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, Copper 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](image)

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

Figure 3. Simulation setting up for coating gasket

Figure 3 shows the setup 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 thickness 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 contact width when the axial force in 40-65kN. Contact width is very different when the axial force start 70-120kN. The contact stress also little 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 stress will decrease. It because of the relationship between stress, force and contact area. If the contact width increase so the contact stress will decrease, see equation (1).

\[ \sigma = \frac{F}{A} \]

where \( \sigma \) = stress (\( \frac{N}{m^2} \)), \( F \) = force (N) and \( A \) = contact area (\( m^2 \))
Figure 4. Simulation result of coating thickness 3μm

Figure 5. Simulation result of coating thickness 2μm

Figure 5 shows the simulation result of modified gasket which thickness 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 stress also little 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 difference in 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 in contact with flange. The contact stress of gasket Cu coated 3μm is higher than 2μm when in contact with flange.

![Figure 6. Maximum contact stress for all type of gasket](image)

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 started 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 similar increase for gasket standard, 2μm and 3μm Cu coated when the axial 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 than 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.

| 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 experimental 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 leakage 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. Conclusion
The conclusion 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 standard gasket based on simulation and experimental result.

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