© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Optimum Design of Laminated Corrugated Metal Gasket Using Computer Simulation

Shigeyuki Haruyama[1], Moch. Agus Choiron[2*], Didik Nurhadiyanto[3*]

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

[2] Mechanical Engineering Department, Brawijaya University
Jl. MT. Haryono 167, Malang 65145, INDONESIA

[3] Mechanical Engineering Education, Yogyakarta State University
Kampus Karangmalang, Yogyakarta, 55281, INDONESIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2019.11.05.004
Received 8 January 2019; Accepted 17 April 2019; Available online 10 August 2019

Abstract: In the previous study, corrugated metal gaskets using single material SUS 304 was developed. The corrugated metal gasket with elastic model for high surface roughness flange produce a leak due to only partial contact occurs. To increase the contact width between flange and gasket, surface layer in the both outside of gasket is required. The layer materials should softer than base material. In this study, Cu-SUS304-Cu laminated corrugated metal gasket is investigated by using computer simulation. Finite element software is used to observe contact width and contact stress on laminated corrugated metal gasket. The design parameter is pitch 1 (p1), pitch 2 (p_2), pitch 3 (p_3), thickness of base material (t), radius (R), height (h), and thickness of laminate (t_2). Based on the helium leak data, the leakage performance of laminated corrugated metal gasket is better than previous corrugated metal gasket. The optimal design is selected by using slope of contact width and axial force curve. Taguchi method used to determine the optimum design by using L18 matrix. The optimal design of laminated corrugated metal gasket are p_1 = 4.5 mm, p_2 = 3.5 mm, p_3 = 4 mm, t = 1.5 mm, R = 1,5 mm, h = 0.35 mm and t_2 = 0.1 mm.

Keywords: Corrugated Metal Gasket, Laminated, Simulation, Optimum Design, Taguchi Method

1. Introduction

Asbestos gasket has superior leak prevention of piping system. Unfortunately, asbestos gasket contains extremely dangerous chemicals and it is causing serious illnesses problems. Therefore, in Japan, the production of asbestos and its usage was banned from 2008 [1]. The development of alternative gasket material to replace asbestos gasket becomes an important social issue. In the previous study, corrugated metal gasket design was developed to reduce the clamping loads and the loss of tightness of bolted flange due to the joint relaxation. A new 25A size corrugated metal gasket is designed with circumferential annular lips to produce spring effect. High local contact stress is generated on a convex portion of the gasket to obtain a low clamping load. The elastic regions on the flat sections produce the spring effect to reduce the loss of tightness of bolted. In the next study, relationship between the clamping load and the contact width for the limits size of contact width was clarified [3]. The gasket contact width is important design parameter and it can be employed to evaluate the sealing performance. The gasket design based on elastic and plastic design was investigated [5]. The flange surface roughness effect to the contact area and contact stress. The real measurement of contact width was studied with considering surface roughness and local contact stress have been examined by using numerical analysis and the distribution of contact stress has been clarified. The previous research used a single material SUS304 [6-8]. By using elastic design and plastic design mode, it can be denoting the gasket design with 1.5 and 2.5 μm flange surface roughness produces no leak, but high clamping load is required. Haruyama et al. investigated the

*Corresponding author: agus_choiron@ub.ac.id

three layers corrugated metal gasket [9]. The layers consist of softer-base-softer materials. The softer materials are Nickel, Cupper or Aluminum. The average contact stress for three layers gasket was lower than single layer and the contact width for three layers gasket was wider than single layer. Karohika et al. investigated the contact stress and contact width of three layers corrugated metal gasket [10]. These studies used simulation analysis, but optimum design is not clarified yet.

Based on the reason, optimal design laminated corrugated metal gasket the corrugated metal gasket is investigated. In this study, the corrugated metal gasket modified using Cu laminated. It consists of base metal gasket and two layers of softer metal in the both outer of gasket. Contact stress and contact width are observed by using simulation analysis. The experimental result with helium leak test for previous corrugated metal gasket and laminated corrugated metal gasket will be compared.

2. Material and Method

The gasket used in this study is circumference beads gasket. The gasket is produced by mold press. On the condition of 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 [11].

The base metal gasket material was SUS304 due to its effectiveness in high-temperature and high-pressure environment. The nominal stress of SUS304 is 398.83MPa, the tangent modulus is 1900.53 MPa and the modulus of the elasticity (E) is 210 GPa. The softer material should stand to high temperature and chemical substance. Cu is used for both outer layer of gasket. The nominal stress of Cu is 195 MPa, the tangent modulus is 1150 MPa and the modulus of the elasticity (E) is 115 GPa. Cupper material is softer material than SUS304 (Fig. 1). The general-purposed flange based on JISB2220 with pressure rating 10K [12] and 25A diameter is used. The lower flange and the joint were welded carefully to avoid a distortion. In this method, the previous 25A-size corrugated metal gasket [6] is called as laminated 0.00 (SUS304).

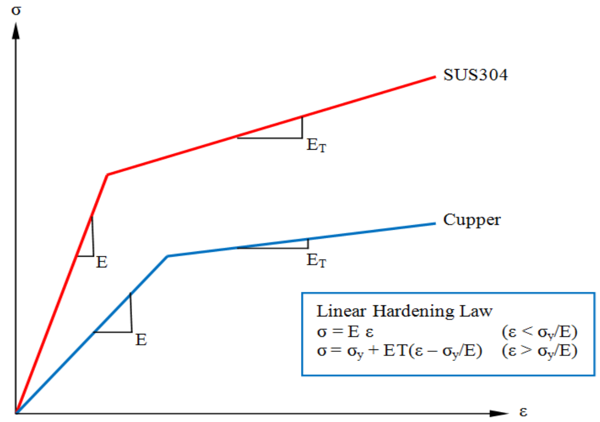

Fig. 1 - Linear strain hardening model for SUS304 and cupper material

The three layers corrugated metal gasket is developed by using three engineering software. Firstly, 2-Dimesional flange and the gasket were built using Solid Work software. Secondly, Hypermesh software was used to mesh the model. Quadrilateral element is used due to the model dominated as rectangular section. Thirdly, the procedure file was configured to perform a pre-processing and run the model on MSC. Marc software. After the computer simulation is completed, the output file can be generated in TXT file and it converted to Microsoft Excel file. The output result contains the contact status, contact width, and contact stress. Contact width is determined from contact element number. The calculation of the contact width versus the axial force is performed by using a multi-step MACRO command.

The gasket material is assumed as deformable bodies. The dies and flange are assumed as rigid bodies. On three layers corrugated metal gasket model, boundary condition between main layer and additional layer is assumed as non-fixed condition. The simulation consists of forming and tightening simulation (Fig. 2). Press forming is performed to produce gasket shape by a punch forces the initial material to slide into a die. Therefore, the forming effect is considered for gasket design modeling assessment. By using forming effect, the limit of contact width on the previous model which excluded forming effect for no leakage will be evaluated. For that reason, the first stage of this study is the gasket shape was produced from initial blank by using forming process simulation. The second stage is the gasket shape from forming simulation is simulated for tightening of the gasket on the flanges to ensure the contact width size. There is no difference between previous corrugated metal gasket and laminated corrugated metal gasket for forming and tightening simulation. The main difference is gasket material. Gasket material for corrugated metal gasket is SUS304 and gasket material for laminated corrugated metal gasket are Cu-SUS304-Cu.

The design parameter is shown in Fig. 2 and the level of design parameter is shown in Table 1. The design parameter are pitch 1 (p_1), pitch 2 (p_2), pitch 3 (p_3), thickness of base material (t_1), radius (R), height (h), and thickness of laminate (t_2). The optimal design is selected by using slope of contact width and axial force curve. Taguchi method is choosing to analyses the effect of each parameter design and predicts optimal design of laminated corrugated metal gasket. The L18 orthogonal array was used to design experimental matrix for seven factors with three levels.

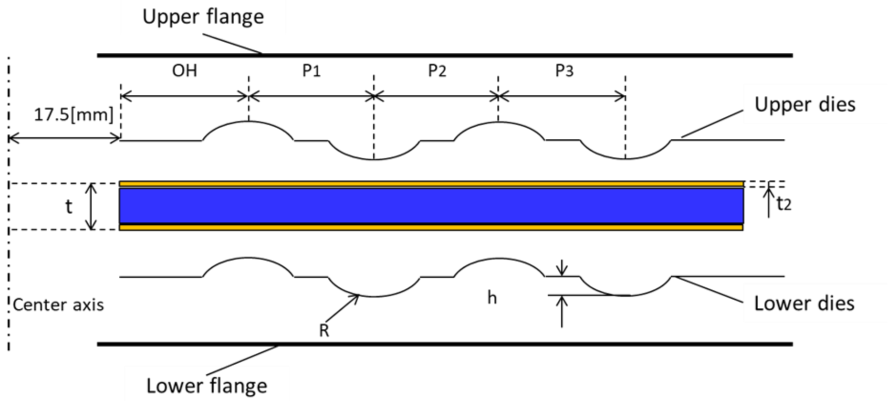

Fig.2 - Forming and tightening model for laminated corrugated gasket

Table 1 - The level of design parameter on laminated corrugated metal gasket

Design Parameter	Level 1	Level 2	Level 3
Pitch 1(p_1)	3.5	4.0	4.5
Pitch 2 (p_2)	3.5	4.0	4.5
Pitch 3 (p_3)	3.5	4.0	4.5
Thickness (t)	1.2	1.5	1.8
Radius (R)	1.5	2.5	3.5
Height (h)	0.30	0.35	0.40
Thickness of laminate material (t_2)	0.1	0.2	0.3

The gasket performance was evaluated using leak measurement. Fig. 3 shows the schematic diagram of a helium leak measurement system built for helium leak rate evaluation of the gasket. The vacuum method which has the highest detection ability in the helium leak measurement method was selected and utilized based on JISZ2331 standard [13]. The minimum helium leak rate which could be identified 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].

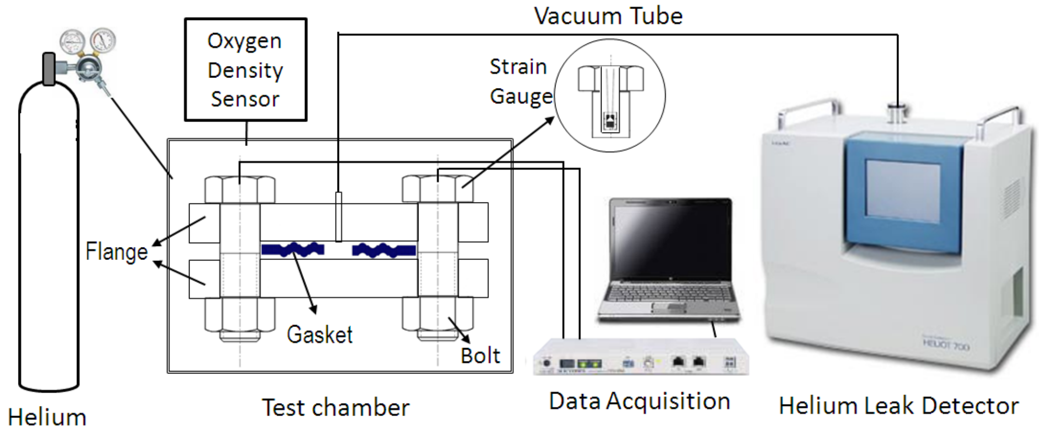

Fig. 3 - Schematic diagram of helium leak measurement system [14]

3. Results and discussion

The simulation result of forming and tightening process are shown in the Fig. 4. In the first stage, the dies were assumed as rigid body in both sides. Axisymmetric model was made to adopt compression displacement in axial direction on pre material gasket (initial blank) in between the top and the bottom of the dies. The second stage is the gasket shape produced by mold press is compressed in axial direction to model tightening of the gasket on the flanges.

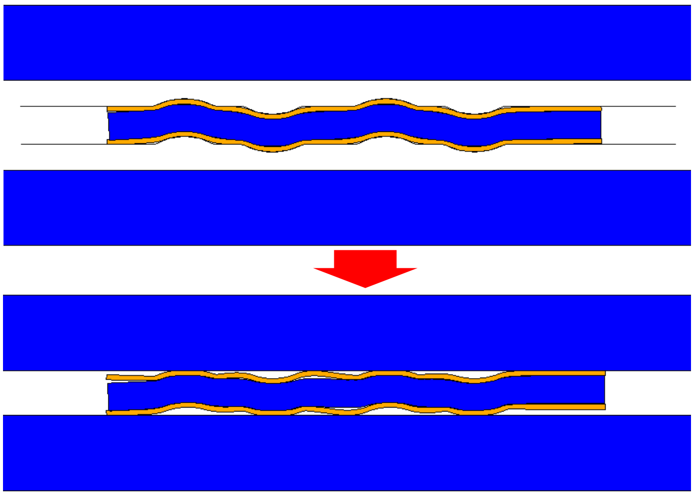

Fig. 4 - Forming and tightening simulation

Fig. 5 shows one of the simulation results on the relationship between contact width and axial force. Based on L18 matrix, the optimal design is selected by using slope of contact width and axial force curve.

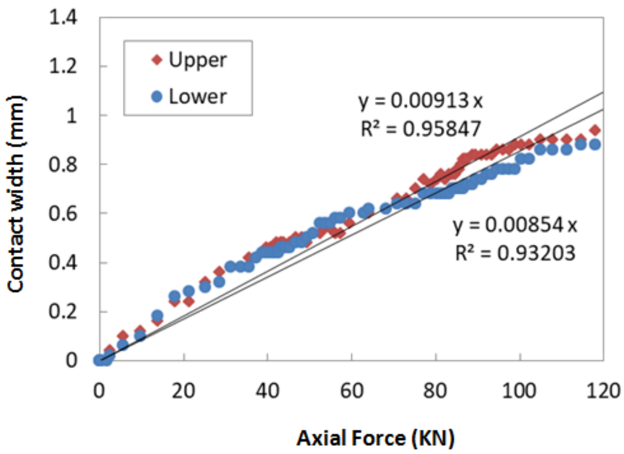

Fig. 5 - Slope of the relationship between contact width and axial force

Fig. 6 shows the main effect of design parameter on laminated corrugated metal gasket. The highest value for each factor shows the highest slope of the relationship between contact width and axial force. The optimum design is obtained as seen in the Table 2.

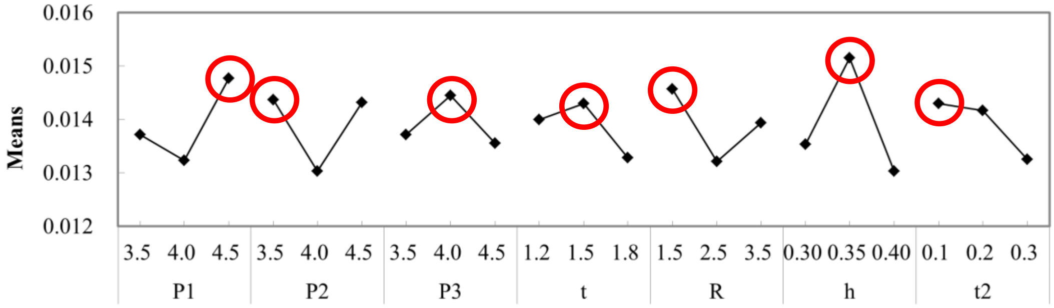

Fig. 6 - The main effect for each design parameter

Table 2 - The optimum design of laminated corrugated metal gasket

Design Parameter	Value
Pitch 1(p_1)	4.5 mm
Pitch 2 (p_2)	3.5 mm
Pitch 3 (p_3)	4 mm
Thickness (t)	1.5 mm
Radius (R)	1.5 mm
Height (h)	0.35 mm
Thickness of laminate material (t_2)	0.1 mm

The leakage performance of previous corrugated metal gasket and laminated corrugated metal gasket are measured by helium leak test (Fig. 7). In the previous corrugated metal gasket, in this study called as laminated 0.00 (SUS304) is shown by using black circle dot. The helium leak test result of corrugated metal gasket are denoted by using blue square dot (laminated Cu 0.1 mm), red triangle dot (laminated Cu 0.2 mm), and oblique square dot (laminated Cu 0.4 mm).

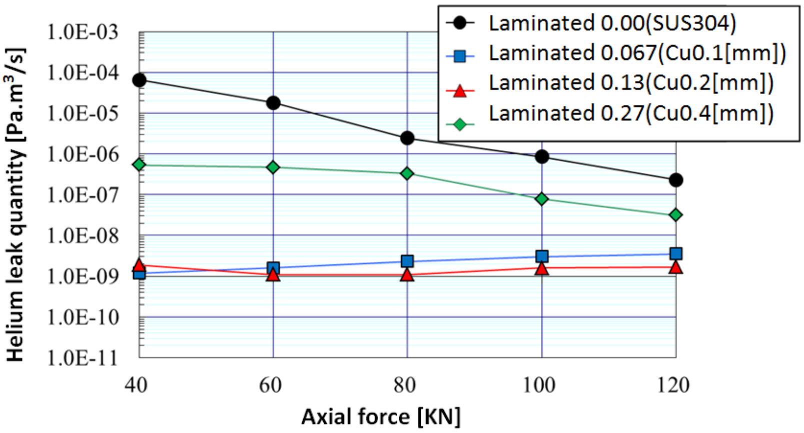

Fig. 7 - The Helium leak test results of previous corrugated metal gasket and laminated corrugated metal gasket

The laminated corrugated metal gasket produces no leak for all axial force (40 KN, 60 KN, 80 KN, 100 KN and 120 KN). The corrugated metal gasket provides no leak only for 120 KN and leak is still occurred in the lower axial force. Based on the helium leak data, the laminated corrugated metal gasket is better than corrugated metal gasket. The laminated gasket will filled the surface roughness of flange to provide no leak.

4. Conclusions

Summarizing the main findings of the simulation and experimental analysis on laminated corrugated metal gasket, following conclusions are drawn:

- The optimum design of laminated corrugated metal gasket was obtained.
- The optimal layers thickness of laminated Cu is 0.1 mm.
- The leakage performance of laminated corrugated metal gasket is better than previous corrugated metal gasket.

Acknowledgement

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

References

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

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

[3] Haruyama S., Choiron M.A, Kaminishi K. (2009), A Study of Design Standard and Performance Evaluation on New Metallic Gasket, Proceeding of the 2nd International Symposium on Digital Manufacturing, Wuhan China, 107-113.
[4] Choiron M.A, Kurata Y., Haruyama S., Kaminishi K. (2011), Simulation and Experimentation on the Contact Width of New Metal Gasket for Asbestos Substitution, World Academy of Science, Engineering and Technology, 5 - 3, 694-698.
[5] Nurhadiyanto D., Choiron M.A., Haruyama S., Kaminishi K. (2012), 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, 6, 661-665.
[6] Haruyama, S., Nurhadiyanto, D., Choiron, M.A., and Kaminishi, K. (2013), Influence of Surface Roughness on Leakage of New Metal Gasket, International Journal of Pressure Vessels and Piping, 111-112, 146-154.
[7] Haruyama, S., Nurhadiyanto, D., and Kaminishi, K. (2014), Contact Width Analysis of Corrugated Metal Gasket based on Surface Roughness, Advanced Material Research, 856, 92-97.
[8] Nurhadiyanto, D., Haruyama, S, Kaminishi, K., Karohika, I.G.M., and Mujiyono (2015), Contact Stress and Contact Width Analysis of Corrugated Metal Gasket, Applied Mechanics and Materials, 799-800, 765-769.
[9] Haruyama, S., Karohika, I.M.G., Sato, A., Nurhadiyanto, D., and Kaminishi, K. (2016), Development of 25A-Size Three-Layer Metal Gasket by Using FEM Simulation, International Journal of Mechanical, Aerospace, Industrial, Mechatronics and Manufacturing Engineering, 10, 527-533.
[10] Karohika, I.G.M., Haruyama, S., Kaminishi, K., Oktavianty, O., Nurhadiyanto, D. (2017), Analysis of Contact Width and Contact Stress of Three-Layer Corrugated Metal Gasket, International Journal of Mechanical, Aerospace, Industrial, Mechatronics and Manufacturing Engineering, 11, 870-879.
[11] JISB2404 (2006), Dimensions of gaskets for use with the pipe flanges, Japanese Standards Associations.
[12] JIS B2220 (2004), Steel Pipe Flanges, Japanese Standards Association.
[13] JIS Z2331 (2006), Method of helium leak testing, Japanese Standards Association.
[14] Choiron M.A, Haruyama S., Kaminishi K. (2012), Studies of Relationship between Contact Width and Leakage on Large Size of New Metal Gasket, Applied Mechanics and Materials, 229-231, 705-709.