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Simulation Analysis of 25A-Size Corrugated Metal Gasket Coated Copper to Increase Its Performance

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Abstract. Previous study, researchers investigated on 25A-size corrugated metal gasket using material SUS304 and it modified. The elastic model design of corrugated metal gasket still leakage and need high axial force for tightening process. The purpose of this study is to analyze coated corrugated metal gasket by FEM simulation. Experimental result used for validating the data. The characteristic of coating material should softer than base material. The coating material will stick and fill in the surface roughness of gasket. The simulation result shows that contact width increase and contact stress decrease after the gasket coated by copper. It mean that the gasket performance increase to stop the leakage.
Keywords: *corrugated, metal gasket, coating, copper, simulation*

1. Introduction

The need of gasket for sealing in oil and mining industries is very high. Asbestos-containing sealing materials is superior in preventing leakage in piping, and it used in several industries. However, it is totally dangerous because chemicals effect and it can cause serious illness. In the world, the production and usage of asbestos materials were banned [1]. But, the need of gasket material to replacement of asbestos material is expensive and have short period of live [2, 3, 4].

Saeed and friends [5] investigated super seal gasket of 25A size metal gasket. The gasket formed the circumferential annular lips. The gasket performance optimization based on the contact width and contact stress. It is an important design parameters. The contact width limit that the leakage did not occur studied by Haruyama et al [6]. They used water pressure test to measure the leakage rate.

Nurhadiyanto et al [7] designed the optimum metal gasket 25A size by FEM simulation based on contact width and contact stress effect considering forming effect. Plastic design of gasket performs better than elastic design. Haruyama et al [8] investigated the effect of surface roughness on leakage. The leakage performance examined by flange surface roughness. Also the axial force examined by flange surface roughness. The low surface roughness is better than high surface roughness for leakage performance.The real contact width result using helium leakage measurement proposed by Haruyama et al [9] and the real simulation result of contact width and contact stress proposed by Nurhadiyanto et al [10]. Both of study considered of surface roughness of flange. The local contact stress has been studied by FEM analysis and they clarified the distribution of contact stress.

The result of previous research that used a single material SUS304 was clarified. The corrugated metal gasket elastic design contact with high surface roughness flange still leaking because of only partial contact occurs. Gasket elastic design and plastic design which contact with surface roughness of flange 1.5 and 2.5 μm is good gasket, but it still used need high axial force. Haruyama et al. [11] studied the three layers corrugated metal gasket. The layers consist of softer-base-softer materials. The softer material are Nickel, Cupper or Aluminum.The average contact stress for three layers gasket lower than single layer and the contact width for three layers gasket was wider than single layer. Karohika et al. [12] investigated the contact width and contact stress of three layers corrugated metal gasket. They concluded that thickness ratio decreased will increase contact width but the average contact stress will decrease. Both article [11] and [12] used simulation analysis, they did not compare the simulation and experimental result. Also, the leakage performance did not clear yet. The springback effect and the deformation every peak of the three layers gasket did not discuss clearly in this research. The influence of thickness layer investigated by simulation in research but it did not investigated by experimentally.

In this light, this study aims to reengineering of corrugated metal gasket by coating using Copper (Cu) material. The Cu material is softer than base material (SUS304). The coating material will stick on the outer surface of metal gasket. The characteristic of coating material should softer than SUS304. When metal gasket contact with flange, after tightening process, coating material fill up the rough surface of flange.

2. Material and Methods

The SUS304 used as gasket material used in present research. This material is very effective in high temperature and pressure. The property of this SUS304 determined using test of tensile based on JISZ2241 standard [13]. Ultimate stress (σ) is 210GPa, elasticity modulus (E) is 398.83MPa and tangential modulus respectively is 1900.53MPa. The stress-strain diagram of SUS304 shown Figure 1. Table 1 shows the characteristic of SUS304 material.

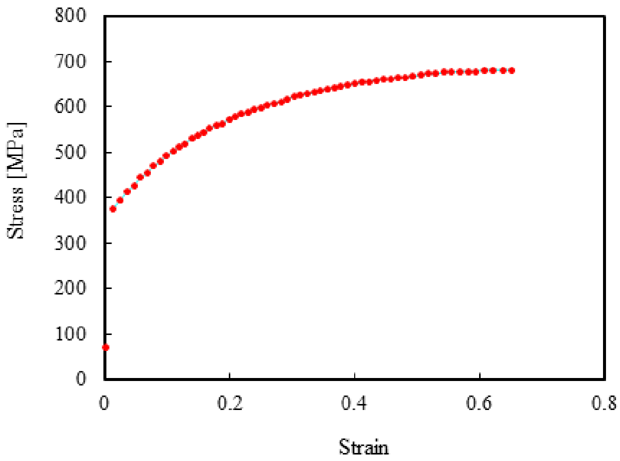

Figure 1. SUS304's stress-strain diagram

Table 1. The material of SUS304

Properties	Value
Yield stress	398.83MPa
Elasticity modulus	210GPa
Tangential modulus	1900.53MPa
Poisson ratio	0.3

The coating material was Cu. Copper is softer than SUS304 and resistant to temperature and chemical material. The characteristic of copper and SUS304 shown in Figure 2.

The simulation process is tightening simulation. The simulation using MSC Marc software [14]. The various design of gasket model generated using four basic steps. Firstly, the 2-D models paramerization using Solid Work software (IGES file). Secondly, using Hypermesh for automatic meshing by batch command to produced NAS file. The next step was computation of preprocessing and running the model. Model run on MSC Marc software. The last step is post-processing in batch mode optimization. The analysis result could be generated in TXT file after the completely of FEM analysis. Each convex position, the stress value, contact status and body force at every time are the output result.

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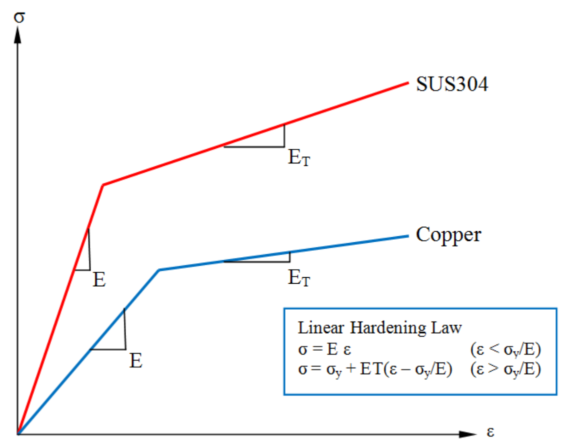

Figure 2. Linear strain hardening model for SUS304 and copper material

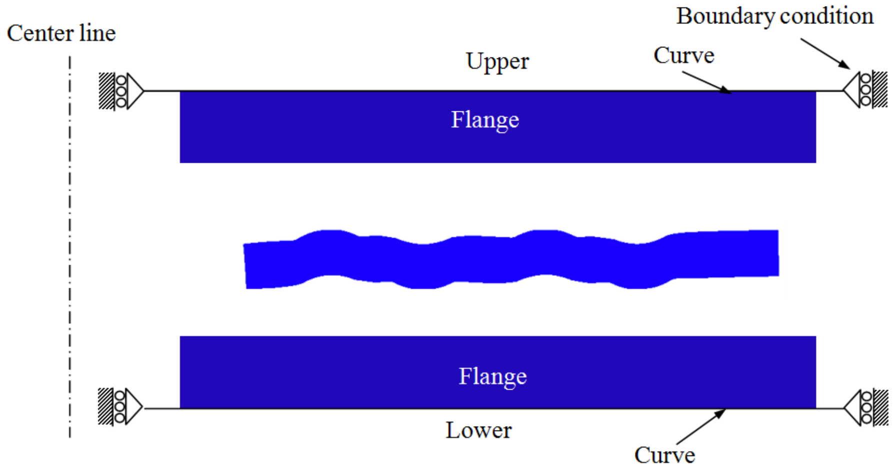

Figure 3. Simulation setting up for coating gasket

Figure 3 shows the set up simulation for coating gasket. The flange, gasket material and coating material assumed deformable bodies. The curve assumed as rigid body. The gasket did not move, but the lower dies moved up and upper gasket moved down.

3. Result and Discussion

Figure 4 shows the contact width and average contact stress result of gasket coated 3µm Cu and standard gasket. The thicness ratio Cu-base-Cu is 3µm-1.5mm-3µm. The contact width increase when the axial force increase. In low axial force (0-70kN) contact width for both type of gasket are similar even there is different cotact width when the axial force in 40-65kN. Contact width is very different when the axial force start 70-120kN. The contact stress also litle bit different when the axial force 40-120kN. This condition caused by the outer layer of gasket. The outer gasket coated by 3µm thickness of Cu, it stick and filled the surface roughness of flange. So, the contact width will increase. The disadvantage is contact strees will decrease. It because of the relationship between stress, force and contact area. If the contact witdh increase so the contact stress will decrease, see equation (1).

$$\sigma = \frac{F}{A} \quad (1)$$

where σ = stress $(\frac{N}{m^2})$, F = force (N) and A = contact area (m^2)

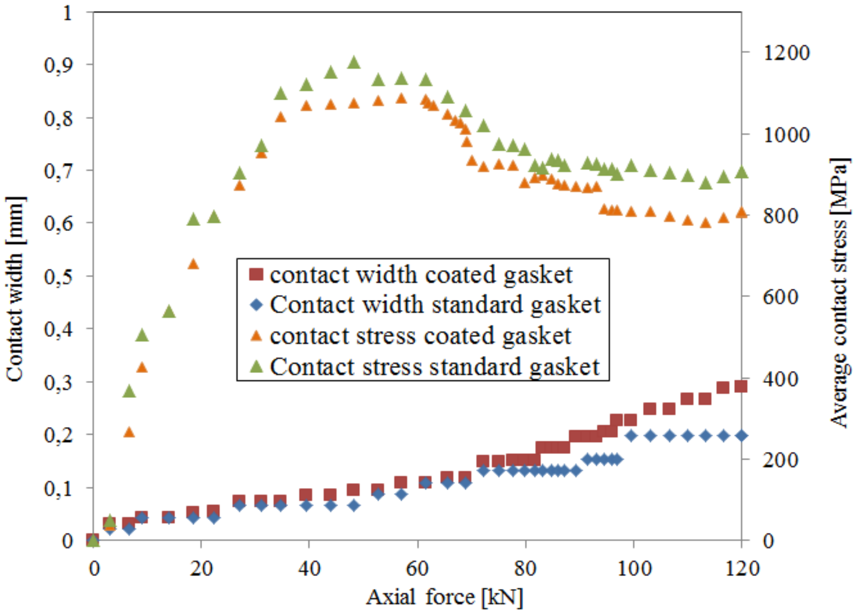

Figure 4. Simulation result of coating tickness 3µm

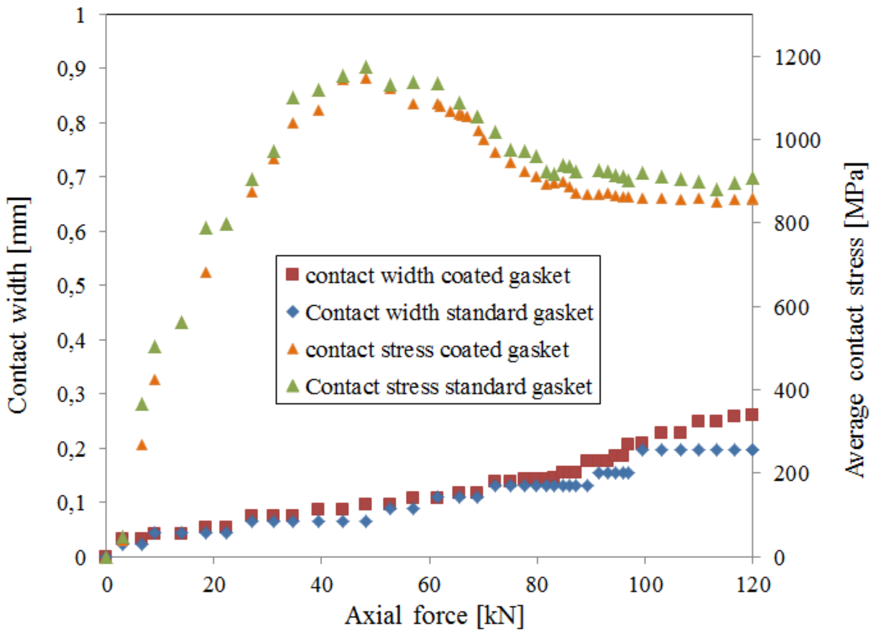

Figure 5. Simulation result of coating thickness 2µm

Figure 5 shows the simulation result of modified gasket which thicness ratio Cu-base-Cu is 2µm-1.5mm-2µm compared standard gasket. In low axial force (0-70kN) contact width for both type of gasket are similar. Contact width is very different when the axial force start 70-120kN. The contact sress also litle bit different when the axial force 40-120kN. This condition caused by the outer layer of gasket. The outer gasket coated by 2µm thickness of Cu, it stick and filled the surface roughness of flange. So, the contact width will increase.

There is a differences of contact width and contact stress between 2µm and 3µm thickness of Cu coated. The contact width of gasket Cu coated 3µm is wider than 2µm when contact with flange. The contact stress of gasket Cu coated 3µm than 2µm when contact with flange.

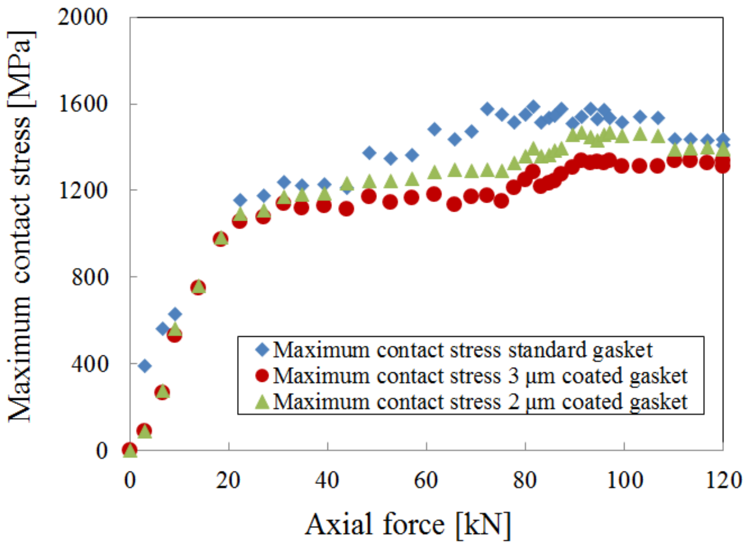

Figure 6. Maximum contact stress for all type of gasket

Figure 6 shows the relationship between axial force-maximum contact stress for standard gasket and coating gasket which has thickness 2µm and 3µm. The axial force start at 0kN until 120kN, it because the experimental axial force was taken 40kN, 60kN, 80kN, 100kN and maximum 120kN. The maximum increase very significant when the axial force 0-30kN, after that the maximum contact stress increase slowly or tend to be constant. The maximum contact stress shows the similary increase for gasket standard, 2µm and 3µm Cu coated when the axal force 0-30kN. When the axial force 30kN above, there is differences maximum contact stress value for gasket standard, 2µm and 3µm Cu coated. The maximum contact stress of gasket standard has highest maximum contact stress than coating gasket. The maximum contact stress of gasket 2µm Cu has higher 3µm Cu. The reason is contact width of gasket standard is lower than 2µm and 3µm Cu coated, using equation (1) if the contact width increase so the contact stress will decrease.

Table 2. Leakage measurement result

Axial force (kN)	Time (second)	Pressure (MPa)	Standard gasket	Cu Coated	
				2µm	3µm
40	600	10	Leaked	Leak	Leak
60	600	10	Leaked	No Leaked	No Leaked
80	600	10	No Leaked	No Leaked	No Leaked
100	600	10	No Leaked	No Leaked	No Leaked
120	600	10	No Leaked	No Leaked	No Leaked

Table 2 shows the experimental result for standard gasket and coated gasket for compared simulation and experimental result. The experimetal using water pressure test. The standard gasket did not leakage when axial force 80kN, 100kN and 120kN. Coated gasket 2µm and 3µm thickness of Cu did not leak when the axial force 60kN, 80kN, 100kN and 120kN. Coated gasket with Cu both thickness 2µm and 3µm has higher performance than standard gasket. This result a good agreement with simulation result that contact width increase when the gasket coated by Cu 2µm and 3µm thickness.

4. Conclussion

The conclussion as follow:

a. Contact width of coated gasket is wider than standard gasket and contact stress of coated gasket is lower than standard gasket.
b. The simulation and experimental result is a good agreement.
c. A coated gasket is better than standar gasket based on simulation and experimental result.

References

[1] Asbestos is hard to replace as Japan heads for ban, *Sealing Technology* 1 2006 1.
[2] Estrada H, Parsons I D 1999 Strength and Leakage Finite Element Analysis of GFRP Flange Joint *International Journal of Pressure Vessel and Piping* Vol 76 p 543-550.
[3] Krishna M M, Shunmugam M S, Prasad N S 2007 A Study on the Sealing Performance of Bolted Flange Joints with Gaskets using Finite Element Analysis *International Journal of Pressure Vessel and Piping* 84 p 349-357.
[4] Ross E, Kockelmann H, and Hann R 2002 Gasket Characteristics for Design of Bolt Flange Connections of Metal-to-metal Contact Type *International Journal of Pressure Vessel and Piping* 79 p 45-52.
[5] Saeed H A, Izumi S, Sakai S, Haruyama S, Nagawa M, and Noda H 2008 Development of New Metallic Gasket and its Optimum Design for Leakage Performance, *Journal of Solid Mechanics and Material Engineering* Vol 2: 1 p 105-114.
[6] Haruyama S, Choiron M A, and Kaminishi K 2009 A Study of Design Standard and Performance Evaluation on New Metallic Gasket, Proceeding of the 2nd International Symposium on Digital Manufacturing, p 107-113.
[7] Nurhadiyanto D, Choiron M A, Haruyama S, and 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* Vol 6 p 661-665.
[8] Haruyama S, Nurhadiyanto D, Choiron MA, and Kaminishi, K. 2013 Influence of Surface Roughness on Leakage of New Metal Gasket *International Journal of Pressure Vessels and Piping*, Vol 111-112 p 146-154.
[9] Haruyama S, Nurhadiyanto D, and Kaminishi K. 2014 Contact Width Analysis of Corrugated Metal Gasket based on Surface Roughness, *Advanced Material Research*, Vol. 856 p 92-97.
[10] Nurhadiyanto D, Haruyama S, Kaminishi K, Karohika IMG, Mujiyono 2015 Contact Stress and Contact Width Analysis of Corrugated Metal Gasket *Applied Mechanics and Materials*, Vol 799-800 p 765-769.
[11] Haruyama S, Karohika, IMG 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*, Vol 10 p 527-533.
[12] Karohika IGM, 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*, Vol 11 p 870-879.
[13] JIS Z2241 1998 *Method of Tensile Test for Metallic Materials*, Japanese Standards Association.
[14] MSC Marc. 2007 *User manual*.

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