Parametric Study for Fix Bolts of a Research Reactor

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1. Introduction

An outlet plenum assembly of a research reactor is bolted into an embedment plate. The outlet plenum shall not slip on the embedment plate by external forces. Bolt preload can be applied to the bolt body to clamp two plates and create friction locks between members against slipping. A parametric study is conducted to investigate the effects of friction coefficient of plates, external forces, and bolt size in bolt quantity. The austenitic steel SA 193 Grade B8M Class 1 (AISI Type 316) is selected for the fix bolts.

2. Methods and Results

2.1 Description

The research reactor is supported on the embedment plate as shown in Fig. 1. The outlet plenum assembly is bolted into an embedment plate using fix bolts. The fix bolts are subjected not only vertical forces but also horizontal force due to seismic loads. To withstand such strong external forces, a certain amount of fix bolts is needed in design.

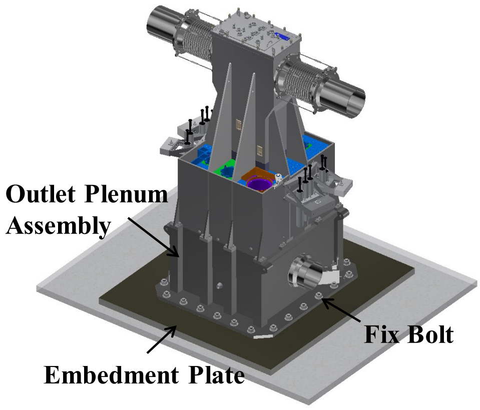

Fig. 1. Research reactor

2.2 Determination of Minimum Preload

The bolt preload is produced when the bolt is stretched twisting the nut or bolt head. Since the members(plates) are fastened by the preload, the clamping force produces tension in the bolt and induces compression in the members. To define the minimum preload, a load factor related to the fastener stiffness(k_b) and member stiffness(k_m) has to be calculated as follows[1][2]:

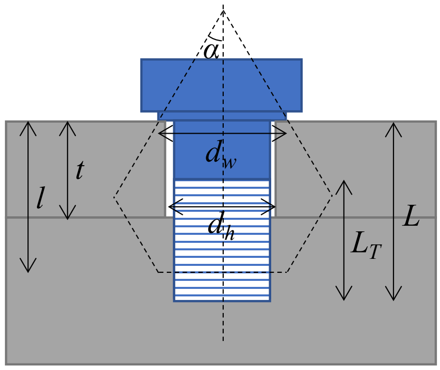

Fig. 2. Fastener and members

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d}$$

$$k_m = \frac{-\pi E d_h \tan\alpha}{2 ln \frac{(l\tan\alpha + d_w - d_h)(d_w + d_h)}{(l\tan\alpha + d_w + d_h)(d_w - d_h)}}$$

$$Load\ factor(\varphi) = \frac{k_b}{k_b + k_m}$$

A_d = area of the bolt (unthreaded portion)
A_t = area of the bolt (threaded portion)
$l_d = L - L_T$
$L_T = \begin{cases} 2d + 6mm, L \leq 125mm, d \leq 48mm \\ 2d + 12mm, 125 < L < 200mm \\ 2d + 25mm, L > 200mm \end{cases}$
$l_t = l - l_d$
E = elastic modulus
α = cone angle
l = grip length
d_w = bearing surface outside diameter
d_h = hole diameter of the clamped parts

According to VDI[2], the minimum assembly preload (F_{Mmin}) can be calculated by the following equation:

$$F_{Mmin} = F_{Kerf} + (1-\varphi)F_{Amax} + F_Z + \Delta F'_{Vth}$$

F_{Kerf} is the clamp load required for sealing, friction grip, and prevention of one-sided opening at the interface of members. The residual camp load(F_{KR}) shown in Fig. 3 has to be higher or equal to F_{Kerf}. By ignoring the loss of preload(F_Z) and change in the preload($\Delta F'_{Vth}$) as a result of different coefficients of thermal expansion of the bolt and the members, the equation is simplified as:

$$F_{Mmin} = \frac{F_{Qmax}}{q_F\, \mu_{Tmin}} + (1-\varphi)F_{Amax}$$

q_F is a number of force-transmitting(F_Q) inner interfaces which are involved in possible slipping/shearing of the bolt, and μ_T is the coefficient of friction at the interface. It should be noted that it is assumed there is no eccentric camping, eccentric loading, and torque-transmitting.

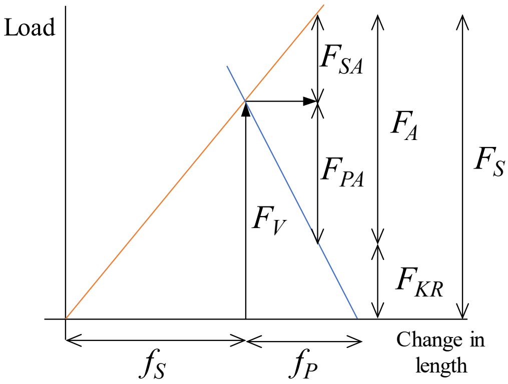

Fig. 3. Joint diagram[2]

F_V = preload
F_{SA} = axial additional bolt load
F_{PA} = additional member load
F_A = working load
F_{KR} = residual camp load
F_S = bolt load
f_S = elongation of the bolt
f_P = liner deformation of the clamped parts

2.3 Parametric Study: Effect of Friction Coefficient of Plates, External Forces, and Bolt Size

Three parameters such as friction coefficient of plates, external forces, and bolt size are selected to optimize the quantity of the bolts. The material for the plates is stainless steel, and austenitic steel SA 193 Grade B8M Class 1 (AISI Type 316) is selected for the fix bolts. Three friction coefficients (i.e., 0.2, 0.25, and 0.41) are chosen according to the ASME Code[3] and the STRANGHÖNER's study[4].

Table I: Effective slip coefficient[3]

Surface Condition	Slip Coefficient
Clean mill scale	0.25
Grit-blasted carbon and low alloy high strength steel	0.41
Grit-blasted heat treated steel	0.25
Hot dip galvanized wire, brushed, scored, or blasted	0.31
Blast cleaned, zinc rich paint	0.31
Blast cleaned, zinc silicate paint	0.45

To obtain an equivalent static load (external force) of a structure, a factor of 1.5 is applied to the peak acceleration of the floor response spectrum. The factor of 1.5, however, is very conservative. Then, a factor of 1.0 is also considered because adequate justification can be provided after conducting spectrum analysis in the future. The additional size of the M52 bolt is selected in the study.

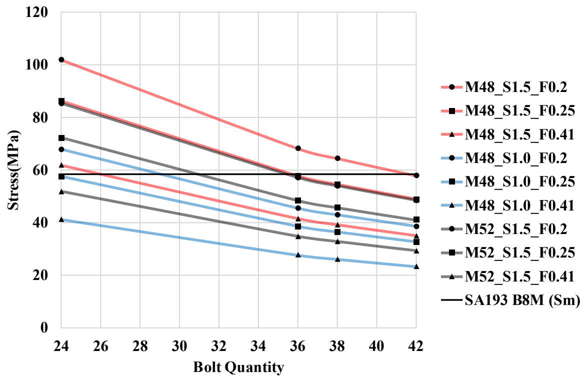

Fig. 4. Analysis results

Figure 4 shows primary membrane stress intensities due to design mechanical loads under the black line satisfy the minimum limit according to the KEPIC MNG 3232.1[5].

3. Conclusions

In this study, it is found that the most effective parameter to reduce the quantity of bolts is to use higher the friction coefficient of plates. The second most effective factor is to use a factor of 1.0 for the equivalent static load, and the third is to increase the size of bolts.

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