THE MATERIALS JOINING EXPERTS
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June 20, 2007

Phil Heitzenroeder
Princeton Plasma Physics Laboratory
P.O. Box 451
Princeton, NJ 08543-0451

EWI Project No. 50782GTH, "Visit Report on Visit to PPPL on June 15, 2007"

Dear Phil:

Enclosed is EWI's report for the above referenced project. One hard copy will follow by mail. Please feel free to contact me at 614-688-5182 if you have any questions or comments regarding this project.

Sincerely,

William C. Mohr

William Mohr
Technology Leader
Structural Integrity

Enclosure

EWI Project No. 50782GTH

Date: June 20, 2007

Submitted to: Princeton Plasma Physics Laboratory

Title: Visit Report on Visit to PPPL on June 15, 2007

Introduction: Princeton Plasma Physics Laboratory is currently winding the modular coils for the National Compact Stellarator Experiment (NCSX). These coils are supported by stainless steel castings. Recently, a design modification was requested to include welds on the inward sections of three types of bolted jointed between these castings. These welds will join the castings to stainless steel shims and join casting to casting across the shims.

EWI was requested to visit PPPL to review the welding plans.

Objectives: Review the welding plans during a visit to PPPL, including general fitness-for-service assessment, along with an assessment of areas of particular concern including weld distortion, and allowable stresses for both static and fatigue conditions.

Approach: EWI Technology Leader Bill Mohr and Business Development Engineer Katie Levesque visited PPPL on June 15, 2007. During that visit several of the modular coil support castings were either assembled or assembly was in progress and a welding trial plate was being cut. The EWI personnel participated in discussions with welders and engineers, including discussions with stress analysts at Oak Ridge National Laboratory.

When the support castings arrived at PPPL, only minor geometrical modifications could be made to these castings at this time. The shims had not yet been fully designed, and the joining method was to bolt the outer and inner flanges of the vessel together. Further review has indicated the need to weld as there is not adequate clearance for the bolt design. One focus of the discussion between PPPL and EWI was the choice of weld and shim design.

EWI supports the choice of an intermittent butt weld design as the primary weld joint design. The intermittent weld design avoids welding across the gaps between individual shim sections which could cause unnecessary stress concentrations.

There were areas where the outer edges of the matching flanges differ from being in the same plane by more than ½ in., such as on several areas of the A-B joint. Several options were proposed and discussed for the design of this joint. The double fillet weld design is preferred in order to allow the welders accessibility to the joint. Peening the weld in between passes can be used to limit the angular distortion. Other options used butt welding of the shim to the shorter flange.

Shim designs were discussed, particularly the shape of the outer edge of the shims. The pocketed design and the smooth outer edge design were both considered as likely to be capable of achieving good integrity joint. The pocketed design will allow a greater area of shim for carrying compressive loads across the joint.

Distortion of the individual castings as a result of welding is expected to be minimal, by limiting heat input and making short intermittent welds. However, angular distortion which would open the gaps between the castings and the shims is considered to be likely if no measures specific to avoiding this distortion are taken. The welds will be on the outside of the flange. The angular

distortion expected from single sided butt welds or fillet welds would be expected to open the weld root, unless measures are taken to avoid this distortion.

Clamping the inward flanges closed during welding and/or using peening for the hot and fill passes was discussed as a way to minimize distortion. Peening was considered not acceptable for the root and cap passes. The discussion indicated that the peening would be the primary in process correction method, with clamping provided by the normal bolting arrangement, without placing additional bolts or clamps.

A portion of the design assessment not yet complete is the assessment of the weld area for fatigue life. EWI recommends a stress range – life assessment (S-N) be performed to determine whether the weld design was sufficiently resistant to fatigue from the design number of pulse cycles. This assessment should consider that the design curves for welded joints in this stainless steel under operating conditions be the same as for carbon steel at room temperature. This is appropriate because the high cycle fatigue resistance of welds is dominated by the elastic behavior of the surrounding metal, which has elastic properties very similar to those of carbon steel at room temperature.

A preliminary estimate based on the limited stress information given in the meeting and AWS D1.1 indicates that the weld shear stresses should be sufficiently low to allow the weld to survive to its design life of more than 500,000 cycles.

PPPL plans two types of welding trials before fabrication of complete welds for the NCSX. One will be a plate welding test to examine the effects of the design of the outer edge of the shim and welding procedure on the ease of welding and acceptability of the distortion. The second will be a full-scale welding trial using castings of the A and B designs with the full compliment of shims. This trial will be fully welded and examined. Then the weld will be removed, so the castings can be wound with their coils and prepared for final bolting and welding. EWI supported the plan for these two types of welding trials.

It may be found valuable to test the fatigue crack growth resistance of the weld metal. This data can be used in defining more accurately the allowable initial flaw size for the welds. Initial estimates can be made based on existing standard guide methods.

Conclusions and Recommendations: The information provided in this meeting indicates that it is appropriate to go forward with welding plans for the inboard sides of the modular coil supports using intermittent welds.

EWI supports the plan for two types of welding trials, one on plate and one on full castings.

EWI will provide a scope of work for a fatigue assessment of the welds.

For more information contact: William Mohr at 614-688-5182.