Tightening Evaluation of New 400A Size Metal Gasket

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Abstract: In this study, tightening evaluation of new 400A size metal gasket is investigated. The sequence of tightening of bolt load is divided into two tightening procedure. The leak measurement result is used to compare both tightening procedures effect by using the relationship between helium leak and the clamping loads of the flange. A three-dimensional FEM (Finite Element Method) model was performed to present effect of the contact stress on both tightening procedures. From the result, the contact stress was increased by increasing the clamping load. The uniform curve line shape of contact stress on both tightening procedures is different due to the rigidity flange creates the gasket wave during tightening. It can be conclude that in order to reduce the amount of helium leak, it considered to operate the tightening procedure that produce high contact stress uniformly.
Key words: Tightening; 400A size metal gasket; Contact stress; leakage

1 Introduction

The gasket alternative research challenge comes from the decision to ban the use asbestos in the Japan from the beginning of 2008. One of gasket alternative for asbestos substitution is metal gasket. Metal gasket is selected due to several advantages such as its high heat and chemical resistance, capability to withstand pressure, recyclability, and most importantly its reliability in critical situations. However, there is another important requirement for metal gasket which is reducing clamping load. Based on this requirement, the corrugated metal gasket, with a small contact area, is preferred to obtain a low loading metal gasket. Saeed, et.all[1]proposed a new 25A size metal gasket that uses corrugated shape. The gasket has metal spring effect and produces high local contact stress to create sealing line with flanges. The result confirmed that the contact stress and contact width were an important design parameter to optimize the 25A size metal gasket performance. However the value of contact width as design parameter is not defined yet. Haruyama S. et.all[2]continues the Saeed research. The limits size of contact width as 25A size metal gasket design parameter was investigated. In this study, two-measurement combination are using to identify gasket leakage; by helium leak test and water pressure test. The quantitative evaluation of helium leak rate and the contact width of the gasket which has no leak by the water pressure test had been carried out. In the next study, Choiron, et.all[3]developed the contact width validation by using simulation analysis and the result is compared to experimental using pressure sensitive paper. In the fact, the flange material is inhomogeneous due to the discrete nature of bolt holes. In the previous study, the number of bolts for 25A size metal gasket is only four; therefore, the reduction of flange stiffness is minor. The 25A size metal gasket model used is two-dimensional axisysmmetry and the flange rotation is not considered. However, when dealing with larger flange sizes, the difference in stiffness becomes considerable and in those cases, a similar procedure that found in ASME code Section VIII should be followed[4]. In the case of solid metal gasket, Fukuoka T.[5]presented a three-dimensional FEM for estimating the scatter in bolt preloads and achieving the uniform bolt preloads when tightening each bolt one by one in an arbitrary order.

In this study, new 400A size metal gasket was investigated. The leak measurement result is used to compare the two tightening procedures that provide better result. A three-dimensional model was performed to present effect of rigidity flange on occurrence of gasket wave. This effect of rigidity is caused by flange rotation due to the bolt. The ASME code attempted to correct this problem by adding a rigidity constraint `J` based on the fixed rotation. This may not be adequate, as the rotation of the flange is not a unique value. Flange rotation causes variable compression across the gasket from the inner radius to the outer radius. Due to this case is different gasket, it requires investigation for new 400A metal gasket size.

2 Material and Method

2.1 Test material

The 400A size metal gasket used in this study was circumference beads gasket as illustrated in

Figure 1 When the gasket is tightened to the flange, each bead of both surfaces of gasket created elastic effect and produced high local contact stress for preventing leakage. This circumstance made the range of conventional clamping load could be possible to use. The gasket material was SUS304 due to its effectiveness in high-temperature and high-pressure environment. In order to ensure the properties of the material, SUS304 was initially validated using tensile test carried out based on JISZ2241[6]. Figure 2 shows the gasket and the flange appearance. Based on JIS B 2404, the flange with dimensions; thickness = 28.1 mm and radius = 560 mm with 10K pressure was used.

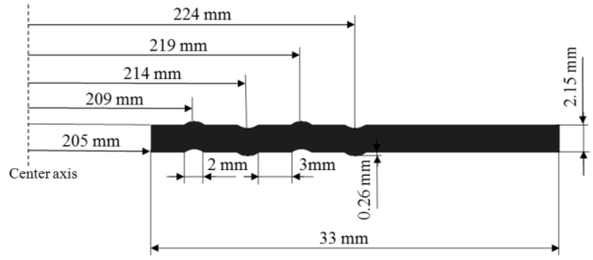


Figure 1 The Gasket Cross Section and Design Parameters

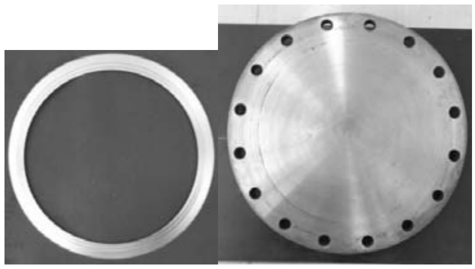


Figure 2 The Gasket and the Flange Appearance

2.2 Leak measurement

In this study, the gasket performance was evaluated by using helium leak measurement. Figure 3 shows the schematic diagram of a helium leak measurement system. The helium leak measurement method was selected and utilized based on JISZ2330[7]and JISZ2331 standard[8]. The minimum helium leak rate which could be detected by this instrument examination was 1.0×10^{-11} Pa.m^3/s, and the maximum was approximately 1.0×10^{-03} Pa.m^3/s. The bolts embedded with a strain gauge were used to measure the clamping load directly. Each bolt was monitored in order to adjust the appointed clamping load with an allowable load error of 3%. The number of bolts in a 400-size gasket is 16. The bolt size is M24 with SCM material. The variation of the clamping load was 22.1, 33.1, 44.2, and 55.2 kN for each bolt. To obtain a stable result, the helium leak rate was measured when the leak flow rate was 300-500 s.

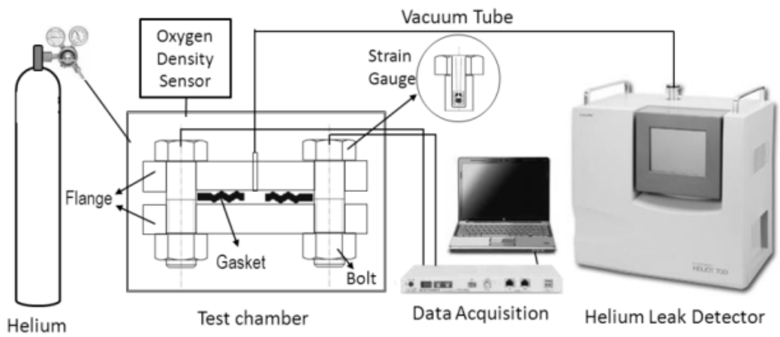


Figure 3 Schematic Diagram of Helium Leak Measurement System

2.3 Tightening procedure

The sequence of tightening of bolt load is shown in the Figure 4. The procedure of tightening of bolt load is divided into two experiments based on tightening procedure.

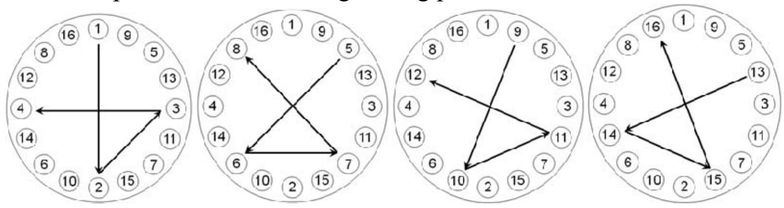


Figure 4 The Sequence of Tightening of Bolt Load

In the first experiment, tightening procedure as follows:

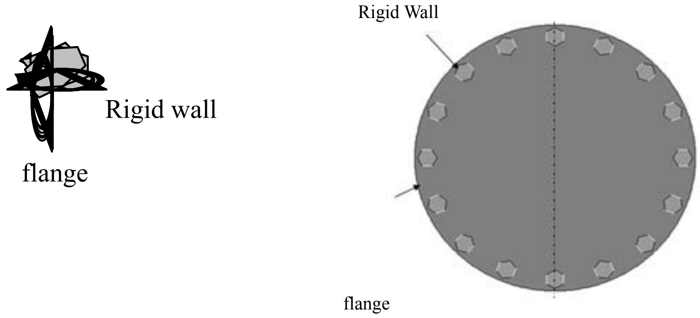
1. Tightening sequence of the bolt started from bolt number 1, then number 2, 3 and 4 with variation of load was 22.1 kN.
2. After condition number 1 was done, with same procedure, bolt number 5, then number 6, 7 and 8 was tightened by using 22.1 kN.
3. After condition number 2 was done, with same procedure, bolt number 9, then number 10, 11 and 12 was tightened by using 22.1 kN.
4. After condition number 3 was done, with same procedure, bolt number 13, then number 14, 15 and 16 was tightened by using 22.1 kN.
5. Procedure no. 1 until 4 is repeated consecutively by using 33.1, 44.2, and 55.2 kN load.

In the second experiment, tightening procedure as follows:

1. Tightening sequence of the bolt started from bolt number 1, then number 2, 3 and 4 with variation of load was 22.1, 33.1, 44.2, and 55.2 kN.
2. After condition number 1 was done, with same procedure, bolt number 5, then number 6, 7 and 8 was tightened by using 22.1, 33.1, 44.2, and 55.2 kN. The value of bolt load no. 1 – 4 will be changed due to effect of tightening other bolts cause change of position of bolt on flange.
3. After condition number 2 was done, with same procedure, bolt number 9, then number 10, 11 and 12 was tightened by using 22.1, 33.1, 44.2, and 55.2 kN.
4. After condition number 3 was done, with same procedure, bolt number 13, then number 14, 15 and 16 was tightened by using 22.1, 33.1, 44.2, and 55.2 kN.

2.4 FEM model

A three dimensional FE models has been developed to adopt compression displacement in axial direction osssn gasket between the top and the bottom of the flange. The model was undertaken using finite element method analysis software MSC. Marc[9]. The flange assumed as rigid body in both sides. From tensile test result, the nominal stress (σ) of SUS304 was 398.83 [MPa], the modulus of the elasticity (E) was 210 [GPa] and the tangent modulus was 1900.53 [MPa]. Two FEM models are developed to simulate the tightening procedures. The quarter model is built to simulate the first tightening procedure (Figure 5a). The full model is used to simulate the second tightening procedure as shown in the Figure 5b. The quarter model uses 131520 elements for gasket and 11040 for each flange. And the full model uses 264060 elements for gasket and 44160 for each flange.



(a) (b)

Figure 5 Schematic of: (a) the Quarter Model and (b) Full Model

3 Results and Discussion

The leak measurement result of the 400A size metal gasket is shown in Figure 6. It is indicated from the figure that the helium leak rate decreased with increasing of clamping load.

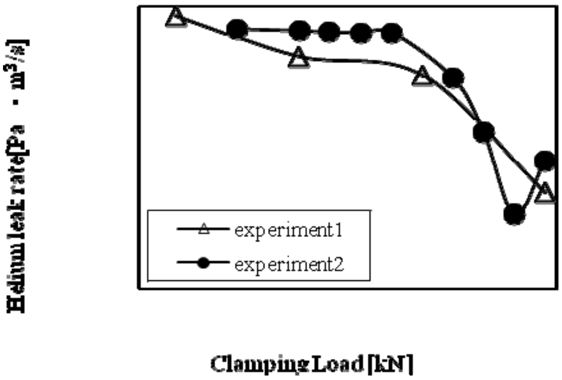


Figure 6 Leak Measurement Result for 400A-size Metal Gasket

In the first experiment produced the decreasing of trend line of helium leak and clamping load in through of curve. It was done by tightening 16 bolt from 22.1 [kN], 33.1 [kN], 44.2 [kN], 55.2 [kN], and 66.3 [kN] load sequentially. In the second experiment, the amount of helium leak tends to linear on the number of tightened bolts is 12 bolts. Then, the helium leak rate decreased significantly after tightening was continued to 16 bolts. Table 1 and 2 show the results of the first procedure and the second procedure of tightening bolt load respectively.

Helium leak test and FEM analysis result is connected. The helium leak rate revealed by the effect of contact stress. Figure 7 shows contact stress distribution along circumference of gasket on each convex section is produced by the quarter model for first tightening procedure. The first experiment produced the helium leak rate decreased significantly on through of curve. It is clarified from the uniform curve line of contact stress in the quarter model result. Contact stress on convex section number 2 and 3 is higher than convex section number 1 and 4. Contact stress on convex section number 1 is smaller due to near inside diameter. The 400A size metal gasket size uses a same gasket shape with 25A size metal gasket size. Knowing the comparatively contact width pattern on the 25A-size metal gasket, it can describe different of contact stress paterns. In the previous study[3], convex section number 2 and 3 produce higher contact width. With the same bolt load operated on higher contact width, higher contact stress is occured.

Figure 8 shows contact stress distribution along circumference of gasket on each convex section is produced by the full model for simulate the second tightening procedure. The contact stress curve tend to high wave line on the number of tightened bolts is 12 bolts. Then, the uniform curve line of contact stress is produced after tightening was continued to 16 bolts. It denote that the uniform contact stress is occurred after tightening bolt was continued to 16 bolts. In advance, it shows that contact stress curve is variated as wave function line. This phenomenon can describe the condition of curve trend of helium leak result in the second experiment. Based on the fact, in order to reduce the amount of helium leak, it considered the tightening procedure that produce high contact stress uniformity. Higher stress condition is better for joint strength due to the fact that 'the higher the stress the better the joint is'[10]. It can be state that the distribution of contact stress has a more dominant effect on gasket performance. Tightening procedures is recommended to control flange stress variation and should be considered as an important parameter to make the joint assembly[11]. By using a three-dimensional FEM approach it can be estimate occurrence of gasket wave and achieving the uniform clamping load when tightening each bolt one by one in an arbitrary order.

4 Conclusions

In this study, the leak measurement result is used to determine the two tightening procedures that provide the best result. A three-dimensional model was performed to present effect of rigidity flange on occurrence of gasket wave. The quarter model built to simulate the first tightening procedure and the full model for the second tightening procedure. The helium leak rate revealed by the effect of contact stress. It can be conclude that in order to reduce the amount of helium leak, it considered to operate the tightening procedure that produce high contact stress uniformily.

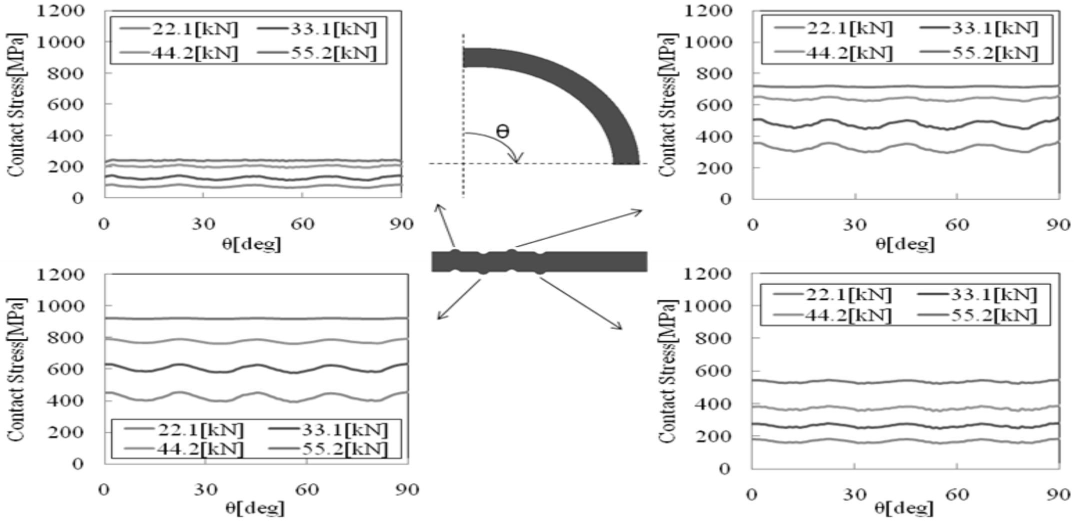


Figure 7 Contact Stress Distribution along Circumference of Gasket on the First Tightening Procedure Model

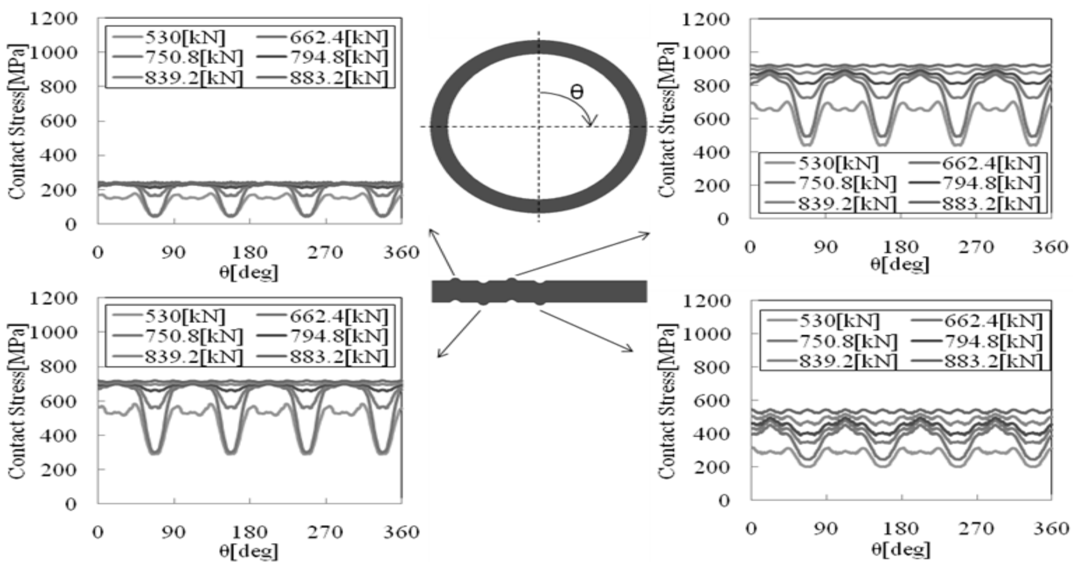


Figure 8 Contact Stress Distribution along Circumference of Gasket on the Second Tightening Procedure Model

Acknowledgements

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