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ScienceDirect
Fusion Engineering and Design 82 (2007) 1942–1947
Fusion Engineering and Design
www.elsevier.com/locate/fusengdes

Results from ITER vacuum vessel sector manufacturing development in Europe

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Received 28 July 2006; received in revised form 30 April 2007; accepted 6 May 2007
Available online 2 July 2007

Abstract

This paper describes the results from several R&D tasks carried out in Europe to improve the prospects for manufacturing the ITER vacuum vessel within the required tight tolerances and to the required high quality. The experience from the manufacture of a part of the sector has highlighted several distortion issues, which can be compensated for. A local machining tool demonstrated the possibility of vibration-free machining without lubrication, as required in the ITER clean conditions scenario. Although a project to establish the feasibility of cold 3-D forming of the walls showed it was with the capacity of available equipment, a problem of buckling instability may make this method unusable. An alternative method of sector manufacture, using e-beam welding, and avoiding the use of one-sided welds, is described.

Keywords: ITER; Vacuum vessel; Manufacture; SYSWELD; 3-D forming; E-beam welding

1. Introduction

Since the previous SOFT conference paper [1] describing the manufacturing development work required for the preparation of the ITER vacuum vessel sector procurement, significant R&D results have been achieved and the design further progressed

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0920-3796/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.fusengdes.2007.05.005

[2]. The contract for the manufacture of a full-size, 20 t poloidal part of the inboard section, fabricated according to the ITER reference manufacturing route, and utilising the methodology which will be required by the RCC-MR Code, including bracing fixtures, welding applications, restraint effects, and fit-up aspects is approaching completion. Since the main aim of the work is to establish the practicability of achieving the tight dimensional tolerances, an accompanying SYSWELD analysis programme (see http://www.esi-group.com/SimulationSoftware/Welding_heat_treatment/) has been validation by instrumented welding coupons, and then used for predicting the distortion of the actual construction. A local machining tool has been developed to allow the requirement for machining of the cylindrical features at a late stage of manufacture. Experimental and analytical work has also been carried out to establish the possibility of 3-D cold-forming large sections of walls of the VV. A manufacturing programme to validate an alternative method of fabricating parts of the double-walled VV, utilising e-beam welding only and avoiding the quality issues of the one-sided access and inspection of the closing welds is in an advanced implementation stage. This paper describes the results of the manufacturing development programme and the future activities.

2. The vacuum vessel poloidal sector model (VVPSM)

(1.1) The contract was placed at the start of 2003 with Ansaldo Richerche, using SIMIC for the manufacturing for the VVPSM, as shown in Fig. 1, which consists of a 5 m high, 2.4 m wide part of the inboard upper section, and fabricated according to the 4-segment manufacturing route complete with 40 t bracing fixtures and 50 t of framework, simulating the rest of the VV sector. Due to the world-wide surge in steel price and demand, the procurement of the required 25 t of special ITER-grade stainless steel 316 L(N) from Arcelor delayed the contract for one year to the end of 2006. The difficulty and risk of the VV construction lies in the achievement of the required tolerances, typically 10 mm, and so the main aim of the VVPSM contract is the monitoring of distortion at each step and the development of methods for their prediction. The first stage of the manufacture, the e-beam welding of the cylindrical housings and keys to the inner wall resulted in 6 mm bending of the plates due to geometric effects as in Fig. 2. The 80 mm thick jigs still allow about 2 mm of transverse (left to right in Fig. 2) shrinkage across the butt welds.

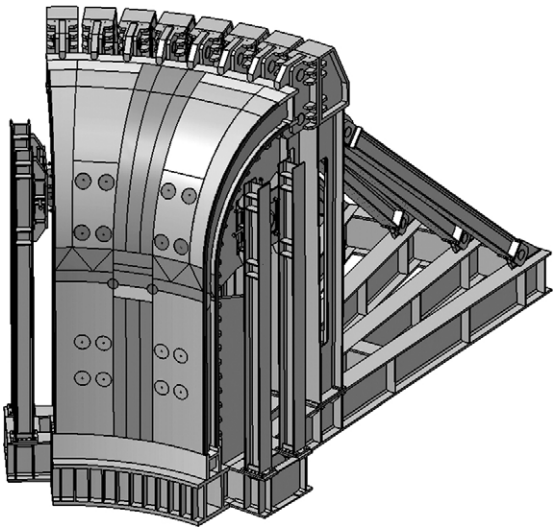

Fig. 1. VVPSM, showing VV part, jigs and frame.

(1.2) Since an important aspect of the contract is to validate the computer modelling activity, an

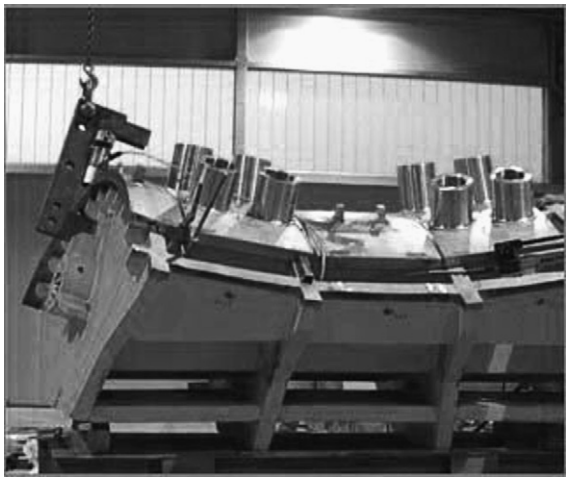

Fig. 2. Inner shell with E-Beam welded housings and key being forced onto the jigs.