Study on Deformed Mode of Thin Metal Gasket Based on Experiment and FEM

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Abstract: In this study, the compression examination of thin metal gasket is carried out using an elastic effect and asbestos substitute gaskets are compared to validate the finite element method (FEM) model. From the FEM analysis result, the deformed mode and the contact width are examined. The deformed mode is divided into two types. The first type is the deformed mode in which the convex section transforms and the flat section makes a hinge at a certain point. The second type is the deformed mode in which most of the convex sections do not transform and the flat section transforms.
Key words: Thin Metal gasket; FEM; Deformed mode; Contact width

1 Introduction

In the piping connection system, gasket material has been used for preventing the leakage of fluids. Previously, asbestos gaskets were used in many industries because asbestos gasket has superior leak prevention properties; unfortunately, asbestos gasket is an extremely dangerous chemical substance and causes serious diseases. Therefore, the use of asbestos gasket in production industries is completely prohibited[1]. However, the substitute of asbestos gasket is expensive. Moreover, the performance of the substitute gasket material used for fabricating gasket is inferior to that achieved by asbestos gasket, and the substitutes have a short period of utilization. Therefore, the development of substitute gasket is a critical issue, and there has been a delay in the development of an alternative material for developing a gasket material.

The gaskets, as shown in Fig.1, are used as a substitute of asbestos gasket to solve the problem mentioned above. The study of the thin metal gasket using an elastic effect has attracted significant attention. The advantage of this gasket shape is that after the gasket material is attached to a flange and the convex section has a contact, it can produce a high contact stress locally. However, the detailed deformation behavior during the time of compression is not clear as yet. Therefore, a simple finite element model is built for the deformation behavior evaluation, and the validity of the model is examined by comparing with the experimental result obtained during the compression.

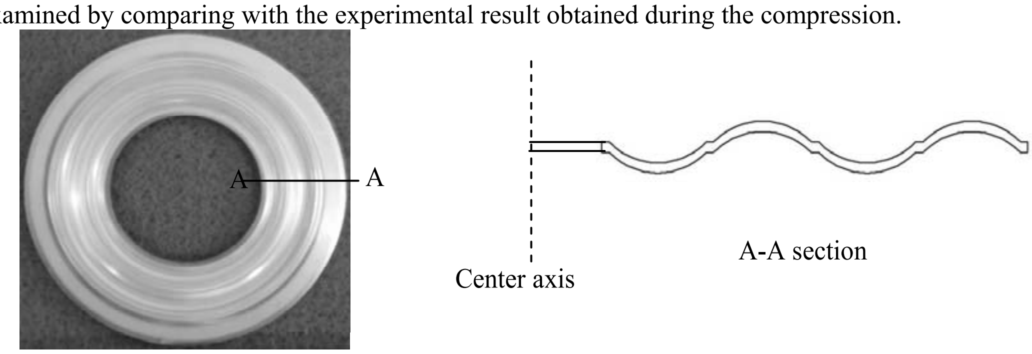


Figure 1 Appearance of Metal Sealing and Cross Section of Gasket Shape

2 Material and Method

2.1 Material

The dimension of the thin metal gasket used in this study is shown in Fig.2. The length of a convex section is denoted as D = 20 [mm]; the height, h = 4.0 [mm]; thickness, t = 0.3 [mm]; and the distance from a central axis, r = 100 [mm]. The length of the flat section is varied as L = 1.5 [mm], 2.0[mm], 4.0[mm]. Further, a JIS13 specimen is used for estimating the mechanical properties of gasket, and a tensile test is carried out. A nominal stress-strain curve is shown in Fig.3.

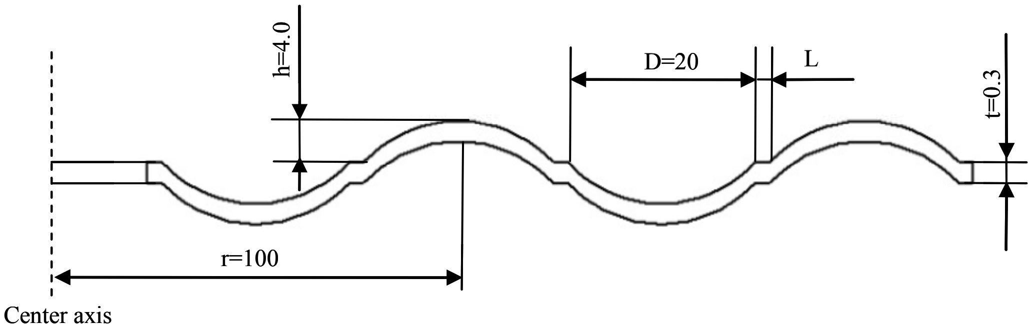


Figure 2 Dimensions of Metal Gasket

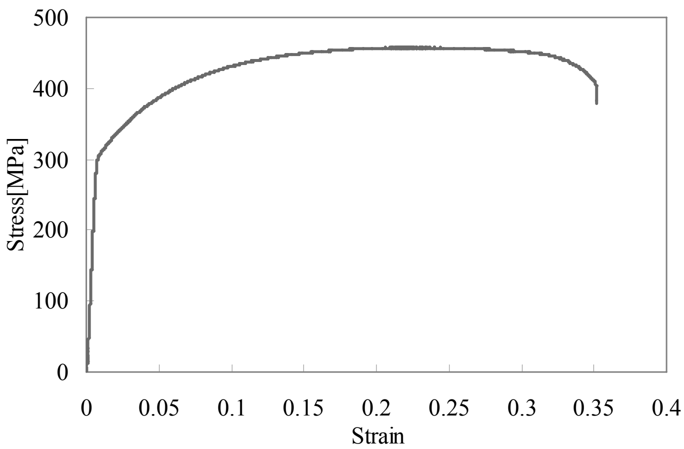


Figure 3 Nominal Stress-Strain Curves

2.2 Method

The experimental device used in the study is shown in Fig.4. By using a laser displacement sensor (SUNX HL-C135C-BK10) on a Tensilon large-sized testing machine (A&D(stock) UTM-I-25000), we monitor the load and the displacement on the sensor interface (Kyowa Electronic Instruments PCD300A) at the sampling speed of 20 [Hz], and the load–displacement curve is produced. The compression speed is assumed to be 5 [mm/min]. For the evaluation, we assume a dry contact condition to simulate the real environment; the lubricating oil is not applied.

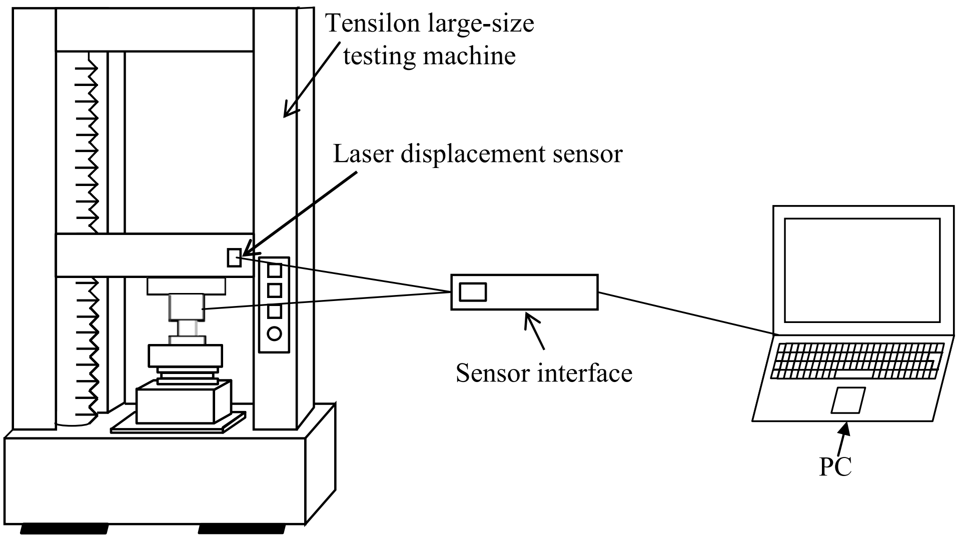


Figure 4 Experimental Device

2.3 Finite element analysis

In this study, a finite element method, general-purpose MSC.Marc, is used for performing the elastoplastic analysis as shown in Fig.5. A two-dimensional analysis is carried out using axi-symmetric shell elements. The material properties are as shown in Fig.3. The elastic modulus is 48.67 [GPa]; yield stress is 300.34 [MPa]; and Poisson's ratio is 0.3. The gasket material model is crushed by the upper rigid body wall using axial displacement to simulate the relationship between the load–displacement and the contact width curves. The lower rigid body wall is assumed to be the fixed boundary condition. Further, the contact width evaluation is performed only on the convex section of the gasket material, which is effective in reducing a leak.

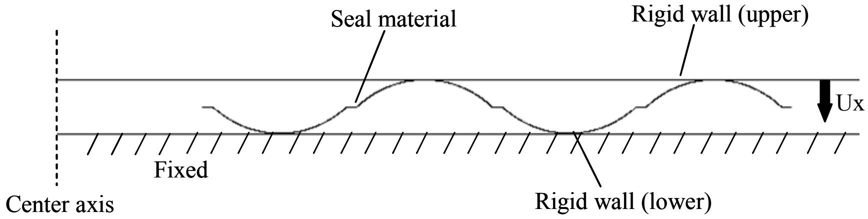
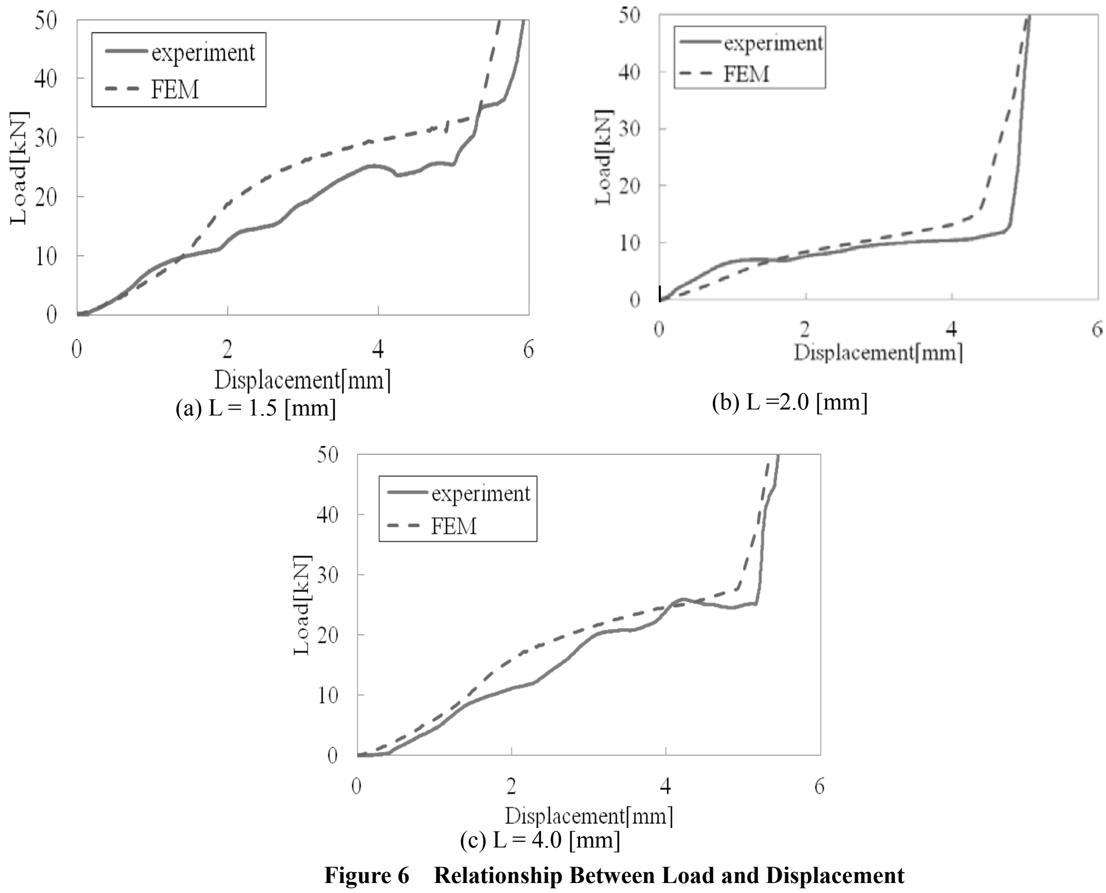


Figure 5 Analyzed Model

4 Results

4.1 Comparison between experimental and analysis results

The load–displacement curve for the experiment and analysis results is shown in Fig.6. The load increases significantly through the curve for L = 1.5 [mm] and L = 2.0 [mm]. Moreover, for L = 4.0 [mm], first, the load increase tends to be constant and then increases significantly. A relatively high value of L produces a decreasing load. By comparing the experimental and the analytical results, we can infer that the dimensions error during the molding process is affected by the load–displacement curve; therefore, the finite element model in this case is sufficient.



(a) L = 1.5 [mm]

(b) L =2.0 [mm]

(c) L = 4.0 [mm]

Figure 6 Relationship Between Load and Displacement

4.2 Deformed mode

The load–displacement curve of L = 1.5 [mm], 2.0 [mm], 4.0 [mm] plotted on the basis of the analysis result and the contact width of the convex section number 2 is shown in Figs.7, 9, and 11, respectively. Moreover, the deformed shape is shown in Figs.8, 10, and 12, respectively.

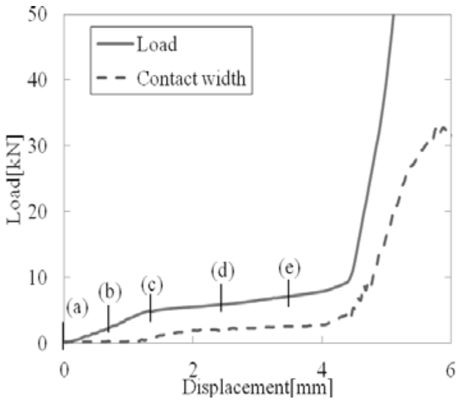


Figure 7 Relationship Between Load and Contact Width and Displacement L = 4.0 [mm]

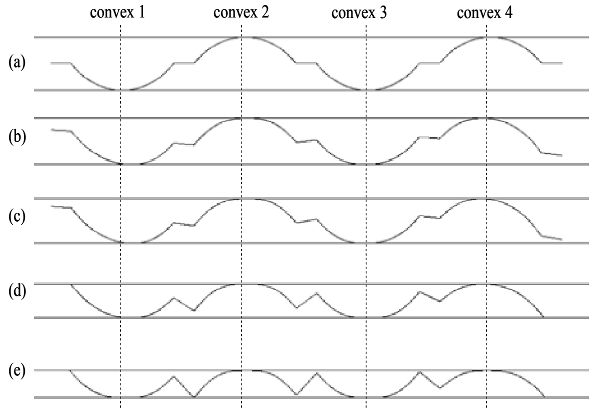


Figure 8 Deformed Shape L = 4.0 [mm]

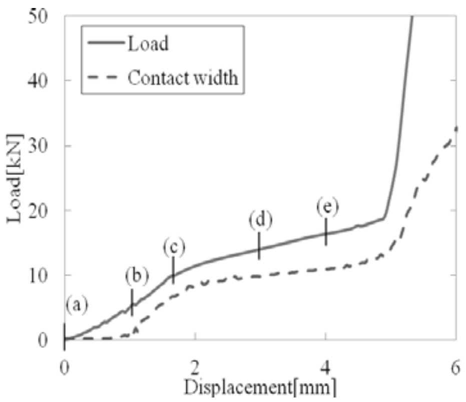


Figure 9 Relationship Between Load and Contact Width and Displacement L = 2.0 [mm]

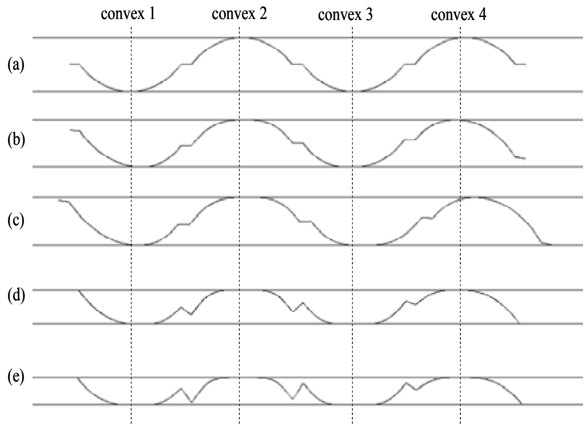


Figure 10 Deformed Shape L = 2.0 [mm]

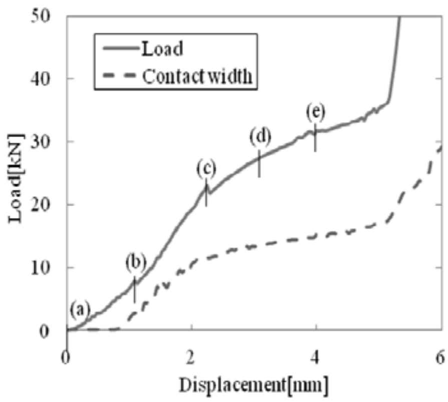


Figure 11 Relationship Between Load and Contact Width and Displacement L = 1.5 [mm]

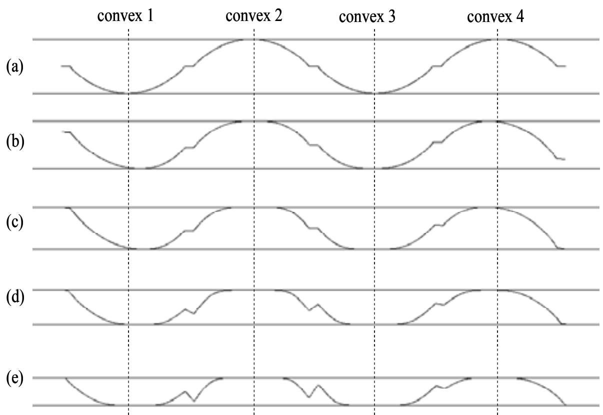


Figure 12 Deformed Shape L = 1.5 [mm]

On the convex section number 2 and the flat section in L = 4.0 [mm], it can be determined that transformation is concentrated in the flat section, and most of the convex sections do not transform (Fig.8). Further, when L = 1.5 [mm] and L = 2.0 [mm], a convex section transforms as shown in Figs.9 and 11, respectively. A plasticity distortion occurs in the flat section at point (c), and the contact width becomes constant because the elastic effect on the flat section. Therefore, with respect to the sealing performance, L = 1.5 [mm] and L = 2.0 [mm] are superior to L = 4.0 [mm].

5 Conclusions

In this study, the validity of the finite element model was examined by comparing the load–displacement curve obtained experimentally with that obtained analytically in a compression test. The FEM analysis was performed in the deformed mode along with the contact width analysis; the conclusions were as follows:

(1) By comparing the analytical and experimental results, although some errors occurred, the validity of the finite element model was clarified.

(2) On the basis of the FEM analysis result, the mode analysis could be divided into two types of deformed modes. The first type was the deformed mode in which the convex section transformed and the flat section had a hinge at a certain point. The second type was the deformed mode in which the convex section did not transform and the flat section transformed.

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