Stress Categories and Evaluation for Component Supports under Thermal Effects

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1. Introduction

The Integrated Head Assembly (IHA) is classified as a support structure and evaluated by the ASME NF [1] code. During plant operating conditions, the IHA is affected by the thermal expansion and heat transfer from the Reactor Vessel (RV). These thermal effects cause thermal loads or stresses on the IHA. However, the ASME NF [1] code states, the evaluation of thermal stress in the support structure are not required for the subsection of this code. This statement may lead to confusion and ambiguity for the structural analysis and evaluation for the IHA under thermal effects. This paper presents the stress categories and the evaluation for support structures under thermal effects.

2. Methods and Results

2.1 Review of ASME NF Code

The statements of evaluation in ASME NF related to thermal effects are summarized as below:

1) According to NF-3111, the loading conditions shall be taken into in designing a support structure including the thermal loads, effects from the piping thermal expansion and anchor and support movement effects etc.
2) Paragraph NF-3112.1 provides requirements that the specified design temperature shall be established, and the metal temperature shall be determined by computation using the accepted heat transfer procedures or by accurate measurement from equipment in service under plant and system equivalent operating conditions.
3) Paragraph NF-3121.2 states that a thermal stress is not classified as a primary stress, but stresses induced in the support structure by the restraint of free end displacements of piping are considered as a primary stress.
4) According to NF-3121.11, the evaluation of thermal stresses in the support structure is not required.
5) Primary membrane stress, primary membrane plus and primary bending stress by the specified mechanical loads excepting all secondary stresses are evaluated only by NF-3221.1 and NF-3221.2.
6) For Service Levels A and B, primary plus secondary stresses shall be limited to a range of 2Sy or Su at specific temperature; whichever is less in Table NF-3522(b)-1.

To recapitulate the above, it is confirmed that the evaluation of supports for thermal stresses is not required according to Subsection NF though, as thermal effects, it requires the thermal expansions and the support movements. So expansion stresses [3] caused by the restraint of free end displacements (i.e. RV thermal expansion) in supports are classified as a primary stress.

Since the supports are generally designed not to subject thermal stresses except stresses due to the restraint of free end displacements of the IHA and the thermal expansion of the RV, it seems that Subsection NF requires no thermal stress evaluation. But in case supports are designed to experience thermal stresses, the thermal stresses should be included. Basically, because thermal stresses are self-limiting stress and are classified as a secondary stress in accordance with the ASME NB [2], we categorize the thermal stresses as a secondary stress for supports. As a secondary stress, Table NF-3522(b)-1 is used for stress limits.

2.2 IHA Thermal Effects

Thermal effects on the IHA are listed as below:

1) RV Expansion (Thermal Expansion of RV Head)
2) Friction (between Bottom Ring Flange and Head Pad/Lift Lug)
3) Heat Transfer (Temperatures of RV Head and CEDM Cooling Air)

In accordance with NF-3112.1, the analysis of temperature distribution on the IHA shall be done to obtain material strength at specific temperature from ASME Section II, materials. By using the material strength, stresses of components are evaluated.

The stresses caused by the RV thermal expansion and friction of the IHA are considered as a primary stress. This is the reason that stresses induced in the support by the restraint of free end displacements and expansion stress of piping in the support are treated as a primary stress according to NF-3111(e) and NF-3121.2. Moreover, excepting the primary stress developed by the thermal expansion and friction of the IHA, thermal stresses of the IHA are produced by the non-uniform temperature distribution, and the relative expansions between IHA components. Although Subsection NF states evaluation of thermal stress is not required, it is included in stress evaluation as stated in Section 2.1. Stress categorization due to thermal effects for each service condition is summarized in Table 1.

Table.1 Stress Categorization due to Thermal Effects

Loadings	Thermal Effects		Service Conditions
	Primary Stress	Secondary Stress	
RV Expansion	O	×	A,B,D
Friction	O	×	A,B,D
Heat Transfer	×	O	A,B

With the mechanical loads, the stresses produced by thermal effects are combined for the Service Levels A through D conditions. The primary stresses of RV expansion and friction are added to the mechanical loads for all service conditions. However, the secondary stress due to the thermal effects is only contained in the Service Levels A and B conditions.

For evaluating Service Levels A and B, we separate load combinations depending on inclusion of thermal stresses as a secondary stress. When the thermal stresses are included, allowable stress limits for primary plus secondary stress in the Notes (4) and (5) of Table NF-3522(b)-1 and NF-3523(b)-1, are used.

2.3 Thermal Analysis of IHA

The IHA is installed on the RV head pad with bolts. The lower part of the IHA consists of the lower cooling shroud shell, and its bottom is welded to the bottom ring flange. There are oversized holes for the bolts in the bottom ring flange to allow the radial expansion of the RV. The heat and expansion from the RV are transferred through the head pad, and the bottom ring flange. Since the bottom ring flange is rested on the head pads, and has an oversized hole, the friction happens on between the two component surfaces. As stated Section 2.2, the thermal expansion and friction from the RV impose the primary loads on the IHA, and heat from the RV applies the secondary stresses. Furthermore, the thermal expansion of the head pad is partially acted on the IHA for the vertical direction without reference to the effect of oversized hole. Thus, the stress induced by the vertical thermal expansion is applied as a primary stress. The heat transfer from the RV to the IHA is applied with the types of conduction, and convection. The film coefficients are calculated and applied to the surface of the IHA in case of convection.

For thermal analysis, two convection cases are considered depending on cooling air temperatures. The temperature distribution provides information on the metal temperature in order to decide material strength at specific temperature. The temperature profiles of the IHA are depicted in Fig.1.

The thermal-structural analysis is performed using the input of the temperature distribution as shown in Fig.1. As stated earlier, the thermal expansion of the RV is simulated with the modeling of the RV as beam elements, and the friction force on the head pad surface is applied as an external load. When the thermal stress is only developed on the IHA, the RV model and the friction condition are removed from the analysis. The stresses resulting from the thermal-structural analysis are combined with the following methods presented in Table 1 for each service condition.

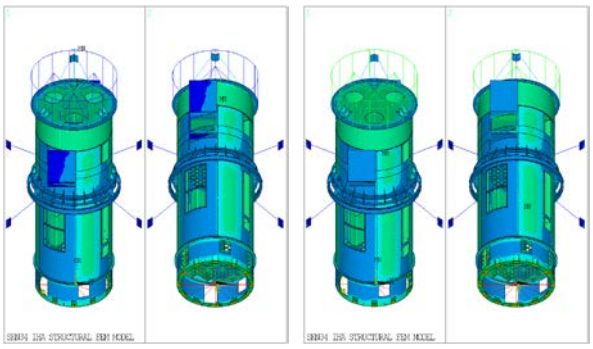

Fig.1 IHA Temperature Profiles (Hot & Cold Case)

3. Conclusions

We present stress categories and evaluation methods for supports ruled by the ASME NF code when the supports are loaded by the thermal effects. The ASME NF code related to the thermal effects is reviewed so that classification of stresses caused by thermal effects is presented. Regarding to this, stresses developed by the restraint of free end displacements of components are categorized into primary according to the code, and it is suggested stresses on supports by the heat from the RV head and cooling air are treated as a secondary stress. When the thermal stresses are evaluated for supports, it is proposed the requirements in Table NF-3522(b)-1 for Service Levels A and B be used for allowable stress criteria. As an application for the IHA under thermal effects, stresses due to the RV thermal expansion and friction are treated as a primary stress, and thermal stresses are included in a secondary stress. Simply stated, this paper provides the effective ways by separating thermal effects, which cause primary or secondary stresses. This method is useful when combined stresses in a service condition are close to allowable limits, and we can reduce the conservatism in a thermal analysis.

REFERENCES

[1] ASME Boiler and Pressure Vessel Code, Section Ⅲ, Subsection NF, Supports, 1995 Edition with 1995, 1996 and 1997 Addenda.
[2] ASME Boiler and Pressure Vessel Code, Section Ⅲ, Subsection NB, Class 1 Components, 1995 Edition with 1995, 1996 and 1997 Addenda.
[3] Uma S. Bandyopadhyay, Companion Guide to the ASME Boiler & Pressure Vessel Code, Third Edition, Chapter 10-Subsection NF-Supports.