

DESIGN IMPROVEMENT OF WELD DESIGN OF RIP MOTOR CASING TO RPV NOZZLE

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1. Introduction

The reactor internal recirculation pump used in the ABWR design is a glandless wet-motor type pump and is evolved from the pump used in the ABB-A BWRs. On the basis of the proven design viewpoint, the pump nozzle of the ABWR RPV to which the reactor internal pump (RIP) is attached, is designed as a sleeve-type nozzle as in the ABB-A BWRs. Several improvements have been made over the ABB-A original nozzle design such as elimination of the weld between the RPV and nozzle stub (by integral forging) and modification of the weld design (optimization of weld-end preparation configuration suitable to automatic machine welding and use of insert ring for quality welding). Extensive experimental and analytical studies have been performed in Japan with the RIP and the pump nozzle to confirm the adequacy of the ABWR RIP and the nozzle design.

However, in view of the importance of the weld in the ABWR, reevaluation was performed to examine if there is room for further improvement in the soundness of the weld joint. The results of the study point out that the ABWR RIP nozzle design can be improved in the following areas:

- (a) Although the resolution of the shot of the weld joint taken by radiographic test (RT) through the casing and stub tube satisfies the Japanese code requirement, the resolution is inferior to usual RT examination because the RT must be taken through double walls (through casing wall and stub tube).
- (b) Confirmation of the integrity of the back surface of the RIP weld is difficult.

Consequently, engineers from TEPCO, Toshiba and Hitachi worked together to improve the inspectability of the weld joint. The modified design resolves the above difficulties and does not lose the benefit of the experience obtained from the ABB-A BWRs and from various testings in Japan. The design modification was reviewed by a special committee under the Japanese government and this improved design has been used in the first ABWRs (Kashiwazaki-Kariwa Units #6 and #7). This paper describes the modified nozzle design in detail, the stress evaluation of the nozzle, and the compatibility with the RIP.

2. Modified Nozzle Design

In the course of the re-design, it was stressed that the modified design should not lose the experience obtained from the current RIP. Therefore, minimum design changes from the original ABWR RIP nozzle were required so that all the major characteristics of the RIP nozzle are retained after modification.

At the initial stage, mockup tests verified that unevenness of about 0.5 mm at the back of the weld of RPV nozzle to RIP motor casing can be identified by RT in the initial ABWR nozzle design. In these tests, a radioactive source was placed inside the nozzle and films were placed outside the nozzle. However, at the same time, it turned out that the soundness of back of the weld cannot be fully justified by RT. Therefore, in addition to the single-wall RT capability, it was decided to modify the initial ABWR RIP nozzle design so that both sides of the weld can be inspected directly. Consequently, it became possible that both sides of the weld could be machined as well. It was not so easy to have these capabilities within the modification constraints mentioned above. The modified design was achieved by development of special inspection tools for working in narrow spaces and of a trepanning tool to make the narrow annulus gap.

The major features of the modification are as follows:

- (1) Make a minimum space at the back of the weld to install a small CCD camera, RT film, temporary nozzles for the liquid penetrant test, and special tools to machine the back of the weld.
- (2) Make an opening (access window) at the outer projection of the nozzle to install the equipment and tools mentioned in (1) above.
- (3) Make the minimum nozzle configuration adjustment for structural strength and inspectability.

The modified design is compared with the initial design in Fig. 1. The actual changes are:

- a. Increase gap between nozzle inner surface and motor casing outer surface from 0.5 mm to 18 mm.
- b. Increase nozzle stub diameter from 420 mm to 445 mm.
- c. Lower weld joint location by approx. 150 mm.
- d. Add special opening with removable cover at nozzle skirt.
- e. Surface finish back of weld.

The 18 mm space in item a. above is set by the space needed to install a high-resolution CCD camera to observe the surface of the back of the weld and this space is used effectively in machining and other inspections. Item b. is needed to keep the stress of the nozzle at the same level as that of the nozzle before the modification (gap expansion). Item c. is provided to keep the weld joint location away from the stress concentration area and to cover the area needed for ultrasonic testing (UT) from the outer surface (back of weld) using the gap. Item d. is needed to install the machining and inspection tools at the back of the weld. Item e. was provided to improve the reliability of the weld by machining out possible flaws related to the first-layer-welding. Machining to a smooth surface also enables UT of the weld from the outside casing.

3. Stress Evaluation

To confirm the structural adequacy of the design modification, extensive 3D FEM

stress analysis was performed. The 3D FEM model used are shown in Fig. 2. The stress intensities at various nozzle locations resulting from primary and secondary stresses are well below $3S_m$ and confirm the structural strength of the modified nozzle.

4. Compatibility with Reactor Internal Pump

The modification was pursued with the constraint of avoiding degradation of the pump function of the RIP. The only significant impact of the modification on the RIP is the change of the impeller-diffusor clearance during high-temperature operation due to the temperature field change of the nozzle.

The temperature fields of the nozzle, before and after the modification, at hot reactor operation were evaluated by 3D FEM models and the deformation of the nozzle was evaluated in detail. In the modified design, the wider gap between the RPV and motor casing reduces heat transfer from the RPV to motor casing, so the temperature of the casing neck is lowered. Since asymmetric heat transfer from the RPV due to the asymmetric RPV bottom configuration at the nozzle is reduced, the axial symmetry of the temperature field at the casing neck is improved. Therefore, the relative displacement of the impeller and diffusor due to thermal deformation is decreased and the modification suppresses changes in the impeller-diffusor clearance during various reactor operating conditions.

The impacts of the modification on other pump characteristics such as the head-flow relationship and vibration were evaluated and there is negligible impact on the pump.

The RIP test facilities of Japanese BWR manufacturers have already been modified according to the modification described here and the preliminary test results justify the modification.

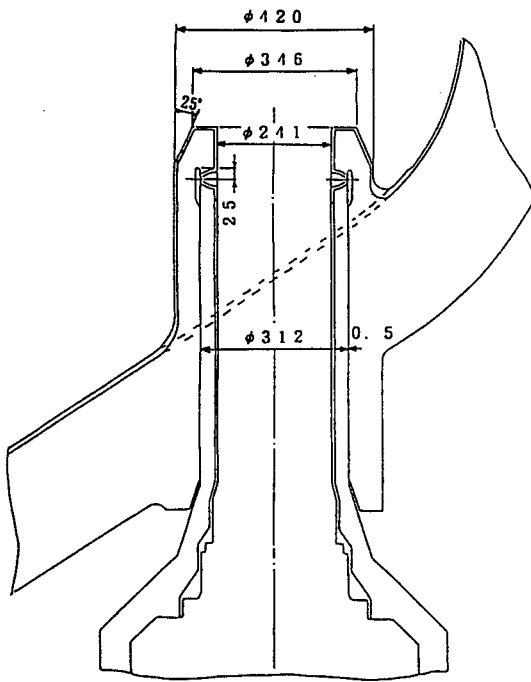
5. Conclusions

On the basis of the proven RIP nozzle design of the ABWR RPV, a modified nozzle design was proposed to further improve: a) inspectability of the weld between the RPV and the RIP motor casing, and b) soundness confirmation capability of the back of the weld. The improvement was accomplished by expanding the gap between the RPV and the pump casing to install a small CCD camera, RT film, temporary nozzle for the liquid penetrant test, and special tools to machine the back of the weld.

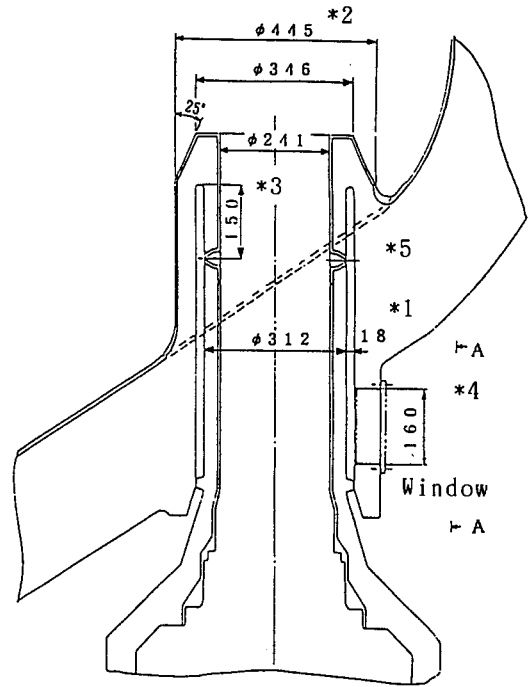
The modified nozzle design has been confirmed to be adequate both in structural strength and pump function.

The modification also enables inspection of the weld between the RPV nozzle and RIP motor casing by external UT without removing the RIP motor.

The modification described in this paper has been applied to the first commercial ABWRs (Kashiwazaki-Kariwa Units 6 & 7).

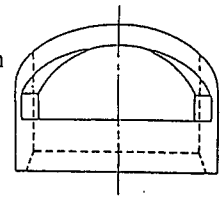


(a) Initial Design



(b) Improved Design

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| <p>a. Increase of gap *1</p> <p>b. Increase of nozzle stub diameter *2</p> <p>c. Lowering of the weld joint *3</p> <p>d. Addition of an access window *4</p> <p>e. Surface finishing of back side of weld joint *5</p> |
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View A-A

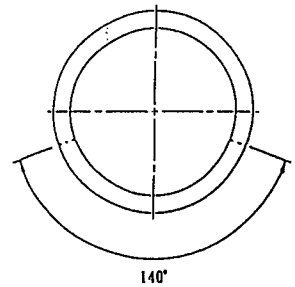


Fig. 1 Comparison of ABWR RIP Nozzle Design, Initial Design vs. Improved Design

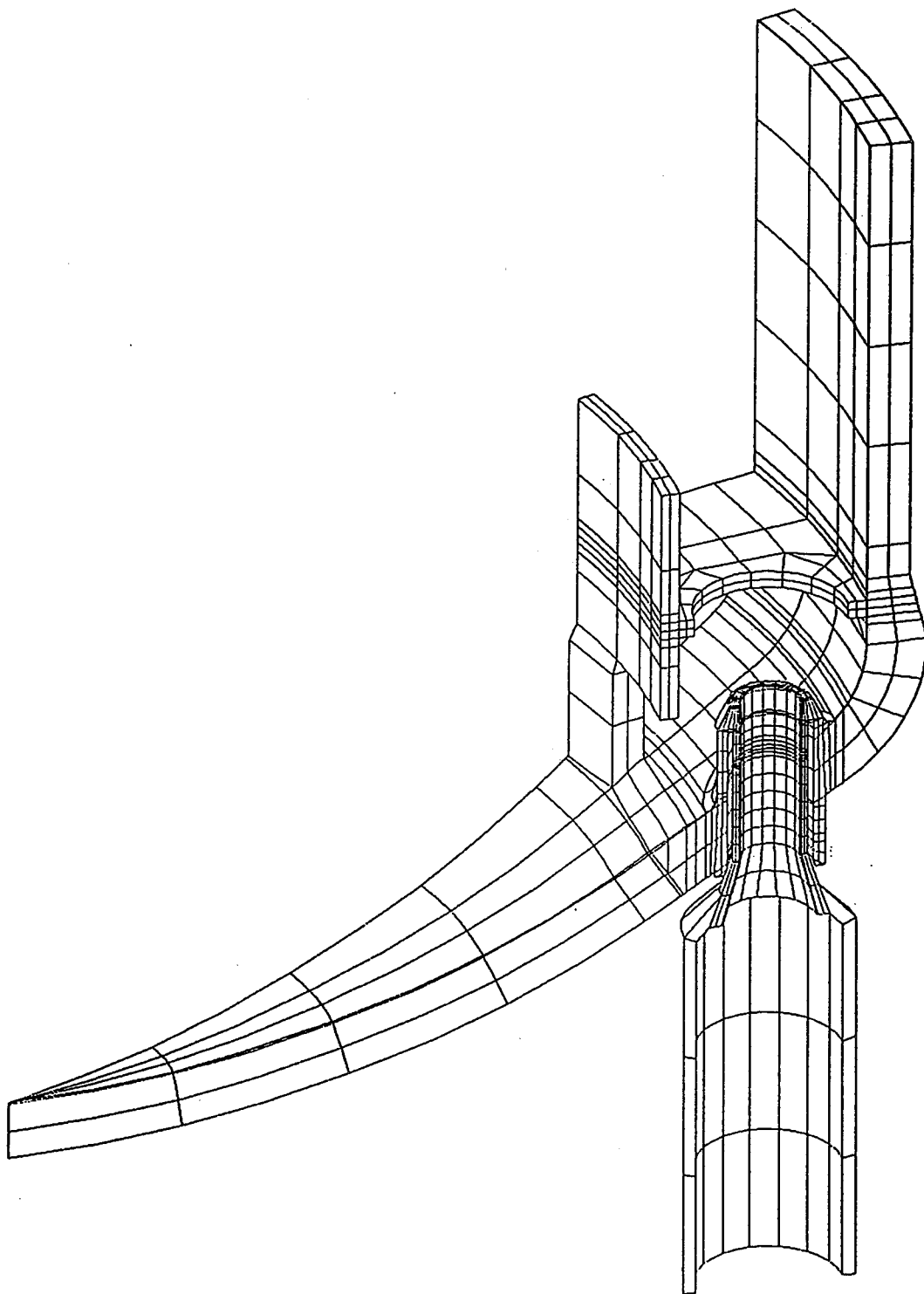


Fig. 2 3D Finite Element Analysis Model

