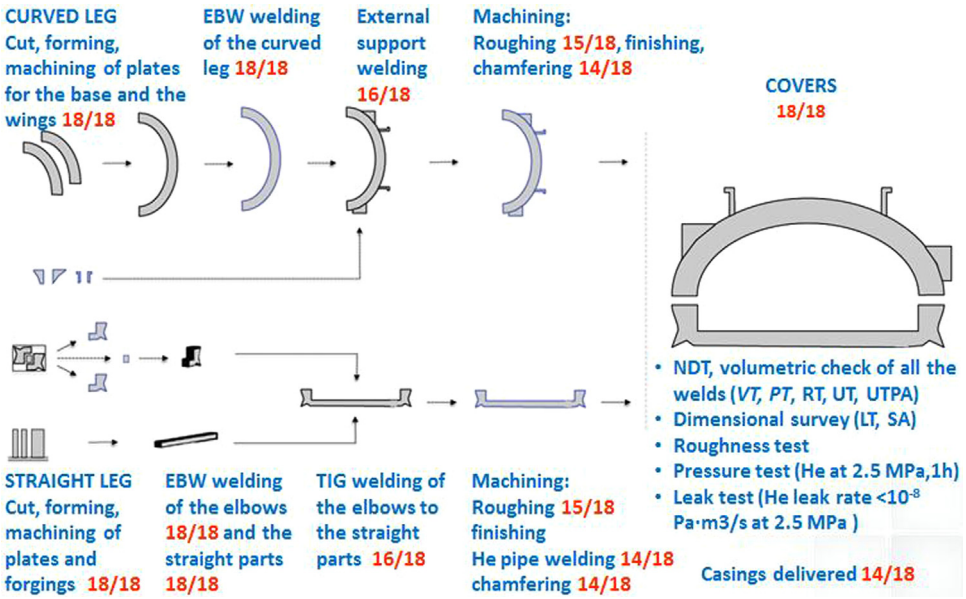

Fig. 1. Main manufacturing steps and status of production.

2. Design and qualification activities

Each TF coil casing [4] is 7.5 m high and 4.5 m wide and consists of two main outboard components, a straight leg and a curved leg and three inboard covers. Other four smaller miscellanea components of the curved leg are procured as loose chamfered plates. Each casing is fabricated by assembling and welding material from rolled plates and from forgings made of FM316LNL, as defined in JSME code [5]. The straight leg is composed of two lateral wings welded to a central core and two elbows welded at the ends. Two cooling pipes are also welded along the internals surfaces of the wings. The curved leg is composed of two lateral wings welded to a central core for a final shape of "D". One vertical port, two supports and one pedestal are welded on the external surface of the curved leg. Casing composition and manufacturing steps are described in [6,7] and in Fig. 1. Design, qualification and manufacturing documentation is complete of 3D CATIA models, drawings, welding books, manufacturing and acceptance procedures and the following test results and certificates.

Detail design was then refined in particular in some interfacing chamfers of the legs and of the covers in order to properly fit the components for the following welding processes performed by ASG and GE. Different types of welding techniques have been qualified for thickness up to 75 mm. Electron Beam (EB) welding was selected for the longest structural welds of the leg wings in order to limit deformations and distortions. Tungsten inert gas (TIG) process was used for the transversal welds of the legs while metal inert gas (MIG) process was left to weld the external pedestals and supports to the curved leg. Vibration stress relief (VSR) technique was validated to reduce stresses after main welding and machining phases. Non-destructive test techniques are used to check 100% of the welds and laser tracker is used for final dimensional checks.

3. Status of manufacturing activities

A complete set of casing components is shown in Fig. 2, where is also visible the milling machine utilized for the final machining phases performed in WT workshop in Chieti.

Manufacturing activities started progressively in 2014 and the first casing was completed and delivered to GE in different stages starting from the straight leg in March 2015, then the curved leg

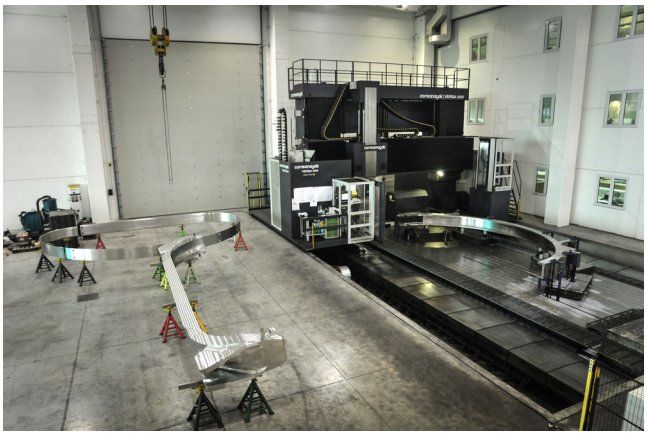

Fig. 2. Casing components in Walter Tosto workshop, Chieti, Italy.

in April and finally the inboard covers in May. The second casing, for ASG, was completed in May 2015 and the covers followed in July 2015. A particular attention was prudentially paid during manufacturing of the first two casings in order to properly recover the deformations and shrinkages induced on the legs after main welding and machining processes. Taking advantage of the extra-material left in the components, the several dimensional checks during machining steps allowed to meet dimensional requirements by repositioning the components during final machining phase.

The gained experience and the acquired confidence improved quality and speeded up the production. The following five casings were then completed within December 2015. The realization of three complete sets of assembling and transportation jigs and then machining of the components on different milling machines permitted to efficiently minimize planning criticality and production queues. In Fig. 3 machining of curved leg external surface in WT workshop in Ortona is shown.

Seven casings were completed during 2015 and the production continued regularly in 2016 with other seven casings realized within the end of September 2016 for a total of fourteen casings, seven delivered to ASG and the other seven to GE. Volumetric checks of all the welds were performed by radiography (RT), ultrasonic testing (UT) and phased array UT (PA UT) based on ASME

Please cite this article in press as: P. Rossi, et al., Status of casing manufacturing for JT-60SA toroidal field coils, Fusion Eng. Des. (2017), http://dx.doi.org/10.1016/j.fusengdes.2017.03.032