Contact Width Evaluation of New 25A-size Metal Gasket Considering Forming Effect

Didik Nurhadiyanto[1], Moch. Agus Choiron[2], Shigeyuki Haruyama[3], Ken Kaminishi[3]
1 Doctoral student at Department of Mechanical Engineering, Yamaguchi University, Japan
2 Mechanical Engineering Department, Brawijaya University, Indonesia
3 Graduate School of Innovation and Technology Management, Yamaguchi University, Ube, Japan
(E-mail: kaminisi@yamaguchi-u.ac.jp, haruyama@yamaguchi-u.ac.jp, agus_choiron@ub.ac.id)

Abstract: In this study, gasket model is simulated by using two simulation stages which is forming and tightening simulation. By using forming effect, the limit of contact width on the previous model which excluded forming effect for no leakage was evaluated. Initial blank thickness is varied by adding 0% ($t_{0\%}$), 5% ($t_{5\%}$) and 10% ($t_{10\%}$) of the final thickness of the gasket. The result shows that the final design shapes produced the defect occurred on the radius shape of convex contact. The lack of die fill defect is decreased with increasing initial blank thickness. The contact stress of forming models is higher than the contact stress of non forming models due to residual stress of forming effect. Based on contact width criteria, the non forming model is still valid for gasket design concept and more efficient for consuming the simulation time.
Key words: Contact width; Residual stress; Forming; Metal gasket

1 Introduction

A new 25A size metal gasket, which uses corrugated shape was proposed for asbestos gasket substitution alternative[1]. 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. Haruyama, et.all[2] investigated the limits size of contact width as 25A size metal gasket design parameter. In this study, the quantitative evaluation of helium leak rate and contact width of gasket which has no leak by water pressure test had been cleared. From the above matter, contact width can be used as a main parameter to optimize the gasket design. The leakage can be reduced with increasing the contact width. Choiron, et.all[3]provided the contact width validation by using simulation analysis and the result is compared to experimental using pressure sensitive paper.

All new 25A size metal gasket model on the previous study use the assumption exclude forming effect. It was known that the forming process produced residual forming data such as characterizing geometric imperfections and residual stresses[4]. The use of simulation is beneficial in the design of metal forming operations because it is more cost effective than trial and error. The development of hardware and software support the metal forming simulation to define the shape and initial material. It is also predict the forces and stresses necessary to execute the forming operation[5]. 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 limits size of contact width. Initial blank thickness is divided by adding 0%, 5% and 10% from the final thickness of the gasket.

2 Material and Method

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]. From the 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].

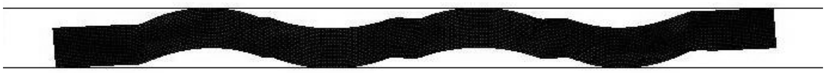
In the previous study[7], the 25A size metal gasket was optimized by using L18 Taguchi method. This model was built with the assumption exclude forming effect. Based on contact width as design concept and considering contact stress on contact width, the optimized gasket is determined as 0 and 400 MPa modes. In this study, a gasket model is divided into two simulation stage by using two pressing model which is forming and tightening simulation. Both stages were modeled using finite element method analysis software MSC. Marc[8]. In the first stage, the dies were assumed as rigid body in both sides. Using two-dimensional assumptions, the axisymmetric model was adopting a forming process simulation in axial direction on initial gasket material (initial blank) between the top and the bottom of the dies (Figure 1a). The second stage is the gasket shape produced by mould press is continuity compressed in axial direction to adopt tightening of the gasket on the flanges (Figure 1b). Initial blank thickness as shown in Figure 2 is varied by adding 0% ($t_{0\%}$), 5% ($t_{5\%}$) and 10% ($t_{10\%}$) from the final thickness (Table 1).

Table 1 Variation of Initial Blank Thickness

Final thickness of blank [mm]	Initial blank thickness [mm]		
	0% ($t_{0\%}$)	5% ($t_{5\%}$)	10% ($t_{10\%}$)
1.2	1.2	1.26	1.32
1.5	1.5	1.575	1.65
1.8	1.8	1.89	1.98

Upper die
Lower die

(a)



(b)

Figure 1 Schematic Section of Model: a. Forming Simulation; b. Tightening Simulation

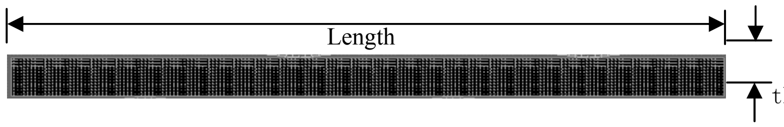


Figure 2 Schematic Section of Initial Blank Model

Flow chart the stage of simulation and optimization the gasket considering forming effect is shown in the Figure 3. A close connection of the information continuity among CAD, Meshing, FEA software's preprocessing and post-processing is developed to fulfill the automatic optimization of process parameters. The virtual gasket model with various designs is generated by using four basic steps. They are the parameterization the models, automatic meshing, computation of preprocessing and post-processing in batch mode and optimization. Firstly, 2-D parameter model is built by utilizing the Solidwork software. To connect drawing data from Solidwork (IGES file) and automatic meshing by using Hypermesh, batch command file is built and a NAS file is produced with this procedure. Then the procedure file is configured to obtain preprocessing and running the model on MSCMarc software. The graphic user interface (GUI) was not appear and the program run command in the background. After the FEM analysis is complete, an output file including analysis results could be generated in TXT file. The TXT result file is transformed to Microsoft excel by using MACRO command. The output result contains the contact status, stress value, and body force at each time at every convex position. Calculation of the contact width versus load on convex position number 1 until 4 is produced with several step of MACRO command.

The optimum design is also determined based on reducing the clamping load. It can be denote by using the slope or gradient of the curve of relationship between contact width and clamping load (Figure 4). The upper and lower contact width is calculated by adding the value of convex contact position number 1 and 2, 3 and 4 respectively. The slope of curve is increased; it will be reduce the clamping load. The slope of curve is built manually by using trend line command in Microsoft Excel. The process of optimization using L18 Taguchi is illustrated as a circulating loop. Due to the optimization design based on increasing contact width is combined with considering contact stress, and the optimized design is selected. The next circulating loop is generated to fulfill the forming effect by adding forming simulation before the tightening simulation. Finally the optimized design considering forming effect could be achieved.

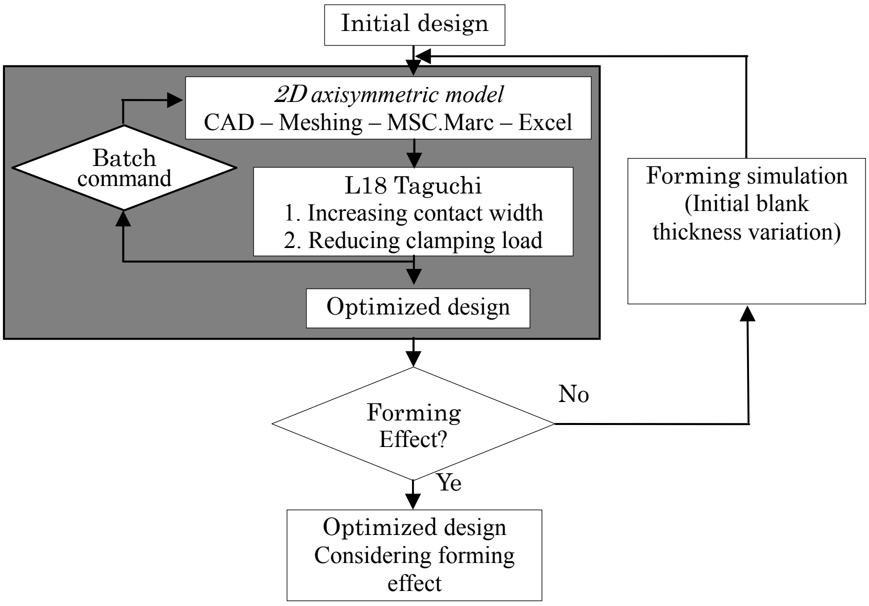


Figure 3　Flow Chart the Stage of Simulation and Optimization the Gasket Considering Forming Effect

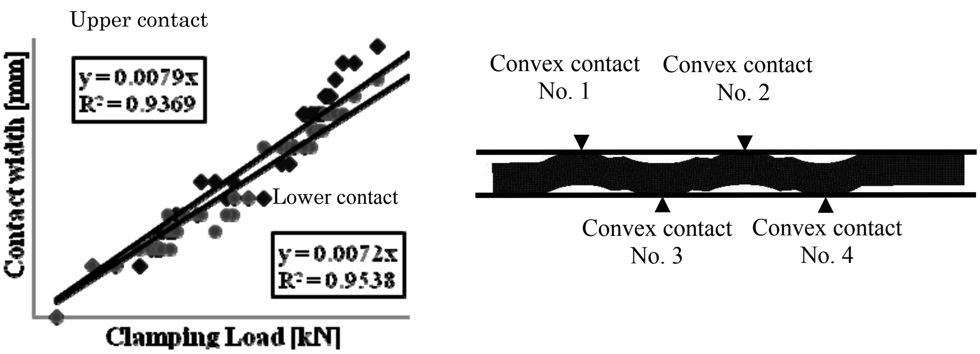


Figure 4　The Slope of the Curve of Relationship Between Contact Width and Clamping Load

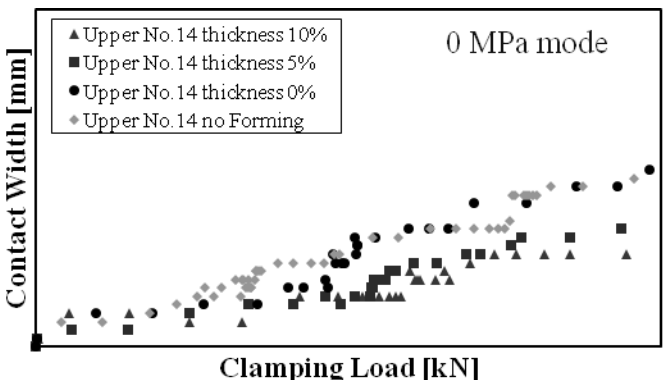


Figure 5　The Simulation Result of the Model Number 14

3 Result and Discussion

The simulation result of one of the model in upper contact is shown in the Figure 5 at different initial blank thickness. The graphic shows that for increasing clamping load increase the contact width. The non forming model and $t_{0\%}$ model produced the contact width larger than contact width of $t_{5\%}$ and $t_{10\%}$ models.

The L18 matrix was conducted and the slope of the curve of relationship between contact width and clamping load as observed values (Y) was calculated for all models as shown in the Table 2.

Table 2 The Result of L18 Test Matrix

Run#	Factor	Slope of curve (Non forming Model)	Slope of curve ($t_{0\%}$)	Slope of curve ($t_{5\%}$)	Slope of curve ($t_{10\%}$)
		0 [Mpa]	0 [Mpa]	0 [Mpa]	0 [Mpa]
1	$A_1B_1C_1D_1E_1F_1G_1H_1$	0.0096	0.00835	0.0067	0.00495
2	$A_1B_1C_2D_2E_2F_2G_2H_2$	0.0097	0.0089	0.00655	0.0058
3	$A_1B_1C_3D_3E_3F_3G_3H_3$	0.0101	0.0085	0.0056	0.00505
4	$A_1B_2C_1D_1E_2F_2G_3H_3$	0.0092	0.008	0.0061	0.00515
5	$A_1B_2C_2D_2E_3F_3G_1H_1$	0.0092	0.00805	0.00575	0.00485
6	$A_1B_2C_3D_3E_1F_1G_2H_2$	0.0094	0.0095	0.00585	0.0055
7	$A_1B_3C_1D_2E_1F_3G_2H_3$	0.0138	0.01165	0.0081	0.00715
8	$A_1B_3C_2D_3E_2F_1G_3H_1$	0.0083	0.0076	0.00705	0.00505
9	$A_1B_3C_3D_1E_3F_2G_1H_2$	0.0082	0.00705	0.0053	0.00435
10	$A_2B_1C_1D_3E_3F_2G_2H_1$	0.0083	0.00675	0.0056	0.00455
11	$A_2B_1C_2D_1E_1F_3G_3H_2$	0.014	0.0108	0.0077	0.00685
12	$A_2B_1C_3D_2E_2F_1G_1H_3$	0.0081	0.00765	0.00555	0.0046
13	$A_2B_2C_1D_2E_3F_1G_3H_2$	0.0073	0.00565	0.0047	0.0044
14	$A_2B_2C_2D_3E_1F_2G_1H_3$	0.011	0.01075	0.00745	0.0066
15	$A_2B_2C_3D_1E_2F_3G_2H_1$	0.0106	0.0092	0.00695	0.00615
16	$A_2B_3C_1D_3E_2F_3G_1H_2$	0.0104	0.0096	0.00715	0.0062
17	$A_2B_3C_2D_1E_3F_1G_2H_3$	0.0071	0.00555	0.00445	0.0039
18	$A_2B_3C_3D_2E_1F_2G_3H_1$	0.0111	0.0102	0.0072	0.00645

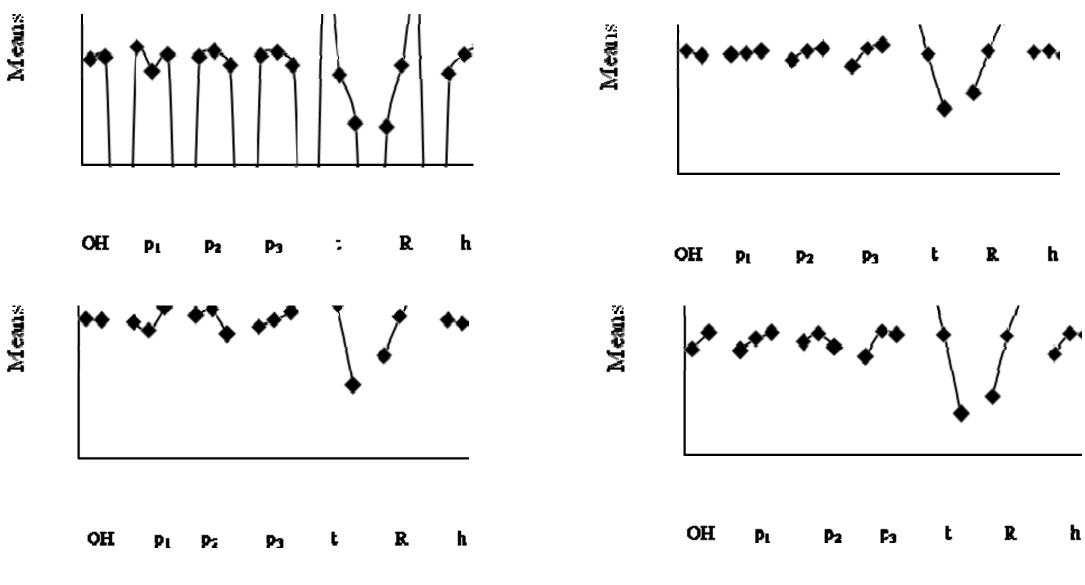


Figure 6 The Main Effects of Each Factor for Various Levels at Slope of Curve on 0 MPa Mode

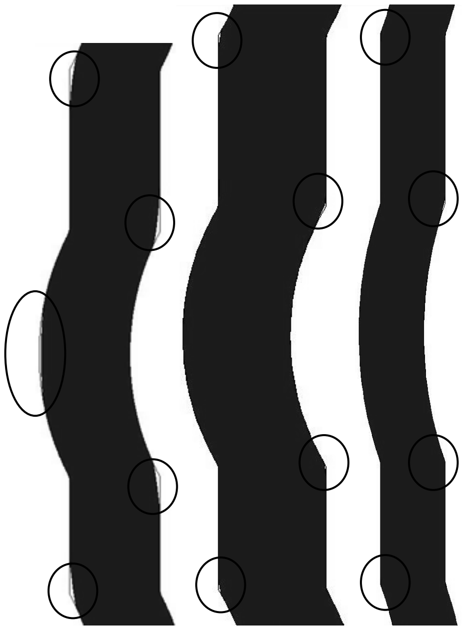


Figure 7 Lack of Die Fills Defect Result on One of Convex Contact

Figure 6 shows the main effects is plotted for a visual inspection of each factor for various level conditions. The highest value for slope of curve is supposed as the clamping load reducing. In this study, the main factor of the design is providing the larger contact width and reducing the clamping load. It denotes that thickness and radius have a stronger influence on the reducing of clamping load. Figure 7 shows the lack of die fills defect result. The $t_{0\%}$ model produced the lack of die fills defect higher than defect on $t_{5\%}$ and $t_{10\%}$ models. The defect is tending occurred on the radius shape of convex contact. As the result of previous study, the radius is as main factor that contributes for increasing contact width. It has different result for radius effect due to lack of die fills in the radius shape of convex contact. Therefore the value of contact width produced by all forming model is smaller than non forming model.

Based on the result as shown in the Figure 5, the non forming model provide contact width trend as similar with the $t_{0\%}$ forming model. With this important fact, modeling on the condition non forming is still valid for optimizing the 25A size gasket design. It is useful due to time consumption for the non forming model is faster (±10 minutes) than forming model (±180 minutes).

Finally, this study suggests the optimum gasket design based on results of each models is shown in Table 3. It denotes that thickness and radius have a stronger influence on the reducing of clamping load on all models. It can be denoted that all models suggest the same level of radius and thickness.

Table 3 Optimum Design of Gasket Considering Forming Rffect

Factor	Non forming model	Forming model ($t_{0\%}$)	Forming model ($t_{5\%}$)	Forming model ($t_{10\%}$)
OH	4.0 mm	3.0 mm	3.0 mm	4.0 mm
p_1	3.5 mm	4.5 mm	4.5 mm	4.5 mm
p_2	4.0 mm	4.5 mm	4.0 mm	4.0 mm
p_3	4.0 mm	4.5 mm	4.5 mm	4.0 mm
t	1.2 mm	1.2 mm	1.2 mm	1.2 mm
R	3.5 mm	3.5 mm	3.5 mm	3.5 mm
h	0.4 mm	0.35 mm	0.4 mm	0.35 mm

4 Conclusions

In this study, by using forming effect, the limit of contact width on the previous model which excluded forming effect for no leakage was evaluated. Initial blank thickness is varied by adding 0% (t0%), 5% (t5%) and 10% (t10%) of the final thickness of the gasket. The result shows that the final design shapes produced the defect occurred on the radius shape of convex contact. The lack of die fill defect is decreased with increasing initial blank thickness. The t0% forming model provide contact width trend as similar with the non forming model. Based on contact width criteria, the previous non forming model is still valid for gasket design concept and more efficient for consuming the simulation time.

Acknowledgements

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