Applied Mechanics and Materials Vols. 799-800 (2015) pp 765-769 *Submitted: 2015-06-22*
© (2015) Trans Tech Publications, Switzerland *Accepted: 2015-07-09*
doi:10.4028/www.scientific.net/AMM.799-800.765

Contact Stress and Contact Width Analysis of Corrugated Metal Gasket

Didik Nurhadiyanto[1, a], Shigeyuki Haruyama[2, b], Ken Kaminishi[2, c], I Made Gatot Karohika[3, d] and dan Mujiyono[1, e]

[1]Mechanical Engineering Education, Yogyakarta State University, Indonesia

[2]Management of Technology, Yamaguchi University, 2-16-1 Tokiwadai, Ube-shi, Yamaguchi, Japan

[3]Doctoral student at Department of Mechanical Engineering, Yamaguchi University, Japan

[a]abbazzahro@yahoo.com, [b]haruyama@yamaguchi-u.ac.jp, [c]kaminisi@yamaguchi-u.ac.jp, [d]md_gatot@yahoo.co.id, [e]mujiyonouny@yahoo.com

Keywords: Contact Stress; Contact Width; Metal Gasket; Corrugated; Simulation; Experiment.

Abstract. Previous studies on corrugated metal gaskets have established that the contact width, contact stress, and surface roughness are important design parameters for optimizing gasket performance. However, the contact stress and contact width considering the surface roughness when the leakage occur did not defined yet. In this study, we determined the real contact stress and contact width when leakage started on 25A-size metal gasket. The contact width determined through a comparison between simulation and experimental results. The contact stress determined through a simulation analysis. The experiment involves a helium leakage test using new metal gaskets having different surface roughness levels. The result justified that the real contact width and average contact stress when the leakage started occur were 0.195mm and 800MPa, respectively. There is a good agreement for contact width both by simulation and experiment result. The contact width for flange having surface roughness 1.5μm is longest than the others.

Introduction

Asbestos—containing sealing material, and as a sealing material which is excellent in preventing superior leak prevention of piping, it has been used in many industries, is extremely dangerous chemicals asbestos, and it is causing serious illnesses problems. Therefore, in Japan, the production of asbestos and its usage was banned from 2008 [1]. For the development of alternative sealing material containing asbestos sealing material is a very important social issues.

Studies have been made on the optimal shape given to the leakage characteristics by many researchers. Using corrugated metal gasket, the researcher studied to reducing the clamping loads for solid metal gasket and the loss of tightness of bolted flange due to the relaxation of the joint. Saeed et al. [2] proposed super seal gasket (SSG), a new 25A size metal gasket that incorporates strategically placed circumferential annular lips. These lips, owing to the spring effect of the metal, form seal line with flanges. When the flange is tightened by bolts, it can be generated high local contact stress on a convex portion of the gasket to obtain a low loading metal gasket. Also, the elastic regions on the flat sections produce the spring effect of metal gasket, and it can reduce the effect of the occurring of loosening of bolts. In addition, from the experimental and theoretical analysis of the finite element method, Haruyama et al. revealed the relationship between the clamping load and the contact width for the allowable limit of the contact width for water leakage does not occur [3]. Choiron et al. [4] revealed that the gasket contact width is important as a design parameter of the experiment using pressure sensitive paper and a theoretical analysis by the finite element method focused on the stress distribution of the elastic-plastic contact region. The result of the present study shows that the contact width can be employed to evaluate the sealing performance. In designing the SUS304, 25A metal gasket, the conditions of contact stress has been clarified using numerical analysis, especially the area/boundary of plasticity and elasticity. In addition, leakage performance and clamping load relationship also has been clarified through leakage test by Nurhadiyanto et al. [5]. While the influence of surface roughness in leakage is big, process design for obtaining the optimal shape has become clear when factors that affect the leakage performance of 25A-size metal gasket has been clarified. From the examination of each conditions of contact stress using numerical analysis which has been mentioned above it is clear that flange surface roughness give effect to the contact area and contact stress, Haruyama et al. [6]. Haruyama et al. [7] studied the real measurement result of contact width, area when surface roughness is considered and local contact stress have been examined through numerical analysis and the distribution of contact stress has been clarified. Then, the gap between result of contact area measurement through surface observation and the result of numerical analysis is proved to be small.

Result of previous research that leakage determined by contact stress and contact width. However, the contact stress and contact width when the leakage started for contact considering surface roughness was not defined yet. In this light, this study aims to determine the real contact stress and contact width when leakage started on 25A-size metal gasket. The contact width determined through a comparison between simulation and experimental results. The contact stress determined through a simulation analysis. The experiment involves a helium leakage test using new metal gaskets having different surface roughness levels.

Material and Method

The gasket used in this research is circumference beads gasket. The shape of gasket is produced by mold press. When a gasket is tightened to the flange, each bead of both surfaces created elastic effect and produce high local contact stress to prevent leakage. The dimension of gasket used is standard dimension based on JISB2404 [8] with 1.45 mm of gasket thickness. The gasket material was SUS304 due to its effectiveness in high-temperature and high-pressure environment. The material is SUS304 which has characteristics the nominal stress of SUS304 was 398.83MPa, the tangent modulus was 1900.53MPa and the modulus of the elasticity (E) was 210GPa.

The general-purposed flange based on JISB2220 [9] with 10 K pressure and 25A diameter used in this test. The lower flange and the joint were welded carefully to avoid a distortion, the information of this gasket completely. Types of flange based on the average surface roughness, are 1.5µm, 2.5µm, and 3.5µm. The new 25A-size metal gasket with corrugated shape was used in this test. In this research, gasket and three levels of flange surface roughness were investigated. The types of gasket, based on plastic design, is 400-MPa mode. The information of this gasket completely in [6].

Simulation method used to obtained the contact stress and contact width correlation with axial force. We foccused the contact stress and contact width when leakage started on 25A-size metal gasket. Beside that the experimental method to obtained the contact width when the axial force 120 KN. The experimental method as validation for simulation method.

Simulation Analysis

A virtual gasket model with various designs generated through four basic steps as described in Figure 1. Forming and tightening analysis were conducted to obtain the contact stress and contact width. First, 2-D parameter models of the flange and the gasket were built using Solid work software. To connect the drawing data obtained from Solid work (IGES file) and the automatic meshing performed using Hypermesh, a batch command file was developed, using which an NAS file generated. We used a quadrilateral mesh for the gasket and flange material because it has a rectangular section. The procedure file was configured to perform the pre-processing and run the model on MARC. The graphic user interface (GUI) does not appear; instead, the program runs commands in the background. After the FEM analysis completed, the output file, including the analysis results can be generated in TXT file that can be converted to a Microsoft Excel file. The output result contains the contact status, contact width, and contact stress force at each time at every peak position. The calculation of the contact width versus the axial force at peak position 1 —4 are performed using a multi-step MACRO command.

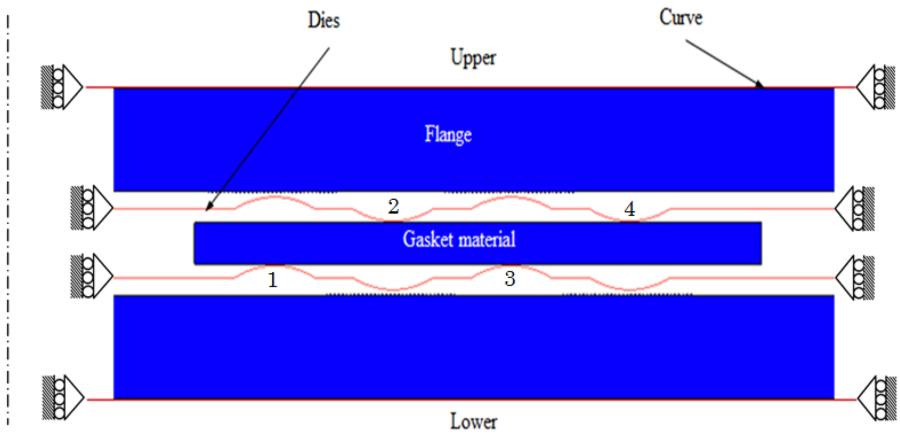


Figure 1 Simulation setting up.

Experimental Analysis

The points of measurement are performed at two point of contact width, which are convex number 2 and 3. Because this part is effective for avoiding leak is taken as evaluation part as explained in [6]. The digital microscope VH-Z250 series with 500x magnification was used to measure the contact width parameter of the proposed the 25-A size metal gasket. Using the microscope we can measure the width of grooves which is the real contact width between the flange and the gasket.

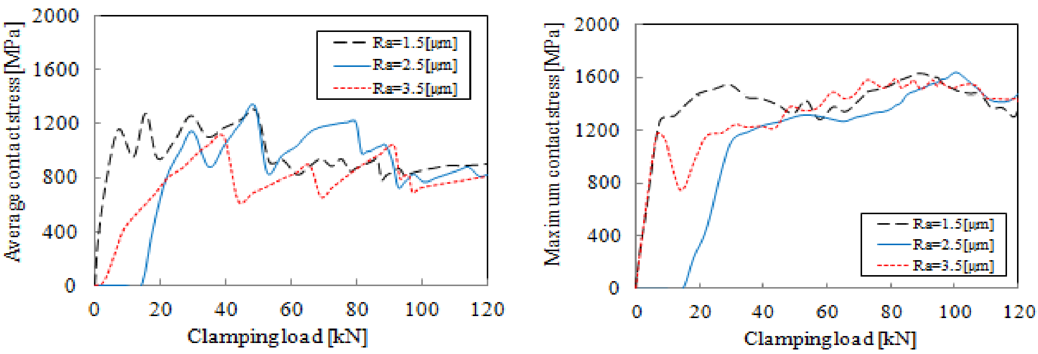
To evaluate the clamping load and leak quantity, the leakage quantity was measured based on the measurement of that of a helium flow. The procedure of helium leakage measurement completely in [6].

Results

Figure 2 (a) shows the simulation result for contacts of a gasket for the average contact stress. The contact stress for a gasket in contact with flanges having surface roughness values of 1.5, 2.5, and 3.5μm was similar. But, the flange having surface roughness 1.5μm showed the highest propensity than 2.5μm and 3.5μm. This figure shows that the average contact stress increases significantly with the clamping load. The average contact stress for flange having surface roughness 3.5μm was lowest than others. To maintain seal integrity, the effective compressive pressure on the gasket must be greater than the internal pressure by some multiple. Usually, the value of the internal pressure in the piping system is around 10MPa. Figure 2 denoted that the contact stress value when the leakage did not occur was around 800MPa; therefore, it is larger enough to reduce the internal pressure effect, which is 80 times internal pressure. Moreover this gasket had been tested by using water pressure test on 10MPa pressure condition and it is observed that leakage is not occurred [4]. On leak test, the bolt load is adjusted again to ensure the effect of pressure tested can be reduced for next applied of clamping load.

The contact width increased due to an increase in the axial force. For the value of clamping load 0-60kN, it can be shown that the contact width increased significantly. In this range, the value of contact stress is elastic distribution, and the phenomena still fulfill the elastic stress condition. However, for values of the clamping load from 60kN to 120kN, the contact width still increase. In this range, the distribution of stress is mixing the elastic and the plastic region. Also the elastic stress distribution in the region between convex contact produce the spring effect that it reduce the value of contact stress, then the graph of the contact stress tend to go down.

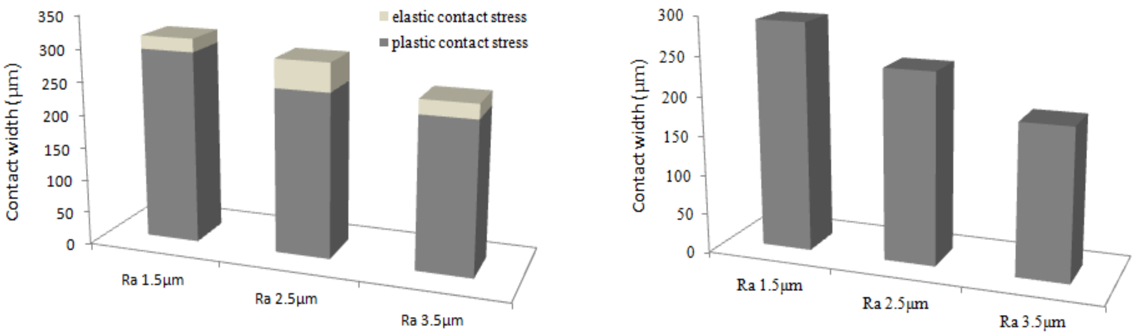
Figure 2 (b) shows the simulation result for the contacts of a gasket for the maximum contact stress. The flange having surface roughness 1.5μm showed the highest propensity than 2.5μm and 3.5μm. This figure shows that the maximum contact stress increases significantly with the clamping load.



(a) average contact stress (b) maximum contact stress

Figure 2 Average and maximum contact stress for gasket in 400-MPa mode.

Figure 3 shows contact width result both for simulation and experiment result when the clamping load 120kN. There is a good agreement for simulation and experiment result. Contact width for flange having surface roughness 1.5μm is longest than the others. The real contact width is sum of the real contact width after the gasket contact with flange. Because of the number of contact for small surface roughness more than big surface roughness. So contact width for small surface roughness is longer than big surface roughness.



(a) simulation result (b) experiment result

Figure 3 Contact width by simulation and experiment result.

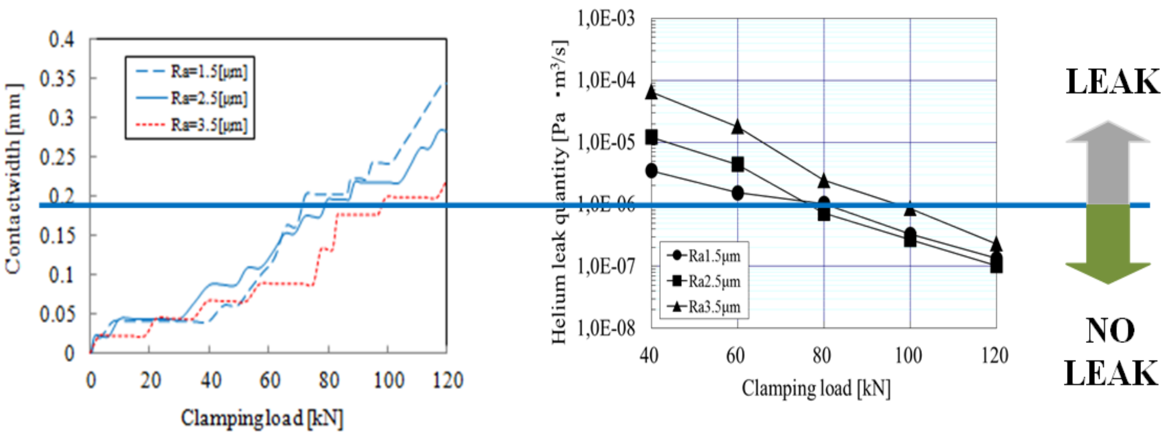


Figure 4 Helium leak mesurement related to contact width for gasket 400-MPa mode.

Figure 4 shows the helium leak measurement related to contact width for gasket 400-MPa mode. From the previous study [4], the helium leak rate 1.0E-06 Pa.m^3/s, it was observed that the leakage by water pressure test did not occur. Gasket contact with flange having surface roughness 3.5 μm the leakage did not occur when the clamping load 100 KN. In that time, the real contact width for simulation result is 0.195 mm. Gasket contact flange having surface roughness 2.5μm the leakage did not occur when the clamping load 80 KN. In that time, the real contact width for simulation result is 0.195 mm. Gasket contact flange having surface roughness 1.5μm the leakage did not occur when the clamping load 80 KN. In that time, the real contact width for simulation result is 0.20 mm.

Conclusions

In this research, based on simulation and experimental analyses, we can conclude that:

- The real contact width and average contact stress when the leakage started occur were 0.195 mm and 800MPa, respectively.
- There is a good agreement for contact width both by simulation result and experiment result.
- Contact width for flange having surface roughness 1.5µm is longest than flange having surface roughness 2.5µm and 3.5µm.

Acknowledgement

This project was supported by the Strength of Material Laboratory, Yamaguchi University, Japan and Yogyakarta State University.

References

[1] Asbestos is hard to replace as Japan heads for ban, *Sealing Technology* 1 (2006) 1.

[2] H.A. Saeed, S. Izumi, S. Sakai, S. Haruyama, M. Nagawa, H. Noda: Development of New Metallic Gasket and its Optimum Design for Leakage Performance, *Journal of Solid Mechanics and Material Engineering* 2: 1 (2008) pp. 105-114.

[3] S. Haruyama, M.A. Choiron, K. Kaminishi: *A Study of Design Standard and Performance Evaluation on New Metallic Gasket*, Proceeding of the 2nd International Symposium on Digital Manufacturing, Wuhan China, (2009) pp. 107-113.

[4] M.A. Choiron, S. Haruyama, K. Kaminishi: *Simulation and Experimentation on the Contact Width of New Metal Gasket for Asbestos Substitution*, World Academy of Science, Engineering and Technology, vol. 5, (2011) pp. 1182-1186.

[5] D. Nurhadiyanto, M.A. Choiron, S. Haruyama, K.Kaminishi: Optimization of New 25A-size Metal Gasket Design Based on Contact Width Considering Forming and Contact Stress Effect, *World Academy of Science, Engineering and Technology* Vol.6 (2012) pp. 661-665.

[6] S. Haruyama, D. Nurhadiyanto, M.A. Choiron, and K. Kaminishi: Influence of Surface Roughness on Leakage of New Metal Gasket, *International Journal of Pressure Vessels and Piping*, 111-112 (2013) pp. 146-154.

[7] S. Haruyama, D. Nurhadiyanto, and K. Kaminishi: Contact Width Analysis of Corrugated Metal Gasket based on Surface Roughness, *Advanced Material Research*, Vol. 856 (2014) pp. 92-97.

[8] JISB2404, *Dimensions of gaskets for use with the pipe flanges*, Japanese Standards Assosiations (2006).

[9] JIS B2220, *Steel Pipe Flanges*, Japanese Standards Association (2004).