Design improvement for partial penetration welds of Pressurizer heater sleeves to head junctures

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1. Introduction

ASME Code, Section III allows partial penetration welds for openings for instrumentation on which there are substantially no piping reactions and requires to have interference fit or limited diametral clearance between nozzles and vessel penetrations for the partial penetration welds. Pressurizer heater sleeves are nonaxisymmetrically attached on the hill-side of bottom head by partial penetration welds.
The excessive stresses in the partial penetration weld regions of the heater sleeves are induced by pressure and thermal transient loads and also by the deformation due to manual welding process.
The purpose of this study is 1) to improve design for the partial penetration welds between heater sleeves to head junctures, 2) to demonstrate the structural integrity according to the requirements of ASME Code, Section III and 3) to improve welding procedure considering the proposed design.

2. Methods and Results

Three (3) dimensional thermal and structural analysis have been performed to determine the range of primary plus secondary stress intensity (P+Q) due to pressure and thermal transient loads during Service level A and B conditions and to calculate associated cumulative fatigue usage factor (U) for the specified life time, 60 years. These evaluations have been performed in accordance with ASME Code Section III using the ANSYS computer program based on the geometries of heater sleeves to bottom head junctures.
Primary stress evaluations due to pressure loads for design, service level C and service D conditions are not performed because stress intensities resulting from pressure induced strains may be treated as secondary stress in partial penetration weld construction according to NB-3337.3 (b) .

2.1 Original Design

3-dimensional analysis for the outmost heater sleeves which have sharp weld roots as shown in Figure 1 has been performed. Figure 2 presents 3-dimensional FEM Model of the original design. P+Q exceeded allowable value of 3 Sm and P+Q without thermal bending stress also did not meet the requirement of the simplified elastic-plastic analysis of NB-3228.5 due to dominant thermal membrane stress and nonaxisymmetric welded shape. So, the original design is required to improve design for the partial penetration welds.

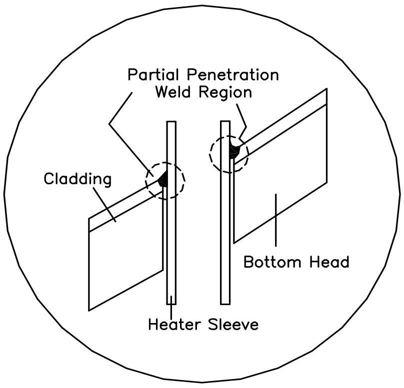

Figure 1 Configuration of the Original Design

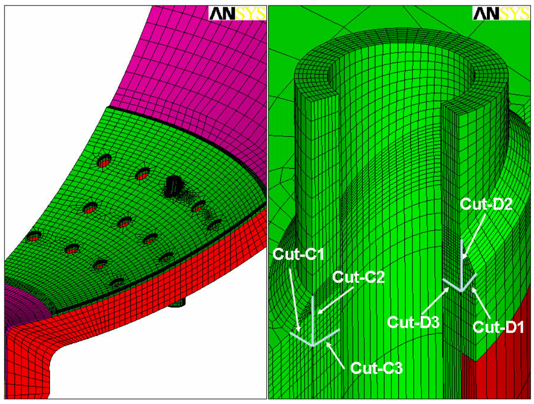

Figure 2 FEM Model of the Original Design

Table 1 Analysis results of the original design

Service Condition	Category	Loc.	Calcu.	Allow.
Service Level A & B	P + Q	Cut-D3 (Inside)	616 MPa	482 MPa
	U	Cut-C3 (Outside)	0.4762	1.0

2.2 Proposed Design

3-dimensional thermal and structural analysis has been performed using the proposed configuration and geometry as shown on Figure 3. The proposed design has a protrusion of a ring type by build-up and also axisymmetric weld roots. Figure 4 presents 3-dimnsional FEM Model of the proposed design.
Although maximum P+Q exceeded allowable value of 3 Sm of Table 2, P+Q without thermal bending satisfied the requirement of NB-3228.5 for the simplified elastic-plastic analysis.

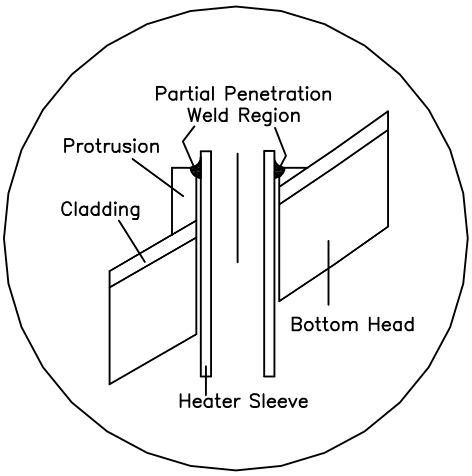

Figure 3 Configuration of the Proposed Design

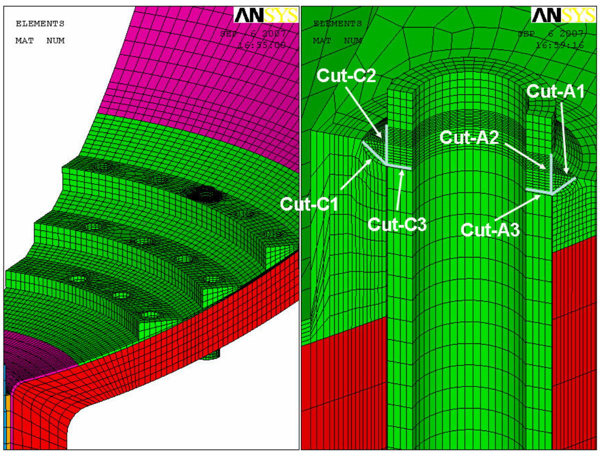

Figure 4 FEM Model of Proposed Design

Table 2 Analysis results of the proposed design

Service Condition	Category	Loc.	Calcu.	Allow.
Service Level A & B	P +Q	Cut-C3 (Inside)	542 MPa	482 MPa
	U	Cut-A2 (Outside)	0.2398	1.0

3. Conclusion

3-dimensional thermal and structural analysis for partial penetration welds for heater sleeves to bottom head junctures has been performed.
As a result, the proposed design of partial penetration welds with a protrusion of a ring type instead of the original design welded at hill-side of bottom head gives better results in terms of the structural integrity. And also the thermal deformation of heater sleeves after welding can be reduced and the automatic welding procedure can also be applicable because partial penetration weld regions have an axisymmetric shape and lie on same plane if the proposed design is accepted.
Additionally, the improved design of partial penetration welds may be available for new nuclear power plant in future.

REFERENCES

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