Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Preliminary Reactor Head Bolt Design of Prototype Sodium-cooled Fast Reactor

In-Su Han [a*], Gyeong-Hoi Koo [a]
[a] *Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseomg-gu, Daejeon, The republic of Korea*
[*] *Corresponding author: his0805@kaeri.re.kr*

1. Introduction

The reactor head of Prototype sodium-cooled fast reactor (SFR) supports main components including In-Vessel Transfer Machine (IVTM), rotating plug (RP), upper internal structure (UIS), intermediate heat exchanger (IHX), decay heat exchanger (DHX), primary pump and internal structures. As structural requirements, the reactor head is designed to withstand all of the pressure, temperatures and forces which are likely to be imposed on it. The bolts that fasten the head to the vessel flange. Design of the reactor head bolts so as to withstand the loads applied should be designed. Currently, preliminary design of the PGSFR reactor bolts is progressed. So far, we have designed and evaluated example. The number and cross-sectional areas of bolts were determined using the procedure given in ASME BPVC Section Ⅲ, Division 1, Appendix E. And the allowable design stress in the bolt material should be used for ASME Section Ⅱ, PART D(METRIC), Table 4. The purpose of this study is to conduct design the number and cross-sectional area of bolts attaching the PGSFR reactor head to the reactor vessel, using the ASME procedure.

2. Methods and Results

2.1 ASME Code Requirement of Bolt design [1]

H = total hydrostatic end force
G = Diameter at location of gasket load reaction. G is defined as follows (Table E-1210-2): when $b_o \leq$ 1/4 in(6mm), G is the mean diameter of gasket contact face; when $b_o \geq$ 1/4 in(6mm), G is the outside diameter of gasket contact face less2b
P = Design pressure
b = effective gasket or joint contact surface seating width (Table E-1210-2)
b_o = basic gasket seating width (Table E-1210-2)
C_b= effective width factor
= 0.5 for U.S Customary calculations
= 2.5 for SI calculation
m = gasket factor obtained from Table E-1210-1
y = minimum design seating stress (Table E-1210-1)

According to the code, the bolt loads used in calculating the cross-sectional area of the bolts are based on two design load, W_{m1} and W_{m2}. W_{m1} is required to be sufficient to resist the hydrostatic end cap force H which is the total force exerted by the design pressure P acting on the area bounded by the diameter of gasket reaction plus an additional gasket reaction plus an additional gasket compression force H_P, which experience has shown to be sufficient to ensure a tight joint. This compression load is expressed as a multiple m of the internal pressure. Its value is a function of the gasket material and construction. The design bolt load for the design pressure W_{m1} is determined in accordance with eq. (1).

$$W_{m1} = H + H_P = 0.758G^2P + (2b \times 3.14\ GmP) \qquad (1)$$

W_{m2} is the minimum initial load needed to seat the gasket initially at ambient conditions without any internal pressure. It is dependent on the gasket material and effective gasket seating area. Where y is the minimum design seating stress. The values of m and y are tabulated in appendix E for a number of gasket material and design.

$$W_{m2} = 3.14bGy \qquad (2)$$

The minimum bolt root cross-sectional area A_m required for both the design pressure and gasket seating is the greater of the values for A_{m1} and A_{m2}, where $A_{m1} = W_{m1}/S_a$ and $A_{m2} = W_{m2}/S_b$. Where S_a is the allowable bolt stress at ambient condition and S_b is the allowable bolt stress at design temperature. Both allowable stresses can be obtained from Table 4 of Section Ⅱ PART D. The ASME code requires that the number(n_b) and diameter of the bolts should be selected such that the total bolt root cross-sectional area $n_bA_b \geq A_m$.

$$A_m = \max\left\{ \begin{matrix} A_{m1} \\ A_{m2} \end{matrix} \right. = \max\left\{ \begin{matrix} W_{m1}/S_a \\ W_{m2}/S_b \end{matrix} \right.$$

2.2 Preliminary bolt design for PGSFR

Consider a figure 1 consisting of a reactor head section and a reactor vessel section each of radial width W and extending circumferentially through a distance equal to the bolt spacing. We assume that the full bolt load is transferred from the reaction head side to the reactor vessel side by the contact area in the gasket only.

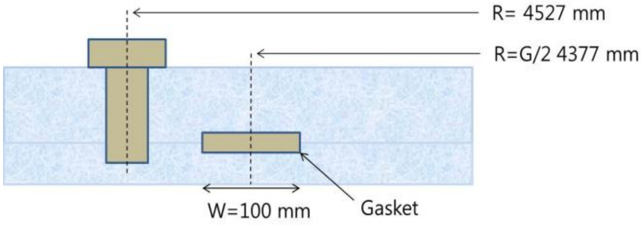

Figure1. Reactor head to vessel connection simple model

The properties of bolt material are as follows:

Gasket Type = Spiral-wound Metallic Gasket
Bolt Material = Alloy 718
Assumed Design Pressure = 10 Bar(1 MPa) [2]
Allowable bolt stress at RT, S_b= 345 MPa[3]
Allowable bolt stress at 150℃, S_a= 323 MPa

According to ASME code, Table E 1210-2, the basic gasket seating width b_0 is given by

$$b_0 = W/2 = 50 \text{ mm} \tag{3}$$

Calculations using eqs. 1-3 showed that W_{m1}=63.07 MN, W_{m2}= 33.53MN and the minimum bolt root diameter cross-sectional area needed is 1.95×10^5 mm^2. A plot of the minimum number of bolts needed vs. bolt root diameter required to provide the cross-sectional area is shown in Fig. 2.

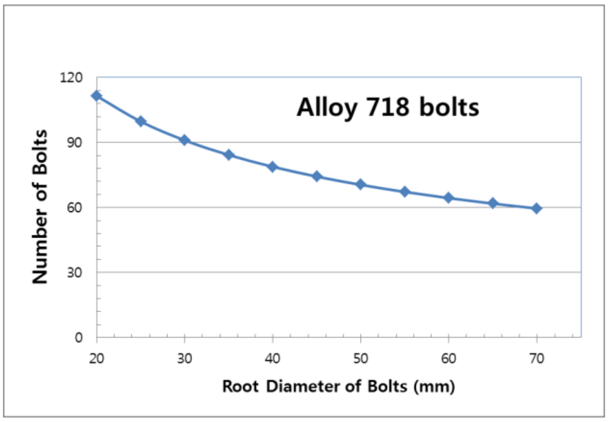

Figure 2. Number of Alloy 718 bolt vs. bolt root diameter as determined by the ASME Code procedure.

3. Conclusions

In this paper, preliminary bolt design for PGSFR was carried out according to the ASME procedure. Detailed calculations were carried out for bolt root diameter = 80 mm and number of bolts N_b = 45. It should be noted that the seating pressure recommended in the ASME code is only a suggested value, not mandatory appendix E. It does not guarantee a leak-tight joint. So these quantities are needed to carry out fatigue analysis of the bolts and to assure leak tightness of the joint during operation. For the future work, the fatigue and seismic analysis will be performed.

REFERENCES

[1] ASME Boiler and Pressure Vessel Code, Section Ⅲ, Division 1, Appendix E, ASME 2013
[2] G.H. Koo, "Study on Analysis Method for Preliminary Conceptual Design of SFR Reactor Structures" KAERI/TR-4524/2011, page 21-24, 2016
[3] ASME Boiler and Pressure Vessel Code, Ⅱ, PART D(METRIC), ASME 2013